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USING INFORMATION AND COMMUNICATION TECHNOLOGIES TO FACILITATE COGNITIVE ACTIVITY AND SOCIAL INTERACTION AMONG OLDER COSTA RICANS

BY
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USING INFORMATION AND COMMUNICATION TECHNOLOGIES TO FACILITATE COGNITIVE ACTIVITY AND SOCIAL INTERACTION AMONG OLDER COSTA RICANS

by

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CV

I am a graduated psychologist and master in Psychological Research from the Universidad de Costa Rica (University of Costa Rica). My master's thesis was an empirical investigation of the cognitive performance of elder people participating in elder´s organized groups.

I worked as a researcher and social promoter at the Costa Rica Gerontological Association. Following that, I worked as a senior research at the Omar Dengo Foundation (FOD) Costa Rica; there I led research projects focused on the use of technology in educational processes. At the same time, I worked as associated researcher at the Psychological Research Institute of the University of Costa Rica. My research focused on cognitive aging and social participation.

I taught research methodology to psychology students at the National University of Costa Rica. In 2014, with the support of the European Commission, I began the Human Centered Communication and Informatics doctoral program (HCCI) at the Department of Communication and Psychology of Aalborg University. During the PhD program, I taught as external lecturer on cognition and aging at Aalborg University.

My interest areas are developmental psychology, aging, successful and active aging, ICT in teaching and learning processes, ICT and successful and active aging, and psychological research (qualitative and quantitative approaches). However, I have collaborated with research projects in a variety of research areas such as sexual behavior, community interventions, animal-assisted interventions for older adults, among others.

ENGLISH SUMMARY

This thesis aims to identify and understand key elements that might be included in designing suitable learning interventions for enabling older adults using information and communication technologies (ICT) (i.e. computers, mobile devices and applications) for enhancing cognitive activity, increasing social interaction, and promoting successful and active aging. The study followed a design-based research (DBR) approach (Coto, 2010). This allowed incorporation of older adults' and their educators' opinions and suggestions into the design of a learning intervention using ICT. Primary goals were to: 1) stimulate autobiographical memory (ABM); 2) facilitate cognitive training; and 3) generate social interaction around such cognitive activities. Older adults participated in the implementation and evaluation of the designed learning intervention and collaborated in identifying areas of improvement. The research findings revealed that specific aspects such as age-related changes, negative emotions associated with the ICT learning process, and social support for ICT learning by older adults should be considered and included in optimal learning interventions. As main products of the research process, this thesis presents design principles and learning approaches that could guide future design efforts.

The outcomes of the learning intervention revealed that older adults are willing and able to include ICT in their daily life for enhancing cognitive performance and social interaction. However, this type of intervention must be adapted to the characteristics, needs, and interests of this population. Results of the cognitive and social interaction activities suggested that ICT could be a potential avenue for cost-effective interventions aimed at reducing the risks of cognitive impairment and dementia.

This thesis is structured as follows:

Chapter 1: Introduction argues for the relevance of this study regarding demographic change. It addresses challenges the aging process poses to individuals and societies in such areas as adaptation, health, and quality of life. Next, the chapter presents successful aging and active aging models that may help to prevent negative consequences of aging, and explores the role of cognitive performance and social interaction in that process. Thereafter, the chapter presents the potential of ICT for supporting successful and active aging in general, and cognitive activity and social interaction in particular. The chapter points out the need for creating suitable learning interventions to enable older people to use ICT for supporting successful and active aging. It also considers the appropriateness of design-based research (DBR) for conducting a learning design sensitive to older people's characteristics, needs, and interests. The Introduction ends by presenting the problem formulation and the research questions.

Chapter 2: Theoretical Framework presents a brief description of successful aging (Baltes & Baltes, 1990; Rowe & Kahn, 1997) and active aging models (World Health Organization [WHO], 2002). The description focuses on key factors that support such processes (i.e. cognitive performance and social interaction). Next, the chapter introduces some strategies to prevent or compensate for cognitive decline (e.g. lifelong learning, cognitive training) and social interactions). Thereafter, key constructs included in the intervention (e.g. ABM, executive functioning and social interaction) are defined and described. In the section that follows, the potential of ICT for supporting lifelong learning, cognitive training, and social interaction is explored. The chapter, further, presents evidence of the benefits of ICT-based cognitive stimulation and training and ICT-based social interaction, as well as their limitations. The chapter ends by presenting some models and guidelines (Ala-Mutka, Malanowski, Punie, & Cabrera, 2008; Vroman, Arthanat, & Lysack, 2015) for designing interventions aimed at facilitating older adults' learning about and using ICT.

Chapter 3: Methodology describes the design of the current study and offers a rationale for the selected methodological approach. The chapter describes the study participants and data collection methods implemented in each one of the DBR phases. Such methods included processing data from the last Costa Rica National Census, questionnaires, focus group, interviews, video observations, narrative accounts of the reminiscence protocol implemented for stimulating ABM, records of participants' performance in cognitive training, and workshops. The chapter includes a description of the analytic strategies implemented for the data generated by each data collection method and offers some reflections on strategies implemented to determine the study's reliability and validity. These reflections consider the relevance of "ecological validity" from the DBR perspective, and argue for the use of multiple data collection methods and strategies of analysis in approaching the authentic learning settings under investigation. The chapter also describes strategies implemented to prevent reaching false conclusions. Finally, the chapter discusses ethical considerations and the measures taken to protect participants' rights and the data gathered during the study.

Chapter 4: Results presents the study´s results. These are provided within the framework of the DBR phases and in the form of four independent manuscripts. Some results not published elsewhere are also included. Manuscript 1 describes patterns of access and usage of ICT among Costa Rican older people and their relationship with socio-demographic variables. It also describes barriers for learning about and applying ICT, and opportunities to promote successful and active aging through its use. Manuscript 2 presents design principles for designing suitable learning interventions for enabling older adults to use ICT for cognitive activity and social interaction. These principles are derived from input from scientific literature, older adults, and older adults´ educators. The design activities section presents the interventions for enabling older adults to use ICT to stimulate ABM and train

executive functions and memory abilities, while socially interacting with peers. The interventions included face-to-face and online learning activities. Manuscript 3 describes barriers to and supportive factors for learning about and using ICT during the intervention. Manuscript 4 shows the results from the reminiscence protocol, the cognitive training, and the social interactions surrounding those activities. The shared personal memories (ABM) accomplished the social function of reminiscence. Regarding online cognitive games, the number of times played had a statistically significant effect on performance improvement, whereas factors such as age, education, and positive attitude toward technology did not. Finally, a participants' evaluation section presents their perspective on the learning intervention and their own suggestions for improving the learning, contents, activities and strategies included therein.

Chapter 5: Discussion presents the study´s results in a general discussion focused on the empirical findings and addressing methodological and theoretical issues. Regarding empirical findings, the chapter discusses the potential of the designed learning intervention and similar interventions to engage older adults in learning about and using ICT for promoting successful and active aging. From a methodological perspective, the chapter discusses aspects of older adults' participation in the research process, the implications of using a BDR approach in terms of ecological validity, and the implications of this type of intervention for the implementation of psychological interventions using ICT. The chapter also summarizes the main contributions of the study to complement and expand the field of ICT learning by older adults and the potential of ICT for supporting successful and active aging. Finally, there are some reflections on the study´s limitations.

The thesis ends presenting possible answers to the study´s research questions in the Chapter 6 Conclusions chapter. Finally, there are some indications of directions for future research.

DANSK RESUME

Denne afhandling har til formål at identificere og forstå de elementer, der kan indgå i udformningen af egnede læringsinterventioner, der gør det muligt for ældre voksne at bruge informations- og kommunikationsteknologi (ikt) (dvs. computere, mobile enheder og applikationer) til at forbedre kognitiv aktivitet, øge social interaktion og fremme vellykket og aktiv aldring. Studiet følger en design-baseret forsknings (DBR) tilgang (Coto, 2010) og fokus er på at: 1) stimulere selvbiografisk hukommelse; 2) lette kognitiv træning og 3) skabe social interaktion omkring sådanne kognitive aktiviteter. Ældre voksne deltog i implementeringen og evalueringen af læringsinterventionen og medvirkede i identifikationen af forbedringsforslag. Forskningsresultaterne viser, at specifikke aspekter som aldersrelaterede ændringer, negative følelser forbundet med IKT-læringsprocessen og social støtte til IKT-læring bør overvejes og indgå i læringsinterventioner. Denne afhandling præsenterer designprincipper og læringsmetoder, der kan styre fremtidige designindsatser.

Resultaterne af læringsinterventionen viste, at ældre voksne er villige og i stand til at inkludere IKT i deres dagligdag for at forbedre kognitiv ydeevne og social interaktion. Denne type indgreb skal dog tilpasses til denne populations karakteristika, behov og interesser. Resultaterne peger på, at IKT kunne være en mulig vej til at skabe omkostningseffektive interventioner med det formål at reducere risikoen for kognitiv svækkelse og demens.

Afhandlingen er struktureret som følger:

Kapitel 1: I indledningen argumenteres der for relevansen af studiet i forhold til demografiske ændringer. Det handler om udfordringer, som aldringsprocessen udgør for enkeltpersoner og samfund på områder som tilpasning, sundhed og livskvalitet. Dernæst præsenterer kapitlet modeller for aldring, der identificerer faktorer som kan bidrage til at forhindre negative konsekvenser af aldring, og undersøger den rolle som kognitiv præstation og social interaktion har i aldringsprocessen. Derefter præsenteres potentialet i IKT til støtte for vellykket og aktiv aldring generelt og især i forhold til kognitiv aktivitet og social interaktion. Kapitlet peger på behovet for at skabe egnede læringsinterventioner, der gør det muligt for ældre at bruge ikt til at understøtte vellykket og aktiv aldring. Det vurderer også hensigtsmæssigheden af designbaseret forskning (DBR) til gennemførelse af et læringsdesign, der tager højde for ældre menneskers egenskaber, behov og interesser. Til slut præsenteres problemformulering og forskningsspørgsmålene.

Kapitel 2: Her præsenteres en kort beskrivelse af vellykket aldring (Baltes & Baltes, 1990; Rowe & Kahn, 1997) og aktive aldringsmodeller (Verdenssundhedsorganisationen, WHO), 2002). Beskrivelsen fokuserer på

nøglefaktorer, der understøtter sådanne processer (dvs. kognitiv ydeevne og social interaktion). Dernæst introducerer kapitlet nogle strategier for at forhindre eller kompensere for kognitivt forfald (fx livslang læring, kognitiv træning og sociale interaktioner). Derefter defineres og beskrives centrale elementer, der indgår i interventionen (fx autobiografisk hukommelse, eksekutive-funktioner og social interaktion). I det afsnit, der følger, udforskes potentialet i IKT til støtte for livslang læring, kognitiv træning og social interaktion. Kapitlet præsenterer endvidere evidens for fordelene ved ikt-baseret kognitiv stimulering og træning og ikt-baseret social interaktion samt deres begrænsninger. Kapitlet slutter med at præsentere nogle modeller og retningslinjer (Ala-Mutka, Malanowski, Punie, & Cabrera, 2008; Vroman, Arthanat, & Lysack, 2015) for at udforme interventioner, der har til formål at lette ældre voksnes læring om og brug af ikt.

Kapitel 3: Her beskrives designet af den aktuelle undersøgelse og den valgte metodologiske tilgang begrundes. Kapitlet beskriver deltagere i studiet samt dataindsamlingsmetoder implementeret i hver enkelt DBR-fase. Metoder omfatter behandling af data fra den sidste Costa Rica National Census, spørgeskemaer, fokusgruppe, interviews, videoobservationer, narrative beskrivelser baseret på reminiscensprotokollen samt optegnelser over deltagernes præstationer inden for kognitiv træning og workshops. Kapitlet indeholder en beskrivelse af analysestrategier, og giver nogle refleksioner vedrørende strategier for at bestemme undersøgelsens pålidelighed og validitet. Her overvejes relevansen af "økologisk validitet" fra DBR-perspektivet og der argumenteres for anvendelsen af flere dataindsamlingsmetoder og analysestrategier for at forstå den undersøgte læringssituation. Endelig diskuteres de etiske aspekter og de foranstaltninger, der er truffet for at beskytte deltagernes rettigheder og de data, der er indsamlet under undersøgelsen.

Kapitel 4: Kapitlet præsenterer undersøgelsens resultater. Disse leveres inden for rammerne af DBR-faserne og i form af fire uafhængige manuskripter. Nogle resultater, der ikke er offentliggjort andre steder, er også inkluderet. Manuskript 1 beskriver mønstre for adgang og brug af IKT blandt Costa Ricanske ældre og deres forhold til socio-demografiske variabler. Barrierer for at lære om og anvende ikt samt muligheder for at fremme vellykket og aktiv aldring gennem ikt anvendelse beskrives også. Manuskript 2 præsenterer designprincipper for læringsinterventioner, der gør det muligt for ældre voksne at bruge ikt til kognitiv aktivitet og social interaktion. Disse principper er basere på input fra videnskabelig litteratur, fra de ældre voksne selv og fra lærere der underviser ældre voksne i ikt. I afsnittet om designaktiviteter præsenterer interventionerne der muliggør at ældre voksne kan bruge ikt til at stimulere den autobiografiske hukommelse, træne eksekutive funktioner og hukommelsesevner, samtidig med at de socialt samarbejder med jævnaldrende. Interventionerne omfatter ansigt til ansigt og online læringsaktiviteter. Manuskript 3 beskriver barrierer og understøttende faktorer for at lære om, og at bruge ikt under interventionen. Manuskript 4 viser resultaterne fra

reminiscensprotokollen, den kognitive træning og de sociale interaktioner omkring disse aktiviteter. Med hensyn til online kognitive spil har antallet af spillede spil en statistisk signifikant effekt på præstationsforbedring, mens faktorer som alder, uddannelse og positiv holdning til teknologi ikke har. Endelig præsenteres deltagernes perspektiv på læringsinterventionen og deres egne forslag til forbedring af læring, indhold og aktiviteter.

Kapitel 5: Her diskuteres studiets resultater med fokus på empiriske fund og metodologiske og teoretiske spørgsmål. Med hensyn til empiriske fund diskuterer kapitlet potentialet i den designede læringsindsats og lignende interventioner til at engagere ældre voksne i at lære om og bruge ikt til at fremme vellykket og aktiv aldring. Ud fra et metodologisk perspektiv diskuterer kapitlet aspekter af ældre voksne deltagelse i forskningsprocessen, konsekvenserne af at bruge en BDR tilgang med hensyn til økologisk validitet og konsekvenserne af denne type intervention til implementering af psykologiske interventioner ved hjælp af IKT. Kapitlet opsummerer også de vigtigste bidrag fra undersøgelsen. Endelig er der nogle overvejelser om undersøgelsens begrænsninger.

Afhandlingen slutter med at fremlægge mulige svar på undersøgelsens forskningsspørgsmål i kapitel 6. Endelig peges der på nogle indikationer på retninger for fremtidig forskning.

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Manuscript 1. Castro Rojas M.D., Bygholm A., & Hansen T.G.B. (2016). Using Information and Communication Technologies to Promote Healthy Aging in Costa Rica: Challenges and Opportunities. In: Zhou J., Salvendy G. (Eds) *Human Aspects of IT for the Aged Population. Healthy and Active Aging. ITAP 2016. Lecture Notes in Computer Science*, vol 9755, (194-206). Springer, Cham. doi: 10.1007/978-3-319-39949-2_19

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Manuscript 4. Castro Rojas, M.D. (Under review). Willingness and performance of older adults using Information and Communication Technologies for cognitive activity and social interaction. *Gerontechnology*.

CHAPTER 1. INTRODUCTION

Nowadays, aging of the world´s population is the most important demographic change. Societies are studying the demographic implications of aging at the global and at the national level. By 2015 the global life expectancy was 71 years (68 for men and 73 for women). In the Americas region, the general life expectancy was 77 years (74 for men and 80 for women) (World Health Organization [WHO], 2015).

In Costa Rica the number of elders (65 and over) is expected to reach more than 600,000 in the next 20 years; this number is equivalent to grow from 7.3% to 11.5% of the country's population (Instituto Nacional de Estadística y Censos [INEC], 2012). Adults over the age of 80 are the fastest growing group worldwide and represent a vulnerable group as the risk of cognitive and physical disabilities increases in very old age (WHO, 2002, 2015). In Costa Rican´s context, the demographic change has introduced interest in providing older people with goods and services to facilitate adaptation to the old age and to ensure a good quality of life, while reducing the economic costs of health care related to negative outcomes of the aging process.

International and national efforts for facilitating adaptation during the aging process are based on theoretical models such as successful aging and active aging that propose that it is possible to age while being functional, independent, and autonomous (Baltes & Baltes, 1990; Rowe & Kahn, 1997; WHO, 2002). Successful and active aging can be defined as making adjustments over the lifespan to maintain optimal physical (including health) and psychological (conscious behavior and cognitive, emotional, and motivational) functioning, as well as high levels of social participation (Baltes & Baltes, 1990; Fernández-Ballesteros, Molina, Schettini, & del Rey, 2012; Rowe & Kahn, 1997; WHO, 2002). Cognitive functioning is associated with instrumental activities of daily living, independence, and social interaction (Hultsch, Hertzog, Small, & Dixon, 1999; Plehn, Marcopulos, & Mclain, 2004; Schooler & Mulatu, 2001; Smith & Kosslyn, 2014). Social engagement is associated with activity and productivity (Baltes & Baltes, 1990; Rowe & Kahn, 1997; WHO, 2002), while social isolation and loneliness in old age are linked to decline in both physical and mental well-being (WHO, 2002).

During the “normal” aging process (in contrast to a pathological process), cognitive functioning typically undergoes a generalized decline which is more marked in tasks associated with working memory, reasoning, and information processing speed (Baltes & Baltes, 1990; Buckner, 2004; Fernández-Ballesteros, 2008; Fernández-Ballesteros et al., 2012; Fernández Ballesteros, García Rodríguez & Caprara, 2005; Lowe & Rabbitt, 2005; Schaie, 2005b; WHO, 2002). However, there are individual differences in cognitive performance among older adults, and there is no uniform pattern of age-related change across cognitive abilities (Baltes & Baltes, 1990;

Buckner, 2004; Lowe & Rabbitt, 2005; Rowe & Kahn, 1997; Schaie, 2005a; Thompson & Foth, 2005). In addition, the decline can be reduced by specific cognitive training and stimulating activities (Anguera et al., 2013; Baltes & Baltes, 1990; Fernández-Ballesteros, 2008; Fernández-Ballesteros et al., 2012; Fernández Ballesteros et al., 2005; Hultsch et al., 1999; Rebok et al., 2014; Rowe & Kahn, 1997; Willis et al., 2006; WHO, 2002).

Concerning social engagement, today, aging is accompanied by changes in roles within social structures. The migration of young people seeking a job, the smaller size of families, and the prevalence of working women lead to a lack of people available for socially interacting with or taking care of older people if needed (WHO, 2002). This could have negative implications, particularly bearing in mind that a positive and robust social environment plays a role in protecting against cognitive decline and promoting successful and active aging (Baltes & Baltes, 1990; Rowe & Kahn, 1997; Seeman, Lusignolo, Albert, & Berkman, 2001; WHO, 2002).

It has been suggested that Information and Communication Technologies (ICT) may help to overcome the challenges of the aging population by supporting successful and active aging in several ways, especially by facilitating cognitive training and social interaction (Ala-Mutka, Malanowski, Punie, & Cabrera, 2008; Commission of the European Communities, 2001; Czaja et al., 2006; Czaja & Sharit, 2012; Sayago, Forbes, & Blat, 2013; Sayago, Sloan, & Blat, 2011; Vroman, Arthanat, & Lysack, 2015). Training healthy older adults using ICT devices and applications, especially cognitive games and video games, can enhance cognitive abilities (Anguera et al., 2013; Ballesteros et al., 2014, 2015; Nouchi et al., 2012, Nouchi, Salto, Nouchi & Kawashima, 2016; Rebok et al., 2014; van der Wardt, Bandelow, & Hogervorst, 2012). ICT can also facilitate interacting with family and friends and with wider social networks beyond geographical proximity. Thereby, older people can be part of online communities where they can share interests and achieve developmental goals such as learning for personal development (Ala-Mutka et al., 2008; Vroman et al., 2015).

Despite the potential of ICT to improve quality of life during old age by facilitating learning processes, cognitive stimulation and training, and social interaction, older adults often do not use ICT tools. By 2016, just 45% of people aged 65 to 74 living in the 28 countries of the European Union were using the internet frequently (every day or almost every day) (European Commission, 2017). In 2011 in Costa Rica just 14% of people in that group were using the Internet (INEC, 2012). In Costa Rica, the digital divide is associated with six basics factors: income, education level, gender, age, geographic location, and disability (PROSIC, 2010).

Barriers to Costa Rican older adults using ICT include: 1) limitations in motor and cognitive functions, 2) resistance to learning about and using ICT because of inappropriate learning experiences (older learners perceive that young teachers do

not understand their learning process and do not have patience when teaching them), 3) being financially unable to afford ICT, and 4) inappropriate support from family and friends for learning (or lack of it) (PROSIC, 2010). This aligns with previous research that evidenced the need for suitable ICT-learning opportunities aimed at fulfilling older learners' needs and interests and including activities that are readily accessible, affordable, and enjoyable for older adults (Ala-Mutka et al., 2008; Charness & Boot, 2009; PROSIC, 2010; Sayago et al., 2013, 2011; Thompson & Foth, 2005). However, many of the research´s findings about enhancing cognitive skills are based on artificial situations such as laboratory experiments and randomized controlled trials (Anguera et al., 2013; Ballesteros et al., 2014, 2015; Nouchi et al., 2012, 2016; Rebok et al., 2014; van der Wardt, et al., 2012), which limit the opportunities for older adults to learn about and use ICT for cognitive training independently and autonomously in their daily routines.

Considering the demands that population aging presents for societies and the potential of ICT for supporting successful and active aging, the present project involved a study following the principles of Design-Based Research, a methodology "aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings" (Wang & Hannafin, 2005, p.6). Its objective was to explore ways of improving educational practices to enable Costa Rican older adults to learn about and use ICT for cognitive activity and social interaction. The project was developed in real educational settings and combined research and design processes (Oh & Reeves, 2010). Specifically, the project involved collaboration between professionals who studied older adults´ ICT-learning and a group of older adults in the design of a learning intervention aimed at facilitating the use of ICT by older adults without cognitive impairment for enhancement of cognitive activity and social interaction. The DBR approach allowed the design and implementation of the learning intervention in collaboration with different participants and testing and refining the learning intervention throughout the research process. Finally, based on the design process and the research findings it is possible to propose advances in the theoretical and pragmatic aspects of the research project (Oh & Reeves, 2010; Wang & Hannafin, 2005). From this perspective, the design allowed a deeper understanding of the phenomenon of study as the research advanced (Coto, 2010)

In line with the previous premises, this research project aimed to understand and conceptualize key elements for the design of learning interventions aimed at enabling older adults' learning about and using ICT for cognitive activity and social interaction and thus supporting successful and active aging. Thus, these interventions could be adapted to older people´s characteristics, needs and interests, and be implemented in their daily-life environments.

With the aim of realizing the potential of ICT for supporting successful and active aging, the main research question of this study is: What key elements must be

included in a learning intervention to enable older adults to use ICT for cognitive activity and social interaction in order to fit their characteristics, needs, and interests related to ICT-use?

The following questions are instrumental to answering the main research question:

What are the ICT-use patterns of Costa Rican older adults?

What are Costa Rican older adults' difficulties and motivations for learning about and using ICT?

What contents, ICT devices, and applications must be included in a learning intervention to facilitate Costa Rican older adults using ICT for cognitive activity and social interaction?

What learning activities, strategies, and materials must be included in a learning intervention to facilitate Costa Rican older adults using ICT for cognitive activity and social interaction?

What resources to support ICT-learning must be included in a learning intervention to facilitate Costa Rican older adults using ICT for cognitive activity and social interaction?

What are the results of implementing a learning intervention to facilitate Costa Rican older adults using ICT for cognitive activity and social interaction?

This research project explored some answers to these questions involving older adults, older adults' educators, and researchers in designing a learning intervention that might be accessible, affordable, and enjoyable for older adults.

CHAPTER 2. THEORETICAL FRAMEWORK

This chapter presents the theoretical foundations on which the present research project was built. This section summarizes successful and active aging models; cognitive functioning and social interaction as determinant factors of successful and active aging. Then, the section describes the potential of ICT for supporting successful and active aging by facilitating different interventions for cognitive activity and social interaction. Evidence on the benefits of specific ICT interventions is presented as well as their limitations. Finally, the chapter presents some approaches to ICT-learning by older adults, as proposing strategies for facilitating this learning is one of the main goals of this study. It is important to note that this research project sought the creation of practical applications of the current scientific knowledge to older adults' daily living.

2.1. SUCCESFUL AGING

There is not a single definition of successful aging, but there are some common elements supporting different approaches to such definition: 1) it is a multifactorial phenomenon, and no single factor can explain it; 3) there are positive and negative" changes related to the aging process; 3) these changes differ at the intra and inter-individual level; 4) there are some strategies that could help people age successfully. Baltes & Baltes (1990) suggested a multifactorial approach to successful aging including such aspects as length of life, biological health, mental health, cognitive efficacy, social competence and productivity, personal control, and life satisfaction. There is no conclusive evidence regarding the relationships among these criteria or their hierarchy. There are also differences between "normal" aging, without biological or mental pathology; optimal aging, which refers to aging under enhanced developmental conditions; and pathological aging, which presents syndromes of illness (Baltes & Baltes, 1990).

Baltes and Baltes (1990) argued that any developmental process involves a set of gains and losses; for example, the specialization of some neuronal developmental pathways occurs at the cost of other developmental pathways. Therefore, the idea of "success" can vary in relation to cultural and personal conditions, and successful aging or adaptive aging/aging well (Freund and Baltes, 1998) can be defined as the adoption by aging people of adaptive behaviors that enable them to adjust to age-related changes and maintain a meaningful life. Based on these considerations, Freund and Baltes (1998, p. 531) define successful aging as the "maximization and attainment of positive (desired) outcomes and the minimization and avoidance of negative (undesired) outcomes".

The balance between gains and losses is based on the following premises: 1) elderly people have reserves that can be activated by learning, exercise, or training; 2) there are limits on reserve capacity, which means that limits on performance cannot be fully eliminated even with extended practice; 3) the balance between gains and losses become less positive with age (Baltes & Baltes, 1990). Baltes & Baltes (1990) and Freund and Baltes (1998, 1999) proposed an adaptation strategy to achieve successful aging which involves components of Selection, Optimization, and Compensation (SOC). The selection component refers to a reduction in the efficacy domains. The number of options usually exceed the internal and external resources available to an individual, then the options need to be reduced by selecting a subset of domains on which to focus individual´s resources; it can involve new or transformed domains and goals of life. Optimization involves a behavioral engagement to enrich, augment, and maximize general reserves, focusing them on the achievement of one's chosen goals. Compensation involves acquiring new resources or activating unused resources for alternative means of pursuing goals. Thus, the individual comes up with alternative means for achieving the selected goals given their limitations. Compensation is related with aspects of the mind and technology. In the cognitive domain, compensatory efforts could include using new mnemonic strategies. Compensation by using technology could be using memory aid applications. SOC contributes to successful aging, but also to successfully adjusting to specific, difficult situations. Ouwehand, de Ridder, and Bensing, (2007) proposed "proactive coping" as the capacity of foreseeing future problems and losses and take appropriate preventive actions to prevent potential losses or minimize their consequences and keep attained to personal goals.

Diverse individual and societal resources must be offered to support each person to achieve their personal successful aging process "it is likely that no single set of conditions and no single trajectory of aging would qualify as the form of successful or optimal aging" (Baltes & Baltes, 1990, p.21). Then, SOC can take many forms in content and timing based on the individualization of resources and opportunities.

Rowe and Kahn (1997) defined successful aging to include low probability of disease and disability, high cognitive and physical functional capacity and active engagement with life. For these authors the relationship among the factors is to some extent hierarchical, assigning greater relevance to low probability of disease and disability (See Figure 1). In this case, beyond the potential for adaptation, successful aging includes individuals´ activities in daily living.

