Older Adults' Collaborative Learning Dynamics When Exploring Feature-Rich Software

by

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Abstract

Feature-rich software applications provide many options through complex structures which can make their learning process difficult. While many studies have investigated software learning, they typically have not focused on older adult users. Given that older adults are increasingly using more complex software, we aimed to investigate how older adults learn feature-rich applications. We focus on a learning scenario where an older adult is learning collaboratively with a partner. In our observational study, sixteen older adults and six younger participants (5 same-age and 6 mixed-age dyads) worked together remotely to explore a new feature-rich application. We collected data via recording participants' interactions with each other and the software, as well as through surveys and interviews. We applied quantitative and qualitative approaches to analyze the data, including open coding to investigate dyadic interactions and thematic analysis for the interviews. Our results show that effective communication and the ability to navigate the software independently enabled a successful collaboration dynamic that empowered learners. Based on our findings, we discuss design implications for technologies that aim to improve older adults' experience of learning feature-rich software both individually and collaboratively.

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Chapter 1

Introduction

Feature-rich software applications have interfaces with many options provided through deep menu structures and complex dialog boxes [46]. Such applications also typically include multiple types of editing/operational modes to enable users to work on sophisticated projects [57]. Some of these applications not only offer many options and features but also require high level of understanding and knowledge about computers and/or a specific domain [46]. Therefore, learning feature-rich applications can be difficult due to their complex nature [42].

In line with an increase in the diversity of the user population of feature-rich software [42,46], older adults (65+) are using these applications more frequently than ever before [42]. The increase in the statutory retirement age [27,53] and work being a vital part of active aging [6] makes older adults the fastest-growing population segment in workplaces where computers are essential elements in daily work tasks [69]. Older adults are also the target users of many new technologies to support independent and healthy living [1,41,58] and to help them build and maintain vibrant relationships [13,54]. While previously older adults used technology for basic activities such as communication and information seeking, results of two research studies about older adults' technology use in 2010 and 2019 shows a progression towards more complex software use by older adults [40,69]. There is much research on how to improve the software learning experience for users [8,10,29,42,46,68], but this prior work has not typically considered older adults as target users. Therefore, it is important to also consider older adults as users of feature-rich software to understand their learning challenges and how we can improve their experience.

While recent research has shown that older adults favor exploration when learning new technologies [52], spending time on exploration can give rise to learning difficulties for older adults [67] that make the experience frustrating [42,52]. To address such difficulties, prior research has suggested social support to approach learning technology [2,56,67], which older adults themselves also favor [4,62,71]. Collaboration has been suggested as an example of social support during learning, however, prior research has focused mostly on collaboration while learning IT/ICT applications and videogames [4,13,35,48,58,71]. These studies reported positive outcomes of collaborative learning, however, the properties of partners' interactions varied according to different factors such as a learning partner's age [13,41,58].

As older adults' technology use is no longer limited to basic applications, in this thesis we focus on older adults learning feature-rich software via exploration and investigate the potential of collaborative learning to support older adults' exploration experience. We conducted an observational study in which sixteen older adults and six younger participants worked in 6 mixed-age and 5 same-age dyads remotely to explore a new feature-rich application. To investigate the differences in collaboration dynamics that might arise from differences in partner's age, we studied older adults' collaboration with a partner of same versus different ages. In this thesis, we use the term "collaborative learning" to refer to the activity. Measuring the impact of this activity on learning outcomes is beyond the scope of this thesis.

1.1. Research Questions

This thesis aims to answer three questions:

1) How do older adults experience collaborative learning in the context of feature-rich software?

2) What type of interaction patterns emerge between learning partners? Are there any observable differences between the interaction patterns of learning partners of same versus different ages?

3) How do the collaboration dynamics between partners affect older adults' learning behaviour and exploration style of a new feature-rich application?

