Senior related IxD research and remote Co-Design with seniors

- A Literature Review and Exploratory Study

Master Thesis

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Title:

Senior related IxD research and remote Co-Design with seniors - A Literature Review and Exploratory Study

Theme:

Human-Computer-Interaction

Project Period:

Spring Semester 2020

Project Group:

Hci1015f20

Participant:

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Supervisor:

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Copies: 1

Page Numbers: 47

Date of Completion:

June 10, 2020

Abstract:

This master thesis presents an exploratory study on Interaction Design (IxD) for and with seniors. It includes two papers. The first paper is an exhaustive literature review, which investigates IxD research for the elderly at the CHI conference from 2000 to 2019. 90 related full papers and 125 extended abstracts have been identified for final analysis. During the literature review, the papers are classified into five research purposes, eight methods and eleven categories of topics. The results provide an overview of the current progress and trends in IxD research for older adults. The second paper is an empirical and exploratory study based on the findings of the first paper. It investigates how to conduct co-design remotely with and for older adults. The design practice includes surveys, a group design workshop and two rounds individual usability testing, which were all carried out online. The paper presents the challenges and opportunities of the conducted online design activities and concludes by providing suggestions for future co-design practices under similar circumstances.

Contents

Preface

This report presents a Master Thesis for the Master Programme (MSc) in IT Design and Application Development at Aalborg University.

The report consists of four chapters and two academic papers in CHI format which can be found in the appendix. The structure of this report is as follows: the first chapter provides an overview of this master thesis and introduces the problem statement including two research questions. The second chapter presents a summary of the contributions from the two academic papers. The third chapter is a description of the research methods utilized in the two papers. The last chapter concludes findings, limitations and future work for this study.

Finally, I would like to thank my supervisor Jan Stage for his immense guidance, feedback and invaluable support.

1.Introduction

Since the beginning of the 21st century, the development of information technology, the improvement of digital equipment and the digital transformation in various fields has become faster and faster, deeply affecting and reshaping our work and lives. At the same time, the world has been experiencing a growth in both the size and proportion of the 65+ demographic group [1]. Having an aging population is becoming a global phenomenon that cannot be ignored. As people age, most of them will experience a clear decline in visual and auditory ability, in working- and long-term memory, as well as in their muscular strength and abilities in control of movement etc.[2]. These changes pose challenges in regard to design for seniors. It is, however, possible to compensate for this decline and provide better conditions for "Aging in place" with good technology design.

In this context, it is both necessary and meaningful to explore how interaction design (IxD) research can contribute to an improvement of seniors' life through technology and technology design. In order to make this contribution, an overall knowledge of the current state and trends in this research field is important, as further exploratory and empirical studies can become more relevant and beneficial, if they are carried out to address research gaps and actual needs. However, there is a lack of studies investigating the trends in topics, methods and purposes of recent IxD research. This research gap needs to be filled as it can serve as a basis for further identifying the challenges and opportunities in current senior related IxD research. For instance, the following questions have not been explored systematically, but can be helpful in regard to discovering potential new research directions: how have research interests developed in regard to research topics? Are the research topics designed to benefit the users or researchers & designers? How have preferences in the choice of research method developed?

With this in mind, it is important that we understand the state and progress of the current IxD research. By identifying research trends and gaps in the methods and purposes, we can further investigate the possibilities for improvement in senior related IxD.

Problem Statement

The aim of this study is to help improve the IxD research for seniors by investigating the following
Problem Statement: *What are the popular topics and methods in IxD research for seniors and what are the challenges and opportunities when conducting IxD research for seniors?*

To answer the problem statement, two research questions have been formulated and answered in the two separate papers, which can be found in the appendix. The research questions are as follows:

Research Question 1: *What is the current state and progress of IxD research for seniors since 2000, in terms of trends in purposes, methods and topics?*
The first research question addresses the development of senior related IxD research by exploring its purposes, methods and topics since 2000. The aim is to present an overview and preliminary analysis of the research progress in this field.

Research Question 2: *What are the challenges and opportunities when conducting an IxD research with seniors?*
Research question Two addresses the involvement of senior users in IxD research. It aims to contribute to the senior related IxD research by identifying the challenges and opportunities occurring during design cooperation with seniors. Thus, an exploratory study was set up to provide empirical findings and analysis in relation to research and design practice.

2.Contributions

This chapter gives an introduction of the two academic papers in the appendix, which comprise the main content of this master's thesis. Each paper is considered as one contribution and is presented with a short summary and main findings.

2.1 Contribution 1

Jing He. A literature review of IxD research for seniors from 2000 to 2019. Department of Computer Science, Aalborg University. 2020.

This paper constitutes the first contribution. It presents a literature review of senior related IxD research at CHI conference from 2000 to 2019. 225 articles were identified as senior related and subsequently divided into two time periods: 2000 to 2009 and 2010 to 2019. Papers from each period were first classified into eleven categories of topics, and then further categorized using a two-dimensional framework containing eight research methods and five research purposes. By conducting these classifications, this paper presents the results of each time period and compares the results to identify both the changes in this research field as well as the current research progress.

The literature review found that there was an increasing interest in senior related IxD research. In the first period, the seniors were considered as weak and passive users, who were very likely experiencing the cognitive decline and loss of companionship. The research in this period, thus, focused on social interaction and cognitive aids. In the second period, the seniors were perceived more positively and were involved into the design process as co-designers or were studied as content creators. The topics that received the most attention were those which attempted to enhance the seniors' wellness, enable their aging in place and understand the seniors in the context of culture, society and economy. At the same time, papers with a primary intention of benefitting "Designers & Researchers" grew both in amount and proportion, surpassing papers with a primary intention of benefitting "Users".

In relation to research methods and purposes, the two time periods have many similarities. The studies in both periods were mostly goal-driven applied research and were mainly carried out in a field or lab environment. Regarding the purposes, "Understanding" was the most popular followed by "Evaluation of Product". However, it's worth noting that many combinations of methods and purposes were

found to be unused in both periods. This situation underwent a slight change in the second period, as some researchers, unlike in the first period, began to employ action research for the purposes "Understanding" and "Evaluation of Method".

2.2 Contribution 2

Jing He. "PillTime": Remote Co-Design of a mobile app for and with seniors. Department of Computer Science, Aalborg University. 2020.

The second contribution presents an empirical study investigating the "remote co-design" method with seniors. It aims at exploring the feasibility of this design method by identifying the challenges and opportunities and further discussing its potential as an alternative to traditional face to face co-design activities. In order to conduct the investigations, five seniors were recruited to participate in co-designing a mobile app "PillTime" remotely. The process includes two surveys, one design workshop, two usability testings and interviews, which were all carried out online.

Seven challenges and four opportunities were identified. The remote co-design method encountered challenges including frequent distractions, unnatural conversation forms, limited interaction, difficulty in envisioning due to lack of design experience, participants' insecurity towards technology, and their own design capabilities. However, the remote method also showed opportunities. It can improve the seniors' willingness to participate because of its flexibility, provides a quiet and separate environment benefitting difficult envisioning tasks, helps the seniors to address their pessimistic perceptions of their own capabilities with technology and design, and finally it enables a continuous communication between participants and designers.

3.Research Method

This chapter introduces the main methods used in the two papers. Each method will be presented with a definition of the methodology and the setting in which it is applied in our research.

3.1 Literature Review

A literature review is *"the selection of available documents (both published and unpublished) on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfill certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed."* [3]

A review of prior relevant literature can serve either as an essential part of an empirical academic work, or as a *"standalone piece that provides a valuable contribution in its own right"* [4]. Furthermore, an effective literature review can be useful as it *"facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed"* [5]. One of the weaknesses of literature reviews, however, is that it can be prone to bias due to subjective sample selection, classification and reading.

This literature review is a standalone piece. It was performed following a procedure borrowed from Vangeli P. & Stage J. [6]. After making minor adjustments to better fit the content of this particular paper, the review procedure consisted of three phases: review focus and filtering, content-based categorization, reading and analysis. In the first phase, the senior related papers on CHI conference were selected as the focus of the review. 225 articles from CHI were identified and served as the review sample. In the second phase, the filtered papers were classified into eleven categories based on their topics. In the last phase, a reading of the papers was carried out, during which special attention was put on classifying the research methods and purposes of each paper.

3.2 Remote Co-design

Remote Co-Design is a method term coined by our study, in order to examine if it is feasible to co-design with seniors remotely.

Co-design (Co-operative Design) is a methodology belonging to participatory design

(PD). PD is characterized by the stakeholders playing a critical role in the design process [7]. Co-design and PD have certain differences. While Co-design focuses on the design-collaboration with users, the PD emphasizes including all stakeholders into the design process. The stakeholders in PD are not necessarily the users. In addition, PD highlights not only the design-collaboration, but also the participation in decision making (on design solution).

The remote co-design method combines the co-design method with spatial separation, to synchronously carry out the co-design activities with seniors online. The main activity of the remote co-design process is the online design workshop. It was performed by using an online conferencing video tool (Skype). The design workshop encompasses three typical steps similar to traditional co-design: idea generation, idea evaluation and idea visualization. First a focus group interview was conducted to understand the users' needs and generate design ideas. Subsequently, a number of design ideas were selected by the participants. Lastly we performed a user sketch session, where the senior participants visualized the chosen ideas with paper prototypes or sketches. The online design workshop was followed by an online survey and an online individual interview, where the participants evaluated the sketches made during the workshop and commented on the design workshop process.

3.3 Remote Usability Testing

Remote Usability Testing (RUT) is a method for usability testing, in which the evaluators and users are physically separate in space and/or time [8]. There are two types of RUT: asynchronous and synchronous. Asynchronous RUT is performed when users and evaluators are separated by time, while in a synchronous RUT, the users and evaluators are separated in space. It is a simulation of the traditional lab-based think-aloud usability testing method that has attracted much more attention from researchers [9].

In our exploratory study on the remote co-design method, two rounds of synchronous RUTs were conducted. We identified three possible ways of conducting the RUT: in the first option, the users would test a high-fi prototype of the mobile app and adjust the camera of their PC or tablet to capture the testing process. We, as evaluators, would observe the whole process by using Skype. The second option was the opposite of the first, as we as evaluators would hold a phone towards the camera, while the users observed through the video conferencing tool and would tell us where we should touch on the phone in order to complete the testing tasks. The third option was to test the mobile app prototype as a web app, which means no real mobile phone would be involved. The prototype would be tested in a web browser and we would observe the testing process by sharing the screen. We ended up conducting the testing

using both option one and three. After the testing, a comparison of the two methods was made. The second option was excluded as it was found that the internet and camera were not sufficiently able to convey high quality real-time images for the users. It would be too difficult for the users to see the small phone screen clearly in a video conference, and thus, the results would be negatively influenced under such circumstances.

3.4 Data Analysis

Meaning condensation

Meaning condensation (MC) is a method for analyzing qualitative interview data. It extracts the central themes from the data and includes five steps: to read through all the data in order to get a sense of the whole, to determine the "meaning units", to thematize the "meaning units", to interrogate the "meaning units" in terms of the study purpose and to tie together non-redundant themes into a descriptive statement [10].

The exploratory study of the remote co-design method included one focus group interview during the online design workshop and two individual interviews along with the two remote usability testings. The interviews were video- and audio recorded, with the consensus from the participants. The recordings were rewatched following the interviews, and from their answers, feedback and comments, the "meaning units" were identified and organized according to their themes. The results of this MC can be seen in Table 2 and Table 3 in the appendix of paper 2 , and contains the identified themes and descriptions of challenges and opportunities occurring in the remote co-design process.

Instant Data Analysis

Instant Data Analysis (IDA) is a technique developed to analyse the data from think aloud usability testings. In an IDA, there is a user, a monitor and a data-logger. The data-logger notes down the incidents occurring during the testing and afterwards brainstorms together with the monitor. During this brainstorm session, they identify the usability problems and categorize them based on their severity. The advantage of the IDA is that it is very time efficient. By using this technique, the analysis of four to six usability testings can be done just in one day [11].

In our practice, the author and the assistant played the roles as moderator and data-logger. The problems or incidents occurring during the testings were documented by the data-logger. Each testing was then followed by a discussion

session between the data-logger and monitor, where the video recordings and notes were checked again. The usability problems were identified and further categorized as "critical", "serious", "cosmetic".