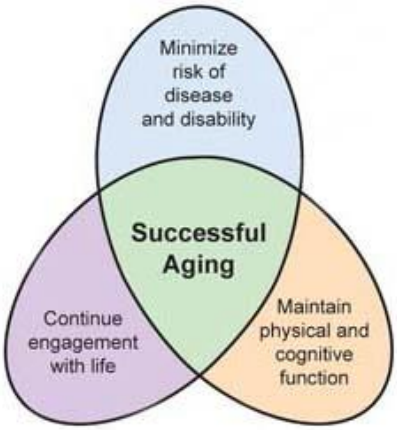

Figure 1Successful aging factors (Rowe & Kahn, 1997)

The risk of disease and disability usually associated with aging relates to lifestyle and other factors that may increase with age (for example, the risk of chronic diseases related to avoidable factors such as the amount and distribution of body fat), but are not caused by aging itself. Thus, environmental and behavioral factors throughout the life span determine the risk of disease in late life. Education appears as a major protective factor against reduction in cognitive function, both because of a direct benefit of early life education for brain development and/or due to the benefit of lifelong intellectual activities (reading, crossword puzzles, etc.) for maintaining cognitive function (Papalia, Blackburn, Davis, Dellmann, & Roberts, 1980; Rowe & Kahn, 1997). Activity in and around the home and self-efficacy were also predictors of cognitive function. The authors also claimed that training can enhance cognitive function in old age and individuals can maintain these improvements over time.

Engagement with life involves interpersonal relations and productive activities. Lack of social ties is a risk factor for health while social support can have positive effects on health. The effectiveness of social support depends on the appropriateness of it to the requirements of the situation and the person. Productive activities include activities for creating goods or services that can be paid or unpaid. Functional capacity, education, and self-efficacy are predictors of productive activity (Rowe & Kahn, 1997). As the predictors of functional and activity levels appear to be modifiable by individuals´ behaviors or by changes in their environments, interventions focused on promoting successful aging must be dedicated to reducing the risk of adverse events and enhancing good conditions in the present.

Both Baltes and Baltes, (1990) and Rowe and Kahn, (1997) present successful aging as a multifactorial phenomenon and regard the dynamic relationship among the different factors as key to maintaining functionality. Successful aging perspectives also claim that there is not a uniform pattern of aging and that there is not a continuous status of success during the aging process. Aging, like any

developmental process, includes gains and losses, but there are some strategies to adapt to these changes during old age and have a transformed but effective life. This implies the use of multiple subjective and objective criteria to recognize individual and cultural variations in successful aging.

2.2. ACTIVE AGING

According to World Health Organization, (2002), active aging is a multifactorial process that includes population and individual factors. At the population level, it requires that individuals have opportunities to realize their potential for physical, social, and mental well-being throughout their lifespan while they participate in society, independently of illness and disabilities. At the individual level, one of the most important factors is maintaining autonomy and independence. The first one defined as the perceived ability to control personal decisions in daily life according to owns rules and preferences. The second one defined as the capacity of performing functions of e daily life and the ability of living independently in the community without help (WHO, 2002).

Then, active aging is "the process of optimizing opportunities for health, participation, and security in order to enhance the quality of life as people age" (WHO, 2015, p.12). The model includes factors as gender and culture as a general framework since there are different attitudes and behaviors toward men and women, for instance, in terms of access to education, health services, and remunerated jobs. The cultural dimension includes different perceptions and values related to acceptance and recognition of older people as fundamental and productive part of societies and communities. At more specific levels active aging include health and social services, behavioral determinants (as smoking and health habits), personal determinants (as intelligence, cognitive performance and motivation), physical environment (adequate infrastructure, clean water), social determinants (social support, education and literacy) and economic determinants (income, social protection work) (See Figure 2).

Figure 2Active aging determinants (WHO, 2002)

From this perspective, personal determinants such as cognitive ability, defined as the capacity to solve problems and to adapt to changes and losses in aging, and social engagement, defined as productive interaction with society, with the community and with a social network, are powerful predictors of active aging (WHO, 2002). This model proposes that societies must develop conditions and resources to maintain quality of life during old age by facilitating access to health services, adequate infrastructure, public services, education, and active participation in all social spheres.

Both successful and active aging approaches have identified general/social factors and individual/behavioral factors related to aging functionally and having a meaningful life. Baltes and Baltes (1990) focused on the balance between gains and losses during aging and proposed a model strategy to achieve adjustment and adaptation to the changes. Rowe and Kahn (1997) proposed three major factors to predict successful aging and emphasized the need for developing strategies to reduce the risks of adverse events and to enhance positive conditions during aging. WHO (2002) included the population perspective and pointed out societies' responsibility for creating appropriate conditions to facilitate active aging. This study considers the described approaches as complementary models to identify general and individual factors that can be modified to facilitate quality of life during old age.

Summarizing the different perspectives, it is possible to define successful and active aging as adjusting processes over the lifespan for maintaining optimal physical (including health) and psychological (cognitive, emotional, motivational and motor conscious behavior) functioning, as well as high levels of social participation (Baltes & Baltes, 1990; Fernández-Ballesteros et al., 2012; Rowe & Kahn, 1997; WHO, 2002).

The Costa Rica welfare system and Non-Governmental Organizations (NGO) take care of health related issues during aging and offer to older adults opportunities for physical activity, social interaction and non-formal education (See www.ageco.org, http://accionsocial.ucr.ac.cr/piam, and http://www.ceg.una.ac.cr/index.php?option=com_content&view=article&id=53). Thus, the present project focused on exploring opportunities for using ICT to facilitate specific cognitive stimulation and training and social interaction for older adults, which is a rarely explored approach in the country.

2.3 COGNITIVE FUNCTIONING AND SOCIAL INTERACTION FROM THE PERSPECTIVE OF SUCCESSFUL AND ACTIVE AGING

2.3.1 COGNITIVE FUNTIONING

According to Smith and Kosslyn (2014), cognition is "the internal interpretation or transformation of stored information. You acquire information through your senses and you store it in memory. Cognition occurs when you derive implications or associations from an observation, fact, or event" (p. 3). Cognition includes mental activities or cognitive abilities such as perception, emotion, and representation in long-term and short-term memory, encoding, working memory, attention, executive processes, decision-making, problem-solving, reasoning, motor cognition, and language.

In the normal aging process, there is a generalized cognitive decline, and it is more marked in tasks associated with executive functioning and memory (Baltes & Baltes, 1990; Buckner, 2004; Fernández-Ballesteros, 2008; Fernández-Ballesteros et al., 2012; Fernández Ballesteros et al., 2005; Lowe & Rabbitt, 2005; Schaie, 2005a,b; WHO, 2002). Two main approaches could explain these changes; a general factor hypothesis claims that cognitive decline including memory falls along a single continuum while a multiple factor framework proposes that cognitive decline targets different brain systems (Buckner, 2004; Lowe & Rabbitt, 2005). Both approaches assert that decline is more evident in abilities related to executive skills.

Executive functioning (EF) is a theoretical concept described in terms of abilities and behaviors. EF includes solving new tasks requiring the formulation of objectives, planning, selecting alternative behaviors to achieve those objectives, and comparing plans regarding success. EF involves adaptive flexibility to implement plans, even when there is no guidance available from previous experiences (Rabbitt, 2005). This implies getting feedback when a change has occurred in the environment and then developing and testing new plans. It also includes the inhibition or suppression of normal or previously used rules, in order to design, select, and implement alternative answers.

EF manages information in long-term and short-term memory, structuring information from the past, exercising control over future actions, and using search strategies in memory. It is also related to control and change of attention to new sources of information, particularly in complex tasks, where several different demands must be controlled simultaneously (Baddeley, Della Sala, Gray, Papagno, & Spinnler, 2005; Rabbitt, 2005; Smith & Kosslyn, 2014). Executive processes occur consciously, unlike automatic or non-executive behavior (Rabbitt, 2005).

Due to the relationships between cognitive functioning and instrumental activities of daily living and social interaction, successful aging (Baltes & Baltes, 1990; Rowe & Kahn, 1997) and active aging (WHO, 2002) models deem cognitive functioning one of the most important determinants of quality of life and independence in old age.

Baltes and Baltes (1990), Fernández-Ballesteros (2008), Fernández-Ballesteros et al. (2012), Fernández Ballesteros et al. (2005), and Rowe and Kahn (1997) agree that adequate cognitive functioning in old age is related to education, activity level outside the home, vital capacity and self-efficacy. It is also associated with cognitive reserve, cognitive change, and learning potential, defined as the ability of an individual to improve his cognitive performance when it is subjected to training (Fernández Ballesteros et al., 2005; Mustafa et al., 2012; Whalley, Deary, Appleton, & Starr, 2004). Cognitive reserve refers to the observation that brain declines do not fully predict cognitive performance across individuals, as compensatory or other forms of reserve factors such as education level and intelligence could mitigate cognitive decline (Buckner, 2004; Stern, 2009).

There are considerable individual differences in the rate and timing of changes in cognition (Baltes & Baltes, 1990; Rocio Fernández-Ballesteros et al., 2012; Rowe & Kahn, 1997; Schaie, 2005b; WHO, 2002). There is no uniform pattern of age-related change across cognitive abilities. Moreover, specific cognitive training or cognitively stimulating activities (Baltes & Baltes, 1990; Fernández-Ballesteros et al., 2012; Fernández Ballesteros et al., 2005; Rowe & Kahn, 1997; Willis, et al., 2006; WHO, 2002) can reduce decrements.

According to the WHO (2002), decline in cognitive functioning is often triggered by disuse (lack of practice), illness (e.g. depression), behavioral factors (e.g. the use of alcohol), psychological factors (e.g. lack of motivation and low expectations), and social factors (e.g. loneliness), rather than aging per se. This agrees with Rowe and Kahn's (1997) proposal that decline is related to risk factors that might increase with age, but are not caused by age itself. Furthermore, these losses can be compensated for gains in wisdom, knowledge, and experience (Baltes & Baltes, 1990; Hertzog, et al., 2009; WHO, 2002). For Baltes and Baltes (1990), compensation implies the use of pragmatics (knowledge-rich cognitive abilities) to prevent or to balance the decline in mechanical intelligence (knowledge-free cognitive abilities); this can be

accomplished, for instance, by the optimization of knowledge systems and the acquisition of compensatory thinking and memory strategies.

Cognitive decline can be offset through participation in social and educational activities and cognitive training (Fernández-Ballesteros, 2008; Rocio Fernández-Ballesteros et al., 2012; Fernández Ballesteros et al., 2005; Hultsch et al., 1999; Rebok et al., 2014). Older adults, who perform cognitive leisure activities and participate in formal educational activities, have better cognitive performance than those who do not practice such activities (Hertzog et al., 2009; Schooler & Mulatu, 2001; Wang, Xu, & Pei, 2012; Wilson et al., 2013).

Due to reserve capacity, older people can increase performance on specifically trained abilities at a rate that is comparable in its magnitude to the aging decline found in untrained people in longitudinal studies (Baltes & Baltes, 1990; Hertzog et al., 2009). Reserve refers to the capacity to enhance cognitive functioning through learning, training and/or environmental support (Buckner, 2004; Logan, Sanders, Snyder, Morris, & Buckner, 2002). The term cognitive reserve refers to compensatory factors or reserve factors such as education level, intelligence or knowledge that mitigate cognitive decline (Buckner, 2004; Fernández-Ballesteros, 2008; Fernández-Ballesteros et al., 2012; Logan et al., 2002; Stern, 2009). On the anatomical level, there is evidence that exercise and cognitive stimulation regulate factors that increase neuronal plasticity and resistance to cell death (Stern, 2009).

Then, the most important factors related to cognitive functioning during old age are education and cognitive activity during the lifespan. Accordingly, there is strong evidence that frequent cognitive activity predicts reduced cognitive decline (Bosma et al., 2002; Hertzog et al., 2009; Hultsch et al., 1999; Rebok et al., 2014; Stern, 2009; Wilson et al., 2013). These findings and the evidence for neuroplasticity in old age imply that lifelong cognitive activity could buffer individuals from cognitive decline and may be particularly important in later age. From the physiological point of view, there is evidence that learning can change and reorganize cortical structure and those changes are related to differences in decline (Mustafa et al., 2012).

Reijnders et al. (2013) found in some studies that cognitive training had a statistically significant effect on experimental groups when compared to untreated groups, but when compared to active control groups, the improvements were no longer statistically significant. This may imply that engagement in different cognitive activities, or a more comprehensive approach than cognitive training, could have a positive effect on both objective and subjective cognitive functioning in older adults without cognitive impairment.

Schaie (1997) found that involvement in intellectually complex activities and stimulating environments, for example, extensive reading, traveling, and participating in learning activities can lead to high levels of cognitive functioning in

older people who do not have cognitive impairment. Fernández-Ballesteros et al., (2012) found that after 3 years in a university course the participants improved their memory and learning performance as assessed by Digit-Symbol Test, compared to a significant decline in the control group. Participants, in contrast to controls, maintained their levels of health and activity, and improved their positive affect and cognitive functioning. Stern (2009) assessed participation in intellectual leisure activities (e.g., reading, playing games, going to classes) or social activities (e.g., visiting friends or relatives) in a population sample of non-demented elderly. Subjects who engaged in more of these activities had less risk of developing dementia. Summarizing, a protective effect of mental activity on cognitive decline has been consistently reported in both observational and interventional studies (Fernández-Ballesteros et al., 2012; Hertzog et al., 2009; Schaie, 1997; Stern, 2009; Wang et al., 2012).

Cognitive training programs targeting different older adult populations and goals evidenced inter-individual differences. For people without cognitive impairment, interventions have sought to improve memory performance, general cognitive functioning, learning abilities, and executive functioning. For people with Mild Cognitive Impairment (MCI), most interventions have been aimed at improving memory performance. The interventions have included different training methods, group-based and individual sessions, and different amount of training hours, making it difficult to compare results, which makes it rather difficult to evaluate the transferability of benefits to new cognitive tasks and to evaluate applicability to everyday life. The wide range of formats used in cognitive interventions also prevents reaching any conclusion about which formats are more effective (Reijnders et al., 2013; Thompson & Foth, 2005; Wang et al., 2012).

Regarding effectiveness of cognitive interventions in older adults without cognitive impairment, evaluations using neuropsychological tests have shown that cognitive interventions can be effective in improving objective cognitive functioning—including memory performance, executive functioning, processing speed, attention, and fluid intelligence—as well as subjective evaluations of cognitive performance (Reijnders et al., 2013; Thompson & Foth, 2005; Wang et al., 2012). Research has also found preservation of the effects of cognitive training for periods ranging from 2 months to 10 years (Rebok et al., 2014; Reijnders et al., 2013; Thompson & Foth, 2005; Wang et al., 2012). However, some studies have found little transfer of function from specifically trained activities to new cognitive tasks (Anguera et al., 2013; Hertzog et al., 2009; Reijnders et al., 2013; Stern, 2009; Thompson & Foth, 2005; Wang et al., 2012). Findings to date indicate that multi-domain cognitive training has the potential to improve cognitive function in older adults without cognitive impairment and slows decline in impaired individuals.

There is no conclusive evidence on the transfer of improvements of trained cognitive abilities to other cognitive abilities and tasks, and the relevance of these

improvements in daily living remain to be seen. It is to be hoped that future research will design appropriate tasks and situations to observe the impact of cognitive interventions on general cognitive abilities and daily living (Reijnders et al., 2013; Thompson & Foth, 2005).

Cognitive interventions can lead to improvements in cognitive performance even in very old age. However, gains tend to be larger for younger individuals, and there is higher adherence to cognitive training in well-motivated participants (Thompson & Foth, 2005). Developing suitable cognitive training programs for older adults must take into consideration aspects such as age and motivation and address challenges such as providing natural conditions instead of laboratory conditions and providing activities close to tasks and activities in daily life environments instead of abstract tasks. Similarly, educational programs for adults should take account of the characteristics, needs, interests, and preferences of participants (Ala-Mutka et al., 2008; Thompson & Foth, 2005; WHO, 2002).

2.3.1.1 Autobiographical memory

The designed learning intervention utilized in this research project includes some activities from a reminiscence (REM) protocol, with the practical objective of helping participants to stimulate their autobiographical memory (ABM). Including REM in the learning intervention to stimulate ABM emerged as part of the research findings at the first phase of the DBR process. However, to facilitate the reading of this dissertation this section includes a brief definition and characterization of ABM and REM.

Both research fields are independent. Nevertheless, the literatures on ABM and REM provide different lenses for observing the recall of personally experienced events from one´s past and concern with the adaptive advantages that personally significant memories have for coping successfully with exigencies of everyday life (Webster, 2003). Traditionally, in the ABM literature its functions are seen as relating to cognitive processing (encoding, storage and retrieval), whereas in the REM literature, REM functions are seen as related to psychosocial outcomes.

First, I present a general definition of ABM and its functions and then focus on the functions of REM and the specific approach followed in the designed learning intervention.

ABM can be defined as the memories about personal experiences and facts about oneself. An autobiographical memory is "an explicit memory of an event that occurred in a specific time and place in one´s personal past" (Nelson & Fivush, 2004, p. 486). Thus, ABM is explicit and declarative, and involves a sense of the self experiencing the event at a specific time and space. It concerns episodes that have personal meaning, which emerges from emotions, motivations, and goals, that

are constructed in interactions with others. ABM is recalled from the unique perspective of the self in relation to others, and includes semantic knowledge or facts about the self. It allows narratives of the self, organized by topics or periods of time (Nelson & Fivush, 2004).

A coherent account of a past event contains a full narrative of aspects such as the context, the meaning of the event, and evaluative information such as emotions and thoughts. Thus, through narrative mediums, specific events can be related to ongoing life frames. Therefore, for Nelson & Fivush (2004), these narratives serve mainly social and cultural functions, and it is about defining the self in time and in relation to others.

Functional approaches to ABM characterize ABM as serving three broad functions: self, social and directive. Although the three functions of ABM have discrete labels, the same memory can serve different functions. So, there might be overlap between the functions of ABM (Bluck, 2003).

In Bluck´s (2003) classification, the self domain involves the function of ABM in maintaining the continuity of the self, which refers to a sense of coherence of the self over time, self-concept preservation and emotional regulation. The social function of ABM involves facilitating social interaction. ABM allows understanding and empathizing with others. ABM has a relevant role and an adaptive value in developing, maintaining and strengthening social bonds. Thus, when ABM is impaired, social relationships can suffer negative consequences. The directive function involves the role of ABM in solving problems and guiding one´s behavior. It allows individuals to ask new questions about old information to solve problems in the present or to predict new events.

Remembering the past or reminiscing and constructing an autobiographical narrative is a critical component of ABM (Bluck, 2003; Nelson & Fivush, 2004; Salazar-Villanea, 2010, 2012, 2015). Reminiscence is a narrative reconstruction of personal events based on ABM, which enables working with memories that are valuable for the self and organized temporally or thematically (Salazar-Villanea, 2010).

Westerhof, Bohlmeijer & Webster, (2010) define reminiscence as

> "The volitional or non-volitional act or process of recollecting memories of one's self in the past. It may involve the recall of particular or generic episodes that may or may not have been previously forgotten, and that are accompanied by the sense that the remembered episodes are veridical accounts of the original experiences. This recollection from autobiographical memory may be private or shared with others". Pp. 698 – 699.

From the perspective of psychosocial outcomes, Webster (2003) and Westerhof et al. (2010) mention eight basic functions of reminiscence: boredom reduction, intimacy maintenance, death preparation, conversation, identity, problem solving, teaching and informing, and bitterness revival. Bitterness revival can be dysfunctional. The authors point out that during interventions with REM the relevant task for promoting mental health is stimulating the positive functions and discouraging the negative ones.

Narrating reminiscences is a positive activity that can be useful for cognitive stimulation (Spector, Gardner, & Orrell, 2011; Spector, Orrell, & Woods, 2010). Reminiscence interventions can be effective in improving wellbeing and alleviating depression (Spector et al., 2011; Westerhof et al., 2010). Moreover, stimulating ABM during old age is important since its social functions are needed for general wellbeing and social interaction when other cognitive abilities are declining (Salazar-Villanea, 2015; Westerhof et al., 2010).

Additionally, reminiscence stimulates memory and language functions; promotes social interaction and openness to personal relationships; supports identity, self-esteem and continuity; changes traditional relationships between patients and therapists by validating personal knowledge of older adults and supporting emphatic communication; and is both intrinsically enjoyable and a positive experience for older adults because of the aforementioned benefits (Gibson, 2004; Spector et al., 2011, 2010).

In Costa Rica, reminiscence is identified as a resource for cognitive stimulation and for preventing depression in non-impaired older adults as well as those with Alzheimer disease (Salazar-Villanea, 2012). Thus, the learning intervention implemented some activities of Salazar-Villanea´s (2010) reminiscence protocol, which has been adapted and validated for Costa Rican older adults. Following Cohen (1998), Salazar-Villanea (2010) summarizes three adaptive functions of reminiscence in older adults: interpersonal/social, intrapersonal and cognitive. The interpersonal/social function includes the occurrence of memory in a social context, creating empathy through individuals understanding and interpreting each other's similar experiences. The intrapersonal function implies private reminiscence for purposes of regulating mood, forming the self-concept, and striving for meaning and coherence in life, and the cognitive function involves integration of information from episodic memory into semantic memory and is an aspect of daily living and problem-solving. For Cohen (1998), the interpersonal or social function of reminiscence is most relevant during old age, and is essential for general wellbeing and social interaction when other cognitive abilities are declining.

Finally, Salazar-Villanea (2015) characterizes reminiscence as a way to promote subjective activity by reflecting on personal identity. This approach represents a balance to the objective activity proposed by successful and active aging

approaches. This vision emphasizes the development of identity and subjectivity over productive activity. Therefore, Salazar-Villanea points out the need for developing tools to promote older adults' construction of meaning of their life experiences in order to promote the narrative development of identity based on autobiographical memories. The present project contributes to the creation of these tools by using ICT devices and applications for implementing some activities of the aforementioned protocol with the purpose of creating social bonds, stimulating general wellbeing, and sharing life experiences and personal knowledge (See manuscript 4 for a detail description of the activities of the reminiscence protocol).

2.3.2 SOCIAL INTERACTION

Social engagement has been related to successful and active aging processes (Baltes & Baltes, 1990; Rowe & Kahn, 1997; WHO, 2002), while social isolation and loneliness in old age have been linked to a decline in both physical and mental well-being (WHO, 2002).

Social support is related to health and positive adjustment over the lifespan (Baltes & Baltes, 1990; Fernández-Ballesteros, 2008; Fernández-Ballesteros et al., 2005, 2012; Rowe & Kahn, 1997). Social support from social relationships may vary in importance at different stages of the life course, for example social support from parents might be central in childhood, and from marital partners or workmates during adulthood, while peer relationships will be important at all stages (Maughan & Champion, 1990). Social support does not only depend on external factors; individuals need to develop skills and have resources to achieve such supportive social relationships. On the other hand, social relationships do not always have a positive effect, as in some circumstances, they can create stress rather than support. It means that individuals have an active role in obtaining the benefits of social support.

Social contact relates to life satisfaction as well. The intensity and frequency of social contact (particularly within the family system) has a positive relationship with life satisfaction (Rudinger & Thomae, 1990). From this perspective, continuity and stability of the social network and social support are important factors for successful aging. Informal social networks such as family, friends, and neighbors, relate to the well-being and quality of life of older adults. For example, satisfaction with family life is one of the main conditions for well-being in old age (Rudinger & Thomae, 1990), and supportive social connections and intimate relations are major sources of emotional strength (WHO, 2002).

Social relationships and social support are also associated with cognitive patterns in healthy, high functioning older adults. Older adults receiving more emotional support had better cognitive performance over a 7.5 year follow-up period (Seeman et al., 2001). This result shows the relevance that social environment may have in

protecting against cognitive decline in the old age. The number of social relations has been hypothesized to protect against cognitive decline because such ties are associated with patterns of social interaction that involve aspects of cognitive functioning. Another protective effect of social network size could be its positive influence in reducing physical health problems or psychological vulnerabilities, such as depression. Levels or frequency of social support might have an influence on psychological factors such as self-efficacy (Seeman et al., 2001). Research results evidenced that besides the links between emotional support and lower depressive symptomatology and higher self-efficacy beliefs, there is an independent contribution of emotional support to more positive patterns of cognitive aging (Seeman et al., 2001)

Rowe & Kahn (1997) define social engagement as a productive interaction with society, with the community and with a social network. It can take many forms but the authors mention two: 1) interpersonal relations than can involve contact and transactions with others, exchange of information, emotional support, and direct assistance; and 2) productive activities, defined as any activity that creates societal value, whether or not it is paid.

These authors recognize that isolation and lack of connectedness with others are predictors of morbidity and mortality (Rowe & Kahn, 1997; WHO, 2002). Similarly, disruption of personal ties, loneliness, and conflictual interactions are major sources of stress (WHO, 2002). On the contrary, belonging to a social network is a predictor of longevity, and it is a health protective factor in two important ways: first, through socio-emotional transactions such as expressions of affection, respect, and liking; second, through instrumental transactions such as physical help or provision of transportation or money (Rowe & Kahn, 1997). Based on multiple studies, the authors reached the following conclusions about the properties of social relations and their effect in aging:

a. Isolation (lack of social ties) is a risk factor for health.

b. Social support, both emotional and instrumental, can have positive health-relevant effects.

c. No single type of support is uniformly effective; effectiveness depends on the appropriateness of the supportive acts to the requirements of the situation and the person (Rowe & Kahn, 1997, p. 483).

Considering the relevance of social support, it is important to remark the role of societies for achieving positive social support during the aging process and old age. From a social science perspective, successful aging is “a quality of the transaction between the changing person and the changing society over the entire lifespan, but especially during a person´s later years” (Featherman, Smith, & Peterson, 1990,

p.50); thus, successful aging is influenced by the nature of society and its social groups such as family, peers, community and their dynamics. The authors, from a transactional point of view, define successful aging as a point of intersection between the developing person and the changing societal context: "successful aging is a social, psychological, and processual construct that reflects the always-emerging, socially esteemed ways of adapting to and reshaping the prevailing, culturally recognized conditions of mind, body, and community for the elderly of a society" (p.52). According to this definition, the focus is on adaptation rather than factors in success.

From this perspective, sociological and historical forces causes individual development and individual differences in adult development during the later years. Thus, successful aging is built on the capacity to respond with resilience to challenges that are unique in old age. For example, older adults live in less formally organized settings, where position and status are fuzzier and do not have a consensual value. In these settings, the roles are more informal in comparison with previous developmental periods (Featherman et al., 1990). Older people are more likely to lose family members and friends and be more vulnerable to loneliness, social isolation, and shrinking social networks (WHO, 2002).

The WHO's (2002) active aging proposal is a "rights based" approach, which pursues the rights of people to equal opportunities in all aspects of life as they grow older. Therefore, besides personal social networks such as family and friends, it supports older adults' participation in the political process and other aspects of community life. Thus, it recognizes the need of balancing personal responsibility (self-care), age-friendly environments, and intergenerational solidarity.

In this regard, the World Health Organization (2002) encourages governments, non-governmental organizations, private industry, and health and social service professionals to foster social networks for aging people. Some of the suggestions include supporting community groups run by older people and facilitating options for volunteer work, neighborhood helping, peer mentoring and visiting, family caregivers, intergenerational programs and outreach services.

One example of the suggested interventions is provide by Fernández-Ballesteros et al. (2012) who showed that older adults who participated in educational programs aimed at promoting personal development and increasing social participation in the form of social relationships and activities improved their positive affect, hedonic balance, personal and social perception and positive affect. These types of university programs for older adults seemed to support their efforts to maintain their activity level, social networks, and positive emotional state; maintaining a positive outlook can improve the quality of life during old age, as positive affect triggers adaptive behaviors (Fernández-Ballesteros et al., 2012).

The authors refer to Fredericson and Losada's (2005) theoretical model for a better understanding of the role of positive emotions, which contribute to broadening people's momentary thought-action repertoires and building their enduring personal resources, ranging from physical and intellectual resources to social and psychological resources. Summarizing, after a 3-years university course older adults showed significantly more positive affect, potentially protecting them from psychopathology and promoting mental health. Similarly, the participants maintained their level of activity, defined as information seeking (reading books and newspapers, hearing news on the radio, etc.), social activities (going to a show, taking trips, engaging in physical exercise, going to church, etc.) and productive activities (adult and child caregiving, shopping, housework and household maintenance, etc.). Following the SOC model proposed by Baltes and Baltes (1990), the participants in the university program seem have compensated for the decline due to age, while the control group lacked the enrichment of their environment and reduced their activities. Thus, as proposed by Havighurst (1963), the decline is due not to age, but to a withdrawal of stimulation, which leads to a decline in functioning due to disuse (Fernández-Ballesteros et al., 2012).