1.2. Methodology and Approach

To investigate these research questions, we conducted an observational study where older adults explore a feature-rich application while they are collaborating with a peer of same age or a younger partner. For the feature-rich software we wanted an application that is easy for novices to start exploring while providing a wide range of options for advanced projects. We selected Gather.Town[1] Mapmaker, a web-based application that allows users to design 2D spaces for virtual gathering. Gather.Town itself is a web-based spatial video-conferencing platform where every user is represented as an avatar, and users meet in virtual 2D spaces while seeing and hearing one another. As the focus of the study was on novice older adult users, we recruited participants who had no prior experience using Mapmaker. Also, to avoid the awkwardness of interaction between strangers, we only recruited pairs of participants who knew each other, such as family members, friends, and colleagues. To prevent one partner taking over the computer and doing all the work we asked partners of each dyad to not be co-located during the study. Therefore, they were communicating remotely with each other and the researcher (me) through Gather.Town while working on prescribed study tasks using Mapmaker.

The study took place over two sessions which were conducted in the same week for each dyad: *Contextual Orientation* session (1 hour) and *Design Tasks* session (2 hours). In the first session, participants had the opportunity to get familiar with the Gather.Town and I also introduced software concepts that were needed for the second session. In the second session, I asked participants to explore Gather.Town Mapmaker software collaboratively and work on three sets of prescribed tasks which increased in complexity. A full description of the study method can be found in Chapter 3.

To gain insight into how participants experienced exploratory learning of a new feature-rich application, I recorded participants' shared screens to capture their interactions with the software. Also, I recorded participants' interactions with each other

[1] www.gather.town

throughout the study to investigate collaboration dynamics and to assess the impact of collaborative learning on older adults' exploration style and learning behaviour. We also collected data about participants' background and their perceptions of the collaboration through questionnaires and separate semi-structured interviews with each participant.

1.3. Contributions

In summary, this thesis contributes to the following:

1. An understanding of how older adults learn and explore feature-rich software when working collaboratively with a partner.

2. An understanding of factors that impact a successful dynamic between learning partners which influence the effectiveness of older adults' exploration of feature-rich software.

3. Insights into implications for technologies that aim to enhance older adults' exploration of feature-rich software both individually and collaboratively.

The remainder of this thesis is organized into five chapters: Chapter 2 summarizes prior work related to this thesis, Chapter 3 describes the design of our observational study, data collection, and analysis methods, Chapter 4 presents the findings of the study, Chapter 5 discusses the main results and implications for design, and Chapter 6 summarizes the contributions and concludes the thesis.

Chapter 2

Related Work

As Fig. 1 illustrates, the focus of this thesis, which is about older adults learning feature-rich software collaboratively, is an intersection of three areas of research. In this chapter, we first look at research related to feature-rich software learning and technology use by older adults. Next, we look into research related to social support and collaborative learning as a method to enhance feature-rich software learning for younger generations. Finally, we focus on research related to social support and collaborative learning to help learn new technologies such as IT/ICT applications and videogames for older adults.

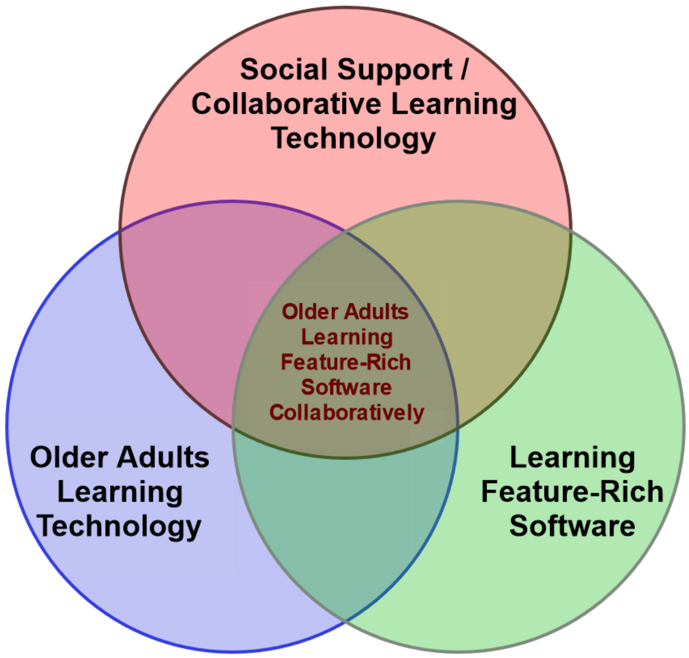


Fig. 1. Venn diagram illustrating the focus of this thesis, which is the intersection of three areas of research.