4.Conclusion

This chapter first summarizes the conclusions of the two contributions, in order to answer the two research questions and the problem statement presented in the Introduction chapter. The chapter then goes on to describe key limitations of the two contributions as well as suggest areas for future work.

4.1 Problem Statement

Research Question 1: *What is the current state and progress of IxD research for seniors since 2000, in terms of trends in purposes, methods and topics?*

The findings of the literature review show that senior related IxD research has been on the rise in both width and depth since 2000. The research topics have become richer over time, just as attention to topics that benefit "Designers & Researchers" rather than "Users" is increasing. The focus of topics and the perception of seniors underwent a transformation during this time. The studies in the second period moved away from only addressing the cognitive decline and basic needs of seniors, and further sought to provide a better overall quality of life for them. Additionally, the image of seniors shifted from being perceived as weak and passive users to being creative co-designers and online content producers. In terms of the research methods and purposes, the preferences are similar in both periods. After "Applied", "Lab" and "Field" were the most popular methods, and the amount of "Field" research surpassed "Lab" in the second period. Both periods presented a lack of diversity in regards to employing various methods for different purposes. For example, there were very few articles using "Case" or "Survey" methods. However, in the second period this situation was somewhat improved as the "Action" method began to be utilized for different purposes. Overall, it demonstrated a trend towards more user-centered and diverse research and it is suggested that the researchers should explore more new method-purpose combinations in the future.

Research Question 2: *What are the challenges and opportunities when conducting an IxD research with seniors?*

During the remote co-design process with seniors, seven challenges and four opportunities were identified. A remote co-design process is confronted by challenges caused by conducting the activities online, including frequent distractions, unnatural

conversation forms and limited interactions. At the same time, some of the difficulties associated with traditional co-design also occurred and were even amplified due to the remote method. These include: problems with envisioning due to lack of design experience, insecurity about dealing with technology and the seniors' slow pace in design activities. The remote co-design method, however, also offers opportunities. First, it improves the seniors' willingness to participate as the access is easy and convenient. Second, it was proved effective in easing the tension associated with envisioning for some participants. Third, it is helpful in regard to addressing the insecurities about technology and pessimistic attitudes towards their own design capabilities for some participants. Lastly it enables a flexible and continuous communication between the participants and the designers or researchers. The remote approach ultimately led to a design solution which the participants were satisfied with. It is concluded that it, despite the challenges, is technically feasible to conduct co-design with seniors remotely and that remote co-design can be considered a viable alternative to traditional co-design. It is suggested that further studies of the method are undertaken in order to investigate potential ways to alleviate the identified challenges.

Problem Statement: *What are the popular topics and methods in IxD research for seniors and what are the challenges and opportunities when conducting IxD research for seniors?*

To answer the problem statement, a literature review of related papers since 2000, as well as an exploratory study on the remote co-design method, were carried out.
In the literature review, 215 articles divided into two time periods, 2000 to 2009 and 2010 to 2019, were examined. The research topics, methods and purposes for each period were identified and classified into two frameworks, which can be read in the first paper in the appendix (*Table 3-6*).
In the exploratory study, the author conducted a remote co-design process and identified seven challenges and four opportunities. These challenges and opportunities were summarized with explanations in two tables and can be found in the second paper in the appendix (*Table 2&3*).

4.2 Key Limitations

The author acknowledges the limitations of the literature review and the exploratory study of the remote co-design method. The key limitations are presented as follows.

Sample Selection Bias
In the literature review, the examined papers were all collected from just one HCI

conference - CHI. Thus, the review cannot cover the trends in research topics, methods and purposes of studies not admitted in CHI. In addition, each HCI conference usually has its own set of central authors [12], which is likely to lead to a bias in the identification of research trends. To overcome this limitation, a relatively long timeframe was chosen for study: from 2000 to 2019. By doing this, a relatively large body of literature was included for reviewing, which is expected to decrease the potential effects of sample selection bias.

User Representativeness
In the exploratory study of the remote co-design method, five seniors were recruited as participants. During the data analysis, it was found that one participant (*P5 in Paper 2*) is the only one with relatively rich design experience due to his previous occupation as an architect. In some topics, for instance, in regards to what conditions play a role in affecting the remote co-design results, this participant's opinions were considerably different from the others'. However, as the project only had one participant with such experience, it is difficult to claim that there is a general difference between seniors who have more design experience and those who have less. Thus, no representativeness is claimed in this study.

Limited Design Activities
In the exploratory study of the remote co-design method, a series of design activities were conducted remotely. According to the study of Sanders E B N et al. [13], there are three types of co-design activities: "Making", "Telling" and "Enacting". It is claimed that some activities belonging to the categories "Making" and "Telling" can be done online, while "Enacting" activities are not yet possible to be carried out online. Since this study included no design activities belonging to the category "Enacting", it cannot contribute any data analysis to support or oppose this claim.

4.3 Future Work

In order to expand on the findings from this research, additional empirical studies, specifically in regard to the remote co-design method, should be carried out as future work. It is suggested, first, to focus on looking for solutions which may compensate for the identified challenges. Second, different categories of design activities, in particular "Enacting" activities, should be included and examined in order to further examine the feasibility of the remote co-design method. Lastly, future work should seek to include senior participants from various backgrounds, for example, with different levels in technology skills or design experience.

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Appendix

(1) Jing He. A literature review of IxD research for seniors from 2000 to 2019. Department of Computer Science, Aalborg University. 2020.

(2) Jing He. "PillTime": Remote Co-Design of a mobile app for and with seniors. Department of Computer Science, Aalborg University. 2020.

A Literature Review of IxD Research for Seniors from 2000 to 2019

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ABSTRACT

With the rapid growth of the aging population, interaction design (IxD) research for seniors becomes an increasingly relevant topic. This paper presents a literature review of senior related IxD research since 2000. 215 papers on CHI were selected and divided into two periods: 2000 to 2009 and 2010 to 2019. The review has two focuses. It first classifies the papers into 11 categories based on the topics. Second it analyzes the papers using a two-dimensional framework which contains 8 research methods and 5 purposes. The findings show that this research field has been growing both in its amount of research and its ever-richer topics. Comparing the two time periods, the dominant focus has shifted from simply fixing seniors' problems with social isolation and cognitive decline towards pursuing a better quality of life with wellness and leisure. At the same time, the perception of seniors underwent a change, from being considered weak and passive users to be seen as creative co-designers and content creators. Additionally, the review of methods indicates a trend towards becoming more and user-centered and diverse.

Author Keywords

Literature Review; Design for Seniors; Cognitive Aids; Understanding Seniors; Aging in Place; Social Interaction; User-Centered; Co-Design; Research Methods.

1 INTRODUCTION

Over the last decades, the global population has been aging rapidly. Between 2017 and 2050, it is expected that all countries will experience a substantial growth in the size of the older population [1]. According to the United Nations, the worldwide number of people aged 65 or more was 703 million in 2019 and will double to 1.5 billion in 2050 [2]. Aging brings a decline in perception, cognition, mobility and control of movement [2], which can lead to unique usability constraints and different needs or preferences for technology design. This expanding demographic group is an important user group and should not be ignored by the Interaction Design (IxD) Research.

Investigating the current progress of senior related IxD research can contribute to future research into the topic by depicting the research gaps in methods and topics. Identifying these gaps is helpful for further adjustments of current research or exploring new potential research directions. While there have been plenty of papers and monographs investigating senior related IxD since 2000, there is still a lack of studies systematically presenting the development of this research field, in relation to its current state and progress in purposes, methods and topics. Given the importance of understanding the development of the IxD research for seniors, this study aims at investigating the following research question:

What is the current state and progress of IxD research for seniors since 2000, in terms of trends in purposes, methods and topics?

To answer this question, the author has conducted a literature review. The reviewed sample was decided to be senior related papers at CHI conference from 2000 to 2019.

The literature review can give a comprehensive understanding of the development of the IxD research for seniors. First, interesting to see what were, have been and are favored themes and methods among senior related IxD research, if there is any change in perception of seniors, what have disappeared and what remain popular. Second, it is meaningful to carry out a literature review for advancing knowledge, as an effective review "*facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed*" [3].

The rest of this paper is structured as follows: first, the following section presents a summary of related research. Then it introduces the literature review method. Next it presents the findings of the review analysis. Last, a discussion and conclusion are conducted.

2 RELATED WORK

No paper or monograph about a literature review on seniors related IxD research from 2000 to 2019 was found. Therefore, this section presents two kinds of related work:

monographs addressing the topic of design for seniors, and papers which conduct literature reviews.

Two types of monographies discussing design for seniors were found. One type of monograph collects relevant papers from HCI conferences and categorizes them according to their topics, but without doing analysis on the papers. For instance, Zhou et al. [4] presented papers related to IxD for older adults from the HCI International Conference 2017. The papers were divided into two parts according to their topics which are meaningful for either users or designers and developers. The other type of monograph aims at giving a comprehensive introduction of the topic design for seniors, which includes the fundamentals of aging and technology, principles or guidelines of design and application areas [1]. Both types of monograph do not, however, provide an overview or analysis of the developments and trends in the research methods.

Papers conducting literature reviews on the IxD research for seniors can be divided into two types as well. The first type focuses on one specific aspect of IxD studies for seniors. For instance, Motti L G et al.[5] conducted a literature review presenting different interaction techniques for older adults, specifically when using touchscreen devices. In addition, similar to the first type of monograph, these papers do not aim at examining the research trends, but mainly seek to identify characteristics or patterns of specific techniques or users' use of technology [5][6]. The second type of paper reviews past research and identifies the research state and trends by grouping the papers and comparing the proportion of papers. Two studies were found belonging to this type. One is a critical review of eight years research on technology for disabled and older

adults [7]. It analyzes 834 papers between 2005 to 2012 and finds that the most commonly researched user group is older adults, while interactions with technology is the most researched topic in relation to different kinds of support for this user group. The other study did a literature review of seniors related papers at CHI from 1999 to 2009 [8], which is closely related to our study. It classified the papers into ten categories according to their topics and found that "enhancing social interaction" and "Interface design" were the most favored themes. However, the studies do not cover an analysis of the research methods and the most recent research.

In summary, in the previous related work, there is a lack of an overview and analysis of the research development, in relation to the trends, areas of attention and research methods.

3 METHOD
There are different ways to approach a literature review. Borrowing from Vangeli P, Stage J. [9], this study carried out the literature review in three phases: review focus and the filtering, categorization and reading and analysis.

3.1 Review Focus and the Filtering
In order to go through related papers and present an overview, the scope of the papers to be examined was narrowed down to the papers at CHI from 2000 to 2019.

Selecting CHI papers as the sample was due to two reasons: first, the large amount of research in this field makes an exhaustive review difficult, therefore, it is necessary to limit the sample size. Second, CHI is the prestigious and long-established HCI conference which has the highest impact (citation by the others) [226]. It accepts high quality papers with the most updated themes from various

Year	Total accepted Full paper (FP)	Related FP	Ratio	Related Extended Abstracts (EA)	Both FP and EA
2000	72	0	0%	2	2
2001	69	1	1%	3	4
2002	61	0	0%	0	0
2003	75	1	1%	1	2
2004	93	1	1%	4	5
2005	93	1	1%	15	16
2006	151	2	1%	9	11
2007	182	3	2%	1	4
2008	157	0	0%	4	4
2009	277	7	3%	3	10
Total	**1230**	**16**	**1%**	**42**	**58**

Table 1. Senior related papers at CHI from 2000 to 2009

Year	Total accepted Full paper (FP)	Related FP	Ratio	Related Extended Abstracts (EA)	Both FP and EA
2010	302	7	2%	7	14
2011	410	7	2%	9	16
2012	370	10	3%	12	22
2013	392	6	2%	5	11
2014	465	10	2%	5	15
2015	379	7	2%	7	14
2016	565	6	1%	8	14
2017	600	7	1%	7	14
2018	666	2	0%	12	14
2019	703	12	2%	11	23
Total	**4852**	**74**	**2%**	**83**	**157**

Table 2. Senior related papers at CHI from 2010 to 2019

perspectives and the number of papers published yearly is relatively high. Taking these reasons into consideration, this body of literature was chosen as a sample for this literature review focus. The time period for investigation was set to be from 2000 to 2019, as papers in this time period cover both classic and current topics and methods. The timeframe was further divided into two ten years periods: from 2000 to 2009 and from 2010 to 2019. This study aims at developing two complete reviews for these two periods and subsequently identifying the research trends in topics, methods and purposes by comparing the review results.