Considering the links between social relationships and social support and health, positive adjustment over the lifespan, life satisfaction, cognitive functioning, activity level, and positive affect, the designed learning intervention included ICT devices, applications, and learning activities that could facilitate social interaction. First, the learning intervention aimed to facilitate social interaction with peers and facilitators and later with other personal social networks.

2.4 THE POTENTIAL OF ICT FOR SUPPORTING SUCCESSFUL AND ACTIVE AGING

Information and Communication Technologies (ICT) including computers, the internet, and mobile devices play a fundamental role in providing opportunities to maintain social contact, accessing information (including health and personal interests) and doing daily life activities such as online shopping or internet banking. ICT facilitates accessing learning opportunities in both formal and informal contexts as well as leisure activities (Ala-Mutka et al., 2008; Dalli, Kroes, & Geoghegan-Quinn, 2011; Elliot, Mooney, Douthit, & Lynch, 2013; Sayago et al., 2013, 2011; Vroman et al., 2015; Wagner, Hassanein, & Head, 2010)

Therefore, ICT might be powerful tools for creating opportunities for older people to be independent and engaged with society. Older adults would benefit from ICT use in a number of ways; these can include forming friendships, having access to products and services, accessing information and social participation in knowledge societies, learning for pleasure and fulfillment, as well as some specific cognitive training (Ala-Mutka et al., 2008).

ICT have the potential to support successful and active aging process in different areas such as work, leisure, and healthcare provision. Charness & Boot (2009) proposes that technology can have different roles such as 1) preventing age-associated impairments and preventing health conditions, 2) supporting augmentation of abilities that decline with age, and 3) helping to substitute for impaired abilities. Through these roles, ICT can support Selection, Optimization, and Compensation (SOC), the strategy proposed by Baltes and Baltes (1990) for achieving successful aging.

Although ICT could support many factors associated with successful and active aging, here we will focus on its potential for supporting cognitive functioning and social interaction. ICT can facilitate learning opportunities by providing more flexible learning models for older adults. ICT can facilitate distance education and provide online resources that could allow older learners to combine self-managed and formal education (Ala-Mutka et al., 2008). ICT can provide older people with new means of improving knowledge, capabilities for practical tasks as well as new ways of being social and interacting socially (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011).

Regarding supporting cognitive activity, ICT can enable lifelong learning processes in three dimensions: a) personal, referring to interest in learning about topics related to personal well-being, as health and safety; b) social and community—opportunities to interact with other people and be socially active; and c) work—meeting the need of senior workers to learn new working methods and tools related to ICT to perform their job. At the same an increasing number of specialized devices and software programs aimed at cognitive training are on the market (Ala-Mutka et al., 2008; Buiza, Gonzalez, et al., 2009; Gamberini et al., 2006).

There is evidence that training healthy older adults using ICT devices and applications, especially cognitive games and video games, can enhance cognitive abilities (Anguera et al., 2013; Ballesteros et al., 2014, 2015; Nouchi et al., 2012, 2016; Rebok et al., 2014; van der Wardt, et al., 2012). Nevertheless, the duration of these effects, their transfer to other non-trained cognitive abilities, and their relevance to everyday functioning remain to be seen.

Concerning the potential of ICT for supporting social interaction, Vroman et al. (2015) showed that the majority of their study participants, adults older than 65 and living independently, used ICT to maintain family and social connections and to access information on health and routine activities. Regarding using ICT for family connections, participants communicated via e-mail with family, exchanged photos and videos and sent greetings. On the social connection side, participants used ICT for staying in touch with distant and local friends.

The next sections briefly describe the potential of ICT for supporting lifelong learning, cognitive training, and social interaction.

2.4.1 ICT AND LIFELONG LEARNING

Regarding older learners, learning should be considered in the broad sense and it can take place in multiple and diverse settings. Consequently, lifelong learning is defined as "all learning activity undertaken throughout life, with the aim of improving knowledge, skills, and competences within a personal, civic, social, and/or employment-related perspective" (Commission of the European Communities, 2001). In this regard, the European Union is working on the Ageing Well in the Information Society initiative, which attempts to address the provision of technologies for well-being, independent living, health and work-life balance.

From this perspective, it is possible to identify different types of ICT-related learning needs among older people, some related to abilities to perform practical tasks and others related to learning as a significant activity that improves personal fulfillment and social connections (Ala-Mutka et al., 2008). Increasing the diversity of adult education and training related to ICT can facilitate older adults obtaining the full benefit from available resources and services, and improving their inclusion in society.

In this vision, the learner is placed at the center, but learning is also considered a social process where learners are co-producers of learning (Ala-Mutka et al., 2008). This might imply individual and collective interventions, for example, personalized mentoring for people with no experience with ICT and allocating experienced learners supporting their peers learning.

Teaching-learning models aiming at facilitating ICT use among older people would combine organized and self-directed learning in different settings, in leisure activities and according to the learning needs of older learners. According to Ala-Mutka et al., (2008), this kind of learning experience does not exist yet, but some elements are emerging in some pilot studies. Thus, in the ICT field, learning is an important tool for improving the quality of life of older people, and “increasing choice and diversity in adult education can widen the participation of adults in education and training, improving the inclusion of older peoples' groups that have not traditionally engaged” (OECD, 2006 cited by Ala-Mutka et al., 2008).

Taking advantage of devices and applications that older adults have shown interest in or already use and including them in learning interventions can help meet their learning needs and requirements. It is also important to understand how older adults engage with ICT and what aspects of it enhance or inhibit their learning progression.

A main challenge in this type of learning intervention is taking into consideration older people´s characteristics, attitudes, and beliefs about ICT in order to overcome barriers and develop effective ICT learning programs. The perceived usefulness and personal benefits for older people and how to aid cognitive abilities that decline with age must be considered as well (Sayago et al., 2013, 2011; van der Wardt et al., 2012; Vroman et al., 2015).

More detailed information about ICT learning and older adults is presented in section 2.5 “ICT learning and older adults” of this dissertation.

2.4.2 ICT AND COGNITIVE TRAINING

General research on the relationship between ICT use and cognitive abilities has found that fluid and crystalized intelligence might be significant independent predictors of breadth of computer use (Czaja et al., 2006). Crystallized intelligence refers to semantic and cultural knowledge, while fluid intelligence is a generic term for different forms of reasoning involving such aspects as information processing speed. The results showed that the use of most of the new technologies seems to require working memory, spatial abilities, reasoning and processing speed, which all decrease with age. Other studies have shown associations between working memory and complex internet search, cognitive flexibility (ability to switch between tasks) and frequency of computer use, use of CD players and cash machines, among other examples. It is also possible that the capacity to use some aspects of ICT becomes part of crystallized intelligence with practice (van der Wardt et al., 2012).

van der Wardt et al. (2012) found that research has linked cognitive abilities such as cognitive flexibility, crystalized intelligence, fluid intelligence, information processing speed, inhibition of a pre-primed response, perceptual speed, spatial abilities, verbal long-term memory, and verbal and spatial working memory to computer and internet use. Therefore, interventions to support digital engagement of older adults should have a focus on aiding cognitive abilities that decline with age.

In their review, van der Wardt et al. (2012) found one study regarding the impact of the use of Internet and computers on cognitive abilities. The results of the study showed that verbal memory, information processing speed and cognitive flexibility did not significantly improve after 4 or 12 months of different modalities of computer training. Although this evidence is limited, it suggests that computer and internet use by itself does not contribute to the improvement of cognitive abilities in healthy older people.

On the other hand, treatments using ICT seem to be effective in older adults with cognitive impairments (van der Wardt et al., 2012), and ICT-based cognitive training can improve cognitive performance in older adults without cognitive

impairment (Anguera et al., 2013; Ballesteros et al., 2014, 2015, Nouchi et al., 2012, 2016; Smith et al., 2009).

Smith et al. (2009) showed that a computerized cognitive training program improved generalized measures of memory and attention in community-dwelling adults aged 65 and older without a diagnosis of clinically significant cognitive impairment. The research used the Brain Fitness Program, designed to improve the function of the auditory system through intensive brain plasticity-based learning, in a multisite randomized controlled double-blind trial with two treatment groups, an experimental group using the computer program and an active control group watching videos and completing some test about the videos. Both groups completed 40 sessions of one hour each during an 8-week period. The training benefits were significantly greater in the experimental group than in the control group. Significant effects favored the experimental group on the performance measure directly related to the trained tasks, and on measures of untrained skills such as overall memory and attention. Additionally, the study design allowed researchers to discard placebo effects, test-taking practice, novelty of computer use, contact with the staff and time being cognitively active as affecting the results, because these factors were all matched between the two groups. However, study demographics (primarily Caucasian and well-educated) limit the interpretation of data from the study.

In their study, Anguera et al. (2013), using a video game called NeuroRacer, trained older adults to improve cognitive control, defined as the control processes required when attempting to accomplish multitasking and deal with interference. The video game consisted of a simulation of driving a car on different types of roads. It included two simple tasks (STT) and one multitask condition (MTT) in which participants performed the two simple tasks simultaneously. The participants were healthy adults older than 60 years considered non-gamers given that they played less than 2 hr of any type of video game per month. They were randomly assigned to one of the three task conditions. Based on a diagnostic version of NeuroRacer, a multitasking cost index was calculated to assess multitasking performance. Older adults who trained by playing NeuroRacer in multitasking mode, on a laptop at home for 1 hr a day, 3 times a week for 4 weeks (12hr of training in total) significantly improved their multitasking index from pre to post training. There were no significant improvements in the active control group or the non-contact control group. Additionally, the multitasking performance gains remained stable 6 months after training without booster sessions. The training led to enhanced cognitive performance on untrained tasks such as working memory and sustained attention.

For Anguera et al. (2013), the "transfer of benefits" suggest that a common, underlying mechanism of cognitive control was enhanced by the MTT with NeuroRacer. Using electroencephalography, the authors offer evidence of robust plasticity of the prefrontal cognitive control system in the aging brain. Finally, participants evaluated the training experience as funny and nice.

Ballesteros et al. (2014; 2015) presented two more studies on brain training using video games. The first study used a randomized controlled trial (RCT) to investigate the effects of 20 1-hr non-action video game training sessions with games selected from a commercially available package, Lumosity®, the same package used in this project, on cognitive abilities such as information speed processing, executive control, attention, spatial working memory, visuospatial memory, visual episodic memory and wellbeing. Forty healthy older volunteers (ages ranging from 57 to 87) were randomly assigned to either the experimental group or the control group. The experimental group practiced the games in a laboratory and the control group met three times with the researchers in a room of the laboratory to discuss general topics related to aging or personal interests. The results confirmed that the trainees improved significantly in the practiced games and that the trained group showed enhancement compared to the control group in: 1) control processing, 2) attention, 3) visual episodic memory and 4) affection and assertiveness. However, the trained participants did not show transfer to executive control and spatial working memory. Additionally, these authors remarked that the effects of this type of training are greater when training is of short duration (1-6 weeks). Summarizing, the findings suggest that non-action video game training might be a promising way to improve certain aspects of cognition that decline with age but not others.

Similarly, Nouchi et al. (2012) found in a RCT that cognitive training using a video game, Brain Age, improved executive functions and processing speed in older adults without cognitive impairment with a mean age of M=68.86 years. The participants were non-players. The experimental and the active control groups played Brain Age and Tetris for about 15 minutes per day, at least 5 days per week, for 4 weeks. The results indicated that there is a possibility that the elderly could improve executive functions and processing speed in short term training using a video game training program. The researchers hypothesized that effects on the prefrontal regions could mediate the improvements. Based on the study design, the authors ruled out the influence of novelty effects on their results. However, the brain training game showed no transfer effect on any global cognitive status or on attention. In another RCT, Nouchi et al. (2016) revealed that playing a processing speed game for 15 min, during five sessions per week, for 4 weeks improved performance in processing speed and inhibition in a group of 36 older adults, M= 69.14 years, without cognitive impairment compared to a an active control group. Nevertheless, the training did not improve performance in reasoning, attentional shifting, short term/working memory, or episodic memory. Moreover, the training reduced depressed mood among experimental participants. These results support the suggestion that training in both short-term and long-term intervention periods has positive effects on cognitive abilities and alleviates depression.

In general, studies of cognitive training using ICT devices shows positive results on the target cognitive abilities. Considering collectively the results from studies of neuroplasticity and these results, it appears that ICT-mediated cognitive training

programs may be effective at countering age-related cognitive decline. Nevertheless, further research is needed to explore whether performance gains are maintained over time, the underlying mechanisms of action contributing to improvements, and transfer to other non-trained cognitive abilities and to activities in daily life. Although the evidence is not conclusive yet, it is promising and supports efforts to facilitate older people's enjoyment of the confirmed benefits of this type of intervention and expose them to the potential benefits.

2.4.3 ICT AND SOCIAL INTERACTION

Today, aging is accompanied by changes in roles within social structures. The migration of young people seeking a job, the smaller size of families, and the prevalence of working women lead to a lack of people available for socially interacting with or taking care of older people if needed (WHO, 2015). Computer-mediated communication can facilitate social interaction, especially when time for regular face-to-face meetings is lacking. Technology helps older adults to keep in touch with families and friends and it has a role in increasing social interaction in general among older adults (Gamberini et al., 2006).

Gamberini et al. (2006) proposed that continued engagement with life (Rowe & Kahn, 1997) can be supported by technologies that facilitate communication, for they are especially appreciated in the case of people who suffer from physical and cognitive disabilities, isolation, frustration, and depression. Similarly, it can be supported by technologies that give older people the possibility to share their experiences in social networks with others who have the same experiences, but could not possibly move from their home or live alone. These authors also remark that entertainment technology can have positive effects in collaborative and pro-social behavior.

In an attempt to stimulate intergenerational relationships, Khoo et al. (2006) developed an interactive game to allow older adults to play together in a physical space with grandchildren, while parents could participate through the internet. In the user studies, older adults were happy and excited about playing the game mainly because of the social and physical nature of the game. Similarly, Ballesteros et al., (2014), after a cognitive training using computer games found a marginal improvement in affection and assertiveness, two dimensions of subjective well-being. The first dimension relates to the degree of confidence and social acceptance and level of satisfaction with the people around, while the second indicates the self-perception of doing good things, being a good person, and contributing to a common goal.

Sayago et al. (2011) conducted a 3-year ethnographical study and showed that older adults make very rich use of Computer-Mediated-Communication (CMC) tools. The participants were 400 older adults (aged 58-70) in an adult education center in

Barcelona. The researchers met the participants for 10 months each year, 2 or 3 times a week for up to 2-3 hours each time. The results showed that interaction with technology issues due to cognition are time-persistent and independent of both experience and practice with ICT. The strategies adopted for older people for coping with all ICT-interaction issues were always targeted at feeling and being included, social, independent, and competent ICT users.

The authors identified three key elements for older adults using ICT: socialization, inclusion (using the same technologies as the most important members of their social circles, children, grandchildren, and close friends) and independence (not relying on anyone else). Analyzing the field material, the authors found that older adults adapt to their interlocutors, as they want to be socially included, and this is worth the effort; this included selecting different CMC tools for communication with different people. So, for example, older adults make the effort to learn and use video chat to keep in touch with their young grandchildren (aged 5-9) because video chat allow more natural and effective communication with them, and used e-mail to engage in asynchronous communication with grandchildren older than 10 years. Participants considered video chatting an awkward way of communicate with close friends (Sayago et al., 2011). These efforts might be due to their motivation to not lose contact with significant people. Another finding was that older adults use CMC tools because they help them feel closer and important to their loved ones. The exchanges with closest family members were very valuable moments, and older adults felt still important and cared about. Nevertheless, video chats did not substitute face-to-face or phone conversations with their close relatives. The research also pointed out that older adults socialize while using tools and put something of themselves into communication; 18 participants set up a blog and included family photos or photos of their holidays. Through these practices, they shared their family moments and reinforced friendship and family ties. Finally, the authors reported that older people were interested in learning about tools to decide how to use them. They wanted to learn about the tools and then decide if they satisfied their needs or which ones fit better for their different needs.

Regarding the issues faced by older adults when interacting with ICT, Sayago et al. (2011) reported that older adults perceived some ICT functions as excessive and inappropriate and they paid very much attention to avoiding making mistakes. The longitudinal study showed that some functions perceived as inappropriate or excessive at the beginning could become useful when older adults gain more experience with ICT. For example, experience with ICT allowed older adults operating visual aid resources on ICT to overcome some vision issues. Nevertheless, the realization that they are non-independent ICT users, their efforts to overcome the mistakes, and their cognitive issues persisted over the time. However, the desire of keeping in touch with their loved ones is so important that it encourages older adults to make the effort to learn about and use ICT as well as their goal of being included and competent ICT users.

As part of the same study, Sayago et al. (2013), besides the participants in Barcelona, also included observations of other 32 older adults in Scotland and reported that learning collaboratively and informally was one of the key strategies of older adults for becoming successful ICT learners. The new approach confirmed that for both groups, being closer to their relatives was a main motivation for learning and using ICT. Interacting with known and new peers during the learning process helped older adults to find learning strategies to master ICT and use these tools to socialize outside the learning environment.

Vroman et al. (2015) surveyed 198 adults older than 65 residing in their communities, and found that the majority of participants used ICT to maintain family and social connections. In terms of devices, most participants used mobile phones and computers. A significant group also used smart phones or tablets. In terms of ICT applications, the majority relied on e-mail. In addition, some of them had experience with text messaging and social networking programs such as Facebook. Only a few participants (7%) communicated via online chatrooms with webcams. Among the top 15 ICT ranked activities, in first place was making family and social connections, and emailing family was the activity performed by most participants (68%). Results did not evidence gender differences in ICT use. By describing what older adults are actually doing online, the authors found that the top ICT activities had personal significance to older adults. In their socio-ecological model explaining and promoting ICT use among older adults, they included at the first and basic level social networking activities with family and friends as the primary interest, need, and most frequent usage pattern. Considering the importance of correlates associated with age such social isolation and changes in health and the positive association of social connectivity with health and well-being Vroman et al., (2015) remark that this level provides the greatest personal value for older adults and is the most positively reinforcing.

In summary, the research results agreed that social interaction with family and friends is one of the main motivations for older adults learning about and using ICT. Moreover, regardless of the devices and applications, ICT tools help older people feel useful, and closer and still important to their loved ones. As stated by Sayago et al. (2011), socialization is a hallmark of the everyday use of different ICT tools by older adults. Thus, ICT became powerful tools to support successful and active aging by facilitating older adults' adaptation to participating in social networks.

2.5 ICT LEARNING AND OLDER ADULTS

Despite the potential of ICT to improve many aspects of daily life, including learning processes, cognitive functioning, and social interaction, older adults often do not use ICT tools. Older adults in Costa Rica have little experience using ICT devices and software; in 2010, just 5.9% of people aged 65 and over had a computer and 5% utilized the Internet (PROSIC, 2010). In 2011, just 14% of people aged 65

to 74 years were using the Internet (INEC, 2012). This hinders them from having opportunities for ICT learning and it becomes an issue in their access to information and services.

In Costa Rica, the digital divide is associated with six basic factors: income, education level, gender, age, geographic location, and disability. Other barriers to Costa Rican older adults using ICT are: 1) resistance to learning about and using ICT because of negative learning experiences (older learners perceive that young teachers do not understand their learning process and do not have the patience to teach them), and 2) inadequate or lacking support from family and friends for learning (PROSIC, 2010).

Accordingly, governmental institutions and NGOs have made efforts to provide ICT literacy courses for older people to facilitate their participation in online social communities. These efforts include providing access to computers in public places and opportunities to participate in courses to learn how to use office applications (Excel, Word, PowerPoint) and social networks (See www.ageco.org, http://accionsocial.ucr.ac.cr/piam). These courses are useful for getting familiar with ICT, but as older adults attending the courses are retired, these ICT tools are not close to their interests and needs. Consequently, they have few opportunities to practice the skills they have learned in real life. It is important to note that older people's motivation to learn depends strongly on how useful they perceive what they are learning to be, and on whether they think they are capable of learning the information or skills (Ala-Mutka et al., 2008).

Considering the perspective of lifelong learning (Commission of the European Communities, 2001), different forms of ICT devices as computers, the Internet and mobile phones have the potential of enabling new ways of accessing learning resources. ICT tools can also provide flexible learning models by combining self-managed and organized education and providing the additional time that many older people need for personal processing and reflection (Ala-Mutka et al., 2008).

However, there are some challenges that must be addressed when designing learning interventions including ICT aimed to older adults. For example, most of the learning tools, methods, and resources have changed since they were active learners and they would need extra effort and motivation to come back to learning, and vision and hearing problems could frustrate many older people´s efforts to engage in the information society. Moreover, one of the most important barriers to learning can be lack of motivation, since older people’s learning needs relate to practical tasks or information needed in everyday life (Ala-Mutka et al., 2008; PROSIC, 2010; Sayago et al., 2013, 2011; Vroman et al., 2015) .

Thus, when designing learning interventions, it is important to consider the needs of older learners in terms of tools, contents, and methods for learning:

> "research should consider the learning content, learning interactions and the related emotional and motivational aspects (…) Involving older people in planning the learning approaches can bring important new insights into the process and also motivate them to participate in these learning opportunities" (Ala-Mutka et al., 2008 p. 24-25).

It is also important to consider differences among older adults and their influence on learning processes, for example, gender and previous education affect learning processes, as more educated people have more experience in self-regulating learning and are more confident in their ability to learn (Ala-Mutka et al., 2008; Vroman et al., 2015). It is important to mention that ICT tools are often not user-friendly for older users, who may have physical limitations and low ICT skills (Ala-Mutka et al., 2008; Czaja et al., 2006; Czaja & Sharit, 2012; Sayago et al., 2013, 2011).

Similarly, difficulties in learning how to use ICT tools may prevent learners from learning about and using ICT and could affect their motivation for learning when ICT tools are involved. Thus, research for developing learning environments and tools to meet the different needs of older people should involve older people as users, experts and senior advisors (Ala-Mutka et al., 2008). This means that learning interventions aimed at supporting lifelong learning processes require a learner-centered approach that allows for providing relevant and high quality learning opportunities equally for everyone (Commission of the European Communities, 2001). This is especially relevant for older learners, for whom technology cannot be important by itself, but can be more interesting if it is related to significant activities such as being active and productive, maintaining cognitive performance, and communicating with family and friends (Ala-Mutka et al., 2008; Czaja et al., 2006; Czaja & Sharit, 2012; Sayago et al., 2013, 2011; Vroman et al., 2015).

Regarding formats of learning interventions, modular instruction, facilitation of a structured learning route, and the integration of informal approaches and structured courses could provide successful learning and support mechanism for older adults (Ala-Mutka et al., 2008). For older adults to engage in learning interventions, there must be a framework to articulate, explore and identify their requirements, motivations and aspirations for learning about and using ICT (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011; Vroman et al., 2015). For Ala-Mutka et al. (2008), the aim of learning interventions for using ICT is allow older adults to explore alternative methods, try them out, and engage in effective and entertaining learning based upon this.

In an attempt to include most of the relevant aspects for designing learning interventions aimed at older adults, Ala-Mutka et al. (2008) proposed a model of ICT learning including learning opportunities in three dimensions: personal, social and community, and work. Here the focus is on the personal and the social and community dimensions as the participants on the present research project are retirees. The authors discussed different ICT-learning approaches for each

dimension: a) learn to know, which alludes to knowledge about concrete issues; b) learn to do, which refers to learning how to do practical tasks, and c) learning as activity, which implies learning for personal development (See Figure 3).

	Personal (home, health)	Social, Community	Work
Learn to know	- ICT provides new information resources e.g. on healthy diet, medication, developed both by experts and peers. - ICT can provide flexible and immediate access to information resources.	- ICT helps to stay updated about activities of the local and other interesting communities - ICT provides new possibilities to find personally relevant (online) communities.	- Learning about new ICT based working methods relevant to know in one's work. - ICT provides new means to search for information about work opportunities.
Learn to do	- Learning to use online banking and shopping, travel services. - Learning to use fall detectors, digital television, mobile phone, medication reminders. - Learning to use internet for finding information and resources.	- Learning to make free video calls to grandchildren living far away. - Learning to participate to online communities. - Informal learning and knowledge sharing when learning to use ICT with peers or younger family members.	- Learning to use the ICT tools needed in the work tasks, e.g. office applications. - Learning to use ICT for entrepreneurship. - Learning with ICT resources for preparing voluntary tasks in the community.
Learning as activity	- ICT-based brain training games combine learning and entertainment. - Learning to use ICT-based learning resources and applications for personal development.	- ICT enhanced learning in community centres (with intergenerational groups). - Participating in ICT-supported distance learning courses, even aiming at achieving university degrees.	- Updating ICT as well as other skills with training certifications to show updated professionalism. - Learning to teach ICT skills for others.

Figure 3Examples of ICT and older people learning (Ala-Mutka et al., 2008)

In the personal field, there could be learning experiences related to home and health, for example, learning to access and manage new information sources on health provided by experts and peers; learning to use online services such as banking or shopping; or learning to use the Internet to find information and resources. The latest skill is also important when approaching learning as an activity, which can include ICT-based cognitive training, for example, games combining learning and entertainment and learning to use ICT for learning and personal development.

In the social and community dimension, ICT can provide new possibilities for finding individually relevant online communities, learning to use new applications to communicate with family and friends, sharing informal learning and knowledge with peers and younger people, and participating in ICT-supported distance learning courses (Ala-Mutka et al., 2008).

Based on their research results, Vroman et al. (2015) proposed a "Community-centered socio-ecological model" to explain and promote ICT use among older adults (See Figure 4). In the first stage, older adults´ usage of ICT is personally focused and reflects primary interests and needs; the most frequent use is social networking with family and friends. The next level is using ICT for practical tasks. This could involve accessing information and carrying out daily instrumental tasks, e.g., banking and shopping. The final level is the least personally intimate network; here, ICT is a link to broader communities, within and outside the person's geographical location, to share common leisure interests and pursuits through online group activities. Comfort with ICT as well as a sense of trust is required to begin accessing and interacting outside one's immediate social circle (See Figure 4).

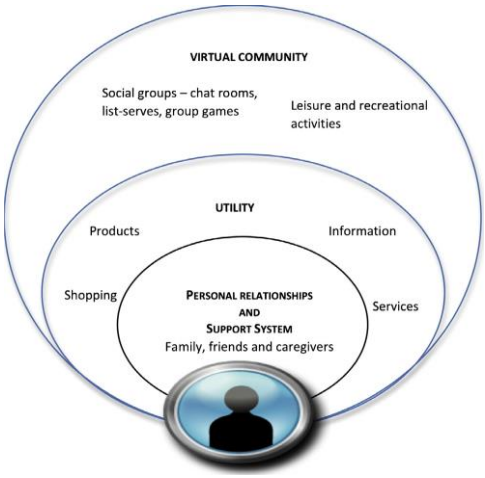

Figure 4 Information and Communication Technology social networking motivation model (Vroman et al., 2015, p. 165)

The model describes social interaction and its relevance for health and wellbeing in old age at the first level of learning and ICT appropriation, while at the final level ICT are conceived as tools to participate and interact in broader communities, which reflects the potential of ICT to enhance the ability to continue living in the community.

Both models are based on a learner-centered approach and present ICT-learning by older adults as a progressive continuum guided by personal interests. These models emphasize social interaction as a main motivation for ICT learning and as a main reinforcing aspect of this learning. The models aim to allow older adults to participate in society, enjoy the benefits of ICT, and remain independent and autonomous during the aging process.

Finally, most of the literature about ICT learning by older adults has been focused on barriers and motivations of older adults for learning about and using ICT and on creating guidelines for designing learning interventions aimed at facilitating that learning. However, Sayago et al. (2011, 2013) in their ethnographic study identified some strategies that older people use over time to become successful ICT-learners and users. To overcome difficulties interacting with CMC tools the strategies adopted for older people were always targeted at feeling and being included, social, independent, and competent ICT users (see ICT and social interaction section for more details) (Sayago et al., 2011). For mastering ICT-use the strategies were: 1) linking learning with real-life needs, 2) learning collaboratively and informally, and 3) adopting appropriate memory aids. They also suggest that when designing learning interventions, it is necessary to distinguish between age-related difficulties and limited experience with ICT.