2.1. Older Adults Learning Technology and Feature-Rich Applications

Computer use by older adults is an active field of study that attracts researchers from different disciplines such as Gerontology, Healthcare, Business, and HCI [69]. Research investigating older adults' technology use has mostly considered IT/ICT and basic Internet skills [2,4,41,63,65,67]. In comparison, older adults' use of more complex technologies such as feature-rich software has received much less attention. Previously, older adults mostly used technology for communication, leisure, and information seeking [69], however, a 2019 survey illustrated a progression to more complex software use [40]. The survey showed an increase in the diversity of computer use by older adults and new categories of technology use such as organization, managing photos, and managing money emerged [40]. These are examples of tasks that often involve the use of feature-rich software. Therefore, we were inspired to consider how older adults learn feature-rich applications.

Among different approaches to learning a new technology, older adults prefer trial and error and exploratory learning [52] but these approaches can lead to challenges during the learning process [42,52]. Common challenges include a lack of awareness of functionality, locating and understanding functionality, and especially understanding task flow [29,42]. Mahmud et al. [42] examined older adults' exploration style while learning MS OneNote as an example of feature-rich software and found that they mostly struggle in understanding system feedback, which leads to repeating wrong sequences of actions.

Reducing the difficulties that older adults encounter during exploration can improve their level of satisfaction and the effectiveness of the exploration approach, which can in turn lead to increased technology use [67]. Increasing older adults' technology use and especially feature-rich software contributes to bridging the digital divide for this generation. In other words, facilitating older adults' learning process will help them benefit from technology by contributing to independent and healthy living, being connected to their community, and getting access to useful information [1,12,40,41,58]. For example, creativity support tools (CSTs) are popular feature-rich software applications that are varied in complexity and enable people to think more creatively while working on simple to complex projects [26,57]. A literature review on different aspects of creativity has shown that creativity is beyond traditional artistic activities and its benefits ranged from increasing older adults' physical wellbeing to psychosocial and physiological benefits [23]. Among different activities that will enhance creativity such as poetry class, journaling, and reminiscence [23], using fun technologies and particularly CSTs might help older adults to engage in creative activity [60]. Inspired by this prior research on the benefits of learning and using feature-rich software, we investigated older adults' experiences as they explore feature-rich applications. We add to this body of literature by exploring the impacts of social support on learning.

Studies exploring older adults' technology acceptance have demonstrated that the availability of support can reduce their perceived difficulty of exploring new technologies [2,56,67]. There are a variety of ways to provide support, such as changing system characteristics by providing exploration-supportive facilities [17,42], improving training materials and programs [47,65,71], and providing mechanisms to enable collaboration, community, or social support [31,52]. Social support, one of the most promising approaches identified, builds on sociocultural constructivism: a theory that frames learning as a collaborative rather than an individual activity, and knowledge creation as a result of social and cultural interactions [61]. We focused on social support as a way to reduce older adults' challenges while learning a feature-rich application.

2.2. Social Support/Collaborative Learning to Enhance Technology and Feature-Rich Software Learning

Researchers have long acknowledged the importance of social support in helping users learn and master complex software. One common approach involves community-based methods, where software users learn from other users. Prior work has investigated several ways to improve community-based social learning, for example, through Q&As that are attached to relevant commands and options in an application's interface [10,44], software tutorials that are augmented with community demonstrations or comments [8,38], and enhanced social media interfaces with special features for sharing software knowledge [20,39]. Prior work has also investigated ways to support community-based "Over the shoulder learning" [68] by helping users identify commands and features that others are using [45]. In addition, social support for technology difficulties has side benefits, for example, it can act as a catalyst to connect, which can enhance older adults' well-being [24]. Collectively, studies in this area have demonstrated the value in helping users learn software by leveraging the experiences and perspectives of others.

Our work focuses on older adults learning collaboratively with a single peer, building on the finding that many users prefer to seek targeted and personalized help from someone they know [33]. In fact, several studies have demonstrated that older adults prefer one-on-one help rather than traditional workshops or classes when learning about new technologies [47,65,71].