The filtering was carried out using the ACM digital library. The keywords utilized to filter related papers includes: old/older, aging/ageing, senior, elder/elderly. There are two types of writing at CHI: full paper (FP) and extended abstracts (EA). FPs are typically 8 to 10 pages long and will be published in the conference proceedings, while the EAs are usually shorter than 8 pages and will not be published physically but only in the digital library. EAs are interesting for this study because they often present up-to-date research. In addition, EAs vary in form, including doctoral consortium, work-in-progress etc.

Through the search and filtering, 90 FPs and 145 EAs were found from 2000 to 2019. 20 EAs were excluded from further analysis, because they were in the form of workshop summaries, panels and video showcases etc., and did not describe any formal study. *Table 1* and *Table 2* were generated to show the final amount of relevant papers from 2000 to 2009 and from 2010 to 2019 respectively. The tables demonstrate the number of related FPs and EAs for each year. It is evident from the tables that the investigations kept growing both in amount and proportion from the first ten years into the second ten years. From 2000 to 2009, there were a total of 16 FPs investigating senior related IxD research accounting for 1% of the total accepted FPs. From 2010 to 2019, the amount of related FPs saw a near fivefold increase to 74, and its ratio also doubled to 2%.

3.2 Content-based Categorization
In this stage, in order to understand the areas of attention of the research, the filtered papers, both FPs and EAs, were categorized based on their content.

In the related work, two different approaches to classifying the different areas of attention were found [4][8]. Both options provide a total of ten different categories. The second option further divides the ten categories into two groups: designers & researchers and users. Considering that the first option was similarly created for a literature review on seniors related papers at CHI, it is particularly applicable for this research. However, it is often difficult to clarify whether studies are more relevant for users or designers and researchers. In order to address this situation, the grouping approach of option two was adopted to adjust the

categorization. During the review, a new category "health care and cognitive aids" was added to better categorize some related papers. Taking all the elements into consideration, the categorization framework for this literature review followed a structure that contained the ten categories from option one and one newly added category, combined with the grouping from option two.

3.3 Analysis Framework and the reading
As discussed in the related work section, many studies investigating this field discussed areas of attention, while research methods and purposes were not covered. To address this, a two-dimensional framework for research methods and purposes [10] was utilized to facilitate this analysis. This two-dimensional analysis framework was initially created to examine computer-aided software engineering (CASE) research [10]. It was then adjusted to accommodate this literature review.

The first dimension presents eight research methods: Case Study, Field Study and Field Experiment (Field), Action Research, Lab Experiment and Simulation (Lab), Survey, Applied research, Basic Research and Normative Writings. The second dimension comprises five research purposes: Understanding, Engineering, Evaluation of Product, Evaluation of Method, Reengineering. **Understanding** is a description of definitions that enable one to understand the entities studied. The original framework contains a purpose "Description", which is used to define or describe an ideal modelling process and what features should a tool include in order to support an ideal CASE environment. As this purpose overlaps with "understanding" and is more relevant for the CASE research, it has been removed from the framework. **Engineering** is the original development of a prototype or a final product, a design solution and a specific technology. The original framework contains only one "Evaluation" purpose, however, in order to better fit the IxD research, this purpose was divided into two purposes: "Evaluation - Product" and "Evaluation - Method" in this study. **Evaluation of Product** is used to determine the usefulness or affect of a product or a design solution or a specific technology. **Evaluation of Method** is used to evaluate a design/research method, or to examine if certain factors will work or affect the design results. Both evaluation purposes include assessment, validation and assurance. **Reengineering** is the re-development of an existing product / design solution or product fragment.

4 RESULTS
This section presents the findings from the literature review on the two aforementioned time periods, in relation to the research topics, methods and purposes.

4.1 Findings on topics from 2000 to 2009
Table 3 provides an overview of the topics of senior related IxD research publications at CHI from 2000 to 2009. 58 articles (including both FP and EA) were identified as

senior related and were further classified into 11 categories. The papers are presented with a reference number in the column "reference" in *Table 3*. It should be noted that one article can be classified into more than one category, and the "rate" of each "Category" (2nd column in Table 3), therefore, exceeds 100% when added up. The first column "Aspect" contains two aspects: "Designers & Researchers" and "Users". These indicate whether a "Category" primarily aims to benefit the designers and researchers or the users. Excluding repeated references in the same "Aspect", it can be seen that there were 25 papers under the aspect "Designers & Researchers" and 39 papers under "Users", showing a clear preference towards topics directly addressing users' needs.

Focus on Companion and Social Interaction
Table 3 shows that "**Social Interaction**" is the most studied research category in this time period. It was a primary concern of many studies that seniors were likely to suffer loss of companionship and therefore researchers sought to

help the seniors avoid isolation or depression through the use of technology [36]. Papers in this category aimed at alleviating the loneliness of seniors, particularly those living alone. By enhancing the seniors' social interaction, the studies sought to boost social well-being and help them cope with cognitive decline. Proposed design solutions include designs such as artificial companions and digital photos, which are mainly set in domestic space, as well as design for outdoor activities, such as socialization through ride sharing etc. A category with similar goals is "**Intergenerational Communication**". It focuses on using design to enable communication between seniors and younger generations, most often referring to communication with younger family members. It is worth noting that some studies served many different purposes at the same time. This is especially visible in the many "exergame" designs that aimed to contribute to social interaction, family communication, positive entertainment and even exercise [31][33][45].

Aspect	Category	Related Topics	reference	total	rate
Designers & Researchers	Interface Design	• Effects of font type and size, usage of hyperlinks of small screens, proxy targets • Robotic walker interface, a relational agent interface, book user interface	13, 19, 27, 34, 52, 55, 56	7	12%
	Understanding Seniors	• Use of mobile phone • age-related difference in social networking, in visual verbs in daily communication, in pen-based selection accuracy	41, 42, 43, 63, 67, 69	6	10%
	Design Methods	• user/human/senior-centered design, co-design • design guidelines, universal design for mobile phones, scenario-based design, design strategy	15, 31, 38, 46, 48, 62	5	9%
	The Web	• web usability • web search approach, adaptive web information search	20, 53, 68	3	5%
	Domestic Technologies	• supporting aging in place, functional and emotional geography of seniors' domestic space	32, 35, 66	3	5%
	Tangible Interfaces	• Touchscreen • book user interface, evocative tangible interface	17, 34, 42	3	5%
Users	Social Interaction	• combat social isolation, alleviate homebound loneliness, artificial/surrogate companion • social interaction coping with cognitive decline, reminiscence and social wellbeing, positive social exchange by dancing • social connectedness, digital fotos/fotos sharing, ridesharing and socialization	14, 17, 22, 24, 27, 28, 29, 30, 31 33, 35, 36, 44, 47, 49, 51, 64	17	29%
	Health Care and Cognitive Aids	• web health information architecture, exercise through dance, aiding name recall, mental health and online communication • Multimodal feedback for visual impairment, multimedia conversation aid in dementia care, assisted-care robot in multiparty communication, health management practice of seniors with diabetes	15, 18, 21, 23, 31, 54, 60, 61	8	14%
	Navigation Aids	• online shop navigation, web navigation approach • robotic walker, test methodology for pedestrian navigation aids • simulated AR windshield display, in-car speech based Information system	12, 19, 26, 40, 53, 65	6	10%
	Intergenerational communication	• family communication • social and physical family entertainment with game	16, 37, 39, 45, 67	5	9%
	Technology Training	• technology accessibility, increasing the accessibility of the pen-based technology • improving the learnability of mobile device applications for older adults	11, 34, 58, 59	4	7%

Table 3. Topics of senior related IxD research from 2000 to 2009

Support for compensation in cognition and health care
As mentioned in the introduction, when people age, they will experience a clear decline in perception, cognition, mobility and control of movement. The selected IxD research also looked into this condition and attempted to use technology design to compensate for this decline. Two categories "**Health Care and Cognitive Aids**" and "**Navigation Aids**" present the studies which aim at supporting aging in place by facilitating health care and compensation for loss of cognition with relevant designs. Many studies in the category "**Health Care and Cognitive Aids**", had older adults with diseases or disabilities as the users groups, for example seniors with visual impairment, dementia or diabetes. The research attempted to reduce the effects of these diseases or disabilities or improve the elderly's health management practices. A popular topic in this category is developing communication aid systems for seniors who have difficulty in making conversation, for example, those with visual impairment or dementia. Besides, there were also studies that emphasised health-related problems caused by technology use. For instance, paper [54] addresses depression and emotional problems which can occur through the use of online communication, by identifying patterns of empathy.

Interests in User-Centered Design
"**Interface Design**", "**Understanding Seniors**" and "**Design Methods**" are the three categories receiving most attention in respect to assisting the work of "**Researchers & Designers**". For this aspect, a clear trend can be observed where the studies seek to deliver user-centered designs.

The "**Design Methods**" category in this time period favored the topic "user/senior/human centered design", where the design process was carried out centered around the users' real requirements. In addition, studies investigating co-design with seniors also emerged, which included seniors as co-designers in the design process [17][48]. "Understanding Users" is often considered as the first step of user-centered design. The research interests in "**Understanding Seniors**" in this time period can also be seen as an effort to come closer to a senior-centered design. Most selected papers in this category aimed to identify the age related difference of IxD topics, such as social networking and visual verbs in communication, by comparing the results between older and younger users. The identified results can be used to address the users' age-related problems. "**Interface Design**" is a classic category in terms with IxD. Among the selected papers, investigations in relation to Interface Design mostly search for optimal design solutions best fitting the seniors' preferences or their different levels of cognitive decline etc. For example, paper [13] aimed at finding the optimal font size and type to enable the elderly to maintain a good reading speed. A novel study [34] presented a "Book as

User Interface" solution to make the technology accessible to seniors with insecurities about technology.

Overall, the review in this time period shows an inclination towards solving users' problems with design solutions, especially in regard to combating loneliness and providing aids for health care and cognitive support.

4.2 Findings on topics from 2010 to 2019
Table 4 presents an overview of senior related topics identified in the time period 2010 to 2019. Compared to *table 3* for the review of 2000 to 2009, the "Related Topics" column of *table 4* has different content. The two aspects and eleven categories remain unchanged. The reviewed papers in this period totals 157, which is a near threefold increase compared to the 58 from 2000 to 2009. Therefore, there were richer topics found for each category in this time period. In relation to the two aspects, again excluding repeated references in the same "Aspect", 88 articles were categorized as "Designers & Researchers", and 83 as "Users". Unlike the results from 2000 to 2009, the topics related to designers and researchers were favored over ones related to users in this period. Regarding each category, in the aspect "designers & researchers", "Understanding Seniors" and "Design Methods" surpassed "interface Design" in this time period to receive the most attention. Additionally, there is a clear increase of papers in the category "Tangible Interface". In the aspect "users", "Social Interaction" and "Intergenerational communication" maintains a high number of studies, but are overtaken as the most popular categories by "Health Care and Cognitive Aids". Following the review, three new trends were identified for this period.

Caregiving, Wellness, Mental and Social health
In the category "Health Care and Cognitive Aids", similar to the previous period, there were a great number of papers discussing how to provide aids for seniors with disease or disabilities, such as cognition impairment, post-stroke and chronic conditions. With the exception of this stable topic, three new trends in terms of the related topics can be observed.