In this framework, I have emphasized the relevance of cognitive functioning and social interaction for successful and active aging and the potential of ICT to support lifelong learning processes, cognitive training, and social interaction. Similarly, I presented models of ICT learning and use by older people and suggestions for designing learning interventions to facilitate older adults learning about and using ICT. Table 1 summarizes the main themes identified in scientific literature and presents the corresponding sources.

Themes	**Sources**
Cognitive functioning and social interaction are important determinants of successful and active aging processes	Baltes & Baltes, (1990); Featherman et al., (1990); Fernández-Ballesteros,(2008); Fernández-Ballesteros et al., (2012); Fernández Ballesteros et al., (2005); Freund & Baltes, (1998); Hertzog et al., (2009); Hultsch et al., (1999); Maughan & Champion, (1990); Mustafa et al., (2012) Ouwehand, de Ridder, & Bensing, (2007); Plehn et al., (2004); Rowe & Kahn, (1997); Rudinger & Thomae, (1990); Schaie, (1990), (2005a), (2005b); Schooler & Mulatu, (2001); Seeman et al., (2001); Smith & Kosslyn, (2014); Whalley et al., (2004); WHO, (2002); (Willis et al., (2006)
Learning processes or educational experiences in late life may buffer cognitive decline in older adults	Baltes & Baltes, (1990); Bosma et al., (2002); Commission of the European Communities, (2001); Fernández-

without cognitive impairment	Ballesteros, (2008); Fernández-Ballesteros et al., (2012); Fernández Ballesteros et al., (2005); Hertzog, et al., (2009); Reijnders, et al., (2013); Rowe & Kahn, (1997); Schaie, (2005b); Schooler & Mulatu, (2001) Stern, (2009); Thompson & Foth, (2005); Wang et al., (2012); Willis et al., (2006); Wilson et al., (2013); WHO, (2002)
Cognitive training during old age improves performance in trained abilities	Anguera et al., (2013); Ballesteros et al., (2014, 2015); Buckner, (2004); Buiza, Gonzalez, et al., (2009); Buiza, Soldatos, et al., (2009); Fernández-Ballesteros, (2008); Fernández-Ballesteros et al., (2012); Fernández Ballesteros et al., (2005); Hertzog et al., (2009); Hultsch et al., (1999); Mustafa et al., (2012); Nouchi et al., (2012, 2016); Rebok et al., (2014); Reijnders et al., (2013); Schaie, (2005b); Schooler & Mulatu, (2001); Smith et al., (2009); Stern, (2009); Thompson & Foth, (2005); Wang et al., (2012); Whalley, et al., (2004); Willis et al., (2006); Wilson et al., (2013)
ICT devices and software have the potential to support learning processes, cognitive training, and social interaction	Ala-Mutka et al., (2008); Anguera et al., (2013); Ballesteros et al., (2014, 2015); Buiza, Gonzalez, et al., (2009); Buiza, Soldatos, et al., (2009); Charness & Boot, (2009); Czaja et al., (2006); Czaja & Sharit, (2012); Dalli, Kroes, & Geoghegan-Quinn, (2011); Elliot, Mooney, Douthit, & Lynch, (2013); Gamberini et al., (2006); Khoo et al., (2006); Nouchi et al., (2012, 2016); Sayago et al., (2011, 2013); (2011); Thompson & Foth, (2005); van der Wardt, et al., (2012); Vroman et al., (2015); Wagner, Hassanein, & Head, (2010).
For older learners, ICT learning is based on personal interests, and is	Ala-Mutka et al., (2008); Buiza, Gonzalez, et al., (2009); Commission of

motivated and sustained through social interaction	the European Communities, (2001); Czaja et al., (2006); Czaja & Sharit, (2012); Facal et al., (2009); Gamberini et al., (2006); Sayago et al., (2011, 2013); van der Wardt et al., (2012); Vroman et al., (2015)
For older learners, ICT learning is a collaborative process	Ala-Mutka et al., (2008); Buiza, Gonzalez, et al., (2009); Commission of the European Communities, (2001); Facal et al., (2009); Sayago et al., (2011, 2013); Vroman et al., (2015)
For older learners, there must be opportunities to apply the skills learned in daily life	Ala-Mutka et al., (2008); Buiza, Gonzalez, et al., (2009); Commission of the European Communities, (2001); Czaja & Sharit, (2012); Sayago et al., (2011,2013), van der Wardt et al., (2012); Vroman et al., (2015)
During learning interventions, cognitive functions involved in learning processes must be supported	Ala-Mutka et al., (2008); Facal et al., (2009); Sayago et al., (2011, 2013); van der Wardt et al., (2012); Vroman et al., (2015)

Table 1 Main themes in the reviewed scientific literature

Following Coto´s (2010) Design- Based Research (DBR) approach, based on the described theoretical propositions and along with suggestions from older adults and adult educators, I designed and implemented a learning intervention aimed to enable Costa Rican older people to use ICT for cognitive activity and social interaction. The next chapters of this dissertation describe the design process and the results.

CHAPTER 3. METHODOLOGY

3.1. GENERAL DESIGN OF THE STUDY

From the reviewed literature emerged the need for designing suitable learning interventions to facilitate the use of ICT for cognitive activity and social interaction that include activities that are readily accessible, affordable, and enjoyable for older adults. These interventions also must meet the needs of older learners and facilitate the use of ICT in daily life.

For exploring and describing key elements to be included in these learning interventions, this project implemented a Design-Based Research (DBR) approach. The project began with the challenge of designing suitable learning interventions to facilitate older adults without cognitive impairment using ICT for cognitive activity and social interaction, and developed practical knowledge than can be applied in everyday learning practices. Through the design and implementation, in collaboration with older adults and adult educators, the project offers principles and guidelines that could guide future design efforts.

The previously described characteristics of DBR are summarized in Wang and Hannafin's (2005) definition of DBR as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (p.6).

DBR is an emerging paradigm in the educational technology field, which aims to improve the efficiency of the teaching and learning in the real educational settings (Oh & Reeves, 2010). Accordingly, in DBR, during the research process the researcher has two roles, as researcher and as designer, and in collaboration with different participants designs and implements learning interventions in a systematic way in order to improve the design and to propose advances in the theoretical and pragmatic aspects of the research project (Oh & Reeves, 2010; Wang & Hannafin, 2005).

In the research role, the researcher is required to conduct significant literature review and theory generation (local or specific theory), use formative evaluation as a research method, and utilize many data collection and analysis methods widely used in quantitative and qualitative research. In the design role, the researcher needs to address practical issues to promote understanding of design, learning and teaching (Wang & Hannafin, 2005). From DBR´s perspective, local or specific theory development is reflected in practice. These theories are grounded in practice and identify new generalizable design principles during the iterative process. Thus,

having a theoretical goal is a key characteristic of DBR, which leads to a consistent concern for the application and refinement of theory (Oh & Reeves, 2010).

Aligned with requirements in both roles in research and design, Hannafin and Wang (2005) summarize some characteristics of DBR as follows:

1) It is pragmatic: the value of theory relates to the extent to which design principles inform and improve practices.

2) It is grounded in theory and in real contexts that are part of the participant's daily life; this aspect allows the designed learning interventions and design principles to have greater external validity that those developed in laboratory conditions.

3) It is interactive, iterative, and flexible: the application of theory in real settings requires researchers and participants working together to address different obstacles and the collaboration aims to improve the design through implementation.

4) It is integrative, using different methods and data from different sources in a complementary way, which supports the validity and applicability of the research, and implementing formative evaluation that allows for identifying and addressing problems and gaps.

5) It is contextual: it is influenced by context-specific and context-dependent variables, but also offers the potential to test the validity of the design by replicating the interventions in other contexts.

Through the cited characteristics, DBR can generate pragmatic and generalizable, context-sensitive design principles and interventions. Wang and Hannafin (2005) defined nine design principles for planning and designing Technology-Enhanced Learning Environments (TELE), defined as "technology-based learning and instructional systems through which students acquire skills or knowledge, usually with the help of teachers or facilitators, learning support tools, and technological resources" (p.5). Table 2 summarizes these principles.

Principle	**Explanation**
Support design with research from the outset	Prior to design, it is necessary to identify relevant resources from available literature and design cases from multiple sources.
Set practical goals for theory development and develop an initial	Set specific goals that can address problems identified in educational practices. Outline a strategy to achieve

plan	the theoretical goals supported by design activities.
Conduct research in representative real educational settings	Innovation derives from both available literature and the analysis of the prospective real-world settings. It is important to account for factors and dynamics that affect participants and the design process.
Collaborate closely with participants	Participants are immersed in the setting and work as collaborators. This promotes researchers and participants adapting their perspectives, beliefs, and strategies.
Implement research methods systematically and purposefully	Use multiple methods and data analysis strategies, and implement constant evaluation during the process while documenting all research procedures.
Analyze data immediately, continuously, and retrospectively	Analysis is conducted simultaneously with data collection to improve the design. Expertise from all participants can contribute to different interpretations in retrospective analysis.
Refine designs continually	Refine continually to reach intermediate goals.
Document contextual influences with design principles	Design principles should be context sensitive, mutually reinforcing, and able to inform practice.

Design-based research reports generally include purpose and goals, framework, setting and processes, outcomes, and principles.	

Table 2 Summary of design principles for TELE based on Wang & Hannafin, (2005)

As a learning intervention for enabling older adults to use ICT for cognitive activity and social interaction can be seen as a TELE, the present study followed to some extent the principles detailed in Table 2; this will be detailed in the next subsections of the methodology and in the results chapter.

After a general introduction to the DBR approach, it is important to describe the key characteristics that contributed to answering the main research question and sub questions of this study: first, the pragmatic approach permitted combined theory and knowledge, experiences, and expectations of older adults and adult educators in the creation of the learning intervention. Second, the inclusion of older adults in the design process allowed for knowing their characteristics, needs, and interests related to using ICT for cognitive activity and social interaction and their suggestion to match those aspects. Third, the insertion of daily life settings, contrary to psychological interventions developed in laboratory or structured environments, allowed older people to include ICT in their daily life environments independently and autonomously. Fourth, the generation of context sensitive local theory grounded in older adults and adult educators' practices in Costa Rica has the potential to be applied in other, similar contexts (the results chapter describes the characteristics of the study participants and their relation to the general aging population in Costa Rica).

Thus, this study developed the design of a learning intervention to enable older people to use ICT for cognitive activity and social interaction based on the theories of successful and active aging, the potential of ICT for supporting successful and active aging, and ICT-learning by older adults. The study also explored empirically the adaptation of the designed intervention to the participants' characteristics and needs.

Once I established the pertinence of DBR to accomplishing the aim of the research project and to contributing to the design of suitable learning interventions to enable older adults to use ICT for cognitive activity and social interaction. I chose to follow Coto´s (2010) DBR approach, which is based on Reeves (2006) and (Wang & Hannafin, 2005) proposals and was implemented in a Costa Rican university context. Nevertheless, the university context is different from the informal learning context of older adults in Costa Rica. Coto´s work is, as far as the literature reviewed informed, a pioneering study in using this approach for adults' education in the country. Thus, the present study relies on the context sensitivity of Coto´s

work and on the common cultural background of adults in Costa Rica. In addition, most of the participants in this project had university level education.

Coto (2010), following Hannafin and Wang (2005) and Reeves (2006), summarizes the DBR approach as a process in which the design allows a deeper understanding of the phenomenon of study as research advances:

> "The design of the methodology entails designing an intervention aimed at proposing a solution to an educational problem identified as significant. This intervention is based on principles drawn from theory, previous research, and literature and it serves as the context for the research. The research includes an interactive cycle of design, implementation, and analysis as well as a redesign that informs about the improvement of the design. In this process, the role of design is critical in the sense that it not only evaluates a theory, but contributes to its development (p.87-88).

Coto (2010), based on the four-phases model of Reeves (2006), proposed a model of design-based research with five phases. See Figure 5.

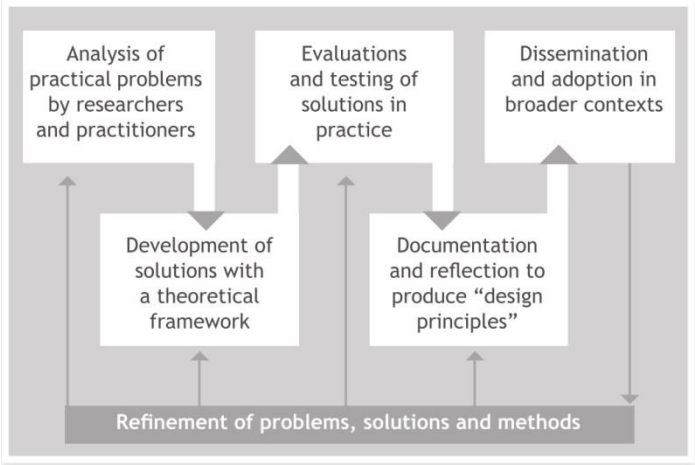

Figure 5 Coto´s (2010) extended design-based research diagram. p.95

The phases are defined as follows:

1) Analysis of practical problems by researchers and practitioners: requires that researchers and practitioners collaborate to identify real educational problems. For McKenney & Reeves (2012), the goal of this phase is a problem definition through contextual analysis, needs assessments, and literature review. In this phase, the project creates a collaborative network of different participants that could be involved in the study. This early participation can foster ownership of the solution.

For exploration, activities can involve site visits, professional meetings, and networking. For analysis, activities can be initial orientation and literature review. The main result from this phase is a better understanding of the problem, and preliminary goals. Partial design requirements and propositions can also be outlined. It should be noted that from this perspective a problem is understood as "the discrepancy between the existing and the desired situation" (McKinney & Reeves, 2012, p.88). Section 4.1 of this presents the processes and results of this phase for the present project.

2) Development of solutions with a theoretical framework: implies the development of prototype solutions based on existing design principles, literature review, and previous research. The developed model should suit the context of its creation and suit the identified learning needs, and should be able to explain how the theoretical principles work in practice and how practice affects theory. Development of the solution with a literature review can be used to propose a preliminary set of design principles. The results section of this thesis describes how the solution—learning intervention—was developed. The theoretical framework of this dissertation presents the literature review. The participants' contributions and the design principles are presented in sections 4.1 and 4.2.

Activities in this phase can vary, as each project is different. However, they can include generating, considering, and checking ideas, defining design requirements and propositions, proposing a skeleton design and detailing specifications, and creating and revising initial prototypes. In this phase, the solution is constructed through a process of prototyping. This process of design and construction leads to new insights, stimulating new cycles until reaching a functional solution (McKenney & Reeves, 2012). Outputs of this phase can range from broader descriptions of the skeleton design to more detailed design specifications and physical or indirect representations of the solution, such as teachers' guides or process guidelines for particular learning processes. Any of these outputs can be the subject of reflection and evaluation (McKenney & Reeves, 2012).

3) Evaluation and testing of solutions in practice: refers to the iterative process of testing and refining design principles and prototype solutions. The learning design is evaluated and modified iteratively. Both successes and failures must be documented, as they allow a better understanding of the relationship between the theory, the design, and the context (Coto, 2010). Section 4.3 presents the testing and refinement of the designed learning intervention.

Besides the evaluation process implemented during the development phase, this phase concerns the evaluation that intend to inform the external scientific community as well to improve the intervention development (McKenney & Reeves, 2012). From this perspective, evaluation is used in a broad sense and refers to any empirical testing of the designed interventions. The present project evaluated the

effectiveness of the learning intervention in two dimensions: 1) the extent to which it accommodates individual characteristics, needs, and interests of older adults, and its applicability in older people's daily life, and 2) the effects of the intervention on cognitive performance and social interaction.

The aim of the evaluation is refining understanding of if, how, and why intervention features work (McKenney & Reeves, 2012). Thus, the result from this phase is "a better understanding of the intervention, the appropriateness of its intentions, what it looks like when implemented, and the effects it yields" (McKenney & Reeves, 2012, p.134)

4) Documentation and reflection to produce design principles: involves the retrospective process of reflection upon the design and its findings, where researchers refine, add, and discard principles that comprise their understanding of the experience (Reeves, 2006). In this phase, the production of a solution that has been tested and refined in the context of use takes place. The retrospective analysis seeks understanding of the interaction between the intentional design, the participants, and the context. This phase also aims at the production of design principles that can transfer the findings to a broader context (Coto, 2010). The design principles and how they emerged are presented in section 4.2. Section 5.1 presents the refinement of principles and guidelines. Reflection on the findings helps generate explanations for the results, and new or refined ideas concerning design and prototyped solutions (McKenney & Reeves, 2012)

5) Dissemination and adoption in broader context: refers to the dissemination, adoption, and sustainability of the educational intervention. The dissemination process "should include both practitioners and the scientific community; and the adoption and sustainability should address the question whether participants are able to make the innovation sustainable after the researchers have left the context" (Coto, 2010, p. 95). Coto (2010) argues that communication of the findings to practitioners and research community must be considered a central part of the intervention, and that the researcher must address issues of scalability and sustainability if they aspire to having their innovations used more broadly, beyond the original research context. The results of this analysis are discussed in section 5.2.

As showed in Figure 5, the model is cyclical, as each phase informs the next phase, and each phase can result in modifications of all the phases, illustrating the iterative refinement nature of the approach (Coto, 2010). These phases allowed the refinement of problems, solutions, and methods during the course of the research process, and sought orientations related to current ICT-uses, ICT-learning needs, motivations, and expectations of Costa Rican older adults, contents, and formatting of learning activities to facilitate participants' use of ICT for cognitive activity and social interaction.

Like every methodological approach, DBR also presents challenges and limitations. Some challenges relate to the difficulty in identifying when the iterative process must finish, since standards of learning interventions´ effectiveness are not available, and every intervention seeks different goals. It is also difficult to determine if the generated design principles valid for a specific context are valid in other contexts. Furthermore, DBR allows multiple research frameworks and methods, making it difficult to identify a specific methodology to guide research and design (Wang & Hannafin, 2005).

Reliability and validity criteria are discussed in section 3.5. Finally, it should be noted that in DBR the data are extensive and comprehensive, but due to time and resource limitations large amounts of data are discarded and research quality can be affected negatively.

Oh and Reeves (2010) add that there is a proliferation of terminology and definitions and a lack of consensus about how design research should be conducted. These authors emphasize limitations for doctoral students, especially time and resource restrictions to conducting DBR, and finally scalability is pointed out as one of the major challenges.

Coto (2010) summarizes the main criticisms of DBR, including a lack of clarity on methodological and epistemological aspects, the need to develop from a set of methods into a rigorous methodology, and the lack of standards to help researchers and practitioners to decide if a given design must be abandoned or sustained. DBR is very time consuming for both researchers and practitioners. Another criticism is that there are some misinterpretations of DBR and consequently some implementations that lack a solid theoretical base and do not seek to produce findings for the refinement and evolution of theory. Finally, Coto pointed out that most of the time just a small percentage of the data collected is needed to induce the findings, and researchers are forced to make a selection of data because there is not enough time and resources to analyze all the collected data.

This research project recognizes the challenges that DBR faces, but also its strengths for improving learning practices and interventions. In this respect, DBR facilitates the implementation of the generated theory in daily practice, because the theory is informed by the context of those practices. DBR seeks the understanding of real educational practices during the design/research process. Thus, the results of each phase are used for the needs analysis in the following iterations. In this way, participants are fundamental for the research process and the data produced in each phase are used to improve the local context and the generated learning intervention, and to improve theories, design principles, and design methodologies (Oh & Reeves, 2010). Another element that supports collaborative work and facilitates the adoption of learning interventions, design principles, and theories in real contexts and practices is the active participation of the researcher during implementation.

Evaluation is a strength in DBR and plays a key role in theory refinement during the iterative process; effectiveness is related to the generation of useful design interventions and refining theories that can produce changes at the local level (Oh & Reeves, 2010). Finally, although DBR focuses on local settings, design principles with context-rich descriptions aid replicability and scalability of the design research outcomes (Oh & Reeves, 2010).

Thus, DBR, by incorporating design into the research activities, allows researchers to have an impact on education and at the same time advance their understanding (Coto, 2010). In this case, it is important to contribute to developing ICT-learning interventions for older adults aimed at promoting successful and active aging and at the same time to get a better understanding of the dynamics between successful and active aging, and the potential of ICT for supporting successful and active aging and ICT-learning by older adults. The design process through the idea of iteration and refinement facilitated the understanding of how older people can include ICT in their daily life environments to facilitate cognitive activity and social interaction, how the design fits the needs and requirements of older adults, and how to modify the intervention to make learning more efficient.

In order to overcome some of the mentioned challenges, this project presents a theoretical framework that supports the design of the proposed learning intervention. To evaluate the suitability and convenience of the designed learning intervention, the project established two dimensions to evaluate effectiveness: a main dimension focused on effectiveness in accommodates individuals' characteristics, needs and interests, and its applicability in older people´s daily life; and a secondary dimension focused on the effects of the intervention on cognitive performance and social interaction. The last dimension is secondary, since there is a considerable body of evidence that supports the effectiveness of this kind of intervention in improving both aspects. Additionally, the thesis offers detailed, context-rich descriptions of the participants, the methods used in each phase of the research process and its purposes, and the conditions under which the data were collected and analyzed. Finally, most of the collected data were analyzed and included in the design/research process since in each phase I contrasted data from different sources, and gathered by different methods, to prevent reaching false conclusions (Hammersley, 2008). Sections 3.3 and 3.4 present detailed information about data collection methods and analysis procedures.

3.2. PARTICIPANTS

The participants were selected strategically based on criteria of accessibility, and compliance with the following inclusion criteria:

1. Adults older than 60 years (this is the criterion used by the United Nations to define older adults, WHO, 2002).

2. Being able to write and read *

3. Having few experience using ICT devices and applications *

4. Having no clinically diagnosed psychiatric, neurological, or neuropsychological disorder *

5. Having a score of 25 points or more in the Mini Mental State Examination (MMSE) (for non-literate 19 points score could be accepted)

* These inclusion criteria were evaluated in an initial interview with potential participants; during the interview, the MMSE was applied.

Recruitment was a two-stage process. First, we put out a general call through governmental and non-governmental organizations and then we screened potential participants for cognitive impairments using the MMSE and interviewed them to verify the inclusion criteria. All potential participants met the inclusion criteria and were included in the study. Initially, 59 older adults were included in the study. As the project advanced the number of participants from the initial 59 changed in each phase. Here I describe the initial 59 participants and then I present the participants in each phase of the DBR process.

The average age of the 59 initial study participants was 67.46 years (SD=5.31) and the mean score on the MMSE was 28.63 (SD=1.29). Women made up 78% of study participants. Table 3 describes demographic characteristics of the participants.

Characteristics	**Participants n=59**
Age group (%)	
60-64	32.2
65-74	61
75-84	5.1
85 and more	1.7
Marital status (%)	
Married/civil union	57.6

Separated/divorced	20.3
Widowed	11.9
Single/never married	10.2
Education Level (%)	
Without any degree	0
Completed /some Primary School	13.6
Completed /some High School	37.7
1-3 years of College	3.4
Completed/ some university	45.8

Table 3 Demographics characteristics of the study participants

Most of the participants were in the younger age group, they were married or lived with a partner, and most of them had university level education. The last characteristic contrasts with the general population of older adults in Costa Rica, whose most frequent educational level is completed or had some primary school. For a more detailed description of the study´s, participants and their relation to the general population of older adults in Costa Rica see manuscript 1. Figure 6 shows the number of participants, starting from the initial 59, involved in each phase of data collection.

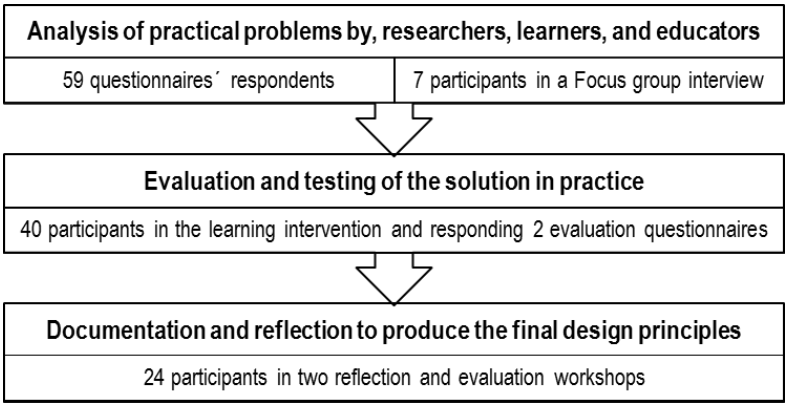

Figure 6 Participants involved in each phase of data collection of the DBR process

Additionally, in phase 1 "Analysis of practical problems by researchers, learners and educators", two interviews were undertaken with professionals working on teaching older adults how to use ICT. The interviewees were the academic coordinator and one teacher in the area of ICT, working on the Institutional Program for Adults and Older Adults at the Universidad de Costa Rica (www.piam.ucr.ac.cr).

The results chapter and Manuscripts 1 to 4 present a detailed description of the participants in each research phase.

3.3. METHODS

As stated previously, DBR allows the use of multiple data collection methods and sources. Using the DBR framework, Table 4 presents the methods used in each moment of data collection.

DBR phase	Methods	Description	Time	Administrated by
1. Analysis of practical problems by researchers, learners, and educators	Processing information from the National Census, 2011 database	Data on socio-demographic characteristics of Costa Rican older adults and their ICT access and usage	Jul–Aug 2015	Researcher
	Questionnaire about Socio-demographics, and access and use of ICT by study participants	Included questions about access to, and experiences with technologies, as well as questions about interest in ICT, expectations of ICT and barriers to learning about and using ICT	Nov – Dec 2015	Research collaborators (one psychologist and one social worker)
	Survey of Technology Use (SOTU) (Scherer & Craddock, 2002)	Explored experiences with technologies and socio-personal characteristics	Nov-Dec, 2015	Idem

	One focus group interview with 7 participants	Explored some aspects that emerged from the questionnaires, such as perspectives about ICT, ICT-learning by older adults, barriers for learning about and using ICT and suggestions for overcoming the difficulties and for the design of the learning intervention	Dec, 2015	Idem
	Two interviews with professionals working on teaching older adults how to use ICT	Explored content, teaching and learning strategies for ICT-older learners, challenges and limitations of older people for learning about and using ICT, and suggestions for the design process.	Dec, 2015	Researcher
3. Evaluation and testing of solutions in practice	Video observations	During the learning intervention, 36 classroom sessions of two and a half hour length each were video recorded for analysis.	Feb-Apr, 2016	Researcher
	Reminiscence protocol	Participants shared personal memories by Facebook® or Blogger® and all their posts and comments were recorded for	Mar-Apr, 2016	Researcher

		analysis		
	Online cognitive games	Participants played cognitive games using the online platform Lumosity®. Each participant had a user ID and all training sessions were recorded for analysis. Comments and post on online platforms related to the cognitive training were also recorded for analysis	Mar, 2016-Jan-2017	Researcher
	Mid –term online evaluation questionnaire	Included questions about aspects of the designed learning intervention such as learning contents and activities, learning strategies, and usefulness of the learned skills in daily life	Mar, 2016	Researcher
	Final-term online evaluation questionnaire	Explored aspects such as participants' learning strategies, support resources for learning, and suggestions for improving the learning intervention	Apr, 2016	Researcher

4. Documentation and reflection to produce the final design principles	Two evaluation and reflection workshops	Explored with the participants possible improvements of the learning intervention	Jun, 2017	Researcher

Table 4 Data collection methods

All data collection activities were implemented on the computer labs of the Omar Dengo Foundation (FOD), a Non-Governmental Organization working with education and ICT in Costa Rica www.fod.ac.cr .

Phase 2, "Development of a solution with a theoretical framework" did not include data collection since based on the data collected in phase 1, I individually developed the learning intervention. During phase 2, I also presented and discussed the designed activities with experts on using ICT for adults´ education. Similarly, phase 5 "Documentation and adoption in broader context" did not include data collection since the main goal is communicating the research findings.

For a detailed description of methods and procedures in phase 1, see manuscripts 1 and 2, for details of phase 2 see section 4.2.2 of this dissertation, and for details of phase 3 see manuscripts 3, 4 and section 4.3 of this dissertation. Methods used in phase 4 are described in section 4.3 of this dissertation.

3.4. DATA ANALYSIS

As the data generated by different methods and from different sources had distinctive characteristics, I implemented different data analysis procedures according to the data's nature.