In the context of collaborative learning for feature-rich software, the focus of prior work has mostly been on younger generations. The findings from this work have been promising. For example, when learning new feature-rich software (a 3D modelling application), the social context provided by collaborative environments can lead to more successful learning outcomes for children as compared to learning in traditional lecture rooms [21,51]. Prior work has also examined how adults (ages 21-56) seek help from software experts, using the findings to design tools that support these types of exchanges remotely [9]. As social support and collaborative learning have been promising ways for the younger generation to learn new technology, we were inspired to investigate social support and collaborative learning as a way to enhance software learning for older adults.

2.3. Social Support/Collaborative Learning to Enhance Older Adults' Technology Learning

While older adults learning feature-rich software has generally been understudied [50], there are several studies on the use of social support for older adults learning basic Internet skills and IT/ICT applications. These studies revealed that among different forms of novice-expert interactions, older adults prefer asking for help from members of their social circle, such as family members, neighbours, and friends [31,52]. Among the different types of social support for older adults, getting help from children or grandchildren is prominent [18,24]. In fact, older adults are often first introduced to technology by their grandchildren, whose enthusiasm can encourage older adults to continue learning [25,66].

There are also downsides to social support from family members, such as the fact that children or grandchildren may not be readily available for older adults [30], and teenagers can be impatient towards them [34]. Disempowering and even ageist practices from younger family members can negatively impact older adults' learning, which can potentially lead to less internet use [11,34,65,71]. Older adults' fear of being a burden on their younger family members can also deter them from asking questions [4,52,72]. Further, the unequal power relationship between older adults and the younger generation has led to older adults waiting to receive support from younger family members, and sometimes the support is never provided [34]. Getting technology help from a peer of the same age (e.g., a life partner) seems to mitigate some of these problems and is consequently becoming more common [43]. In fact, getting support from another older adult has been identified as an "untapped resource" [31]. In other words, it has been suggested that older adult peers who are a few steps ahead in knowing the technology might be better candidates for providing support for older adults [41]. We add to this literature by studying an example of a more equal setting: collaborative exploratory learning with older adults in the context of feature-rich software.

Regarding older adults' collaborative learning, which is a different type of social support than asking someone for help, studies have explored learning basic IT/ICT applications and videogames [4,35,58,70–72]. The HiHtaST[2] project [4] organized a peer-to-peer network for mutual support for older adults, where participants from five European countries could learn IT skills together. The opportunity for collaborative learning provided a way for older adults to share tips and exchange knowledge, which in turn reduced their fear of learning new technology and increased their self-efficacy. When playing videogames with a partner, results have shown that the negotiation and discussion sparked by collaboration increased older adults' understanding of the game and reduced mistakes, which made the experience less frustrating than when playing individually [48].

While collaborative learning has been a promising approach to learning technology for different types of pairs, there might be differences in dynamics when an older adult is learning with a younger versus a same-age partner [58]. When older adults play videogames with a partner of their age, they can understand each other's language easily [58], which helps with gameplay [48]. Also, observing a same-age partner performing a task can increase an older adult's confidence, making them more comfortable exploring

[2] Hand in Hand to a Social Tomorrow

the technology and applying the actions that they already have learned [35,41,48]. Older adults found learning from someone of the same age pleasant which led to successful learning outcomes [4]. In other words, learning with a peer of the same age has been reported as an enjoyable and effective experience as a same-age partner had faced similar challenges and had similar experiences [71]. On the other hand, playing videogames with younger generations has the benefit of breaking the stereotypes that both generations hold towards each other [13]. Also having a younger partner increased older adults' perception of the game's ease of use, compared to playing with older adult partners [58]. However, older adults sometimes found it difficult to get help and support from younger generations as their style of learning might be different [71].