First, the papers on the topic "caregiving" increased both in total amount and in care types. Unlike the previous period, these studies start investigating not only how to improve home care, but also clinical care and residential/hospital care. Common themes include communication among family and respite caregivers and support of different care settings using ICT. A new theme worth particular attention is a new way to access health care service. Here studies seek to enable the patients to see the doctors remotely or acquire clinical diagnoses more effectively, resulting in design solutions such as the telehealth bot [204] and virtual training doctors for shared decision making [205]. Second, beside the studies focusing on home care or medical care, there was a clear preference for investigating topics related

to enhancing wellness and mental and social health. In order to maintain regular physical activities, applications for personal training or exercise were developed to encourage or assist seniors [71][100][193]. An interesting finding is that game design, more specifically exergames, was a particularly popular topic for many researchers in this period. The exergame combines exercise with gaming, and is able to motivate the seniors to exercise more, as the exergame is considered more entertaining regular exercise. Additionally, there were investigations exploring the effect of games or exergames in improving social interaction and intergenerational communication. Playing a game or exergame with others was found to have the potential to

Aspect	Category	Related Topics	reference	total	rate
Designers & Researchers	Understanding Seniors	• Cultural dependency • Game preference, Exergame, Engage in Leisure Activities • Socio-economic life: design for different status, social relations with emotions, mobility eco-feedback • Privacy & security concern • age-related difference in web search, in exploratory learning, in Smartphone Authentication, perceptions of companion robots	70, 74, 76,77, 78, 81, 82, 84, 103, 104, 111, 118, 121, 123, 126, 136, 137, 140, 142, 163, 165, 168, 170, 171, 177, 183, 184, 185, 186, 188, 198, 202, 203, 214, 215, 221, 222, 225	38	24%
	Design Methods	• Participatory design, co-design, OAs as content producers • cognitive modelling, creation of personas, Design Fictions	101, 110, 113, 114, 115, 116, 125, 128, 131, 139, 146, 154, 156, 169, 175, 176, 179, 195, 196, 199, 206, 212, 215, 220, 223	25	16%
	Interface Design	• haptic UI, automotive UI, voice UI, web eye-tracking, cursor relocation, point and click, multiple notification modalities, Skeuomorphism	71, 93, 96, 97, 122, 129, 134, 145, 150, 193, 197, 207	12	8%
	Tangible Interfaces	• touchscreen, pointing facilitation on tablet PC, input method • interactive plant design, tangible game, tactile Aid	75, 76, 79, 92, 130, 142, 148, 164, 167, 173, 192	11	7%
	Domestic Technologies	• Home activity life logging with sensor • Smart home, supporting independence and comfort at home	73, 82, 94, 149, 207	5	3%
	The Web	• web information credibility assessment, web search strategy, contextual help for web tasks	74, 77, 96, 147	4	3%
Users	Health Care and Cognitive Aids	• Improve wellness and health, personal training app., wellness in senior centers, remote exercise system • Design for OAs with tremors, with cognitive impairment,with Alzheimer, with post-stroke, with multiple chronic conditions, with low-visions, with diabetes, with rehabilitation needs, with fall risks • Game for exercise, for rehabilitation, for mental and social health • Communication with medical or home caregiver, support clinical care and residential care, telehealth bots, virtual training doctor, Exoskeleton Technology, context-aware cognitive assistent • function of service robots, reminder system, HCI and Menopause	71, 72, 74, 75, 76, 80, 84, 85, 87, 88, 89, 91, 92, 94, 100, 105, 106, 109, 112, 115, 117, 119, 120, 127, 132, 133, 135, 141, 146, 148, 155, 159, 161, 164, 166, 174, 178, 180, 190, 191, 193, 204, 205, 210, 213, 216, 217, 219,224	47	30%
	Social Interaction	• communication needs of OAs with diseases, therapy robot • online social networking, collaborative consumption, connecting through storytelling • Game as socialization aids, physical and social activity	83, 86, 88, 90, 95, 99, 102, 106, 109, 124, 138, 166, 187, 200, 218	15	10%
	Intergenerational communication	• Family communication in hospital care, for AD patients, for elderly fallers, for hearing impaired OAs, remotely • Games, video sharing service, aligned social interaction space	69, 107, 108, 126, 151, 152, 153, 160, 178, 181, 201, 208, 211	13	8%
	Technology Training	• accessibility and appeal of surface computing , learning programming • mobile phone personalization, Customizable Assistive Approach	76, 79, 98, 157, 158, 172, 182, 209	8	5%
	Navigation Aids	• car dashboard displays, In-Vehicle Navigation Map, support mobility with ridesharing, pedestrian navigation app	93, 134, 144, 162, 189, 194	6	4%

Table 4. Topics of senior related IxD research from 2010 to 2019

build social connections and thus to improve mental and social health [99] [141] [209].

Seniors as Co-Designer and Content Producer

Table 7 shows a clear growth in amount and proportion of the category "Design Methods" from 2010 to 2019. In this period, there was a strong tendency towards researchers exploring the empowerment of users as co-designers or content creators.

Co-design (Co-operative Design) and participatory design are important design methods in relation to user involvement. Participatory design (PD) focuses on involving different stakeholders in the design process. Co-design is a way to conduct participatory design, that is characterized by emphasizing the role of users in the design process. In the Co-design method, users cooperate with designers or developers to deliver design solutions together. While there were only 2 papers identified as dealing with Co-design or PD from 2000 to 2009, this number increased to 17 from 2010 to 2019. Related studies included investigations of the methods themselves, by studying their benefits and weaknesses as well as approaches to applying the methods on real design practices. Regarding design practices, the researchers collaborate with senior participants to design products such as an enhancing toilet system, falls rehabilitation tools and Internet of Things applications [115][176][223]etc. Similarly, some research identified the potential role as content producers for seniors and sought to understand how they worked online to create content and share the content with others [131] [169] .

New topics to understand seniors

In the category "Understanding Seniors", some new types of topics were identified, in addition to the classic topic "age-related difference in usage of technology etc.": varying cultural attitudes towards concepts, games and entertainment, concern about privacy and security, and lastly the influence of their socio-economic background.

Peoples' perception towards design concepts and usage of technology can be affected by their culture. In order to develop designs which are in accordance with the seniors' cultural patterns, it is necessary to have an initial understanding of the related cultural dependency or attitude. For example, the study [145] discovered that Caucasians preferred minimum interface design, while East Asian seniors preferred the rich interface augmented with security. The findings of such investigations can be further applied for interface design for older adults with different cultural attitudes towards uncertainty.

Game design is another topic that appears between 2010 and 2019. In addition to discussing games' positive effects on health care and socialization, researchers have also investigated how seniors can use games as an entertainment aid to provide leisure and entertainment [109].

There was also a growing concern about internet privacy and security in this time period. Studies on privacy mainly aimed at understanding the seniors' perception of privacy, their concern about sharing data and their privacy needs for aging in place [82][203][214]. Studies in relation to security attempted to analyze the online security risks, such as cybersecurity attacks, scams, phishing emails etc., and especially discussed its effects on seniors with cognitive impairments [186][221][222]. The research aimed to reduce the security risks for the senior users. For instance, paper [221] developed a cybersecurity information access framework, which highlights shortcomings in seniors' choice of information sources. The results of these studies can be helpful for designers and researchers to develop design solutions which incorporate the seniors' needs for privacy and security.

The socio-economic conditions of seniors was identified as a new important topic. Unlike the traditional topics dealing with understanding, which aim at uncovering the age-specific difference in physical aspects such as cognitive level, this topic focuses on understanding the seniors in a societal context, as their social relations and economic status play important roles in affecting their life and forming their requirements. In this time period, much attention was given to investigating the actual needs of seniors with different socioeconomic statuses as well as its effect on other aspects. The research is especially aimed at those with low income and/or minorities[84][215]. Furthermore, seniors' social participation and their ideas of environmental protection were also investigated in this period [165][177].

4.3 Findings on methods and purposes from 2000 to 2009

Table 5 depicts the research methods and purposes of the relevant papers from 2000 to 2009. It should be noted that many papers employ different research methods and have more than one purpose, therefore, the reference number of one paper can appear in more than one category in the analysis framework table. The calculation of the total amount for both dimensions, however, excludes repeated numbers.

Favored Methods and Purposes

It can be seen from *Table 5* that the purpose "Understanding" was the most favored with 35 papers, followed by "Evaluation-Product" and "Engineering" with 27 and 23 papers each. In terms of methods, 50 papers with a practical goal to be applied for "Engineering" or "Evaluation-Product" were found and classified as "Applied" research. Except "Applied" , "Lab" and "Field" are the most commonly utilized methods from 2000 to 2009, with 36 and 27 papers respectively. These two methods were also found to be applied to the majority purposes. In addition, it can be noticed that a great number

Methods \ Purposes	Case	Field	Action	Lab	Survey	Applied	Basic	Normative	Total
Understanding	30, 54	14, 22, 24, 25, 32, 33, 35, 37, 44, 50, 57, 60, 66		12, 13, 15, 18, 20, 21, 23, 26, 52, 56, 58, 63, 67, 68	25, 28, 41, 46, 64			11, 38	**35 (60%)**
Engineering		16, 17, 25, 30, 31, 44, 45, 51, 60		16, 19, 21, 24, 29, 32, 33, 35, 36, 37, 38, 43, 49, 58, 61		16, 17, 19, 21, 24, 25, 29, 30, 31, 32, 33, 35, 36, 37, 38, 43, 44, 45, 49, 51, 58, 60, 61			**23 (40%)**
Evaluation - Product		16, 17, 27, 28, 30, 31, 36, 39, 44, 47, 51, 60, 64		12, 16, 21, 25, 26, 29, 33, 34, 35, 42, 49, 55, 58, 61, 65		12, 16, 17, 21, 25, 26, 28, 29,30, 31, 33, 34, 35, 36, 39, 42, 44, 47, 49, 51,55, 58, 60, 61, 64, 65			**27 (47%)**
Evaluation - Methods		48		20, 40, 52, 53, 59, 62					**7 (12%)**
Reengineering									**0**
Total	**2 (3%)**	**27 (47%)**	**0**	**36 (62%)**	**5 (9%)**	**50 (86%)**	**0**	**2 (3%)**	

Table 5. Research Methods and Purposes from 2000 to 2009

of articles were classified as having more than one purpose or method. A very common combination of purposes is "Engineering" plus "Evaluation-Product". In many investigations, researchers first developed design solutions or products and subsequently tested them together with users in a lab or field environment. These studies were categorized as having both the "Engineering" and "Evaluation-Product" purposes. For instance, we can see that among the papers using the "Field" method, 9 papers were identified having the "Engineering" purpose, and that 7 out of these 9 papers simultaneously have the "Evaluation-Product" purpose.

Research Gaps in Methods and Purposes
It cannot be overlooked that, in addition to the aforementioned popular methods and purposes, there are 27 empty combinations out of the total 40 cells in *Table 5*. In regard to purposes, only seven papers were identified as "Evaluation-Method", making up 12% of the total amount.

This is considerably less than the papers classified as "Understanding", "Engineering" and "Evaluation-Product", each making up more than 40%. In addition, no papers were categorized as Reengineering. It should be pointed out that if an investigation has an iterative process, including iterative design and evaluation, it is classified as "Engineering" rather than "Reengineering", as the development is not finished until the iterations are fully completed. In terms of methods, no publications were found to be "Action" or "Basic" research. Articles identified as "Case", "Survey" and "Normative" writings were also very few, with 2, 5, 2 papers respectively. Furthermore, these three methods only occured with the "Understanding" purpose.

4.4 Findings on methods and purposes from 2010 to 2019
Table 6 gives an overview of the review results on methods and purposes for 2010 to 2019.