Data from the 2011 National Census, the questionnaire about socio-demographics, access and use of ICT, and the Survey of Technology Use (SOTU) were analyzed using the Statistical Package for the Social Sciences, SPSS 22. I calculated descriptive statistics to describe the patterns of ICT access and usage among older Costa Rican people, how ICT usage related to socio-demographic characteristics and older adults' motivations, and barriers for learning about and using ICT. For detailed information, see manuscript 1.

For analyzing the data from the focus group interview and the interviews with adult educators, I conducted an inductive process of content analysis (Hsieh & Shannon, 2005). Following Mayring (2000), I listened to the audio data from both sources, and defined a set of codes and analytical categories. After 10% of the material had been reviewed, I revised the codes and categories, and I did this again after 50% of the material had been reviewed. At both intervals, codes and categories were subsumed and new ones were created.

After the coding system was created, I coded the audiotaped data from the interviews and the focus group using the NVivo 11 software. Finally, I identified four main categories and analyzed the meanings and relationships between those categories and the themes extracted from the theory (McQueen et al., 2009). See manuscript 2 for more details.

Video observations were analyzed using the procedure of inductive content analysis (Hsieh & Shannon, 2005; McQueen et al., 2009) described for the focus group and interviews. After the coding process, I grouped the data into two main categories presenting barriers and supportive aspects for older adults learning about and using ICT for cognitive activity and social interaction. The data were coded using NVIVO 11 software. See manuscript 3 for a detailed description of the procedure. I also implemented the same inductive content analysis procedure for analyzing data from the open questions in the two evaluation questionnaires. These data were also coded using NVIVO 11 software. Descriptive statistics were calculated for closed questions in the questionnaires. See details in section 4.3 of this thesis.

As the designed learning intervention implemented a reminiscence protocol validated for Costa Rican older adults (Salazar-Villanea, 2010), I analyzed the participants' reminiscences by a classic content analysis procedure (McQueen et al., 2009) and using the analytical category system proposed by Salazar-Villanea (2010). The analytical category system includes three main categories: structural characteristics of the narration, narrative characteristics according to the proposed topic, and type of memory. Each story was a unit of analysis. The data were coded using NVIVO 11 software. See a detailed description in manuscript 4.

The improvement in cognitive games was modelled by a linear mixed effects model with random effects of game and user. The random effect of the user can be interpreted as a user level; some users are good at playing games and some are not as good. The interpretation of the random game effect is similar; some games are difficult and some are easy. We used the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) and the pbkrtest package (Halekoh & Højsgaard, 2014) in the statistical software R and the REML approach for unbalanced data.

To test the effect of the fixed effects, number of times played, age, education, and positive attitude toward technology, each effect was added in turn, and the effect

was tested by an F-test with the Kenward-Roger approximation. The model also tested if the fixed effect of number of times played was significant when the fixed effects of age, sex, education, and positive attitude toward technology were already in the model. See a detailed description in manuscript 4.

I used descriptive statistics, and the described inductive content analysis approach, for analyzing all the posts and comments shared through Facebook and Blogger related to the reminiscence protocol and online cognitive games. See manuscript 4 for more details.

Finally, I systematized and organized the agreements reached with the participants on the evaluation and reflection workshops and synthesized their suggestions for improving the learning intervention. See section 4.3.3 for details.

3.5. RELIABILITY AND VALIDITY CRITERIA

As described by Coto (2010), reliability concerns the fit between what researchers consider data and what actually occurs in the natural setting being investigated. However, this does not mean uniformity in the interpretations, as it is assumed that our knowledge of reality is gained only through social constructions such as language, consciousness, shared meanings, documents, tools, and other artifacts (Klein & Miyers, 1999). Thus, there might be as many interpretations as researchers analyzing the data.

Regarding interpretation, Silverman (2001) proposes that high reliability is related to low-inference descriptors, and it involves recording data as concretely as possible, including verbatim accounts of participants, instead of general reconstructions of the discourse by the researchers. In this research, the data can be considered as low-inference, as participants' actions and discourses were recorded directly, through audio and video recording for interviews and during the learning intervention. Textual records of posts and comments in online platforms were kept, as well as written answers in questionnaires and evaluative workshops. The main findings of this research are supported with excerpts from the data, which contain the participants' own perspective.

In order to improve reliability and validity of the project, I drew on and contrasted data from different sources (theory, participants, and adult educators), and gathered the data using different methods (literature review, focus group, interviews, video observations, questionnaires and workshops). Thus, I tried to reduce the chances of reaching false conclusions, and to provide complementary information concerning the aspects being studied (Hammersley, 2008; Mayring, 2000).

Triangulation between methods (Hammersley, 2008; Mayring, 2000) was implemented by assuming that by comparing data from different sources, one can

try to determine what interpretations of phenomena are more likely to be valid. It is worth noting that the implemented formulation of triangulation denies the possibility of absolute certainty and does not treat any source of data as having priority.

Validity means that "you are observing, identifying or 'measuring' what you say you are" (Mason, 2002). Mason proposes that you can demonstrate validity in at least two ways. First, validity of the data generation methods, which refers to reflecting about what the data sources and methods can tell the researcher about the phenomena being studied. In Table 4, I described how particular methods and data sources contribute to each research phase and the type of information they generated to contribute to answering the project's research questions.

From this perspective, Mason (2002) thinks of the concept of triangulation (conceived as multiple methods) as a way that allows the researcher to approach their research questions from different angles "and to explore their intellectual puzzles in a rounded and multi-faceted way" (Mason, 2002, p.190). This does enhance validity, in the sense that it suggests that a phenomenon is multidimensional, and that the study has managed to grasp more than one of those dimensions.

The second way of thinking about validity is validity of the interpretations. This involves questions about how valid the data analysis and the interpretations are (Mason, 2002). This aspect is dependent upon validity of the methods, but goes further by directing attention to the quality and rigor with which the researcher interprets and analyses the data in relation to the research questions. For Mason (2002), validity of interpretation is contingent upon the "end product", including a demonstration of how that interpretation was reached. In this regard, in section 3.4 I have offered a general description of the data analysis procedures implemented during each research phase. In addition, in manuscripts 1 to 4 I offer a detailed description of each data analysis procedure, so the reader can trace the process to arrive at the proposed interpretations. In manuscripts 1 to 4, I also explain how I wove sections of data together to produce an interpretation (Mason, 2002). In this way, I tried to make transparent how I reached my interpretations and I traced the logic for my methodological choices.

Additionally, throughout the learning intervention participants evaluated the appropriateness of the interpretation of the data collected in the first phase of the DBR process by evaluating to what extent the learning intervention fit their characteristics, needs, and interests. Furthermore, during the evaluation and refection workshops the participants knew and discussed the main research´s findings and expressed their own perspectives on them. I presented the findings in a simple way, using daily life language and avoiding technical jargon so the participants could understand and elaborate upon them. Accordingly to Mason (2002), the applied approach does not imply that research participants can

unequivocally validate the research interpretations; instead, I argue that participants can contribute to the accuracy of the findings and to preventing reaching false conclusions.

Altogether, inspired by Mason (2002), in this project I tried to demonstrate validity of method and interpretations through a careful retracing and reconstruction of the route by which I reached the findings and interpretations. Validity for statistical tests was evaluated using standardized validity measures detailed in manuscript 4.

Generalizability involves the extent to which researchers can make wider claims based on their research and analysis, rather than stating that their analysis is entirely idiosyncratic and particular (Mason, 2002). The present research project does not attempt to make empirical generalizations, but instead it seeks to contribute to generating cross-contextual generalities from strategically focused local/contextual studies (Mason, 2002). Thus, in manuscript 1 I offered a detailed description of the context of the research and the research participants. Additionally, I contrasted the study participants to the general population of older adults in Costa Rica, in order to clarify the scope of the findings. Similarly, I described the participants in each phase of the DBR process in manuscripts 1 to 4.

By offering these rich descriptions of the context, participants, design process, relationship between theories and design, methods and procedures for data collection and data analysis strategies, this thesis attempts to facilitate the possibilities of generalization of the findings to other particular contexts.

In a complementary way, this research project followed a set of principles for conducting and evaluating interpretative field studies in information systems (Klein & Miyers, 1999). While not all of the principles may apply in every situation, their systematic consideration is likely to improve the quality of interpretive studies in information systems or in this case in studies related to ICT.

1. Hermeneutic circle: This principle suggests that all human understanding is achieved by iterating between considering the interdependent meaning of parts and the whole that they form. This was derived in the analysis by moving between different sources perceived as parts, different participants, technologies, and applications to understand the whole phenomenon.

2. Contextualization: requires critical reflection on the social and historical background of the research setting, so that the intended audience can see how the current situation under investigation emerged. To fulfil this principle I offered a contextualization of the demographic change, the relationship between ICT and older adults, and a detailed description of the context and the study participants.

3. Interaction between the researchers and the subjects: requires critical reflection on how the research materials (or "data") are socially constructed through the interaction between the researchers and participants.

4. Abstraction and generalization: requires relating the details revealed by the data interpretation to the application of principles one and two and to theoretical general concepts. Therefore, intrinsic to interpretive research is the attempt to relate particular situations as may be described under the principle of contextualization to ideas and concepts that can apply to multiple situations.

5. Dialogical reasoning: requires sensitivity to possible contradictions between the theoretical preconceptions guiding the research design and actual findings. These contradictions are discussed in the results section and on manuscript 1 to 4.

6. Multiple interpretations: requires sensitivity to possible differences in interpretations among the participants as are typically expressed in multiple narratives or stories of the same sequence of events under study. The study presented the findings to the participants on several occasions in order to grasp complementary interpretations of the data. Similarly, the study included multiple viewpoints, from ICT-users and non-users, adult educators, and researchers to generate multiple accounts of the phenomena being studied.

7. Suspicion: requires sensitivity to possible biases and systematic distortions in the narratives collected from the participants.

DBR approaches support the need for addressing reliability, validity and generalizability issues to ensure the scientific rigor of the DBR methodology (Coto, 2010). In order to improve reliability, DBR recommends the use of method triangulation, repetitions of analyses across cycles of iteration, and the use of standardized instruments (Design-Based Research Collective, 2003, cited by Coto, 2010). Regarding validity, the Design-Based Research Collective, 2003, cited by Coto (2010), locates the validity of the findings in the processes of iteration and collaborative partnership that characterizes DBR.

The inclusion of multiple methods and sources, the collaboration among researcher and participants and the implementation of the learning interventions in natural settings contribute to ecological validity. As DBR is committed to developing theoretical insights and practical solutions simultaneously in real educational settings (as opposed to laboratory) together with stakeholders, their goals and methods are rooted in the complex variation of real settings (McKenney & Reeves, 2012). Therefore, "ecological validity" refers to the fact that research is conducted in natural educational settings, or other settings where learning occurs, which require multiple methods to study the phenomena within the complex system of authentic settings (McKenney & Reeves, 2012). Thus, "in an ecologically valid study, the

methods, materials, and the settings of the study approximate the real life situation that is under investigation" (Brewer, 2000, cited by McKenney & Reeves, 2012, p. 8). Furthermore, for these authors, the ability of the study´s results to be generalized increases when conducted in real settings.

At this point, it is important to remind the reader of some of the characteristics of DBR and highlight how they could support reliability and validity. First, developing practical activities allows for studying the design process itself and consequently the resultant design principles have the potential to have greater external validity that those developed in laboratory conditions, as they since provide the opportunity for replication within and across contexts (McKenney & Reeves, 2012; Wang & Hannafin, 2005). Second, its integrative and complementary use of different methods and data sources supports the validity and applicability of the research by facilitating the understanding of different dimensions and phases of the phenomena under study. Similarly, implementing formative evaluation during the process allows for identifying and addressing actual problems and gaps in the designed solution. Third, its contextual nature offers the possibility of testing the validity of the design by more interventions in more contexts (Wang & Hannafin, 2005).

Finally, generalizability supports the goal of design-based research in developing theories that go beyond particular contexts. However, generalization in DBR is framed in very specific and context sensitive educational interventions that continuously adjust to the context and participants. Thus, design based researchers should share their findings from specific contexts, making tentative generalizations but without the expectation of universality. Coto (2010) argues that the readers/consumers of the research should evaluate the usefulness of specific DBR studies for other contexts. Thus, results from DBR studies can take the form of guidelines for future design efforts, and then can be refined through further cycles of iteration towards generalizability of findings. Thus, generalization can be boosted, to some extent, by replication (McKenney & Reeves, 2012). Following Coto (2010), this thesis offers rich descriptions of the context, participants, and each research phase, to facilitate readers' evaluation of the relevance of the research findings to their particular contexts. In this approach, generalization can be seen as two sided; on one hand the DBR researcher is obligated to describe the intervention and the context in which it is implemented, and on the other hand when using the research findings it is the reader/consumer who must make the transfer to other specific contexts (McKenney & Reeves, 2012).

3.6. ETHICAL CONSIDERATIONS

The study was approved and conducted in agreement with the guidelines of the Costa Rican Institute of Clinical Research (ICIC) and the Health Ministry of Costa Rica. All the participants gave their written consent before the study started. As part of the follow-up procedures implemented for the ICIC,I submitted an activity report

every 3 months during the research period from July 2015 to December 2017, to inform the Institute about participants´ activities in the project and dropouts.

The ICIC reviewed and approved all methods and procedures for data collection, and the learning intervention before their implementation. Additionally, during October 2016 the ICIC implemented an ethics audit to evaluate how well the research met the ethical standards of scientific research in Costa Rica. The results from the audit process evidenced the fulfillment of ethical standards related to the respect of participants' rights, custody of participants' information, management of the data gathered during the research process, and the publication process.

CHAPTER 4. RESULTS

This section presents the results of the present research project following the framework of DBR research phases 1 to 3. The results are presented in the form of four independent manuscripts: one published book chapter corresponding to a peer-reviewed conference proceedings, one published peer-reviewed article, one peer-reviewed article currently under review and one submitted peer-reviewed article. Additionally, I present two reports that have not been submitted or published elsewhere. To facilitate the reading and comprehension of the different actions of the project, I present the DBR stages consecutively. However, some of them were developed simultaneously, and some occurred during the whole research period.

4.1. ANALYSIS OF PRACTICAL PROBLEMS BY RESEARCHERS, ADULTS´ EDUCATORS, AND OLDER LEARNERS

4.1.1. MANUSCRIPT 1: USING INFORMATION AND COMMUNICATION TECHNOLOGIES TO PROMOTE HEALTHY AGING IN COSTA RICA: CHALLENGES AND OPPORTUNITIES

The first manuscript is a published chapter in the proceedings of the Human Aspects of IT for the Aged Population. Second International Conference

Aim of the manuscript: the purpose of this manuscript is to describe the ICT access and usage patterns among Costa Rican older adults in general and among the study participants in particular. The manuscript also explored the interests, expectations, and motivations of the study participants, and the barriers they experienced in learning about and using ICT in their daily life.

Summary: Data from the last Costa Rican National Census were analyzed to describe patterns of ICT access and usage among Costa Rican older people and its relationships with socio-demographic variables. Fifty-nine volunteer participants answered two questionnaires. One questionnaire included socio-demographic questions so that we could compare our participants to the general population; it also included questions about access to, and experiences with, technologies, as well as about interests in ICT, expectations of ICT, and barriers to learning about and using ICT. The other was the Survey of Technology Use (SOTU) (Scherer & Craddock, 2002), which explores experiences with technologies and socio-personal characteristics.

Results showed that around 19% to 25% of Costa Rican older adults had access to a desktop, laptop, and Internet at home, while 69.3% had access to a mobile phone. The study participants had better access to ICT devices than the general population

and the majority of the study´s participants represented the active users from the older population at the national level; they were living in urban areas, and had more education and higher socioeconomic status than the general elderly population. In both groups, the most commonly used ICT device was the mobile phone.

Among the study participants, the most commonly used applications were those related to social interaction (mobile messaging, social networking and email) followed by leisure applications (video sharing and online games) and finally functional applications (reminders, weather, Internet browsers and banking). Smartphones were used for social interaction and, to a certain extent, in support of instrumental activities of daily life. Despite the potential of ICT to facilitate learning, few older people were using ICT for formal or informal learning. Internet users took advantage of ICT to enhance their social interaction, but they tended to be passive consumers of information from the Internet and did not take advantage of its interactivity to produce and share information; this reduces its potential to promote social inclusion.

The most frequently cited motivations for using ICT related to instrumental activities and social interaction. Participants' biggest difficulties in learning and using ICT related to their cognitive performance (declining memory and attention), followed by courses not being appropriate/suitable for older people and lack of learning opportunities. Sensory and psychomotor impairments were not important barriers for them. Participants mentioned individual factors such as "fear" and "shame" as other barriers to learning about and using ICT. Participants felt that people teaching them did not have enough patience and such situations made them feel ashamed and anxious. They also reported being afraid of making a mistake that would damage equipment or result in loss of information.

The majority of participants who were ICT-users described their current experiences with technologies in positive terms (being satisfying, adding to their creativity, encouraging and bringing them closer to people). They were favorably disposed to using technology, and in the "personal and social characteristics" subscale the majority of users described themselves in positive terms.

According to the Information and Communication Technology Social Networking Motivational model (Vroman et al., 2015), the study participants were in the first level of ICT adoption, i.e., they used ICT mainly to support personal relationships and for social networking with family and friends. They also used ICT to access information, an activity associated with the second level of the model; the other component of this second level is "performing instrumental tasks online".

In conclusion, the main challenges for using ICT in the promotion of healthy aging among older Costa Ricans include ensuring that most older people benefit from ICT, promoting the "higher" levels of ICT adoption, and promoting learning as an

activity which includes learning for personal development. The main identified opportunities to promote successful and active aging through the use of ICT include use of public infrastructure and community-based learning services to increase the number of ICT users, and facilitating the progression from social networking to activities supporting the maximization of functional status such as instrumental activities and learning.

4.2. DEVELOPMENT OF A SOLUTION WITH A THEORETICAL FRAMEWORK

This section presents one manuscript published in a peer-reviewed journal and the general description of the design activities that has not been submitted or published elsewhere.

4.2.1. MANUSCRIPT 2: EXERCISING OLDER PEOPLE ´S BRAINS IN COSTA RICA: DESIGN PRINCIPLES FOR USING INFORMATION AND COMMUNICATION TECHNOLOGIES FOR COGNITIVE ACTIVITY AND SOCIAL INTERACTION

The second manuscript is an empirical article published in a peer-reviewed journal. This manuscript contributes to the problem definition in DBR phase 1. However, its main contribution is to the definition of the theoretical framework in the form of design principles for designing the learning intervention to enable older adults learning about and using ICT for cognitive activity and social interaction.

Aim of the manuscript: this manuscript presents a set of preliminary design principles for guiding the design of learning interventions aimed at facilitating older adults learning about and using ICT for cognitive activity and social interaction. It also presents the theoretical framework and suggestions from older learners and ICT adult educators and the relationships between them that support the created design principles.

Summary: the paper summarizes common themes and suggestions for design present in the scientific literature on successful and active aging, ICT and successful and active aging, and ICT-learning by older adults. Data from a focus group with seven study participants and two interviews with professionals working on teaching older adults how to use ICTs were analyzed as well as their relationships with the reviewed theory to create design principles for guiding the design of the learning intervention.

Results identified four common themes in the reviewed scientific literature related to ICT and older adults: 1) ICT learning is based on personal interests, and it is motivated and sustained through social interaction; 2) ICT learning is a collaborative

process; 3) there must be opportunities to apply the skills learned in daily life; and 4) cognitive functions involved in ICT learning must be supported.

Data from participants and adult educators complemented the themes identified from the theory, offering detailed examples of them and older adults´ personal perspective. The data evidenced that ICT-learning seems to promote a more balanced participation in the learning processes by allowing women to explore the technology domain and by facilitating male social participation in learning environments during old age. Participants were active in multiple activities and consequently willing to invest time in learning only if they found content and activities useful and necessary for their wellness and daily living. They knew of the considerable amount of information available concerning ICT. However, they either lacked access to such information, or lacked the skills to manage it according to their needs and interests. This lack of knowledge on how to navigate information on ICT sometimes makes them feel overloaded and places them in a vulnerable position, as others (younger people) have specific knowledge and they must enter into a dependency relationship to gain access to that knowledge.

For participants, ICT-learning related to two emotions, fear of damaging the equipment and the consequences of this, and shame of asking questions, making mistakes and being "slow" learners. Their main complaint was that their relatives and members of their social networks did not have enough patience to teach them about or help them to use ICT. Consequently, older learners agreed that the best way to learn to use ICT is in a structured learning process with other older adults, avoiding negative reactions from family and friends. Teachers remarked on the need for identifying, understanding, and accepting those negative emotions to offer resources to support older adults' ICT learning processes.

Despite some internalization of stereotypes of older adults and their perception of being slow ICT-learners, participants perceived themselves as willing and capable of learning new content and skills. For participants, the general explanation of changes in their learning process is aging, but they did not appear to understand the specific age-related changes in their cognitive functioning. Having knowledge of age-related changes in cognition could allow older adults to have a better understanding of these changes and to identify some strategies to cope with them. Thus, it seems important to include opportunities to analyze changes in cognitive functioning and stereotypes of aging in the learning interventions.

Older adults perceived that ICT learning aimed at personal development and obtaining positive learning outcomes reinforced their self-esteem and supported positive perceptions about themselves. Obstacles to ICT learning included aspects that made learners feel vulnerable, such as the need for constant external support and the perception that their knowledge and experience in other areas is not valued.

Practical suggestions for design from teachers and participants included the creation of a respectful, friendly, and safe environment in which learners can feel comfortable asking for as much help as they need, and in which they can share with peers, in relation to both the learning process and social aspects. Both learners and teachers suggested developing learning on a continuum from an introduction to different devices and applications to a personal pathway matching personal needs and interests. The learning intervention must promote independence when using ICT so that older adults can decide what they want to do with ICT and how and the support resources they need to achieve their goals.

Suggestions also included using ICT for promoting social interaction in balance with face-to-face interaction, and having a learning process that is structured but flexible enough to combine different activities, developmental tasks, and sharing of older adults' own knowledge. Finally, educators noted that evaluating suitable learning interventions must address their effectiveness in satisfying individuals' needs.

In conclusion, from the data analysis the following eight design principles were derived that argue for a respectful learning environment, in-depth comprehension of age-related changes and support for adaptation to such changes. They also encourage providing time and space to reflect on emotions and stereotypes related to learning about and interacting with ICT, and acknowledging participants' individuality.

Design principles for learning interventions for using ICT for cognitive activity and social interaction included:

1) Organize the learning activities around interesting topics for older adults.

2) Encourage individual participation and support a collaborative learning environment.

3) Support social interaction and social networking.

4) Facilitate spaces to explore and reflect on emotions and stereotypes related to learning about and using ICT as older learners.

5) Offer a sustained support system.

6) Provide resources to support declining cognitive abilities.

7) Develop a broad perspective concerning ICT and how to match them to personal interests and needs.

8) Provide a safe learning environment in which participants' experiences and knowledge are respected.

The proposed design principles reflect that this kind of learning intervention, besides focusing on traditional aspects, such as length, content, activities, and materials, must include aspects such as age-related changes and strategies to cope with them, the interaction needs and preferences of older adults, the emotions and stereotypes related to learning about and using ICTs, and social support needed for older adults for ICT-learning.

These context-sensitive principles guided the design and implementation of learning facilities to accommodate learners' needs and preferences in a suitable learning intervention to enable older people to use ICT for cognitive activity and social interaction. The next section presents the design process and activities.

4.2.2. DESIGN ACTIVITIES

Based on the detailed results from DBR phases 1 and 2 and guided by the design principles, I designed a learning intervention for enabling older adults to use ICT to 1) stimulate autobiographical memory (ABM) and 2) train executive functions and memory abilities while socially interacting with peers. The learning intervention included classroom "face-to-face" learning activities and online learning activities developed using the Moodle platform (Modular Object-Oriented Dynamic Learning Environment). Table 5 shows a list of learning facilities to accomplish the design principles.

Design principle	**Learning facilities**
Organize the learning activities around interesting topics for older adults	Using ICT devices and applications to implement a reminiscence protocol to stimulate ABM. Working with reminiscence allows older people to share personal stories about their life and share their knowledge; this creates a friendly environment and mutual understanding among participants. ABM also helps to develop identity during the aging process and helps to improve other cognitive abilities (Salazar, 2010) Exploring and using a web-based game application LUMOSITY for training cognitive abilities that decline with age. This combine cognitive training with leisure activities Exploring different ICT devices (computer desk,

	laptops, smartphones, and tablets) and applications (e-mail, virtual learning tools, video-call tools and social networking tools) in order to help participants to develop a wide perspective about ICT potential uses in their life Having a strong focus on ICT tools and applications to support the learning process Implementing a blended learning environment with classroom activities and online activities in Moodle
Encourage individual participation and support a collaborative learning environment	Integrating participants with different level of experience using ICT, and with different socioeconomic statuses and life experiences in common groups. Thus, more advanced users can help less experienced users Having a co-facilitator to support individual's needs while the facilitator is working with the general group Facilitating group work and sharing learning strategies among participants Offering spaces for individual learning sessions when required for participants
Support social interaction and social networking	Having a strong focus on communication and social networking applications such as Skype®, Facebook and Blogger, and using them to share about the learning process Using communication and social networking applications to reflect about the individual learning process (Metacognition) and about the emotions experienced during the learning process Learning to use ICT devices and applications to communicate with family and friends and explore new social networks beyond personal relationships and online learning process

	Promote a climate of trust and understanding
Facilitate spaces to explore and reflect on emotions and stereotypes related to learning about and using ICT as older learners	Including programed spaces and ICT tools to share and reflect about the emotions experienced during the learning process in the activities Acknowledge participants individuality and their individual learning process Bring positive reinforcement to participants´ personal efforts and advances Help participants to understand their personal learning process. Provide a safe place to make errors and experiment
Offer a sustained support system	Offer opportunities to get help on both an individual basis and in a group format Suggest opportunities to get support from family and friends when learning to use ICT Offer online opportunities to get support from peers and facilitators Make learning materials (tutorials, presentations, user guides, etc.) available in different media formats at any time
Provide resources to support declining cognitive abilities	Encourage the creation of personal artifacts to support memory during the learning process, such as notes, drawings, records, etc. Ensure the learning resources are always available in the online platform. Encourage asking questions and multiple rehearsals/repetitions of the learned skills. Facilitate opportunities to apply the learned activities in real settings and make connections with daily life activities.

	Facilitate spaces to reflect about the personal learning process (Metacognition).
Develop a broad perspective concerning ICT and how to match them to personal interests and needs	Provide opportunities to explore different devices (it includes provide the devices if it is needed) Offer opportunities to explore different web applications for different purposes and select what is suitable for them Encourage the development of a wide perspective about ICT resources based in their interests and needs. Support motivation to keep exploring, learning, and using ICT beyond the learning process
Provide a safe learning environment in which participants' experiences and knowledge are respected	Facilitate participants to talk and reflect about their life experiences Encourage them to perceive different personal backgrounds as an advantage for learning Encourage participants to evaluate their own learning process based on their own personal skills, and not by comparison with other participants. Facilitate spaces to reflect about the personal learning process (Metacognition). Provide a safe place to make errors and experiment

Table 5 Set of learning facilities to accomplish the design principles

After defining the learning objectives and facilities, I defined the learning contents related to cognitive abilities and social interaction. They included successful and active aging approaches, cognition and aging (ABM, executive functions, and memory), and social interaction and aging. For stimulating ABM the learning intervention implemented some activities from a reminiscence protocol adapted for Costa Rican older people (Salazar-Villanea, 2010). For training executive functions and memory, participants had access to LUMOSITY (www.lumosity.com), a commercially available online platform that offers cognitive games designed to train attention, flexibility, problem solving, memory, and processing speed abilities. Then I defined the ICT devices and applications and their uses in the learning intervention. Table 6 lists the selected ICT devices and applications and their uses during the learning intervention.