Methods \ Purposes	Case	Field	Action	Lab	Survey	Applied	Basic	Normative	Total
Understanding	72, 87, 110	78, 82, 83, 85, 90, 91, 100, 103, 104, 105, 108, 109, 119, 120, 121, 127, 132, 133, 137, 140, 142, 144, 145, 147, 148, 149, 150, 151, 155, 159, 161, 163, 165, 170, 172, 174, 177, 178, 183, 184, 186, 187, 188, 194, 195, 202, 210, 211, 217, 222, 224, 225	119, 175, 216, 218,	74, 76, 77, 81, 84, 93, 96, 99, 111, 115, 118, 123, 124, 129, 130, 134, 138, 162, 173, 185, 190, 197, 198, 203, 204, 207, 208, 209, 213, 221	88, 136, 150, 168, 169, 171, 182, 189, 200			214	**97 (62%)**
Engineering		73, 83, 85, 86, 90, 95, 106, 107, 108, 112, 146, 152, 153, 154, 176, 183, 187, 195, 212		69, 71, 72, 89, 91, 97, 100, 101, 102, 114, 125, 127, 134, 135, 143, 147, 151, 156, 164, 166, 167, 173, 180, 181, 191, 192, 193, 196, 198, 206, 219		69, 71, 72, 73, 83, 85, 86, 89, 91, 95, 97, 100, 101, 102, 106, 107, 108, 112, 114, 125, 127, 134, 135, 143, 146, 147, 151, 152, 153, 154, 156, 164, 166, 167, 173, 176, 180, 181, 183, 187, 191, 192, 193, 195, 196, 198, 206, 212, 219			**49 (31%)**
Evaluation - Product		73, 75, 83, 86, 94, 95, 106, 107, 131, 133, 141, 145, 146, 148, 152, 153, 156, 157, 158, 159, 160, 163, 165, 195, 201, 202, 223		69, 71, 72, 79, 80, 91, 93, 97, 98, 100, 101, 102, 105, 117, 122, 125, 126, 127, 135, 147, 162, 173, 180, 181, 191, 192, 197, 204, 205, 206, 207, 208, 209		69, 71, 72, 73, 75, 79, 80, 83, 86, 91, 93, 94, 95, 97, 98, 100, 101, 102, 105, 106, 107, 117, 122, 125, 126, 127, 131, 133, 135, 141, 145, 146, 147, 148, 152, 153, 156, 157, 158, 159, 160, 162, 163, 165, 173, 180, 181, 191, 192, 195, 197, 201, 202, 204, 205, 206, 207, 208, 209, 223			**61 (39%)**
Evaluation - Methods		128, 139, 154, 176, 179, 188,199, 215	175	70, 92, 96, 99, 113, 115, 138, 193, 196, 220					**19 (12%)**
Reengineering									**0**
Total	**3 (2%)**	**77 (49%)**	**4 (3%)**	**70 (45%)**	**9 (6%)**	**110 (70%)**	**0**	**1 (1%)**	

Table 6. Research Methods and Purposes from 2010 to 2019

In regards to favored methods and purposes, it has many similarities with the results in the previous period. "Understanding" and "Evaluation of Product" are still the most popular purposes with 62% and 39% of investigations respectively, followed by "Engineering" and "Evaluation of methods". Most papers (70%) were identified as goal-driven "Applied" research. Excluding the "Applied" method, "Lab" and "Field" remained the most favored among the rest of the methods, with 49% and 45% articles each. What differs from the previous period is that "Field" overtook "Lab" to become the overall second-most popular method, behind "Applied". When considering methods utilized to each individual purpose, "Field" is the most used for the purpose "Understanding", while also often being applied for the purpose of "Engineering" as well as "Evaluation" of both product and method.

Research Gaps and Changes

There were, again, no papers identified with Reengineering as the purpose just as none was identified as Basic research. The methods "Case", "Survey" and "Normative" were likewise only used for studies with the "Understanding" purpose. However, despite these similarities with the previous period, there were still differences, notably the introduction of the "Action" research method. Thus, compared to the 27 empty table cells in 2000 to 2009, this number was cut to 25 in this period, which means there were studies employing purpose-method combinations which were not utilized before. These new changes occured in the two combinations: "Action" plus "Understanding" and "Action" plus "Evaluation-Method". In this time period, four papers were identified as "Action" research, compared to none in 2000 to 2009. These papers were mostly addressing participatory design topics, where the researchers joined groups of seniors, such as creative groups or electronic artefacts groups [175][206] to collect first hand data by experiencing the lived reality of the researched group. These studies aimed at either understanding the users or evaluating the participatory design method.

5 DISCUSSION

This section presents a discussion of the trends identified in the two different time periods.

5.1 Classic Cognitive Aids and Social interaction

In both periods, categories providing cognitive aids and companionship were investigated by a number of papers. Researchers seek to compensate for seniors' decline in cognition and support their aging in place with technology design. However, it can be seen that in the period 2010 to 2019, there was a move towards much broader definitions and ideas about how technology can improve the lives of seniors. Rather than merely focussing on how technology may alleviate the negative impacts of aging, researchers have begun to investigate how they can assist in improving conditions for seniors in a much broader sense. While the research from 2010 to 2019 still holds a strong interest in classical topics, such as improving health care and social interaction for the seniors, a move from only covering their most basic needs, towards supporting the seniors improving their quality of life in more diverse ways can be seen. This change in scope is likely to stem from an improvement of the technology available to develop such solutions, but it may also be an indication of a shift in the way that designers and developers perceive seniors. Instead of being a group who should only have their most basic problems alleviated, seniors are increasingly considered a group who can benefit from modern technology on a much more general level, comparable to that of other user groups.

5.2 Positive Image Change of the seniors

Aclear change can be noticed in the perception of seniors. From 2000 to 2009, the image of the seniors was considered mainly as passive and weak. As a result, the primary concern of IxD research in this time period was to help the seniors overcome issues such as loneliness and social isolation. In addition, they were also often associated with disabilities and diseases. Therefore, many studies sought to develop products and interface design solutions to assist the seniors with their cognitive impairments or diseases. This perception of seniors underwent a positive transformation in 2010 to 2019. This is particularly evident in the design methods participatory design and co-design, where the seniors begin to play the role as co-designers. In these studies, seniors were perceived as resources that have the ability to be creative and generate usable designs. This transformation is also seen in the investigations of seniors as online content creators or producers.

5.3 User-Centered Research

The review of research methods and purposes of both time periods showed that the tendency to employ user-centered approaches became more evident over time. This characteristic is demonstrated by the increasing preference for the research method "Field" and the purposes "Understanding" and "Evaluation" (of product or method). User-centered approach is characterized by the design being driven by the user's requirements and the final design solution or product should be usable by the users. In this sense, "Understanding" and "Evaluation" are the most meaningful purposes for a user-centered process, as the users' needs are acquired in the "Understanding" stage and the design solutions are validated by the users in the "Evaluation" stage. The method "Field" focuses on conducting research in a natural setting, making it suitable for user-centered research. First, to get to understand the users, the data collected from their real life or work environment will be more reliable. Second, users will ultimately utilize a design solution in a real environment

rather than in a lab, and thus, the results of evaluation activities will more accurately resemble real life use.

5.4 Towards a more Diverse Research

The review of the research methods and purposes reflects the current research state and trends as follows.

First, in its current state the senior related research has a number of purpose-method combinations that are not employed by any study during the two periods (See the empty table cells in Table 5 and 6). This phenomenon could be a result of the user-centered tendency, that is discussed above. However, the senior related research should still seek to include more diverse methods, as each different method-purpose combination has its own unique advantages and pitfalls. For instance, as the currently under-used "Survey" method is environment independent, and no particular setting is required, it is suitable for collecting data with large samples [10]. Therefore, if a study, for example, aims to uncover behavioural patterns or underlying attitudes towards a certain design solution, rich data from a large number of senior users for quantitative analysis will be ideal. In this case, "Survey" will be an appropriate method to apply to collect evaluation responses. Second, in spite of this current state, a slight trend towards utilizing more combinations was noticed as "Action" plus "Understanding" and "Action" plus "Evaluation-Method" began to be used in the second period. The research is in this sense moving towards a more diverse direction. By continuing to explore new combinations, researchers may discover novel findings that can otherwise be elusive within the current commonly utilized research designs.

6 CONCLUSION

This paper has presented a literature review on the senior related research papers at CHI with two time periods, one from 2000 to 2009, the other from 2010 to 2019.

Overall, the senior-related research received increasing attention since 2000. With the growth of research papers both in total amount and in its proportion of CHI papers, the related research topics have been enriched both in depth and in width. In the first period, research focused on addressing the negative effects of aging by enhancing seniors' social interaction and providing cognitive aids. In the second period, the emphasis of studies has been shifted. Rather than merely seeking to fix seniors' problems and cover basic needs, researchers were more interested in exploring approaches in areas such as wellness and exergames to improve their quality of life. Understanding the seniors in their cultural dependency, socio-economic status etc. thus became necessary and several studies were conducted exploring these topics. Moreover, seniors' image underwent a positive change, from being seen as weak and passive users in the first period to being considered creative co-designers or content producers in the second period. At the same time, researchers showed greater interest in

conducting studies intending to benefit the "Designers & Researcher" rather than for "Users". In relation to research methods and purposes, the review indicates that the current research is characterized by the use of user-centered approaches. In both periods, it is found that many combinations of methods and purposes are not used. There was, however, a slight trend towards a greater diversification of research with the inclusion of novel purpose-method combinations in the second period.

Limitations

The author acknowledges the limitations connected to this narrative literature review. First, as the body of literature examined was selected from only one conference, CHI, there can be a sample selection bias, and it is possible that the papers in this sample cannot cover research topics and methods of papers not included in CHI. For instance, as each HCI conference has a different set of central researchers [226], this centrality could affect the representativeness of the publications from that particular conference. In this study, most reviewed articles were identified as "Applied" research and none as "Basic" research, which is the main method to build theory or to be applied for fundamental research questions [10]. This evident difference is potentially a result of a more technique-oriented acceptance preference of CHI. Second, the two-dimensional framework for analyzing methods and purpose originally stem from CASE research. As a result, the two dimensions may not be completely aligned with the methods and purposes of the IxD research.

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"PillTime": Remote Co-Design of a Mobile App for and with Seniors

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ABSTRACT

A significant amount of research has investigated the user involvement method, participatory design or co-design with seniors In such research, all involved participants are present physically. his paper presents an empirical study aiming to identify and discuss the problems and opportunities regarding co-design with seniors remotely. Five Older Adults participated in a remote co-design of a Mobile App. The activities, which were all conducted online, include two surveys, a design workshop and two rounds of usability testings. The investigations identified several problems: frequent distractions, unnatural conversation form, limited interaction, insecurity of Tech etc., but as well opportunities: improvement of participation willingness, ease tension and continuous communication etc. Remote co-design is technically feasible and can be a potential alternative for face-to-face activities, especially when it is carried out with proper guidance and communication from the moderator, a slow pace, and a well prepared structure etc.

Author Keywords

Remote Co-Design; Older Adults; Remote Usability Testing; Design Workshop; Mobile App Design.

1. INTRODUCTION

Many countries in the world are experiencing a growth of the 65+ demographic group. Globally, there were 703 million people aged 65 or over in 2019 and this number is projected to double to 1.5 billion in 2050 [1]. As people age, they will experience a reduction in their cognitive and perceptual ability. Their muscular strength and capabilities to control their movement also begin to decline around age 60 [2]. The way they interact with technology and technology design is likewise affected by this reduction of capabilities. It results in various different needs for the Interaction Design (IxD). Accordingly, it can be observed that researchers' interests in IxD for seniors has kept increasing in line with the growth of this demographic group. Between 2000 and 2009, there are 16 full papers investigating the interaction design for the elderly at CHI conference, making up 1 % of the total papers. This number has doubled to 2% from 2010 to 2019 with 74 elderly-related papers [3].

Regarding the design methods, researchers have shown a great interest in User-Centered Design (UCD) and the Participatory Design (PD) [3]. Both methods consider user involvement as a priority. PD emerged from Scandinavia in the 70s and 80s to empower people in their workplace [4]. The main difference between PD and traditional design is that the user plays a critical role in designing in PD [5]. Cooperative Design, known as Co-Design, is a way to do PD. While PD emphasizes including all stakeholders participate in the design process, Co-Design focuses on design collaboration. In this method, the users are empowered as co-designers, while the professional designers play a supportive role to facilitate the process.

From 2010 to 2019, the perception of aging has undergone considerable change. Older Adults are considered as creative individuals rather than weak and helpless. Following this, many IxD researchers adopted the co-design method and attempted to involve older adults in co-designing. Examples count the development of a smart pen reminder system [6], an evocative tangible interface [7], an enhanced toilet system [8], Custom electronics [9], falls habilitation tools [10], digital payments [11] and game concepts [12] etc. These Co-Design investigations, however, are all carried out in a face-to-face manner. At the beginning of this project, the Covid-19 pandemic broke out and remote work was implemented in most workplaces. Since older adults are among the groups of people most vulnerable to Covid-19 [13], this new situation raises a challenge for co-design with seniors, as design activities have to be done without any physical contact.

It is therefore relevant to explore the co-design method under circumstances where the researchers and senior participants are spatially separated. In this paper this method will be referred to as "Remote Co-Design". In a "Remote Co-Design" with seniors, the elderly are supposed to participate through online video conferencing apps while being physically separate. Taking all of the above mentioned factors into consideration, the following research question has been specified:

What challenges and opportunities occur when co-design with seniors is carried out remotely?

1

This research question aims to examine the feasibility of the remote co-design method with seniors, and to discuss potential improvements for the method.

The paper is structured as follows: First it introduces the work related to co-design with seniors, remote usability testing and remote co-design. The second section will account for the methods applied during this project. In the third section the results will be presented and analyzed. Finally, it will provide a discussion and conclusion.

2. RELATED WORK

No related research in the field "remote co-design with seniors" were found by the time this paper was written. Therefore, the related work presented in this section is divided into the following three areas: Co-Design with older adults, Remote Usability Testing and Remote Co-Design.

2.1 Co-Design with Older Adults

Participatory design or co-design with seniors is becoming a popular research topic. Just at CHI, there are already 19 papers dealing with this topic between 2000 and 2019, among which 17 papers are from 2010 to 2019 [3].

An increasing amount of research seek to investigate the opportunities and strategies of co-designing with seniors. The seniors are assumed to be creative designers or content-creators, that can also have unique ideas and deliver creative solutions. The research shows that co-design with older participants can lead to rich, creative and non-stereotypical results, which surprised even the researchers [12]. Regarding the co-design strategy, it is important to have a good information policy and build mutual trust among the seniors, facilitators and moderators, as this helps to elicitate actual needs and receive honest feedback [14]. Besides, the environment and process of co-design should keep a slow structural pace and ensure that seniors of all skill levels can follow [15]. It has proven useful to make the older users feel the technology is understandable by providing demonstrators or tangible crafts [8][15].

Beside opportunities, co-design with the seniors also face many challenges. First, older people usually show a lower acceptance of technology and are more likely to perceive the new technology as not being useful just as they are afraid that they will fail more when using it compared to younger users.[16] This mindset can make it difficult to engage them as active co-designers. However, researchers found that the problem lies primarily with the methods used to involve them in the use of new technologies. They will show higher interest in engaging with technology when these issues are properly addressed [16]. Researchers also found that many senior citizens do in fact have the motivation to learn, and that it actually brings the seniors intellectual and emotional satisfaction when they are learning to use something novel [14]. Maintaining focus and structure, representing and acting on Issues, envisioning intangible concepts and designing for non-tasks are also found to be difficult tasks in a co-design session, as the

elderly are not experienced in design, especifically in technology design or interaction design. Research found that establishing an appropriate atmosphere and using envision-assistive tools, such as Video Prompt Creation [16] can be a way to cope with these problems, especially in relation to maintaining focus and creating a vision.

In regard to approaches of conducting a co-design with seniors, researchers often follow a three-phase-process. First, they attempt to get a deeper understanding of the users and their' requirements for a service or product. Two types of methods are usually utilized to collect data for this goal. One method is done by asking users relevant questions to elicit information. Interviews or questionnaires are classic approaches for this purpose and usually takes place in a laboratory setting. The other method attempts to understand the users in a real environment. Researchers can, for example, conduct ethnographic inquiries by observing, interviewing and "probing" the senior participants at home[12]. This phase is followed by a co-design workshop aiming at ideation with the support of researchers acting as moderators and facilitators. Generally, it consists of the following three steps: idea generation, idea evaluation and idea visualization. Many approaches have been developed for idea generation, such as cultural probes, user/persona scenarios, and card sorting The result of a design workshop is the visualization of visions: user sketches, storyboards, paper/low-fi prototype or other artefacts [12] [16]. The last step of this co-design process is usually an evaluation session by conducting usability testing, which aims at evaluating if the co-design results can meet the users' requirements. In large and long-running projects, this process tends to be iterative and allows regular meetings with different user groups [17].

2.2 Remote Usability Testing

Although the Remote Usability Testing (RUT) is not an internal part of a Co-Design Session, it is still an important method to involve the users remotely. This user-centered approach serves as evaluation of the remote Co-Design results. Thus, it is an important part and related topic to the whole process.

RUT emerged between 1994 and 1998 [21]. Traditionally, Usability Testing takes place in a laboratory with users and evaluators. RUT, however, takes place under circumstances where the evaluators and the users are separated in space and/or time [22]. The RUT is becoming an increasingly prevalent research method as the rapid development of the software industry has created an increasing demand for usability testing. In addition, RUT generally only requires a stable internet connection and a digital device (preferably a PC). These requirements are easily fulfilled with the global spread of the internet and PCs.

There are two types of RUT methods: synchronous and asynchronous RUT. Asynchronous RUT has various forms and it is done when the user and evaluators are separated by time. Synchronous RUT, also called remote synchronous usability testing (RS), has received the most attention from researchers. It stimulates the traditional lab-based

think-aloud usability testing [21]. The RS is favored by some authors because it is cost efficient, timesaving and it provides freedom from facilities [23]. In an RS, the evaluators and the facilitator collect data and manage the testing with a participant who is based remotely. In contrast to asynchronous RUT, the evaluators collect the data in real time and the facilitator can interact with the user during the data collection [23]. For example, in a classic RS for a web application, the user and the evaluator are physically located in different places but they are present at the same video conference online with their PCs. The user shares their screen during the testing, so that the evaluators and the facilitator can assess the data in real time. In addition, the video and audio will be recorded for later data analysis.

2.3 Remote Co-Design
As mentioned above, "remote" in RUT refers to the characteristic, that a usability testing is carried out when the users and evaluators are separated in space. In order to investigate how a co-design with the seniors can be conducted when the participants and the designers geographically apart, the "remote" aspect of RUT is utilized in conjunction with the Co-Design methodology to create the "Remote Co-Design" approach used in this study.

Unlike the topic "Co-Design with Older Adults", there is no research investigating the method of Remote Co-Design. Therefore, research of the, somewhat similar, approaches Distributed Participatory Design (DPD) and web-based Co-Design were examined and included as well as they can provide some insights, especially regarding the identified benefits and problems of their design practices.

An online Co-Design have many restrictions when compared to a face to face Co-Design Session. Sanders E B N et al. briefly touches upon the feasibility of conducting an online participatory design using video conferencing app [18]. They assume that only limited design activities regarding "Making tangible things" and "Talking, Telling and Explaining" can be done online, and that "Acting, Enacting and Playing" activities are not possible yet. Because some "making" and "Talking" activities interact with real materials, for example the 3D mockup utilizes foam, clay or lego bricks, and "Enacting" activities generally require physical interaction with other participants.

DPD, or Distributed Co-Design, deals with two areas: Distributed Software Development (DSD) and Participatory Design (PD) [19]. It aims at involving different geographically scattered stakeholders in the development process. Instead of focusing on cooperative designing with the users, DPD is an attempt to engage more stakeholder groups. Gumm D C. has found that the geographical distribution is a challenge, but there are still a number of successful examples. It is suggested to explore how to gain a mutual understanding especially in the user-developer-relationship, as distributed settings often lead to misunderstanding due to cultural and organizational differences.

The web-based Co-Design method applies social media to co-design with users to deliver the new products or services [20]. "Web-basedness" refers to web-based social media tools being the only arena of co-design. The tools enable sharing of content, commenting, posting and user profiles. In this method, potential users work with designers synchronous or asynchronous over distance via social media. Benefits such as Flexibility in time and location and Agility due to quick feedback were identified. However, the design practices also found some difficulties in this method: First, participants may not be sufficiently representative for different user groups. Second, as the users are empowered as designers, they may not be able to make neutral evaluation on the solution or product which is co-designed by them. Lastly, it is difficult to build a community for the co-design, if the participants do not know each other or have sufficient mutual trust.

3. METHODOLOGY
To gain an understanding of the remote co-design process with seniors, especially in terms of its approaches, difficulties and opportunities, a series of remote research activities were conducted. This section describes the remote co-design procedure with its participants, settings and materials, and finally the data collection and analysis.

3.1 Participants and Procedure
Through my social network, five Danish older adults have been recruited to participate in a series of activities throughout the whole procedure. *Table 1* summarized the basic information of the five participants from the first

Participant	Age	Gender	Occupation	Self-perceived IT Skills (0 to 10)	Design Experience
P 1	62	female	Occupational Therapist	3	Rarely
P 2	62	male	Lawyer	3	Never
P 3	62	female	Occupational Therapist	2	Sometimes *(hobby in knitting)
P 4	72	female	(retired) Kitchen Manager	5	Never
P 5	72	male	(retired) Architect	6	Sometimes *(professional work)

Table 1. Overview of the participants
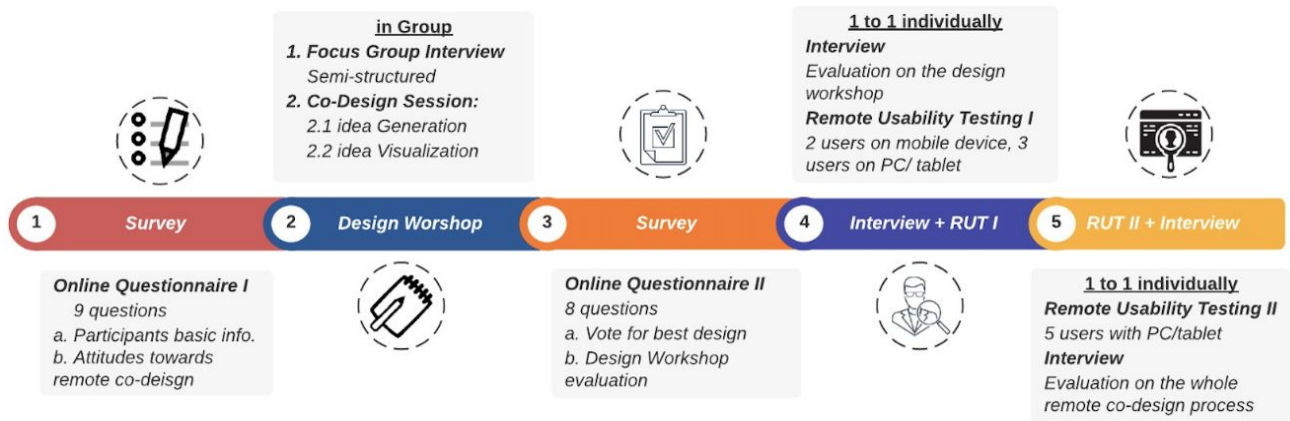
Figure 1. The procedures of our remote co-design project

survey. It can be seen that they have in general low technology level and few design experience, except the P5.

In order to carry out a remote co-design process, a mobile app idea "PillTime" was chosen to be the co-design object. "PillTime" is used to assist the elderly to take their medication on time. It was chosen for two primary reasons: first, health care has been the most favored function in IxD for seniors in the last ten years [3], as it is a common topic for the elderly. Second, due to the quick growth of smartphones and tablets, older adults are very likely to already have some experience with using mobile applications and they will therefore have their own opinion on what constitutes good mobile application design. It is assumed that the participants will feel more involved when they design a system where they are familiar with the topic (the functions) as well as the form (the interface).

The procedures of this study (see Figure 1) contain a variety of activities which took place during April and May 2020. The completion of the entire procedure took around one month. The author started the procedure by sending out an initial survey to the participants, inquiring into their basic information and preconceived ideas about participatory application design. Afterwards, a design workshop was conducted consisting of a focus group interview and a co-design session. This design workshop was immediately followed up by a second survey. One week later, the first remote usability testing for the high-fi prototype took place. The second remote usability testing was conducted a week later and the whole process was wrapped up with a final interview.

The author and one Danish student participated in the design workshop and usability testings remotely as well and played the roles as moderator and facilitator. The design workshop was carried out in a group, with all the five participants, the author and the facilitator being present online together at the same time, but physically separate at their own place (home). The two usability testings, together with the interviews, were conducted by the author and the facilitator individually with each participant.

3.3 Settings and Materials

All procedures were conducted remotely. The two surveys were sent out as online surveys and filled out by the participants in ca. 2-3 days. The design workshop, two usability testings and interviews were carried out using an online-conferencing application (Skype) with everyone's camera of their devices turned on. These procedures were recorded and the participants were informed about this in the very beginning of each procedure. Three of the participants used laptops while two used tablets.

The two surveys of the project were made in the survey application "surveymonkey", and were filled out using a web browser. The first survey marked the beginning of the participatory part of the study. It consisted of nine questions with two purposes: The first purpose was to get some background information of the participants. The second purpose to understand their attitudes and expectations towards mobile app design and remote cooperation. The second survey was sent out after the completion of the design workshop. It contained seven questions and a field for entering their name. This survey was constructed with two objectives in mind. The first objective was to evaluate the results of the design workshop. Here, the participants were asked to vote for their favorite user sketches visualising the discussed ideas. The second objective was to receive their feedback and evaluation of the quality of the design workshop process, in relation to the procedures, the results and especially the setting which required them to participate via video conferencing rather than face to face.