ICT devices / applications	**Uses**
Desktop, laptop, tablets and mobile phones	All the learning activities could be accomplished using any of the selected devices. To facilitate the transfer of the learned skills to daily life routines and environments, participants could bring their own devices to the learning intervention. Desktops and tablets were available at the FOD during the face-to-face learning sessions. For those participants without access to personal devices, the computer labs at FOD were also available during the online weeks. Furthermore, I offered references to community based labs in order to facilitate access to public ICT infrastructure. Mobile devices were included to facilitate incorporating learning activities into daily routines and independence in using ICT devices.
E-mail (Gmail)	The learning intervention included Gmail, as having a Google account is a requirement for creating blogs in the Blogger® platform. Email was used for official communication between facilitators and learners, and informal communication between learners.
Moodle	An online classroom in the virtual campus www.upe.ac.cr served as a repository of learning materials such as the learning intervention program and calendar, and manuals and tutorials in different media formats. Participants also could find guidelines and instructions for the online learning activities. The online questionnaires to evaluate the learning intervention were also delivered on Moodle.
Skype	This telecommunication application was used for online group meeting where participants reflected about the learning process and the personal emotions related to it. Participants also socialized about their life and routines using Skype.
Facebook	Half of the participants used the online social networking platform to share their personal memories from the reminiscence activities and to comment on other participants´ personal stories. These participants also

	shared their reflections on the cognitive online games through Facebook. They also used Facebook to socialize and to consolidate personal relationships with other participants.
Blogger	Half of the participants used the blog-publishing service to share their personal memories from the reminiscence activities and to comment on other participants´ personal stories. These participants also shared their reflections on the cognitive online games through Blogger.
Lumosity	Participants used the online platform to play games aimed at improving memory, attention, flexibility, speed of processing and problem solving abilities.

Table 6 ICT-devices and included in the learning intervention

Finally, I defined specific learning contents, learning tasks, and resources for the learning intervention. Following Coto (2010), McKenney & Reeves (2012), and Wang & Hannafin (2005), I shared and discussed the prototyped learning intervention with an expert in adult education, learning design, virtual learning environments, and problem based learning (PBL) from Alborg University (AAU). She was in charge of designing and implementing e-learning platforms in AAU, dealing with ICT and learning, e-learning, and different platforms supporting learning. She has published in national and international journals within the areas of "Technology Enhanced Learning," "Networked learning," "ICT," "Social Media and Learning" and "e-Learning". Based on the inputs for this reflection and discussion process I implemented some changes in the design. Then, I shared and discussed the final version of the designed learning intervention with the supervisory team of this PhD project and implemented some final changes. See detailed information about the learning intervention implemented in Manuscripts 3 and 4.

4.3. EVALUATION AND TESTING OF THE SOLUTION IN PRACTICE

This section presents two manuscripts under review in peer-reviewed journals and the participants' evaluation that has not been submitted or published elsewhere.

4.3.1. MANUSCRIPT 3: BARRIERS AND SUPPORTIVE FACTORS FOR OLDER ADULTS LEARNING ABOUT AND USING INFORMATION AND COMMUNICATION TECHNOLOGIES FOR SUCCESSFUL AND ACTIVE AGING

The third manuscript is an empirical article submitted to a peer-reviewed journal. In this article, I analyzed video data from the classroom / face-to-face sessions to identify barriers and supportive factors during the intervention for older adults to learn about and use ICT for cognitive activity and social interaction.

Aim of the manuscript: the paper describes in detail barriers to and supportive factors for learning about and using ICT for cognitive activity and social interaction presented during the face-to-face sessions.

Summary: Results from an inductive process of content analysis of 22, 5 hours of video data showed that lack of experience with ICT, particularly gaps in ICT literacy, negative emotions related to the learning process and limited individual support were the main barriers that participants faced for learning about and using ICT for cognitive activity and social interaction. During the face-to-face learning sessions, participants identified as active ICT-users evidenced problems recognizing basic icons and functions such as the on/off, enter, and help buttons. They also experienced problems with usernames and passwords, mainly because they did not know them or did not remember them, and/or they made typing mistakes. Participants also experienced problems transferring knowledge and skills across devices and platforms, and managing technical hitches, such as updating software. The cited difficulties evidenced that most of the participants identified as ICT-users were non-independent users and that for participants being ICT-users had a particular meaning.

Issues related to lack of experience, making mistakes and failures provoked stress, negative perceptions about themselves, and fear in the participants. Due to the lack of experience of participants, sometimes it was not possible to satisfy the demand for individual support and sometimes participants had to wait before getting help. Even though these situations were not common during the learning intervention, they must be avoided, as they might influence participants´ mood and motivation to learn. Peer support was a positive alternative for this limitation.

For overcoming or compensating for these barriers the main supportive factors were: a collaborative learning environment, principally spontaneous peer support, motivation for becoming efficient and independent ICT-users, and the use of learning strategies focused on supporting cognitive abilities and lack of experience with ICT, mainly repetition and practice inside and outside the classroom.

Peer support was the most evident supporting factor, and it refers to the participants' willingness to help each other spontaneously during difficulties. Becoming independent ICT-users was a main motivation for participants, so that the realization of personal progress in the acquisition of new skills gave them satisfaction and a sense of achievement that facilitated perceiving themselves as able to learn, and to balance the negative emotional status previously mentioned. The participants also evidenced a desire for ownership and appropriation of their ICT devices and applications. Finally, the learning activities focused on learning by doing, repetition, and practice (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011; Vroman et al., 2015) allowed participants to learn at their own pace and improve little by little their performance.

It is important to note that due to the constant presence of issues of lack of experience with ICT, it was not possible to distinguish these issues from memory problems, as they can be confused (Sayago, et al., 2013). This fact raises the need for methods and interventions that differentiate these issues from one another and provide specific support for each of them.

In conclusion, the article contributes to the scarce literature about how older adults actually learn about and uses ICT (Sayago et al., 2013) by identifying and describing specific barriers that older people faced during this learning process and supportive factors that helped them cope with those barriers for learning about and using ICT for cognitive activity and social interaction. By providing detailed examples and descriptions, the manuscript identifies aspects to be included in future designs of ICT-learning interventions for older adults.

4.3.2. MANUSCRIPT 4: WILLINGNESS AND PERFORMANCE OF OLDER ADULTS USING INFORMATION AND COMMUNICATION TECHNOLOGIES FOR COGNITIVE ACTIVITY AND SOCIAL INTERACTION

The fourth manuscript is an empirical article under review in a peer-reviewed journal. This paper analyzes the results from the reminiscence activities and the online cognitive games.

Aim of the manuscript: the article sought to describe participant´s willingness to include the cognitive activities in their daily routines, adequateness of ICT applications to support cognitive activity and social interaction, and participants' performance in the cognitive activities.

Summary: Results from the reminiscence intervention showed that participants were willing to recall stories from their personal past and share those using online platforms; they also actively read and commented on other participants' stories. Both used online platforms (Blogger and Facebook) presented similar numbers and

types of stories and resources for text and multimedia to present the personal memories, and both seemed adequate for sharing reminiscences. However, Facebook presented more comments and social interaction. On Facebook, the interaction among participants was more dynamic and unstructured, mixing interactions related to the learning activities but also personal interactions.

Classic content analysis (McQueen et al., 2009) showed that most of the memories shared by the participants presented a coherent and organized structure, they were about childhood, reflected a positive emotional valence, and accomplished the social function of reminiscence-stimulating social interaction, bonding, and intimacy, and promoted positive feelings in the learning groups (Westerhof et al., 2010). The majority of the stories were episodic memories, which indicates that participants made efforts to recall detailed memories and thus stimulated ABM, which is related to general cognitive stimulation, wellbeing and personal satisfaction during old age (Reker, Birren, & Svensson, 2012; Salazar-Villanea, 2010, 2012, 2015).

Most of the participants played the online cognitive games during the intervention and a significant fraction played beyond that period. Even though the number of players decreased over time after the intervention finished, it is remarkable that 11 participants kept playing independently and autonomously during 9 months after the learning intervention. Participants included the cognitive training in their daily life. They improved performance in online cognitive games by repetitive practice.

For study participants' performance on cognitive games, I analyzed the relative differences between when people play the same game several times and which factors might influence this improvement. The results from a linear mixed effect model analysis, with fixed effects for the number of times played, age, education, positive attitude toward technology, and random effects of game and user, showed that the number of times played had a statistically significant effect on performance improvement, whereas factors such as age, education, and positive attitude towards technology did not. These results seem to support findings of the positive effects of online games for enhancing cognitive abilities in healthy older adults (Anguera et al., 2013; Ballesteros et al., 2014, 2015, Nouchi et al., 2012, 2016; Rebok et al., 2014). The group that played more improved more. It can be concluded that participants learned how to solve the cognitive tasks of the online games regardless of their socioeconomic status and attitude towards technology. Therefore, this type of cognitive training seems suitable for older adults from several socioeconomic and cultural backgrounds.

Regarding social interaction derived from the online cognitive training, participants shared and commented on their impressions throughout both platforms (Facebook and Blogger), but the feedback was more dynamic on Facebook.

In summary, the results showed that older adults are willing and able to incorporate ICT in their daily life environments for cognitive activity and social interaction. The online platforms used were suitable for older adults to perform cognitive activities and engage in social interaction. However, social and cognitive training platforms need to adjust their features to older users, and current older adults need formal instruction in order to understand a platform´s features. Participants shared episodic memories, exercising different autobiographical memory abilities and accomplishing the social function of promoting social interaction and openness to personal relationships. The most important factor for improvement in cognitive games was practice. Studies with similar results have also found improvement in trained cognitive abilities.

4.3.3. PARTICIPANTS´ EVALUATION OF THE LEARNING INTERVENTION

During the learning intervention, the participants evaluated the contents, activities, and resources of the learning intervention and their main results as learners. They completed two online questionnaires delivered on Moodle using the platform Survey Monkey® with ten questions each.

4.3.3.1 Mid-term evaluation questionnaire

This questionnaire included questions about learning contents and activities, learning strategies, and usefulness of the learned skills in daily life. The participants completed the questionnaire at the end of the classroom sessions. Thirty-eight participants, 19 from groups 1 and 2—who used Facebook—and 19 from groups 3 and 4, who used Blogger, answered the questions in the classroom as a learning activity to get familiar with online questionnaires. Here is a selection of relevant questions to grasp participants' opinions of the learning intervention. Table 7 shows the three most important learning contents for the participants.

Order	Content	# of participants	%
Groups 1 and 2			
Most important content	Online classroom in Moodle	9	47.37
2nd most important content	Skype	6	31.58
3rd most important content	Lumosity	5	26.32

Groups 3 and 4			
Most important content	Email /Lumosity	6 each	31.58 each
2nd most important content	Online classroom in Moodle	5	26.32
3rd most important content	Reminiscences / Skype	4 each	21.05

Table 7 Most relevant learning contents for participants

Out of seven options, the online classrooms in Moodle, Skype, and Lumosity were among the most important learning contents for all participants. This selection reflects the participants´ interest in learning processes, as their experience with an online classroom in Moodle opened to them the possibility of attending new online learning experiences. The selection of Skype as a central content reflects the participants' need for social interaction, as the application emerged as a balanced option between face-to-face interaction and ICT mediated communication. Selecting Lumosity as a relevant content shows the participants' interest in understanding their aging process and coping with changes related to age. These results align with findings in manuscript 3 and 4, which refers to participants' motivation for learning, the relevance of including content focused on supporting cognitive abilities that decline with age and participants' willingness to include cognitive activity in their daily routines. Participants from groups 3 and 4 also included reminiscences and e-mail as relevant contents, which confirm the participants' inclination toward social interaction and cognitive stimulation.

Table 8 shows the ICT applications and features that the participants intended to include in their daily life after finishing the learning intervention.

ICT-application	**# participants**	**%**
Skype	37	97.37
Lumosity	34	89.47
Email	32	84.21
Mobile devices' camera to make photos and	32	84.21

videos		

Table 8 ICT-applications that participants would use in their daily living

Out of seven options, the participants selected ICT-applications that supported social interaction and cognitive training. A lower percentage were willing to use the online classroom, 76.32% mainly because they did not know opportunities to engage in online learning process, Facebook or Blogger, 71.05%, and to share reminiscences, 34.21%, after the intervention. As most of the participants did not have previous experience with Skype and Lumosity, their interest could be related to novelty. It could be also the case with email, as before the learning intervention they were not using it independently (See manuscript 3). On the other hand, Skype offers a balance between online interaction and face-to-face interaction, which, as mentioned in manuscript 2, is a requirement for participants to engage in ICT-mediated social interaction.

Table 9 shows the most frequent difficulties faced by participants during the learning intervention.

Difficulties	**Frequency**
Problems with usernames and passwords	13
Problems accomplishing learning activities or using specific ICT-applications	12
Personal issues	5
Having a good performance in online cognitive games	3
Quality of the Internet service	3
Do not have personal ICT-devices for practicing at home	2
None	2
Transferring knowledge and abilities across ICT-devices and applications	1

Table 9 Most frequent difficulties faced by participants during the learning intervention

From an open question, it was possible to group participant answers in the previous seven categories. Thus, the most frequent difficulty cited by participants was problems with usernames and passwords. This referred to different aspects such as forgetting the information:

"When logging in into the online classroom, I did not remember the password and I had to request a new one several times", (Female, 60 years).

"Remembering usernames and passwords, because I am a very disorganized", (Male, 74 years).

Problems with usernames and passwords also reflected difficulties understanding how ICT-applications work:

"The most frequent difficulty was logging in into the applications, because it is difficult to understand that all of them need different usernames and passwords", (Female, 72 years).

"Frequently, I confused the usernames and passwords across applications" (Female, 63 years).

These answers support the findings in manuscript 3 and reinforce the difficulty of distinguishing whether these problems relate to cognitive abilities' decline or to lack of experience with ICT.

The second most frequent difficulty referred to problems with specific ICT-applications, and the most common was problems creating and posting in a blog, as participants in groups 3 and 4 had no previous experience with blogs. Personal issues referred to time limitations because of multiple activities, and health or/and family issues. Having a good performance in online cognitive games referred to difficulties achieving higher scores on cognitive games (See manuscript 4). Since in Costa Rica, there are internet services of different quality and the quality is often lower outside of the capital city, some participants experienced problems with the service during the learning intervention. Two participants did not have personal ICT-devices and the alternative resources such as public libraries did not work as expected. These participants went to public libraries and there were available devices, but not the support to use them, which limited their opportunities to practice outside the classroom. Two participants reported they did not have difficulties, and one participant reported being confused when he/she had to change from one learning activity and/or ICT-application to another. It is important to note that the main difficulties reported by participants agreed with those identified in the video-observations (see manuscript 3).

In sum, besides difficulties related to lack of experience with ICT and cognitive ability decline, participants reported difficulties associated with their daily life and living environments such as a busy life style, multiple family responsibilities, and problems with the internet in their living areas.

Finally, the participants indicated the most important lessons derived from the learning intervention. Table 10 shows the participants' answers for this question.

Learnings	**Frequency**
Discovering their abilities for learning / recovering motivation for learning and sharing knowledge	12
Gaining self-confidence to interact with ICT	11
Using specific ICT-devices and applications	10
Training cognitive abilities	8
Sharing with peers and facilitators	7

Table 10 Most important learning according to participants´ perspective

From an open question, I grouped participants' answers into five categories. Results revealed that for many participants discovering their capacity as older adults of learning new subjects and skills—not just related to ICT-use—was the most important thing learned during the process.

"I have been afraid of technologies for a while. I thought I could not learn how to use them. Now I am happy and I like technologies, and I like all we can do with them to have a better life, better communication, and to get new knowledge", (Female, 74 years).

Interacting with ICT offered the participants the opportunity of gaining self-confidence to learn about and use ICT in the future

"Overcoming the fear to use the computer and knowing that I am able to learn and practice what I have learned in the course", (Male, 67 years).

Using specific ICT-devices and applications referred to preferences of the participants; some of them considered playing online cognitive games to be the most important thing they learned, others mentioned learning how to use Skype, etc. Training cognitive abilities referred to learning about age-related changes in cognitive functioning, and resources to cope or prevent them. Finally, for some participants the most important thing learned was to share with new people and use ICT-applications for social interaction.

4.3.3.2 Final-term evaluation questionnaire

This questionnaire explored aspects such as participants´ learning strategies, support resources for learning, and suggestions for improving the learning intervention. Thirty-four participants from the four groups completed the online questionnaire in their living environments after finishing the learning intervention.

When participants faced a difficulty during the classroom activities, the two most important strategies to cope with it were "reading my notes in my notebook" and "asking the course´s facilitators", 97.06% each. In addition, 50% of the respondents affirmed that they "tried to understand and to solve the problems by themselves" and 47.06% "asked for help from another participant." The answers reflected that participants relied on their own notes as a learning resource, as observed in manuscript 3. Notebook notes were as important as teachers´ help, and a combination of both allowed participants to progress during the learning intervention. Fewer than 50% of participants reported asking for peers´ help. However, most of the time peers offered their help spontaneously (see Manuscript 3).

Table 11 shows the strategies implemented by the participants to solve difficulties during the online activities.

Strategy	**# of participants**	**%**
Asking help to a relative or friend	19	55.88
Reading or watching the learning resources on the online classroom	19	55.88
Asking help to another course´s participant	10	29.41
Waiting until the next classroom session and asking the facilitators	9	26.47
Booking an individual work session	8	23.53
Do not complete the online activities	5	14.71
Calling the facilitators by phone to ask help	3	8.82
Sending an email or message asking for help	3	8.82

Table 11 Reported strategies for solving difficulties during online weeks

From the eight answer options offered, asking for help from relatives and friends and consulting the learning materials on the online classroom were the most important for solving difficulties at home, which evidenced that participants perceived the online materials as valuable resources for supporting learning. Most of the participants made an effort to complete the online activities and just five of them decided do not complete the activities and avoided to face the difficulties. Finally, less traditional ways of learning support such as phone calls and ICT-mediated communication were the less implemented strategies for asking help.

Regarding the social support from family and friends received for learning about and using ICT, 27 participants evaluated the help as effective, "relatives/friends helped them and they could do what they wanted" (79.41%), while three participants reported that they "received help but they could not do what they wanted," and therefore the help was not effective. Two participants reported that they "did not receive help because their relatives/friends did not have time to help them" (5.88%), and one participant reported that they "did not receive help because his/her relative or friend did not have the knowledge to help him/her". Finally, one participant reported that his/her relative or friend "was not willing to help him/her." These results seem to indicate that when older adults have structured help requests for using ICT, relatives and friends are more likely to bring appropriate support to complete the activities.

However, four participants faced limitations in getting help from their social networks during the learning process. These results align with manuscripts 2 and 3 in pointing out that social support from family and friends is a key factor for older adults learning about and using ICT, and needs to be strengthened and supported during ICT-learning interventions targeted to older adults.

Table 12 summarizes participants´ suggestions for learning material.

Learning materials	**Frequency**
No other learning materials are needed	12
Printed material (book, printed cards, booklet)	7
Personal ICT-devices	6
Others (more time, more multimedia resources)	3

Table 12 Participants´ suggestions for learning materials

Most of the participants opined that the learning materials were enough to accomplish the learning activities and reach the learning goals, and they also appreciated the materials available in the online classroom:

"I think you brought us all the needed material. Having access to the online classroom was a big help", (Female, 74 years).

The participants that suggested printed material wanted to have physical material to read it as much as they needed, use this material after the intervention, and use it for asking help from family and friends:

"A booklet with all the information and procedures would be useful in the future, after the course, if you have doubts" (Female, 63 years).

The need for learning material seems to relate to personal preferences, but not to age, as most participants were satisfied with digital material regardless of their age. Six participants considered that having some personal ICT-devices at home could facilitate the learning process; this relates to difficulties using public infrastructure mentioned in the mid-term questionnaire.

Table 13 shows participants´ suggestions for additional support resources for future learning interventions.

Support resources	**Frequency**
No additional support resources are needed	14
More course hours and practice hours	9
Printed learning materials	4
Other (Personal ICT-devices, individual sessions, a third facilitator)	3
No response	3

Table 13 Suggestions for support resources for learning interventions

From an open question, most of the participants positively evaluated the supporting learning resources offered during the learning intervention; they mainly referred to the facilitator's availability to answer their questions and to support them to accomplish the learning activities. The second suggestion refers to have more learning sessions or more hours each session. The participants also commented on the need for more supervised practice so they could ask for as much help as they

needed. Other suggestions are similar to those described for the learning materials suggestions. Finally, three participants did not offer any answer.

For participants, support from family and friends was an important factor for learning about and using ICT, and they have many complaints in this regard, as shown in manuscript 2 and 3. However, they did not mention family/friends' support as a required or desired support resource, which could reflect that they perceived the ICT-learning process as an individual task which did not involve their personal networks. This could be related to experiences or stereotypes about older adults' learning, as they were mentioned in manuscript 2 and 3.

Finally, participants offered the suggestions in Table 14 for changes in the learning intervention.

Suggestions	**Frequency**
No changes are needed	18
More course hours and practice hours	9
An intervention for different ICT-user levels (beginner, intermediate, advanced)	2
A continuation course	2
Others (an informative meeting, more breaks during the classroom activities, more advice on privacy and security online, more supervision on assignments and tasks)	4
No response	1

Table 14 Suggestions for changes in the learning intervention

The personal opinions from participants reflected that most of them were satisfied with the learning intervention, evaluated the experience positively, and reported there was no need for changes. The most important suggestion was having more time, as described in the previous question. The participants suggested implementing the intervention according to different ICT-user profiles—beginner, intermediate, and advanced—as a strategy for saving time and progressing in a similar rhythm. In this way, nobody would be left behind. A continuation course referred to a new and complementary learning intervention to consolidate the learned skills and to learn new content and skills.

Summarizing, participants' evaluation showed that they found the learning contents, activities, materials, and support resources offered during the learning intervention relevant to their daily living. They evaluated the learning process and the knowledge and abilities acquired as meaningful and useful for their aging process, social interaction with families and friends and for lifelong learning. The main difficulties for learning about and using ICT for cognitive activity and social interaction were aspects related to lack of experience with ICT.

From participants´ perspective, the main benefits of the intervention were discovering their ability to learn and/or recovering motivation for learning and sharing knowledge, and gaining self-confidence to interact with ICT. Most of the participants positively evaluated the learning materials and support resources offered by the learning intervention. However, some of them suggested printed material such as a book or booklet for supporting the learning process, and more classroom hours and practice hours to consolidate the learned skills.

CHAPTER 5. DISCUSSION

From my understanding of the DBR framework, phase 4 ("Documentation and reflection to produce the final design principles") and phase 5 ("Dissemination and adoption in broader contexts") allow discussion and reflection upon the findings and scope of the research project. Regarding phase 5, the discussion is built upon the research´s empirical findings and methodological and theoretical considerations, thus presenting a set of refined design principles. Concerning phase 5 also, the discussion deals with the potential of the designed learning intervention to be implemented in broader contexts.

5.1. DOCUMENTATION AND REFLECTION TO PRODUCE THE FINAL DESIGN PRINCIPLES

This phase developed along the research process. Accordingly, I shared, reflected upon, and discussed the preliminary design principles, learning intervention design, and data from implementation and evaluation with my advisor team, external experts, and research collaborators. This continuous process of reflection and discussion led to identifying possible improvements to the designed learning intervention and to refinement of the design principles. However, reporting all these activities can be overwhelming. This section, then, presents the relevant aspects derived from study participants´ reflections on the research process and the learning intervention, and my own reflections on the results (described in the Results chapter). Three sections comprise the discussion: Empirical findings, Methodological considerations, and Theoretical implications. Finally, there is a set of design principles refined during the reflection process.

5.1.1. EMPIRICAL FINDINGS

5.1.1.1 Participants´ evaluation and reflection workshops

Due to limitations of time and resources, it was not possible to have more iterations of the learning intervention. However, during the implementation period, micro-cycles of analysis and refinement (Sandoval, 2004) were applied to provide a better adaptation of the learning intervention to the participants and create a positive learning environment. Micro-cycles (for example, daily) of analyses allowed changes to the intervention as it occurred; these were followed by retrospective analyses (Sandoval, 2004). As part of these analyses, participants reflected, discussed, and agreed on possible modifications for improving the learning intervention.

In June 2017, 13 months after the learning intervention was completed, 24 participants out of 38 who finished the intervention participated in two evaluation and reflection workshops (90 minutes each). From the four groups of the learning intervention 12 participants from groups 1 and 2 worked together in workshop 1, and 12 participants from groups 3 and 4 worked together in workshop 2. The activities were the same in both workshops.

During the workshops, I presented five possible changes for the learning intervention derived from the data analysis results and participants´ suggestions in questionnaires 1 and 2 (see Section 4.3.3, "Participants´ evaluation"). The participants in small groups of three or four members discussed the changes and expressed their level of agreement with them and their own suggestions. Each small group was asked to write on posters their negotiated agreement (they had the opportunity to express individual opinions on Post-it notes on the group poster). After that, there was plenary time to share the answers of the small groups and try to reach a general agreement on each change. In the second part of the workshop, the facilitator presented the main results from the interviews and focus group (Manuscript 2) and from reminiscence activities and online cognitive games (Manuscript 4). Then, the participants had the opportunity to pose questions and offer comments on the results.

Below I present the five proposed changes stemming from the discussion and agreements reached in the workshops. These changes are derived from the data analysis process, the results presented in the previous section of this thesis, and from participants' evaluation of the learning intervention.

Change 1: Grouping participants by ICT-user level (beginner, intermediate, and advanced)

This change must include the design and implementation of a performance "test" to identify the actual ICT-user level of the participants (Manuscript 3 addresses some details regarding these concerns). In workshop 1, one small group did not support the change; they argued that mixing different people with different ICT-user levels offers opportunities for collaborative learning and group integration. However, they also pointed out some disadvantages: 1) more advanced ICT users could be bored at the intervention, and 2) it takes time to help beginners reach the required level. At the personal level, some participants remarked, "Who knows more can help more".

Other groups supported the change, arguing that learners from each level would receive what they needed, starting from level 0 (basic knowledge) to the advanced level (more complex and new needs). At the personal level, beginners perceived it as an advantage to learn with people with the same needs and requirements. However, they identified some disadvantages as well, such as do not have the opportunity of learn from more advances classmates and do not have challenges to reach other

participants´ ICT-user level ("Do not learn from more advanced classmates" and "Am not challenged by reaching other classmates' level"). After the discussion, the general agreement was to mix people from different levels, but to identify specific functions or roles that allowed advanced users to help their classmates (thus preventing possible boredom).

In workshop 2 the participants supported the change. They mentioned various advantages (e.g. starting from the beginning would allow a good basis for the learning process). They also said advanced groups could progress faster, and that separation could prevent beginners from being stressed about trying to reach other classmates' levels. They also remarked that one possible disadvantage could be not receiving help from more experienced classmates. At the personal level, one beginner wrote, "In an advanced group we built weak knowledge, because our bases are not good".

Both general groups perceived that grouping participants in different levels presents advantages for both beginners and active users. The beginners can avoid stress and pressure, and advanced ICT users can progress faster. However, both groups recognized the relevance of having advanced ICT users supporting the learning process of beginners. Both proposed solutions lead to practical considerations first, designing appropriated tools to identify the participants´ ICT- user profile as discussed in manuscript 3 and second, defining roles for advanced learners in mixed groups.

Change 2: Excluding computers (laptops and desktops) and focusing on mobile devices

All the six small groups from workshops 1 and 2 supported the change. They argued that, nowadays, mobile devices allow accomplishing all the activities of the learning intervention and facilitate learning and practicing at any place and moment (ubiquitous learning). Further, older adults are more familiar with smartphones and tablets than with computers. As possible disadvantages, they mentioned that the screen size could be a limitation for people with impaired vision or hearing or motor problems such as Parkinson disease or arthritis. At the individual level some participants commented, "I like my computer because it is big and I can print", "On my smartphone the keyboard is uncomfortable and memory is always full", "There are some problems with the Internet on mobile devices", "Some people do not have mobile devices, the institution can facilitate them during the course". These disadvantages referred to design features such as screen and keyboard size, technical and infrastructural issues such as the quality of Internet services from different mobile networks, and to partial knowledge related to ICT (e.g. it is possible to print information from mobile devices as well and there are procedures to optimize memory features on mobile devices). Finally, a limitation referred to socio-economic and/or cultural factors, as some older adults cannot afford to buy mobile

devices or because they do not consider mobile devices necessary or useful. Designers need to consider all these aspects in future designs and implementations.

Change 3 had two alternatives. The first option proposed focusing on Facebook for interacting, sharing learning materials, and accomplishing cognitive activities; this implies not using Moodle as a repository for sharing learning materials. Similarly, it implies not using Blogger for sharing personal memories or social interaction around the stories or for sharing personal experiences about online cognitive games. Thus, Facebook would be the main platform used in the intervention. The second option proposed concentrating the cognitive activities (sharing and commenting on personal memories and experiences in online cognitive games) into Facebook and keeping Moodle for sharing learning materials and learning activities. These changes also proposed including social interaction on Moodle through blogs, forums, and chats.

In this case, participants had to choose an option and defend their selection. In workshop 1 the three small groups chose to keep the use of applications as the study was implemented. They argued that learning about several ICT platforms and using them for specific purposes would keep them, as users, updated and active. It also would provide the opportunity to have cognitive stimulation (as they must process more information and use each platform correctly). They also argued that the online classroom in Moodle is a private space; further, it conveys a sense of classroom. As well, learning how to navigate on Moodle opened participants to new possibilities for engaging in other online learning opportunities. As a disadvantage, they remarked that because of age they could forget or confuse information about the different platforms. However, participants concluded that, though they faced many challenges learning new contents, they overcame such difficulties (and thus perceived themselves as successful learners). At the individual level, some participants suggested, “Deepening the different functions of each application”, and “incorporating WhatsApp into the learning intervention”.

In workshop 2, the three small groups supported the change. These participants used Blogger instead of Facebook. They mentioned that a closed group on Facebook would allow having all the materials and interactions in one application, thus keeping privacy and maintaining a sense of cohesion. Moreover, most of the participants reported being familiar with Facebook. With this change, they would need to remember only one username and one password. From the individual perspective, one participant expressed that she was not interested in having a Facebook profile, mainly due to privacy issues. As detailed in Manuscript 3, it is important to know the Facebook user´s profiles of the participants, to match the learning contents and activities to the appropriate level. On the other hand, it is also necessary to consider online privacy and security issues in posting learning-related content.

The participants in both workshops presented different ways of approaching ICT learning. Consistent with the SOC model (Baltes & Baltes, 1990; Freund & Baltes, 1998) older adults in workshop 1 reflected an optimizing strategy aimed to enhance the learned skills throughout deeper understanding and practice, whereas participants in workshop 2 evidenced selection and compensation strategies selecting contents that are more familiar and compensating memory abilities by reducing the amount of information to memorize. In both cases, the goal is adaptation to the old age. Nevertheless, it is important to recall, regarding ICT learning, it is difficult to distinguish between lack of experience with ICT and decline in cognitive abilities (Manuscript 3). Therefore, the design of this type of intervention must achieve a balance of adaptive strategies while offering participants some opportunities to select and optimize relevant skills for their development and implementation in daily life.

Thus, the learning intervention could exclude personal blogs, as they did not generate as much social interaction as does Facebook. Similarly, blogs seemed not useful for participant's daily life (see Manuscript 4). However, the skills to navigate online classrooms on Moodle could be useful for lifelong learning processes; in this regard, they contribute to ongoing personal development and support successful and active aging. These aspects must be considered when implementing the proposed changes.

Change 4: Providing more activities in pairs or small groups outside the classroom

The six small groups in both workshops supported this suggestion. They remarked that more activities in pairs or small groups would offer opportunities for improving skills using online interaction tools such as Facebook and Skype. In their regard, it would be useful to practice new skills and thereby improve communication and social interaction with peers. Participants preferred to work in groups (maximum four people) to be sure they could practice even if one or two members were unable to attend the session. As possible difficulties, they mentioned problems with accessing electronic services, particularly the cellular network.

Change 5: Providing printed learning materials

All small groups agreed on including printed learning material. Discussing their participation in the creation of their own learning material, the participants agreed on having a semi-structured guide/booklet with basic information and blank spaces to represent their own understanding of information and instructions. They conceptualized the booklet as a detailed guide they could customize. Some suggestions for the booklet´s contents included: 1) step-by-step procedures for operating ICT devices; 2) basic functions and icons of ICT devices; 3) information on each ICT application such as names and pronunciation, features, and icons; 4) step-by-step procedures for using ICT applications; 5) diagrams or illustrations of

step-by-step procedures; 6) spaces to create one's own step-by-step guide, 7) spaces to write notes and memory aids; 8) spaces to write doubts and questions; 9) exercises or practices and spaces to write the results of these practices; 10) information about online privacy and security; 11) spaces for writing usernames and passwords; 12) spaces to register the processes and results of team work; and 13) spaces to create memories about the learning process (phone numbers of classmates, pictures, anecdotes, etc.).

To be effective, the booklet must be written in plain and simple language and follow the same order as the classroom and online activities; also, spaces for customization must offer instructions or guides to be completed. From an individual standpoint, six participants would prefer a digital guide, accessible from any mobile device. The participants ultimately agreed that each person could choose to have a digital or printed guide. The relevant concern is that it contains all information needed to support the learning process. Participants´ suggestions sought to acquire and consolidate new knowledge and to compensate for cognitive abilities they perceived as declining.

Participants' agreements and suggestions showed: 1) their willingness to continue learning and using ICT for cognitive activity and social interaction; 2) their interest in learning strategies to cope with lack of experience with ICT and address age-related changes in cognitive abilities; and 3) their enthusiasm for gaining mastery over ICT usage. Their suggestions particularly reflected their need for independence and mobility when interacting with ICT, the need to balance different strategies for adaptation to changes in their learning process during the aging process, and their interest in social interaction and collaborative learning.

5.1.1.2 Findings from the manuscripts

5.1.1.2.1 Sociodemographic and ICT-user profile of the study participants

The research project found that few older adults in Costa Rica were using ICT at the time the study was conducted (Castro et al., 2016). However, most of the study participants were active ICT users and fit the profile of ICT users in the population; non-users in our study also shared the same profile as non-users in the general population. In contrast to the general population, not only were most of the participants active ICT users, their socio-demographic characteristics indicated that the digital divide also relates to socio-economic factors and socio-cultural backgrounds. Socio-cultural backgrounds might help elucidate the gap between access and usage in Costa Rican older adults.

Most of the study participants were using mobile ICT devices for social interaction and leisure activities. Based on their self–reports, they could be located in the first level of ICT adoption according to Vroman and co-workers' (2015) model. Nevertheless, as the research advanced, findings showed that they were non-independent users: Even into the first level of the Vroman et al.´s (2015) model, they relied on only basic features of ICT devices and applications. Thus, participants were not ready to progress to the next levels of model (see Manuscript 3).

These findings raise several challenges for the design of learning interventions aimed at enabling older adults to learn about and use ICT for supporting successful and active aging. First, the results suggest the need for interventions that will assist in using ICT for lifelong learning and performing instrumental tasks in daily living. This means moving in a continuum from basic uses to advanced levels of ICT use, corresponding to "learning as activity" in Ala-Mutka and colleagues' (2008) model and "virtual community" in Vroman et al.'s (2015) model. These learning interventions must be continuous in older adults' daily lives and occur over long periods of time (thus responding to the characteristics of lifelong learning processes (Commission of the European Communities, 2001).

Second, the findings present a challenge in terms of defining access to ICT devices and applications among older adults. Since data from the last Costa Rica National Census 2011 showed that just 50% of older adults with access to ICT were using such devices, it is appropriate to question access relative to ownership or availability of ICT devices and applications in the daily living environment. This project argues that ICT access must include access to the benefits of using ICT (Czaja et al., 2006; Czaja & Sharit, 2012) for social interaction, instrumental activities and learning, among others aspects. This posture would lead to the discussion of the role of societies and social networks to facilitate and support older adults accessing those benefits.

Third, the findings also lead to problematize the concept of ICT use among older adults since as detailed in Manuscript 1 and 3 most of the participant reported as active ICT-users tended to be passive consumers of information and did not take advantage of ICT potential for interacting, producing and sharing information (Castro et al., 2016). Furthermore, they were non-independent users and presented important gaps in basic ICT literacy. Evaluating to what extend older adults ICT-use satisfies their needs and interests might be a parameter to conceptualized ICT-use among older adults. In this study, ICT-use by participants did not satisfy their needs and interests as they wanted to be active in several areas, become independent users, and include ICT in their daily environments (See manuscript 3 and 4). Another important discussion that must be carried out is whether current ICT use by older adults facilitates social participation and social inclusion, as defined by WHO (2002). The current findings indicated that social participation facilitated or mediated by ICT is limited to communication with family and friends, and that older

adults are not independent performing these activities. Thus, a main challenge is to promote higher levels of social participation in different social domains; an alternative to this is facilitating the progression of ICT adoption by older adults through the different levels proposed by Vroman and colleagues (2015).

Fourth, another relevant challenge is ensuring that most older people can enjoy the benefits of ICT. This implies reaching the majority of older people in Costa Rica who have primary school education and medium to low income. It also includes involving in these processes older adults living in rural areas and presenting some disability. To address this challenge it is necessary to involve government institutions, civil society organizations, communities, and families. Using public ICT-infrastructure effectively and creating community-based learning opportunities suitable for specific groups of older adults implies a whole range of future research to create learning opportunities that fit this population's needs and interests.

Finally, study participants and the general population of older adults reported lack of suitable learning opportunities and inadequate learning environments (Castro et al., 2016; PROSIC, 2010) as main barriers to learning about and using ICT. These findings reinforce the call to societies to facilitate older adults' enjoying the benefits of ICT. At the same time, the findings urge the recognition of characteristics and interests of different groups of older adults and the need to create suitable learning interventions. As shown by this research project (see Section 4.3.3, "Participants´ evaluation"), including older adults in different phases of the design process might be a valid strategy to create compatible learning interventions (that enable older adults to use ICT for supporting successful and active aging).

5.1.1.2.2 Widening the scope of ICT learning interventions aimed at facilitating the use of ICT for supporting successful and active aging

Research findings showed that the design of ICT learning interventions aimed at supporting successful and active aging, besides including traditional aspects such as format, content, activities, and materials, must focus on other factors related to the learning process. These include age-related changes, emotions related to learning, stereotypes related to older adults and ICT learning, and social supports needed for ICT learning by older adults (see Manuscripts 2 and 3).

The present research project expanded upon previous research on barriers for older adults learning about and using ICT (Ala-Mutka et al., 2008; Czaja & Sharit, 2012; PROSIC, 2010; Sayago et al., 2011; Vroman et al., 2015). It also focused on identifying and describing negative emotions related to this activity by older adults. In this regard ICT learning, for the study participants, was marked by fear and shame. During the research process, participants evidenced fear of damaging the

equipment and the consequences of this, they expressed shame about asking questions, making mistakes, and being "slow" learners (see Manuscripts 2 and 3). Thus, including emotions related to the learning process as learning content, and identifying structured and unstructured spaces and activities to reflect and work on them, was a useful strategy to facilitate learning and make progress across the learning intervention. Analyzing the causes and reactions to these emotions allowed to the participants to manage them and achieve their learning goals.

When analyzing negative emotions, they related to stereotypes about older adults and older adults and ICT learning, negative ICT-learning experiences, and unappropriated family and friend support for ICT learning. Reflecting on these issues allowed the study participants to: 1) achieve a balance between the negative issues and their personal characteristics and coping strategies; and 2) find the motivation for becoming successful learners and independent ICT users. Group reflections also enabled the sharing of common experiences and validation of negative emotions.

Another aspect that facilitated coping with negative emotions was including learning content on age-related changes. As stated in Manuscript 2, the study participants perceived some changes in their learning process, but did not appear to understand the nature of those changes. Learning about and discussing "normal" aging and cognitive decline might facilitate understanding of and adaptation to age-related changes in learning.

In this regard, during the learning intervention, it was not possible to distinguish between difficulties related to a decline in cognitive abilities and those related to lack of experience with ICT (see Manuscript 3). Although before the learning intervention 40% of initial participants identified memory and attention decline as a major barrier for learning and using ICT, this was not the case during the learning intervention and the activities aimed at evaluating the learning intervention. In the latest phases, participants did not identify cognitive decline as a barrier, but they did identify lack of experience with ICT as a deterrent to learning and using the technology (see Manuscript 3 and Section 4.3.3, "Participants' evaluation"). Sayago et al. (2011, 2013) concluded from their longitudinal study that difficulties related to lack of experience with ICT could be overcome with time and practice, but difficulties related to cognitive decline could be time-persistent. More research is needed to distinguish difficulties associated with cognitive decline from those related to lack of experience with ICT, and to develop resources to cope appropriately with both types of issues. In this project, learning by doing, repetition and practice (McKenney & Reeves, 2012) and the availability of learning material seemed to be effective in promoting learning and the inclusion of ICT in daily routines and environments (see Manuscripts 3 and 4; Section 4.3.3, "Participants´ evaluation").

Finally, negative emotions stemmed from inappropriate social support from family and friends for learning about and using ICT. During the research project, the participants complained that their relatives, particularly their children, did not have time or patience to teach and help them to use ICT. Previous research on ICT learning and older adults did not deal with the role of close social networks. The literature in the field (Ala-Mutka et al., 2008; Czaja & Sharit, 2012; Sayago et al., 2013, 2011; Vroman et al., 2015), for example, has identified social support as a key factor in older adults learning about and using ICT. However, the references to this aspect are brief and general, and research on how societies can support such learning is scarce. This is a sensitive issue from the perspective of active aging (WHO, 2002), considering the potential of ICT to support the realization of individuals´ potential for physical, mental, and social well-being, and the key role of societies in supporting adaptation during the aging process.

This aspect notes the necessity of working in communities and societies to create adequate conditions and opportunities for promoting successful and active aging, in this case, using ICT. From the perspective of (Featherman et al., 1990) it raises the question on how societies are adjusting and can adjust in the future to support older adults' ICT learning and use for successful and active aging. Then, the need to elicit proper social support from older adults´ ICT-learning emerged as a topic that requires further research.

5.1.1.2.3 Potential of the designed learning intervention for supporting successful and active aging by enabling older adults to use ICT for cognitive activity and social interaction

The implemented DBR strategy seems to be appropriate for including older adults and adult educators' perspectives in the creation of suitable learning interventions to enable older adults to learn about and use ICT. Participants shared their experiences, fears, expectations, and suggestions for working with the technology (see Manuscripts 2 and 3), whereas adult' educators complemented that information with references about their professional experience and suggestions for designing the learning intervention. The proposed design principles derived from phase 1 of the DBR process allowed the design of learning facilities, design propositions, learning contents, and learning tasks and resources that fit the individual needs and interests of the participants (see Manuscripts 3 and 4; Section 4.3.3, "Participants´ evaluation"). Some key aspects of the designed learning intervention to engage participants in learning about and using ICT are as follows:

1) As stated in previous studies (Ala-Mutka et al., 2008; Commission of the European Communities, 2001; Sayago et al., 2013, 2011; Thompson & Foth, 2005; Vroman et al., 2015), the participants´ perception of the benefits of the learning outcomes guided their openness and willingness to engage in the learning

intervention and include ICT in their daily life. For the present study, the perceived benefits included participating in a long-life learning experience, including ICT in their daily life environments, participating in cognitive training process to buffer cognitive decline, and interacting socially with peers. Participants also perceived the learning intervention as an opportunity for becoming ICT independent users.

2) Through implementation of several opportunities for practicing the learned skills in older adults' daily environments and the availability 24/7 of learning materials online, the learning intervention supported cognitive abilities that decline with age and, as well, facilitated older adults becoming independent ICT users. Practicing outside the classroom allowed participants to control such aspects as location, schedule, and length of the practice. They also had sufficient flexibility to combine learning activities with daily life activities (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011). Finally, using their own mobile devices allowed mobility and facilitated appropriation of participants' own ICT tools (see Manuscript 3 and 4).

3) Working with reminiscence-facilitated participants' communication of their own life knowledge and experiences allowed them to share mutual and individual experiences framed in a common historical period. Furthermore, sharing personal reminiscences stimulated social interaction, bonding, and intimacy, and promoted positive feelings in the groups (Westerhof et al., 2010). This generated a positive learning environment and increased social bonds among the participants (Reker et al., 2012; Salazar-Villanea, 2015; Westerhof et al., 2010). As well, reminiscing exposed the participants to potential benefits such as stimulating language functions; promoting openness to personal relationships; supporting identity, self-esteem, and continuity; and validating personal knowledge (Gibson, 2004; Spector et al., 2011, 2010; see Manuscript 4).

4) Training cognitive abilities by playing online cognitive games combined learning, training, and leisure activities (Ala-Mutka et al., 2008). Therefore, participants found training to be a fun and enjoyable experience. Participants included cognitive training in their daily routines and improved their performance by repetitive practice; these results align with previous studies that also found improvement in trained cognitive abilities (Ballesteros et al., 2014, 2015, Nouchi et al., 2012, 2016; Rebok et al., 2014). Given these findings, online cognitive games might have significant potential to maintain and improve cognitive abilities that generally decline with age.

5) The learning intervention was responsive to older adults' learning needs; it was adjusted on a daily basis (Sandoval, 2004) according to older adults' performance and emotional status. Having spaces to talk and reflect on negative emotions and stereotypes allowed participants to be aware of them, validate each other's experience, receive support from peers and facilitators, and find some strategies for coping with them. By participants sharing these experiences, they became common

activities that were included in the learning intervention and into daily work in the classroom and online. By reflecting on their personal performance and previous learning experiences during the learning intervention, participants experienced a sense of achievement and gained motivation for learning about and using ICT (see Manuscript 2).

6) Focusing on social interactions and using ICT applications that can be applied in other social settings (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011; Vroman et al., 2015) supported participants´ interests and commitment to the learning intervention. The participants perceived ICT applications as useful for family and social relationships in their daily living environments and implemented the learned skills to satisfy interaction needs.

7) Having a safe and respectful learning environment (Ala-Mutka et al., 2008; Czaja & Sharit, 2012; Sayago et al., 2013, 2011; Vroman et al., 2015) allowed participants to feel comfortable asking for as much help as they needed and, as well, offering and receiving support. Participants assisted each other spontaneously, independent of their level of experience with ICT. Peer support helped participants cope with various issues during the learning process (see Manuscript 3).

8) The learning intervention sought a balance between physical and productive activities during aging (Baltes & Baltes, 1990; Rocío Fernández-Ballesteros, 2008; Rowe & Kahn, 1997; WHO, 2002) and the development of identity and subjectivity (Salazar-Villanea, 2015; Spector et al., 2011, 2010; Tornstam, 2005; Westerhof et al., 2010). Thus, aside from learning about and using ICT for cognitive activity and social interaction, participants found a space for sharing and reflecting on their life experiences, the aging process, and experiences with ICT learning.

9) The learning intervention sought to support participants´ independence and autonomy interacting with ICT. By implementing the learning intervention in a natural learning setting (Coto, 2010; McKenney & Reeves, 2012; Oh & Reeves, 2010; Wang & Hannafin, 2005), including online components, offering opportunities for practicing in daily living environments, and using their own devices, participants gained independence using ICT devices and applications. They also learned strategies for asking for help and coping with difficulties (see Manuscripts 3 and 4; Section 4.3.3, “Participants’ evaluation”).

In sum, implementing the proposed design principles and designing learning facilities to accomplish them facilitated the emergence of the key aspects listed, which responded to participants’ needs, characteristics, and expectations. Thus, the designed learning intervention seems to fulfill the first established criterion to evaluate effectiveness stated in the methodology section as the extent to which it accommodates individual characteristics, needs, and interests of older adults, and its applicability in older people’s daily life. These findings support continuing to refine

and improve the learning intervention through more implementations in new contexts and, as well, including the final changes proposed. Nevertheless, more research is needed to evaluate the fulfillment of the second effectiveness criterion, "the effects of the learning intervention on cognitive performance and social interaction". Specifically, there is need for exploring: 1) the effects of reminiscence on general cognitive functioning and personal well-being; 2) the effects of cognitive online games on trained cognitive abilities as well as their long-term and real-life efficacy; and 3) the benefits of participating in learning and cognitively stimulating activities on cognitive performance and social engagement (Ballesteros et al., 2014, 2015; Fernández-Ballesteros et al., 2012; Nouchi et al., 2012, 2016; Rebok et al., 2014; Reijnders et al., 2013; S Wang et al., 2012; Wilson et al., 2013). Similarly, future studies need to analyze the possible effects of sharing and interacting on online social platforms on cognitive performance.

Finally, the designed learning intervention might be a valid venue and a guide for future design of cost-effective interventions aimed at supporting successful and active aging by reducing the risks of cognitive impairment and dementia. The capacity of this type of intervention to involve a greater number of older adults simultaneously, the fact that some older adults already have personal ICT devices, and that current public infrastructure in Costa Rica facilitates access to ICT devices and applications, all support the viability of these types of psychological interventions. However, some challenges still need to be overcome (i.e. including older people from different geographic locations and cultural backgrounds in the design of suitable learning interventions for different groups of older adults, planning the use of available public ICT infrastructure to support older adults currently without access to personal ICT devices, and designing community-based learning services for increasing the number of older adults receiving benefit).

Implementing this type of intervention might be an effective response to some of the challenges of the aging population. It could facilitate adaptation to old age, ensure a good quality of life for older adults, and reduce the costs of health care related to negative outcomes of cognitive impairment and social isolation. The implementation of this type of intervention in broader contexts requires the commitment and joint work of governmental institutions, non-governmental organizations, communities, and, as well, families.

5.1.2 METHODOLOGICAL CONSIDERATIONS

This section presents methodological issues that arose during the research process, strategies implemented to compensate for them, and suggestions for mitigating such issues in future research projects. The section focuses on older adults' participation in the research project, limitations for more iterations of the learning intervention, researcher´s roles and profile, and the large amount of data collected and their relationship to ecological validity of the results (see McKenney & Reeves, 2012).

Finally, this section presents a brief reflection on the implications of using DBR for implementing psychological interventions.

5.1.2.1 Older adults' participation during the research project

This project was concerned with older adults' characteristics, needs, interests, and expectations for learning about and using ICT for cognitive activity and social interaction; a related goal was to create a suitable learning intervention. Therefore, the project included older adults' voices by involving participants in different phases of the design/research project. The project offered spaces for mutual learning and validation between participants and researcher to create the conditions for a collaborative design process (McKenney & Reeves, 2012; Oh & Reeves, 2010). However, conditions such as time and resources constrained older adults´ participation and collaboration. The research period was limited to 36 months, the length of the doctoral program. Since I was attending doctoral studies in Denmark and local collaborators in Costa Rica had limited time to invest in the project, meeting the participants and including them in comprehensive research activities such as implementation of the learning intervention, evaluation, and reflection was confined to two visits to Costa Rica during the research period (February–May 2016 and June 2017).

Time and resource limitations for doctoral students conducting DBR has been mentioned by Oh and Reeves, (2010). However, the potential benefits of this approach for designing inclusive and suitable learning interventions motivated the methodological choice, as discussed in the Methodology section. The project included participants in research and design activities as much as resources allowed, and describes in detail participants in the different phases, participant activities, and results from those activities. Older adults' participation can be summarized as follows:

1) Sharing their needs, interests, and expectations on learning and using ICT devices and applications by answering two questionnaires and participating in a focus group (DBR phase 1).

2) Participating in the implementation of the learning intervention by attending classroom and online sessions and accomplishing the learning activities (DBR phase 3).

3) Evaluating the learning intervention through a formative evaluation process by answering two online evaluation questionnaires. (DBR phase 3).

4) Reflecting on the final learning intervention, discussing possible changes and improvements, and discussing the intervention´s results during evaluation and reflection workshops (DBR phase 4).

On the other hand, practitioners´ participation was also limited. Adults´ educators were involved in the analysis of the practical problem. Following the literature on ICT and older adults and cognitive training (Ala-Mutka et al., 2008; Czaja & Sharit, 2012; Sayago et al., 2013, 2011; Thompson & Foth, 2005; Vroman et al., 2015) the project prioritized investing available resources in older adults´ participation to achieve a suitable learning intervention. Participants´ evaluation supports the potential of the designed learning intervention to fit their characteristics, needs, and interests. Nevertheless, involving older adults and adults´ educators in defining learning contents and designing learning activities and material could improve adaptation of the design to the characteristics of older adults. It also could improve the engagement of different groups of older adults in the designed learning interventions (Ala-Mutka et al., 2008). Involving older adults and adults' educators in data analysis could improve the validity of the reached conclusions by complementing the researcher's perspective (Mason, 2002); this complementarity implies learning and validation for both perspectives (i.e. that of researcher and participants). As such, it could lead to a more comprehensive understanding of the research findings.

5.1.2.2 Limitations for more iterations of the learning intervention

DBR, through systematization and iteration, allows the improvement and refinement of educative interventions implemented in real educational settings (Coto, 2010; McKenney & Reeves, 2012; Oh & Reeves, 2010; Reeves, 2006; Wang & Hannafin, 2005). Nevertheless, there still are some limitations in identifying standards and guidelines to define how much iteration is sufficient to produce an appropriate learning intervention. Similarly, there are no fixed criteria to evaluate the success of an intervention and finish the iterative cycle (McKenney & Reeves, 2012; Oh & Reeves, 2010; Reeves, 2006; Wang & Hannafin, 2005). Due to the diverse nature of DBR projects, their goals, and the implementation´s contexts, it does not seem possible to set common standards for any type of DBR investigation (McKenney & Reeves, 2012). Thus, the suggestion is to: 1) evaluate the appropriateness and effectiveness of DBR projects according to their own goals and contexts of implementation; and 2) ensure the possibility of replication across different settings and contexts to enable further refinement (Coto, 2010; McKenney & Reeves, 2012).

Iteration is also limited by objective conditions of the research projects (Coto, 2010; McKenney & Reeves, 2012; Oh & Reeves, 2010). Time and budget can limit the possibilities of several iterations of the designed solutions. However, strategies such as micro-cycles of analysis (Sandoval, 2004) can support the evaluation of the

intervention during implementation and allow changes, refinements, and improvements as interventions develop in the educational setting. Micro-cycles of analysis allow changes as the learning intervention is taking place; they must be followed by retrospective analyses (Sandoval, 2004).

In order to deal with the above-mentioned methodological and objective limitations, this research project implemented two general criteria to evaluate the effectiveness of the designed learning intervention and determine the relevance of continuing its refinement. The first criterion involved the extent to which the learning intervention accommodates individual characteristics, needs, and interests of older adults, and its applicability in older people's daily life. The second criterion focused on the effects of the learning intervention on cognitive performance and social interaction. The results (detailed in Manuscripts 3 and 4; Sections 4.3.3, "Participants' evaluation" and 5.1.1.1, "Participants' evaluation and reflection workshops") seem to support the effectiveness of the designed learning intervention to fit the characteristics, needs, and interests of the participants. The results also support further exploration of the effectiveness of the intervention on cognitive abilities and social interactions.

On the other hand, the project implemented daily micro-cycles of analysis (Sandoval, 2004). During these micro-cycles, the facilitator and co-facilitator reflected on the adjustment of the learning activities and materials to the participants' characteristics and learning processes. These analyses resulted in changes in the learning contents, for example, including new contents (see Manuscript 3) and eliminating others, and changes in the length of the learning activities, for instance, devoting more time than planned to accomplishing them. Finally, participants analyzed retrospectively possible changes and improvements for the learning intervention; these proposed changes and the participants´ perspectives are detailed in the Discussion chapter to facilitate its inclusion and evaluation in future replications. The proposed changes also informed the final set of design principles presented in this section.

5.1.2.3 Researcher roles and profile

In DBR approaches the researcher has two roles: as researcher and as designer (McKenney & Reeves, 2012; Oh & Reeves, 2010; Reeves, 2006; Wang & Hannafin, 2005). This double role implies collecting and interpreting data, finding and revising theories, and including the implications derived from the data, the theory, and the relationships between both of them in the design process. It also implies close collaboration with participants and practitioners. From my understanding, the main challenge in this position is to find a balance between research and design tasks and competencies. As a researcher, I had some experience in investigations considering ICT in education, yet had no experience in designing learning interventions. Thus, research skills were fundamental to finding appropriate theories and design

guidelines applicable to older adults´ learning to use ICT for cognitive activity and social interaction. This was also important for maximizing participants' and adults' educators' valuable inputs in the design process. Another helpful resource for reinforcing the design tasks was networking with and consulting colleagues from Aalborg University and Omar Dengo Foundation (who are experts in designing learning interventions for adults). Similarly, I shared and discussed my progress in research and design with the expert Mayela Coto who previously implemented a DBR approach in developing an educational program for university teachers in Costa Rica and, as well, has implemented DBR in several research projects. Finally, I included the input and suggestions from all the sources into the research and design process.