The design workshop consisted of a focus group interview and a co-design session. The focus group interview was conducted with all five participants present and constructed as a semi-structured interview. The interview was constructed in order to acquire information regarding two key questions: What is, in general, a good mobile app interface design for the participants? And how is their need for, or experience with, a pill reminder mobile app.? During the interview it was strived to avoid asking too many direct questions, but rather stepping back and create a natural conversation atmosphere. The participants are encouraged to talk more and add comments for each others' responses.

Their answers or comments served as prompts to continue the interview.

The Co-Design Session constituted the main part of our design workshop and took place immediately after the focus group interview. It included the idea generation and the idea visualization. First, a brainstorming session for the functions for the mobile app "PillTime" was conducted. A persona scenario was used to help inspire the participants. The participants were encouraged to envision and discuss what would be the top three key functions for the app. Second, the moderator presented six color schemes and ca. 40 icons. The participants were asked to choose and discuss what kind of color scheme or icons they would like to use for the design solution and to collectively make a decision on a color scheme or several icons. Third, the participants were encouraged to do a paper prototyping for the three functions we discussed. In order to assist the participants envisioning potential designs, the moderator introduced an example of "Crazy 8", which provided one A4 paper with 8 boxes simulating phone screens containing simple icons and texts. For each function, the participants were given 5 minutes to draw their vision. They were told that their sketches could vary from just some icons that they think are relevant to a detailed low-fi prototype phone page. They were furthermore encouraged to ask questions or seek advice from other participants or from the moderator and the facilitator during the sketching session.

Two rounds of RUT were conducted for the participants to test the high-fi prototype which was developed based on the results of the co-design session. We chose to utilize the Remote Synchronous Usability Testing (RS) as it is close to a laboratory-setting and allows assessment of the data in real time. However, testing for a mobile app poses challenges, compared to testing a web app, as it is not possible for the user to simply share their screen with the evaluator through the video conferencing application that was running on their laptops.

Three options were considered to test the mobile app remotely: The first option required the participants to download an application to their mobile device in order to test the high-fi prototype. The participants should then put the phone on a desk and adjust their PC camera to a position where it can capture the mobile phone screen and his or her interaction with the prototype. The second option involved the evaluators positioning the phone in an angle convenient to the camera and let the user tell the evaluators how to interact with the phone screen in order to complete testing tasks. The third option was an approach similar to RS for a web app. Instead of using a mobile phone, the prototype would be tested as a web app on the PC, with the mouse clicks simulating the finger movement.

We wanted to test all the options to see how they worked. However, option two was not utilized for any testing in the end, as the web camera and internet cannot convey sufficiently good quality real time images. The elderly users struggled to see the details of the prototype clearly, and thus it would be difficult for them to think aloud during the

evaluation and even complete the tasks properly. Thus, the RUTs were finally conducted using option one and three. In the first RUT, two participants tested the prototype using option one, which resembles the laboratory environment the most. For the remaining three participants the option three was used. It was easier to get the participants agree on using the option three, as option one caused some participants' concern as they feared that downloading a new app to their phone may entail certain risks regarding security and privacy. Additionally, it requires extra work dealing with software, which the users consider difficult. Lastly, some of the participants were using tablets instead of PCs, making option one unfeasibly as they could not adjust the camera of the tablets to capture their testing process for us. In order to compare the difference in the user experience between option one and three, the two participants, who used option one in the first RUT, tried option three in the second RUT. Six scenario tasks were prepared for the users to complete for each round of testing and they were encouraged to think aloud during the testings.

During the two RUTs, two individual interviews were carried out with each participant. The first focussed on the evaluation of the design workshop. The second interview sought to elicit user feedback about the whole co-design process including the testings. It consisted of mainly open-ended and likert scale-style questions. Participants were asked about their attitude towards co-design in order to illuminate if a change had occurred in comparison to their initial attitude.. They were further asked to evaluate the methods (co-design and remote) for each activity throughout this process. Users were also asked to comment on how they believe the process would have been different if the activities had taken place in a laboratory-setting with physical attendance instead of remotely.

3.3 Data Collection and Analysis
Data gathered from these activities includes survey responses, design artefacts, observation notes, audio and video recordings.

Meaning Condensation
In order to analyze the qualitative data derived from the design workshop and interviews, we adopted the Meaning Condensation (MC) method from Kvale S. et al.. Kvale S. et al. constitutes one form of the MC developed by Giorgi on the basis of phenomenological philosophy. The MC works to extract the central themes from the data. It encompasses five steps: Getting a sense of the whole by reading through the complete interview, determining the "meaning units", thematizing the "meaning units", interrogating the "meaning units" in terms of the study purpose and tying together non-redundant themes into a descriptive statement [24].

After the focus group interview and co-design session, the video and audio recordings were watched and each participant's answers, comments or complaints were analyzed and thematized into meaning units. The most important themes were noted down and grouped into themes which are meaningful in relation to this study, for

example what they found difficult technically, what tasks they were unable to finish and why, what kind of approaches were helpful and useful, their reflections on the co-design practice and the remote method, etc. Lastly, the categorized themes were read through again and summarized as a document. The result is not only used for retrieving our final findings, but also used for designing questions for following activities such as the second survey and interviews.

Instant Data Analysis

Instant Data Analysis (IDA) was utilized for analysis of the usability testings. IDA is a technique developed for an efficient usability testing analysis, which aims at completing the analysis on the day of the testing. In the IDA, a data logger records incidents or problems during several think aloud usability testing sessions. After the testing sessions, the data logger and the test monitor conduct a one hour brainstorming and analysis session. The result of this evaluation is a list of usability problems they have identified in the testings. [25].

The two remote usability testings were carried out by the author with the assistance of the facilitator with each participant individually. The problems and incidents that occurred during the testings were noted down. Right after the testing, the problems that the participants experienced were discussed and analysed, based on the notes and the video recording. At the end, the identified usability problems were collected in a list and ranked based on severity. The usability problems were categorized as either critical, serious or cosmetic.

4. RESULTS

This section first gives a general overview of the results from each phase of the study. Second, it delves into the results of the design workshop in order to identify the challenges of remote co-design as well as effective approaches to alleviate said challenges. Lastly, it presents the opportunities of the remote co-design approach when conducting with seniors.

4.1 Overall co-design and evaluation results

In the design workshop, the participants discussed the mobile app. design and agreed that the most important principles are that the app should be simple and intuitive. The participants came up with three functions, which they considered essential for an app like "PillTime": an alarm-like reminder, a historic record of all activities and an option to contact of doctors and hospitals. The participants decided on green-white as the basic color scheme and chose some icons that would be useful for the interface design, including icons representing a doctor, pills, a clock, graphs etc. This discussion was followed by a user sketch session. The participants drew from one to four screens to visualize each function. The screen contents varied from simple icons to a complete paper prototype. They voted for their favorite sketches later in the second survey. A high-fi prototype of "PillTime" was created based on their favorite design ideas and contained the before-mentioned three functions. Finally, it was tested in the remote usability testings. *Figure*
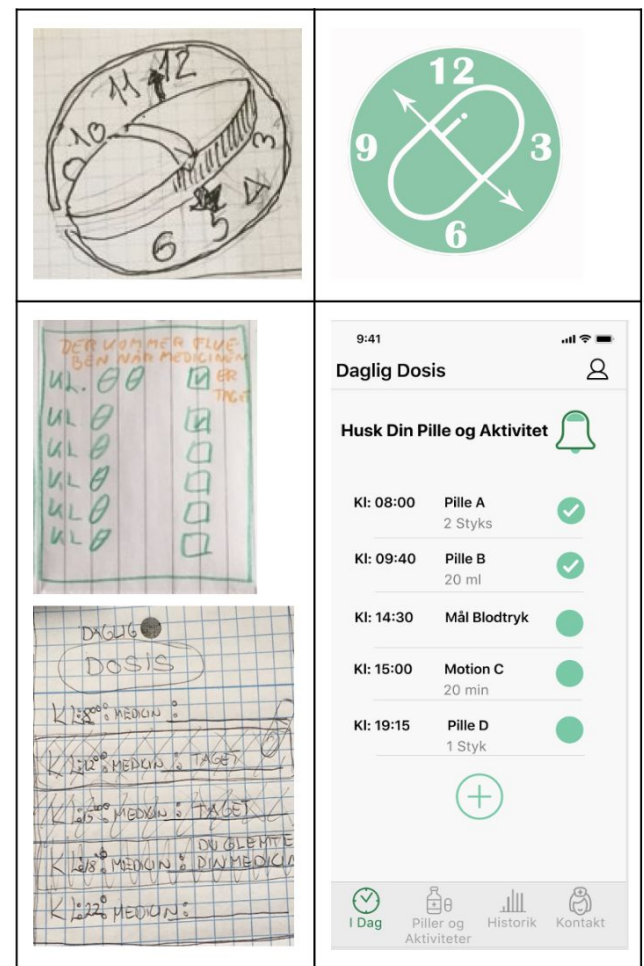

Figure 2. Some User Sketches and final prototyping

two shows some user sketches of the app logo and the pill reminder page on the left side and the corresponding prototype developed based on their drawings on the right side.

Regarding the remote-aspect of the method, the first survey showed that the participants expected that all the activities would be "somewhat worse" online compared to conducting them face to face. In the second survey, most of the participants reckoned that the co-design workshop went well,.P2 commented that

"*I think that the process was well prepared and that we were led professional through, in an understandable and good way.*"

In the final interview, the participants rated the final co-design result as 8 on average on a 10 points scale and expressed that they were satisfied with the co-design results. P1 commented on the process that

"*the process was fine and has been quite fun to do*".

P3 had a similar evaluation, stating that

"*It was an eyeopener to see that something good could come out of it and it was exciting to experience […] I think the result was very good and also better than i would have thought.*"

Themes	Description
Frequent Distractions	• The online conference form distracted participants from focusing on the discussion. • Participants are used to communicating face to face rather than through a screen. • Lack of eye contact and reduced influence of body language decreases focus
Unnatural conversation form	• Using online conferencing, participants feel uncomfortable bringing up topics they are unsure whether are particularly useful or helpful for the discussion. • Perceived greater pressure when speaking.
Limited interaction	• Impossible to have body contact, pass things and look at each others' artefacts or user sketches during an online co-design session. • Most participants believe they would have been inspired more in the user sketch session if they had been better able to exchange ideas with other participants or moderators.
Time Constraint	• Participants believe they could have performed better if given more time, even after the time for drawing each function was increased from the initial 5 minutes to 7 or 8 minutes.
Lack of Design Experience	• Most participants did not have any experience in design, and felt unprepared for the sketch task, despite being informed beforehand of the co-design session, • Participants struggled to get started with the drawing process despite having been shown examples and icons
Insecurity of Tech.	• Doubts of their own IT skills affected participants' belief in their ability to contribute and and come up with constructive ideas
Incapability of Drawing	• Some participants believed that preexisting design abilities, e.g. if one is creative and has sufficient artistic skills, determines the quality of contributions, regardless of other conditions such as time or physical presence

Table 2. Challenges Identified on the remote co-design process with the seniors

4.2 Challenges in remote and co-design approaches

Table 2 shows the major reasons that participants found it difficult to contribute in the remote design workshop, based on a thematic analysis. The most commonly mentioned reasons were challenges caused by the remote approach, ie. conducting activities using an online conferencing platform. The participants were not used to doing video conferencing where they are supposed to carry out discussions online. Two participants stated that they had almost no experience conferencing tools beforehand and more than half of other the participants had problems installing or using the application. The online conferencing brought several problems: first, they found that they were easily distracted when participating online. P5 commented on the online conferencing form that

"It is hard to keep track of it all"

while P3 thought that there are *"many ways to get distracted when you are sitting at home in front of your screen. Both in relation to what is happening around you, but also in relation to what is happening on the screen itself."*

Second, participating remotely impaired the participants from talking and asking questions during the design workshop. It appeared to the participants that they should only say something if it was really meaningful or important. Third, it was seen as very inconvenient to interact with other participants or moderators, for instance to check the other participant's drawing and exchange design ideas. P2,

commented on the lack of interaction in sketch task, stating that

"sitting alone may be good for some people, but it is easier for me to be creative together with other people."