Due to limited resources, I assumed a third role as main facilitator during implementation of the learning intervention. At the time this took place, I had experience as professor at the University level and was familiar with adults´ teaching and learning processes. I had experience in community work with older adults, and as clinical psychologist. However, I did not have experience facilitating learning in older adults or teaching about ICT. Further, I consider myself a regular ICT user. Regarding the latest aspect, I introduced myself to the participants as a non-expert on ICT and presented learning about ICT as a shared experience for facilitator and learners. This enabled a more horizontal relationship and helped participants feel comfortable asking for as much help as needed (see Manuscript 3). As part of the learning intervention, there were some experts on ICT available to solve technological issues beyond my capacity.

My professional background as a psychologist and my experience working with older adults helped to talk about and reflect on emotions and stereotypes during the learning process. During face-to-face and online sessions, I guided participants to identify and make explicit their emotions and consider them as a means of finding some coping strategies; by such means emotions were validated and included as a component of the learning process. My knowledge of cognitive aging facilitated conducting and accomplishing the learning activities and understanding and supporting older adults' own learning processes. Finally, my experience as a clinical psychologist allowed me to manage some experiences of bitterness revival during the reminiscence activities (see Manuscript 4).

To reduce the risk of reaching false interpretations due these multiple roles, I contrasted data and interpretations from several sources and gathered these using several methods (Hammersley, 2008; Mason, 2002; McQueen et al., 2009). I also discussed transparently my progress with experts in designing for learning in adults' education and DBR and with the study participants. Reflecting retrospectively on my roles during the learning intervention, I would suggest it might be useful to have a facilitator profile that includes a psychology background. This would enable

addressing negative emotions during the learning intervention, dysfunctional ways of reminiscing (see Manuscript 4), and cognitive changes related to age.

5.1.2.4 Large amount of data and its relationship with ecological validity

One of the marked weaknesses of DBR involves limitations in analyzing and reporting results from all the collected data (Coto, 2010; McKenney & Reeves, 2012; Oh & Reeves, 2010). This often is due to limited resources. As DBR occurs in natural settings and intends to account for multiple aspects of these contexts, it requires collecting data from multiple sources on different aspects. The logic behind this requirement is that natural settings such as classrooms or older people's daily life environments are much more complex than laboratory settings. They consequently need to be studied from different perspectives in order to specify particular characteristics of the context and key elements of the interventions (Sandoval, 2004). Thus, in DBR contexts are specified; the local theories thereby derived are particular and context-sensitive, yet still open to generalizations (McKenney & Reeves, 2012; Oh & Reeves, 2010; Wang & Hannafin, 2005).

DBR commitment to developing practical solutions and usable knowledge also supports the use of multiple methods to study learning interventions in the complex systems of authentic settings for reinforcing ecological validity (McKenney & Reeves, 2012). Thus, an ecologically valid study uses several methods to approximate the real-life situation under investigation and, by such means, increases external validity. The present study analyzed and reported almost all the collected data either in independent manuscripts or in different sections of this dissertation. Having multiple and complementary perspectives allowed the study to present comprehensive accounts of the phenomena at hand, and also guarded against false interpretations as may arise from isolated points of view or analysis (Hammersley, 2008). Using multiple methods and sources also allowed including multiple voices in the learning intervention and facilitating different ways of participation for older adults during the research process.

Although this research project implemented some strategies for data reduction (see Manuscripts 3 and 4; Section 4.3.3, "Participants' evaluation"), the complete datasets were observed and listened to in order to conduct the qualitative and quantitative analyses reported. Only the analysis of the online group meetings is reported neither on a manuscript nor in this thesis. Nevertheless, audio data from online group meetings supported the micro-cycles of analysis during the learning intervention and analysis of the other datasets. By analyzing and reporting almost all the collected data, the present study tries to approximate the complexity of aspects it encompassed, from emotions related to learning to technical hitches involved in designing and implementing learning interventions aimed at enabling older adults to

use ICT for cognitive activity and social interaction. To facilitate the understanding of this complexity, the project offers detailed descriptions of the strategies used to identify and interpret the research findings and, as well, descriptions of the national and local contexts in which the research was conducted.

5.1.2.5 Implications for psychological interventions using ICT

Finally, it is important to note that the DBR approach was an appropriate methodology to include older adults and adults' educators in the design of learning interventions: it fit older adults' characteristics, needs, and interests for learning about and using ICT (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011; Vroman et al., 2015). Their participation allowed the inclusion of activities that are readily accessible, affordable, and enjoyable for older adults (Thompson & Foth, 2005). This applies especially to the psychological interventions for cognitive stimulation and cognitive training included as part of the learning intervention.

It is known that older adults require training for using ICT (Ala-Mutka et al., 2008; Commission of the European Communities, 2001; Czaja et al., 2006; Czaja & Sharit, 2012; PROSIC, 2010; Sayago et al., 2013, 2011; Vroman et al., 2015). Thus, in order to contribute to realizing the potential of ICT for supporting successful and active aging, the present study developed the design of a learning intervention for using ICT to implement psychological interventions aimed at stimulating cognitive abilities and supporting social connections. The present project is based on psychological research on aging, cognitive training, and social interaction during the aging process, as detailed in the Theoretical Framework chapter. However, DBR enabled expansion of the scope of psychological interventions by: 1) allowing the exploration of several aspects not contemplated in controlled intervention environments (e.g. participants´ interaction and emotional reactions when interacting with ICT); and 2) supporting the transfer of the learned skills to older adults' daily life environments. Accordingly, DBR approaches might facilitate the design and implementation of psychological interventions using ICT that can be inclusive and can support older people in realizing their potential during old age as prescribed by WHO (2002). In this regard, the designed learning intervention has the potential to be adjusted and implemented in community-based services and contribute to increasing the number of older adults involved in psychological interventions aimed at supporting successful and active aging. Further, on a broader level, DBR could facilitate the design of learning interventions for using ICT in the implementation of several psychological interventions aimed at improving older adults' quality of life.

5.1.3 THEORETICAL CONSIDERATIONS

This section presents the main contributions of the present research to complement and expand the study of ICT learning by older adults and the potential of ICT to support successful and active aging.

5.1.3.1 Describing the role of negative emotions in ICT- learning by older adults

Previous investigations have identified older people's personal barriers to learning and using ICT, for example, mental barriers (PROSIC, 2010), lack of belief in one´s capacity to learn, lack of motivation (Ala-Mutka et al., 2008), and lack of interest (Sayago et al., 2011). However, focusing on negative emotions that influence older people's interactions with ICT appears to be relatively new. This project identified fear and shame as two emotional reactions that mediate older adults' ICT learning and use. The study offers detailed descriptions of these emotional reactions and some of their causes and effects at different points in the learning process. Manuscript 1 presents shame and fear as one of the main barriers for learning about and using ICT. Manuscript 2 describes participants' experiences with these emotions before the learning intervention and elements of a respectful learning environment that might mitigate such feelings. Similarly, older adults´ educators noted the relevance of talking about and working on coping strategies to deal with these emotions. The proposed design principles included managing such emotions as a fundamental part of designing for ICT learning by older adults. Manuscript 3 describes participants' experiences with these emotions during the face-to-face sessions of the learning intervention. The manuscript also describes the effect of these emotions on participants' learning process and their strategies for reducing fear and shame.

The learning intervention included learning contents related to the "normal" aging process, cognitive aging, and its effects on the learning process to facilitate participants' understanding of changes in their learning process and searching strategies to compensate these changes, if required. The learning intervention also included formal spaces in which to talk and reflect on emotions related to the learning process and to find strategies to manage them in a positive way. As described in Manuscript 3, the learning environment allowed participants to name their emotions, share them with peers and facilitator, and work on them before continuing with the learning activities.

This study contributes to the creation of a person-focused approach (Vroman et al., 2015) for ICT adoption among older persons. However, as older adults are a heterogeneous group, it is possible the design of a standard learning intervention is not suitable for all of them. Thus, the study contributes to identifying specific

personal factors that might be explored and included in ICT-learning programs for older adults, which aim to accommodate their needs and interests. The descriptions of emotional reactions of older adults related to interacting with ICT also contributes to overcoming the lack of detailed information on personal and emotional aspects of ICT learning (as indicated by Sayago et al., 2011).

5.1.3.2 Discussing the relevance of social support for ICT learning by older adults

Several studies have identified social support as a key factor in enabling older adults to learn about and use ICT (Ala-Mutka et al., 2008; Czaja & Sharit, 2012; Sayago et al., 2013, 2011; Vroman et al., 2015). Nevertheless, references to this aspect in the literature are brief and general, and research on how societies can support this learning is scarce.

The present study describes participants' perception that their families, particularly their children, do not have the patience, time, or skills to help them learn about and use ICT (see Manuscripts 1, 2 and 3). Consequently, older adults felt in a vulnerable position as ICT learners. This relates to the negative emotional reactions reported by participants and to their motivation to become efficient and independent ICT users (see Manuscript 3).

Extending the required social support for ICT learning by older adults escaped the possibilities of the present research project. However, the need to elicit proper support from older adults´ families and friends emerged as a topic requiring further research (see Manuscripts 1, 2 and 3). These aspects noted the necessity of working in communities and societies to create adequate conditions and opportunities for promoting successful and active aging (WHO, 2002), in this case, through the use of ICT. Successful aging is a transactional process between aging people and their society (Featherman et al., 1990). Since participants are interested, motivated and actively participating in ICT-learning opportunities, the remaining question is how societies are adjusting and can adjust in the future to support older adults' ICT learning and use for enabling successful and active aging.

Future research might focus on exploring the characteristics of current social support for ICT learning from different social groups such as families, caregivers and adults´ educators, and identifying strategies of social support suitable for older adults and their social networks. This research would represent an innovative approach by including in the research field of older adults and ICT other social groups, which have not traditionally been included. This could expand the focus of the research field beyond older adults and commercial interests and include older adults' social networks, which might contribute to the knowledge base on societal conditions for supporting successful and active aging and independent living.

5.1.3.3 Understanding ICT-use as a form of independence during aging

Adapting to changes related to aging, being active, having a good quality of life, and living autonomously and independently are primary goals of successful and active aging (Baltes & Baltes, 1990; Fernández-Ballesteros, 2008; Rowe & Kahn, 1997; WHO, 2002). Autonomy is defined as the perceived ability to control personal decisions in daily life according to one's own rules and preferences; independence refers to the capacity to perform functions needed in daily life and the ability to live on one's own in the community without help (Rowe & Khan, 1997; WHO, 2002).

In this regard, studies on ICT and older adults have remarked on the potential of ICT tools and applications as a means for supporting independent living by facilitating instrumental tasks such as online banking, online shopping, and health care, among others (Ala-Mutka et al., 2008; Charness & Boot, 2009; Czaja et al., 2006; Czaja & Sharit, 2012; Vroman et al., 2015). The potential of ICT for supporting social interaction with local and virtual networks (Ala-Mutka et al., 2008; Sayago et al., 2013, 2011; Vroman et al., 2015) also have been noted as an aid to supporting independent living and preventing social isolation. However, study participants indicated that in addition to the possibilities of using ICT as tools to perform other activities or tasks, using ICT independently is a form of independent living. Thus, learning about and using ICT independently became part of a goal for independent living.

Lack of knowledge and experience with ICT places older adults in a vulnerable position as others—family, friends, and teachers—have specific knowledge. Thus, they enter into a dependency relationship with their close networks, especially their children, to gain access to ICT knowledge and skills. As detailed in Manuscripts 2 and 3, in this dependency relationship older adults face negative reactions from family and friends when they make mistakes, do not understand directions, forget information about ICT, or ask the same question several times. As noted earlier, participants reported that families and friends push them to learn fast, and do not have patience and/or time to teach them. Since older adults are non-independent users, they experience limitations on when and how to use ICT; consequently, sometimes they must wait long periods of time before receiving help (which is subject to availability of their relatives). Consequently, in some cases older adults have a basic and limited use of ICT devices and applications.

Thus, for participants, becoming an efficient and independent ICT user is one of the main motivations for learning and using ICT. The aspiration of using their own devices efficiently and thereby solving problems without depending on their relatives—particularly their children—motivated participants to engage in ICT-learning experiences and keep learning despite the difficulties they faced (see

Manuscript 3). For the study´s participants, using ICT autonomously and independently appeared to be a performative act of being independent.

This understanding widens the perception of ICT use as a means of being independent and places it as a goal for independent living. This also has implications for the design of learning interventions aimed at enabling the use of ICT for supporting successful and active aging. These interventions might have a focus on promoting using ICT autonomously and independently as a realization of successful and active aging, and offer appropriate support resources and materials to achieve this goal.

5.1.4 FINAL DESIGN PRINCIPLES

Based on the previous considerations and reflections, this section presents a refined set of design principles that could guide future design efforts. These design principles are a contribution to the creation of local and specific theory for the design of learning interventions aimed at enabling older adults to use ICT for cognitive activity and social interaction. Thus, these principles might be considered prescriptive local theory (McKenney & Reeves, 2012) that might be included in the design and refinement of learning interventions with similar goals. These design principles can be refined by replicating the designed learning intervention in broader contexts.

Table 15 presents the original design principles (see Manuscript 2), some new learning facilities´ specifications, and three new design principles (9,10,11) and their corresponding specifications—all of which emerged from the process of documentation and reflection.

Design principle	Learning facilities specifications
1. Organize the learning activities around interesting topics for older adults	These topics might include: The "normal" aging process, vs. pathological aging, cognitive aging, and changes related to age that could affect the learning process Models to achieve adaptation during aging such as successful and active aging Strategies to cope with age-related changes

	Strategies for cognitive stimulation such as reminiscence, which allow sharing of personal knowledge and experiences and forming social bonds with peers Cognitive training that combines entertainment and leisure activities with training such as cognitive online games Mobile devices and free applications for social interaction with local and virtual networks
2. Encourage individual participation and support a collaborative learning environment	Structuring peer support during the face-to-face and online sessions, but allowing spontaneous peer support during the learning intervention Defining roles and tasks for more experienced users to support "beginners" Presenting collaborative online learning activities
3. Support social interaction and social networking	Implementing social interaction with peers regarding personal interests and subjects using online platforms Having some mediation, on online social platforms to stimulate and guide interaction, when needed
4. Facilitate spaces to explore and reflect on emotions and stereotypes related to learning about and using ICTs as older learners	These spaces might provide: Opportunities and resources for systematizing different coping strategies to deal with negative emotions and stereotypes Structured approaches, for example, relaxation techniques, to face negative

	emotional statuses
5. Offer a sustained support system	Having help online or by phone to solve ICT- related issues. It would be a phone/online helpline available after the learning intervention that older adults could call and receive help
6. Provide resources to support declining cognitive abilities	Providing some scaffolding for the creation of customized learning resources and memory aids Encouraging the co-creation and circulation of learning resources and memory aids among the participants
7. Develop a broad perspective concerning ICTs and how to match them to personal interests and needs	Exploring the range of mobile devices as they fit the needs of independence and mobility of active older adults Encouraging the exploration of participants' own devices' features in face-to-face and online sessions Identifying participants´ user profile for different devices and applications and adjusting the learning process to that profile Providing some sessions before the learning intervention to explore devices and applications and collect information needed for the learning intervention such as users names and passwords
8. Provide a safe learning environment in which participants' experiences and knowledge are respected	Including learning contents and activities in which participants can share their life experiences in different areas such as family, education, work
9. Identify and include suitable	Structuring help requests for family

strategies for social support from family and friends for assisting older adults ICT-learning	and friends Following up the support received from family and friends and offer alternatives for support such as individual sessions, online and phone help
10. Promote autonomy and independence in using ICT	Promoting practice in daily life environments Promoting the exploration of online help resources that can be accessed at any time Promoting the creation of customized learning resources that can be accessed at any time
11. Define a facilitator profile	Describing facilitator required competences to develop the contents defined following Principle 1 of this table and the designed learning activities Providing alternative sources of support to compensate for areas of weakness of the facilitator

Table 15 Final set of design principles and specifications for its realization in future design processes

The final design principles and specifications complement the former ones presented in the Results chapter. In both moments, the design principles were operationalized in concrete learning facilities and specifications to facilitate their implementation in different learning settings. This final set of design principles is intended to include some issues that emerged during the learning intervention. Thus, the final design principles and those presented in Table 5, used in a complementary way, may guide design of learning interventions aimed at promoting the use of ICT for supporting different aspects of successful and active aging.

5.1.5 DISSEMINATION AND ADOPTION IN BROADER CONTEXTS

During the different phases of the research process, four scientific articles were produced (manuscripts and their publication processes are detailed in the Results chapter). Partial results were presented at two international conferences in order to share the findings with the external scientific community. Participants in the study knew and discussed the main research results and offered suggestions for improving the design.

Regarding sustainability of the learned skills, it is remarkable that many participants continued playing the online games autonomously and independently up to eight months after the intervention was completed. Similarly, some participants continued interacting using the Facebook groups created during the year following the learning intervention (this was verified during the evaluation and reflection workshops). Unfortunately, follow-up of the implementation of learned skills by older adults beyond the research period escaped the scope of this project. Nevertheless, the continued implementation of learned skills during the year following the learning intervention might suggest sustainability of the learned skills in participants´ daily lives after the researcher has left that context (Coto, 2010). Follow-up studies are needed to explore this aspect of learned skills' sustainability in older adults' daily environments. Another aspect to consider on sustainability after the intervention period is the inclusion of community managers on social platforms (see Manuscript 4). This may support interaction among participants and consolidate the networks created as part of the intervention as permanent social communities in older adults' life.

Concerning sustainability and implementation in broader contexts beyond the original research context, it is necessary to consider external factors, such as institutional interest in implementing this type of intervention and, as well, the availability of economic resources associated with implementation. Even if it exceeds the goals of this study to guarantee sustainability and scalability of the designed learning intervention, three reasons argue for seeking such elements based on their potential to support successful and active aging among the Costa Rican elder population. First, older people are willing and able to learn about and use ICT in general, and for cognitive activity and social interaction in particular (see Manuscripts 1 to 4). Second, the designed learning intervention fits participants' characteristics, needs, and interests for learning about and using ICT (see Manuscript 4; Section 4.3.3, "Participants' evaluation"). Third, this type of approach would be a cost-effective avenue to prevent negative outcomes of aging since it can include simultaneously many older people from different socio-cultural backgrounds in psychological interventions (see Manuscript 4).

The designed learning intervention also has the potential of supporting social inclusion since the virtual learning component implemented by Moodle, Blogger

and Facebook can reach older people living in rural areas, or older people with mobility limitations. Similarly, promoting an active use of online platforms for social interaction has the potential of supporting social participation of older people in the family, community, and even at the national level. Finally, the learning intervention, design principles, and learning facilities offer sufficient flexibility to widen the scope of future interventions and include different components of successful and active aging.

The suitability of the learning intervention relates to working closely with the participants and adults' educators. Thus, replication of the learning intervention would lead to refinement and adaptations to different contexts. New adaptations can be useful to motivate and engage older adults in learning and using ICT for different aspects related to health care.

Finally, as explained in section 3.5 generalization of the research findings and suitability of the designed learning intervention for other contexts is supported by offering to the readers detailed descriptions of each phase of the research process and each step followed to build the research findings. Thus, the readers/consumers of this research can evaluate the usefulness of the learning intervention and design principles with respect to their own contexts.

CHAPTER 6. CONCLUSIONS

This section presents possible answers to the main research question and secondary questions that guided the present study. These answers are based on the findings from the data and the research process in general. Finally, there are some brief suggestions for future research, as emerged during the investigation.

The lack of suitable ICT learning opportunities is one of the main barriers preventing older adults from benefiting from the potential of ICT to support successful and active aging. Therefore, the present project explored key elements that might be included in ICT learning interventions aimed at enabling older adults to use ICT for enhancing cognitive activity and social interaction.

The research found that few older Costa Rican people were using ICT. Most active users were between 64 and 75 years old, living in urban areas, and high school graduates or had some university education. They also tended to have a medium or high income and lived without disabilities (see Manuscript 1). Most of the study participants fit the profile of ICT users in the general population, and they mainly used mobile ICT devices for social interaction and leisure activities. The least frequent activities involved learning processes, social participation, and instrumental endeavors. Thus, according to the Information and Communication Technology Social Networking Motivational model proposed for older adults (Vroman et al., 2015), the study participants represented the first level of ICT adoption, they used ICT mainly to support personal relationships and for social networking with family and friends (see manuscript 1).

Participants´ main motivations for learning about and using ICT related to performing instrumental activities in daily life, remaining active, being up to date in ICT, and communicating with family members (See manuscript 1). During the learning intervention emerged an additional motivation, they wanted to becoming efficient and independent ICT-users (See manuscript 3). Before the learning intervention, participants reported as main limitations for learning about and using ICT declining memory and attention, inappropriate or limited ICT learning opportunities for older people, and negative emotions (fear and shame) related to the learning process (see Manuscripts 1 and 2). During the intervention, the most important obstacles to learning to use ICT were: lack of experience with ICT, negative emotions (fear and shame) when interacting with ICT, and restrictions on individual support (see Manuscript 3). Due to the constant presence of issues relating to lack of experience with ICT, it was not possible to distinguish these issues from memory problems. This highlighted the need for methods and interventions to differentiate both factors and provide specific support for each.

The implementation of the DBR approach allowed working closely with the participants and including their voices in the creation of the design principles and guides, and the learning intervention and its refinement (see Manuscripts 2 and 4; Section 5.1.1.1, "Participants´ evaluation and reflection workshops"). The final set of design principles presents context-sensitive design guides that include wider aspects that influence ICT learning by older adults. These principles encouraged the construction of respectful learning environments for older adults, in-depth comprehension of changes related to aging, the inclusion of emotions into the learning process, and recognition of and respect for older adults' individuality.

Following the proposed learning principles, the contents for this type of intervention might address aspects such as: age-related changes in cognitive functioning and strategies for coping with them; interaction needs and preferences of older adults; negative emotions and stereotypes related to ICT learning by older people; and the social support, particularly from family and friends, needed for older adults learning and using ICT (see Manuscripts 2 and 3). Negative emotions related to the ICT learning process were associated with the support participants received from their closer networks for learning about and using ICT (see Manuscripts 2 and 3). This relationship highlighted the need for including social support from social networks and social environment in the field of ICT learning by older adults. Doing so enhanced the role of societies in enabling older adults to realize the benefits of ICT for successful and active aging (WHO, 2002).

Specific contents for cognitive activity and social interaction might include strategies for cognitive stimulation that allow sharing of personal knowledge and life experiences, forming social bonds with peers, and cognitive training that incorporates entertainment and leisure activities (see paper 4).

Regarding ICT devices and applications, the research findings revealed that participants preferred the use of their own mobile devices. Using their own technology facilitated mobility and connectivity, encouraged using ICT independently and autonomously, and ensured inclusion of learned skills in participants' daily living environments (see Manuscripts 1, 3 and 4).

Concerning learning activities, strategies and materials, the research findings showed that participating in a collaborative learning environment, motivation for becoming efficient and independent ICT users, implementing learning strategies focused on supporting cognitive abilities, and lack of experience with ICT were important factors to be addressed when supporting older adults' learning about and using such technology. Further, engaging in a learning environment that adapted participants' knowledge and experience with ICT and allowed peer support facilitated their help requests. Peer support was a key factor during the learning intervention as participants helped each other accomplish the learning objectives, encouraged each other to keep learning, and supported each other in dealing with

negative emotions and stereotypes. Participants' motivation for becoming efficient and independent users encouraged them to face difficulties during the learning process. In this regard, it seemed that ICT learning was driven by both instrumental and self-realization goals.

Facilitating older adults´ understanding of age-related changes, learning by doing, repetition and practice, and having multiple opportunities to apply the learned skills in daily environments were useful approaches during the learning intervention. These factors helped participants arrive at strategies to compensate for declining cognitive abilities, mitigate stereotypes regarding ICT learning by older adults, gain familiarity with ICT devices and applications, and become more efficient using ICT for cognitive activity and social interaction (see Manuscript 3). Having online materials available at any time and customized notes about the learning contents also were valuable elements supporting cognitive abilities and encouraging independence and autonomy using ICT (see Sections 4.3.3, "Participants´ evaluation" and 5.1.1.1, "Participants´ evaluation and reflection workshops"). However, participants offered specific suggestions to support them in the creation of customized learning material and memory aids (See section 5.1.1.1 "Participants´ evaluation and reflection workshops").

The results from the designed learning intervention showed that participants were willing and able to incorporate ICT devices and applications for cognitive activity and social interaction into their daily routines. Including reminiscence activities allowed them to share episodic memories, thus exercising ABM and promoting mutual understanding and openness to personal relationships (Reker et al., 2012; Salazar-Villanea, 2015; Spector et al., 2010; Westerhof et al., 2010).

Participants also included playing online cognitive games in their daily routines. Most of them trained autonomously and independently after the learning intervention finished; some of them played up to eight months after the intervention period. Participants evaluated their training with online cognitive games as a fun and enjoyable experience. They improved their performance on the different cognitive tasks by repetitive practice; this aligns with results from previous research that also found improvements in trained cognitive abilities (Ballesteros et al., 2014, 2015, Nouchi et al., 2012, 2016; Rebok et al., 2014). Thus, online cognitive games might have a significant potential as a strategy to buffer cognitive decline. Furthermore, the analysis showed that age, education, and positive attitude towards technology did not influence performance improvement; this might indicate that this type of intervention is suitable for older people from different sociocultural backgrounds (see Manuscript 4).

Both platforms Facebook and Blogger, used for sharing and commenting on reminiscences and sharing experiences and reflections on the online cognitive games, seemed to be appropriate for social interaction among older adults. However,

the social network presented more dynamic interactions among the participants (see Manuscript 4); further, it was more familiar to participants (see Section 5.1.1.1, "Participants´ evaluation and reflection workshops").

In general, by implementing a DBR approach the research project managed to design a suitable learning intervention for enabling older people using ICT for cognitive activity and social interaction. The designed learning intervention accommodated the characteristics, needs, and interests of older adults for learning about and using ICT in their daily living environments. Participants found the learning contents and the learned skills relevant and meaningful for their daily lives (See Sections 4.3.3, "Participants´ evaluation" and 5.1.1.1, "Participants' evaluation and reflection workshops").

The designed learning intervention also achieved positive results in the implemented strategies for cognitive stimulation, cognitive training, and social interaction (see Manuscript 4). Furthermore, for the participants the main learning from the intervention was "discovering/recovering motivation for learning and sharing knowledge," which aligns with the approach of lifelong learning and evidences a progression toward more advanced levels in ICT adoption such as "learning as activity" in Ala-Mutka et al.'s (2008) model and "virtual community" in Vroman et al.'s (2015) model. Thus, the designed learning intervention has potential for supporting successful and active aging by implementing psychological interventions aimed at improved cognitive abilities and social interaction and, as well, promoting older adults´ participation in learning and cognitive stimulating activities (Ballesteros et al., 2014, 2015; Fernández-Ballesteros et al., 2012; Nouchi et al., 2012, 2016; Rebok et al., 2014; Reijnders et al., 2013; Wang et al., 2012; Wilson et al., 2013).

Since this type of intervention has the potential for including simultaneously several older adults from different sociocultural backgrounds in psychological interventions aimed at preventing the risks of cognitive impairment, dementia, and social isolation, they could be a potential avenue for cost-effective interventions aimed at preventing the negative outcomes of aging in modern societies.

In sum, this thesis offers empirical findings and methodological and theoretical considerations for widening the study of ICT learning by older adults and realizing the potential of ICT for supporting successful and active aging. The proposed design principles have the potential for guiding future design efforts aimed at using ICT for implementing diverse psychological interventions for supporting successful and active aging.

Regarding future research, it is important to note that a high proportion of the study participants fit the profile for ICT users in the Costa Rican older adults' general population. There is thus a need to include in future design processes older adults

who are non-ICT users, have disabilities, and live in rural areas. Further research also is needed to examine the effect of the intervention on cognitive abilities as well as its long-term and real-life effectiveness. Likewise, future studies need to analyze the possible effects of sharing and interacting on online social platforms on cognitive performance.

New studies could deepen the identification of effective strategies to address negative emotions and stereotypes associated with ICT learning by older adults. Similarly, future research could contribute to the construction of effective strategies for including close social networks, communities, and societies in supporting older adults' enjoyment of the benefits of ICT. The present research also evidenced the need for strategies to distinguish difficulties during the learning process associated with lack of experience with ICT from those related to cognitive decline, and the need of designing specific support resources for each condition

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