In addition to attending remotely, the participants named a few other aspects affecting the co-design results. First, the time allocated for the user sketches was seen as too short, especially considering that they were not experienced in designing. The participants further saw it as very difficult to draw a specific mobile app. interface when they rarely drew anything in the first place. Second, users had the mindset that they were simply not good with technology, affecting their ability to maximize their design potential. Lastly, some users took the view that some people are simply not creative and thus incapable of drawing. As P1 commented:

"It is hard to design anything when you are just not creative".

This aspect, however, is not influenced by the remote approach or conditions such as time constraints.

In the second survey and the follow up interview, the participants evaluated the remote aspect of the design workshop, compared to a face to face approach. Most participants believed that the focus group interview and discussion would have better results if it was not online (see Figure 3), while they had very different opinions towards the remote aspect of co-design session. Less than half the participants agreed that the co-design session could be better if it was conducted face to face. The reasons why the participants found the remote aspect difficult is covered
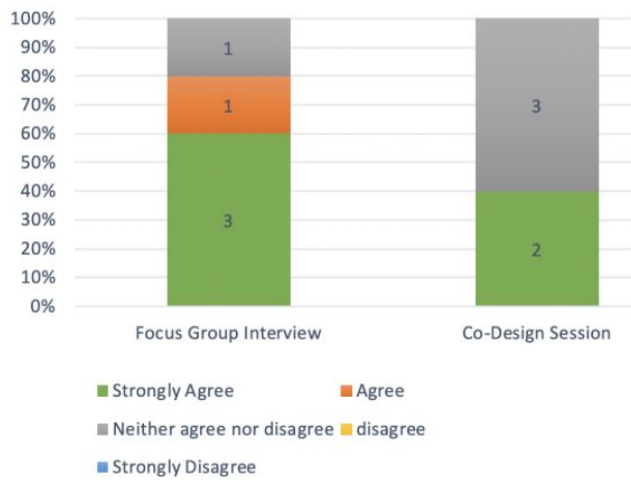
Figure 3. Answers to the question - "How much do you agree with the following statement: if this activity was done face to face, its results will be much better."

above, and includes distractions, limited interaction and unnatural form of conversation etc.

In spite of these identified challenges, the co-design results were considered as satisfactory by the participants, as mentioned before. This positive evaluation was, according to the survey and interviews, also a result of multiple conditions in the procedures. In regard to the focus group interview and discussion, the participants agreed that they were conducted at a suitable speed, that the questions were clearly formulated and constructed in a way which is relevant and useful for the co-design session afterwards. P1 commented that

"The focus group interview was very good and there were good inputs from the different participants who were all engaged in the discussion. The time allocated was fine."

Regarding the co-design session, the participants thought the presentation of color schemes, icons and the Crazy 8 example did help, in the sense that they were inspired to envision the UI of "PillTime". A consensus was reached with the participants regarding some potential approaches to improve the co-design session: slower pace, idea presentation and exchange sessions (initiated by the moderator), a reflection and discussion session afterwards etc.

4.3 Remote approach as an Opportunity

As mentioned earlier, the remote method has not only challenges but also its strengths. *Table 3* presents the opportunities identified during the remote co-design process.

First, the remote aspect can be seen as an opportunity to improve the users' willingness to participate in the co-design activities. Because of the flexibility in time and location, all participants reckoned that it is very convenient and time-saving to participate online. This is particularly visible in our Remote Usability Testings (RUT). In the last interview, all participants stated that they would choose usability testing remotely from their home over face to face at another place. As mentioned in the methodology section, the testings were conducted using different devices. In the first RUT, three participants did the testing on a web browser on their PC/tablets while the other two, P1 and P2 tested the prototype on a mobile phone. In the second RUT, all participants finished the RUT on their PC/tablets. By doing this, we were able to compare the difference of these two options not only between different participants but also for the same participants. By comparing the time used to complete each scenario tasks, it can be observed that there was no clear difference in the speed of completing tasks using different devices. The participants who tested on both a mobile phone and a PC, did not have any particular problems or failures when using either device. When asked

Themes	Description
Improvement of participation willingness	● Practical and convenient, as it is unnecessary to go to a specific place to participate in design activities ● Being home immediately after finishing activities and removing the financial and time costs of transport lowers barriers to participate.
Easing tension and creating a comfortable environment	● Being at home creates a more comfortable setting compared to participating at a lab ● Enables the participants to draw their design ideas in peace. ● Helps ease tensions for participants not experienced in technology design.
Positive change in attitude towards technology and design	● Despite initially being skeptical of their ability to design, and exhibiting insecurity about working with technology, participants had a positive perception of both the remote co-design process and their own technology design abilities, at the end of the project ● Can improve user involvement and help users overcome insecurities by providing convenient technology access and professional guidance remotely. ● All partcipants expressed willingness to participate in remote co-design again.
Continuous communication	● Enables an easy continuous communication between users and designers or developers. ● The users can add feedback or suggestions for the design process without being restricted by time or location

Table 3. Opportunities Identified on the remote co-design process with the seniors

about a comparison, P1 slightly prefered testing on a phone, because

"it is more intuitive and I can see the different buttons easier."

However, P3 thought that

"doing it on the web was just as good and the two test methods were equally easy."

Based on the task completion results and feedback, it can be inferred that the difference between using a web browser on PC/tablet and using an app in a mobile phone is non-significant, and testing through a web browser thus also constitutes a viable option..

The second opportunity is that the remote characteristic can ease tension for the participants, especially in the co-design session. Due to the little experience in design and the insecurity about technology, the participants did not feel comfortable drawing something when sitting face to face with others. Being able to stay at a comfortable place and doing the sketch task alone, makes some participants feel less nervous and easier to concentrate. This perception can be observed from the answers in Figure 3. P3 commented that

*"The drawing part, however, worked fine using skype, and maybe even better than if we were in the room togethe*r*"*.

Similarly P4 believed that when drawing something remotely,

"you have more peace to focus on what you were going to do".

The third opportunity is about the participants' attitude towards technology and design. The participants initially had a mostly pessimistic attitude towards designing a mobile app, especially under remote co-design conditions. Some expressed concerns about their low understanding of technology which they thought may affect the co-design results. However, the participants completed the procedures to a satisfactory level, despite many concepts, applications and tasks being totally strange to them. After testing the high-fi prototype, which was developed based on their own design ideas and sketches, the participants showed a positive change in the perception of their own design abilities and ability to contribute to a remote co-design process. The remote method, which inherently includes the use of technology such as online video conferencing, thus also contributes to the participants becoming more comfortable with using technology and overcoming their initial averseness towards it. In this sense, the remote approach helps to overcome their insecurity of technology and pessimistic perception of their own capability, which has the potential to contribute to a higher user involvement in the process.

Lastly, the remote approach enables a continuous idea exchange between the participants and the designers, as the the participants' feedback can be sent through multiple applications without being restricted by a certain time or location.

To sum up, remote co-design is technically feasible. It can be used for co-design activities with seniors, and can potentially improve users' participation willingness, ease their tensions towards designing, alleviate their insecurity of technology and provide an opportunity for continuous communication.

5. DISCUSSION

This section will discuss the findings on the co-design method with the elderly, the remote aspect and the limitations of this project.

5.1 Seniors as Co-Designers

The final co-design result received a favorable evaluation from all participants and it also changed the participants' attitude towards co-design and their perception of their own design capabilities. The results reveal that, despite their lack of design experience and low level IT Skills, senior citizens can provide a good resource for design and they can play the role as co-designer to contribute to a mobile app design.

The participants in general underestimated their design potential. They were not confident and did not believe that they could provide valuable design ideas. Despite this, their sketches constituted decent paper prototypes for further development. In order to evaluate their work from a professional perspective, two senior UX designers from a design agency in Aarhus were invited to review the sketches. Their comments are, contrary to the seniors' impression, much more positive. The sketches are considered *"a decent basis for working with a pill reminder functionality"* and they *"no matter the detail - are a great asset and capture the essence of including the users"*

and one designer said that he

"wouldn't expect anything else from 15 minutes of co-ideation and refinement".

This negative mindset of the participants did affect their participation to some extent, as they tended to be less active in the co-design process when they did not believe they could make contributions. Thus, it is important to communicate with the seniors and encourage them to overcome their distrust in themselves. In addition, the moderator should actively involve them into the design workshop and give them immediate, especially positive feedback.

5.2 Remote Co-Design as a potential alternative

From the remote Co-design practice with seniors, several challenges and opportunities are identified, both with regards to co-design with seniors and the remote aspect.

In terms of co-design with seniors, some challenges were introduced in the related work section above. Two serious challenges this study identified were also discussed in related research, specifically that: the senior participants have difficulty envisioning a design idea and difficulty staying focused on the process. These problems were even

more amplified in our practice as our co-design procedures were all carried out remotely. The participants found it harder to focus or get inspired when they sat in front of a screen without seeing others' body language and were unable to talk in a natural way with others. Based on a discussion with the participants in the last interview, these challenges may be compensated with a well prepared structure, frequent interaction initiated by the moderator and some more design materials.

For co-design in general, one difficulty mentioned in the related work section, is that it can be hard for the users to be unbiased in their evaluations, as the final product is a result of their own co-design. In our remote co-design, the participants rated the final prototype on average as 8 out of 10 as well, and more than one participant commented that "*there is nothing I can think of to be improved*". This issue may be addressed by also inquiring opinions from external professional designers, to ensure the impartiality of the evaluation. In our case, two professional designers were invited to comment on the final prototype and they agreed on that the though the final result needed some adjustments and "*needs more work, both in graphical and UX design*", no critical problems were identified.

Despite of the difficulties, opportunities of the remote approach were also identified. It not only provides flexibility and a comfortable environment, but also stimulates the participants use of technology and offers continuous communication. In addition, all participants had a positive evaluation on both the process and the results of this project. Taking all factors into account, remote co-design may not be able to completely replace a traditional face to face co-design, but it should be considered as a method with great potential to be improved and serve as viable alternative to traditional co-design with seniors, both in research and in design practice.

6. CONCLUSION

This section will conclude upon the initial research question:

What challenges and opportunities may occur when co-design with seniors is carried out remotely?

Compared to a traditional face to face co-design with seniors, an online co-design has to confront challenges such as frequent distractions, unnatural conversation forms, and limited interaction. Simultaneously, some of the typical problems of traditional co-design with seniors also occurred and were even amplified: the difficulty in envisioning caused by their lack of design experience, their insecurity surrounding technology and the seniors' slow pace in design activities. The opportunities found in the method, however, include making the co-design process easy to access for the senior participants, ensuring a quiet and separate environment for some of the activities the participants may be nervous about doing in a group, helping to address some senior participants' pessimistic perception of own technology and design capabilities, and lastly enabling a continuous feedback between users and designers or developers. Additionally, the users all reckon that the remote aspect of the procedures makes the activities time efficient and flexible, increasing their likeliness of participation.

The findings show that, regardless of the challenges, the remote co-design with seniors is technically feasible and effective in relation to deliver a user-satisfactory design solution. It should be considered as a viable design method and this topic deserves more investigation, especially in regard to providing solutions to overcome the identified challenges in order to improve the method.

Limitations

There are two major limitations of this project: the representativeness of users and the limited design activities. The small sample amount restricts the representativeness of the study. Among the five participants, only P5 is experienced in designing as he worked as an architect before his retirement. He answered some questions in a manner considerably different from the others. For instance, he maintained the idea that the co-design results were most affected by your own design ability, while most other conditions, such as working remote or face to face, more materials or guidance etc. will not play an important role in regards to changing the results. It is interesting to observe this difference, but as our recruitment only included a single participant with such a background, it is impossible to state that this difference would be applicable as a general difference between those with more design experience and those with less experience. The other limitation of this study is that the co-design process did not include many different types of design activities. Thus, the evaluation of the feasibility of the remote co-design approach is limited. For instance, Sanders E B N et al. [18] claimed that online participatory design is not viable for "Acting, Enacting and Playing" design activities. As there are no design activities belonging to this category in our project, we are not able to contribute data or analysis to support or oppose this claim.

Future Work

There is a general lack of empirical research papers investigating the topic remote co-design, thus, additional empirical studies should be performed in order to further explore how this method is perceived by different groups of elderly users, as well to investigate solutions to compensate for the identified problems from this study. Such research can contribute to fulfill the potential of the remote approach as an opportunity for future co-design and usability testing. Besides, investigations examining different types of co-design activities should be conducted to offer a more comprehensive evaluation and comparison on this topic.

7. ACKNOWLEDGEMENT

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