While collaborative learning has been a promising approach for younger generations to learn a new feature-rich application and for older adults to explore IT/ICT technologies or videogames, its impact on older adults' exploration of feature-rich applications is unknown. The nature of exploratory learning of feature-rich applications is different from learning basic IT/ICT applications due to their complexity. With videogames, which are arguably the closest in terms of application complexity, younger and older adult learning partners often bring vastly different domain expertise to the collaborative learning experience [13], but this may not be the case with other feature-rich applications. Also, it is unclear what characterizes an ideal partner for older adults learning feature-rich software. Our work contributes to this research area by investigating the effects of partner interactions on older adults' exploration of feature-rich software when the partners are a similar age and when the older adult is collaborating with a younger partner.

2.4. Summary

In this chapter, we described prior research that has explored and suggested social support and collaborative learning as ways to enhance learning technology. The literature has demonstrated the benefits of social support for younger generations when learning feature-rich software. Prior research has also investigated collaborative learning with older adults in the context of basic IT/ICT applications and videogames. This work has shown that the age of an older adult's partner might lead to different dynamics and potentially different advantages and disadvantages. In the next chapter, we discuss our study design and how we aim to explore the impact of collaborative learning on older adults' exploration of feature-rich software.

Chapter 3

Study Design

In this chapter, we describe the design of our observational study to investigate how older adults experience exploring a feature-rich application for the first time while collaborating with a learning partner from their social circle. Our goal was to understand what type of interaction patterns would emerge between partners in different age dyads and how those interactions would impact older adults' exploratory learning behaviours. As there are so many confounds that impact learning, and there is no agreed upon way of measuring learning of a feature-rich application, we did not focus on measuring the amount of learning, but rather focused on the interactions and experiences of older adults while learning.

3.1. Feature-Rich Application

In selecting a feature-rich application to use in the study, we aimed for an application that is easy for novices to start exploring while still providing a wide range of options and editing modes for advanced projects. These criteria align with the principles of a well-designed "creativity support tool" (CST) [57]. Resnick et al. characterize 'good' CSTs as having 'low walls' and 'high ceilings', which make it easy for novices to get started while still providing enough complexity to allow deep skill development and unlimited creative possibilities [57]. These tools usually support trial and error [57], which can remove some of the fear associated with exploration [41,48].

With these criteria in mind, we chose the Gather.Town Mapmaker as the feature-rich software for the study. Gather.Town itself is a web-based spatial video-conferencing platform where every user is represented as an avatar, and users meet in virtual 2D spaces where they can move around and explore the world together and interact with objects while seeing and hearing one another via proximity chat (Fig. 2).

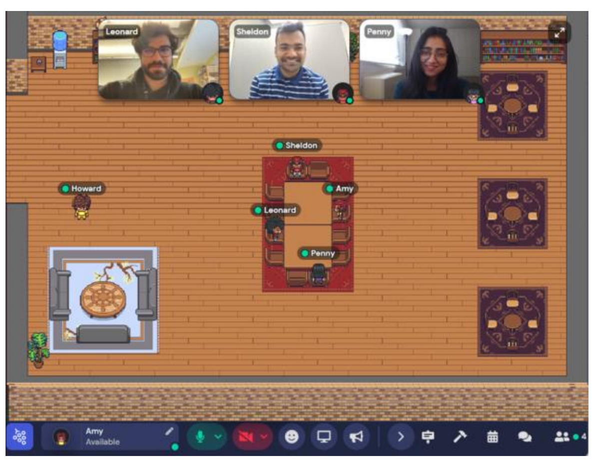


Fig. 2. Users having a conversation in the Gather.Town platform. Only video feeds of those who are in the proximity chat are shown to the user.

The spaces that users inhabit in Gather.Town are designed using the Gather.Town Mapmaker (GTM). GTM is a web-based application that allows users to design 2D virtual spaces for Gather.Town (GT) either from scratch or by starting with provided room templates. GTM is similar to systems that designers use to lay out the different worlds/levels in an adventure-style videogame. In this study, each participant created a virtual room that we referred to as a cottage.

In addition to satisfying the feature-rich and CST software criteria, another advantage of using GTM is that we were able to leverage GT's video conferencing capabilities as part of the study. In the study, as participants designed their spaces, they could go into GT to look at their spaces and could also talk to each other through GT's video-conferencing. Fig. 3 depicts how users could switch back and forth between GT and GTM.

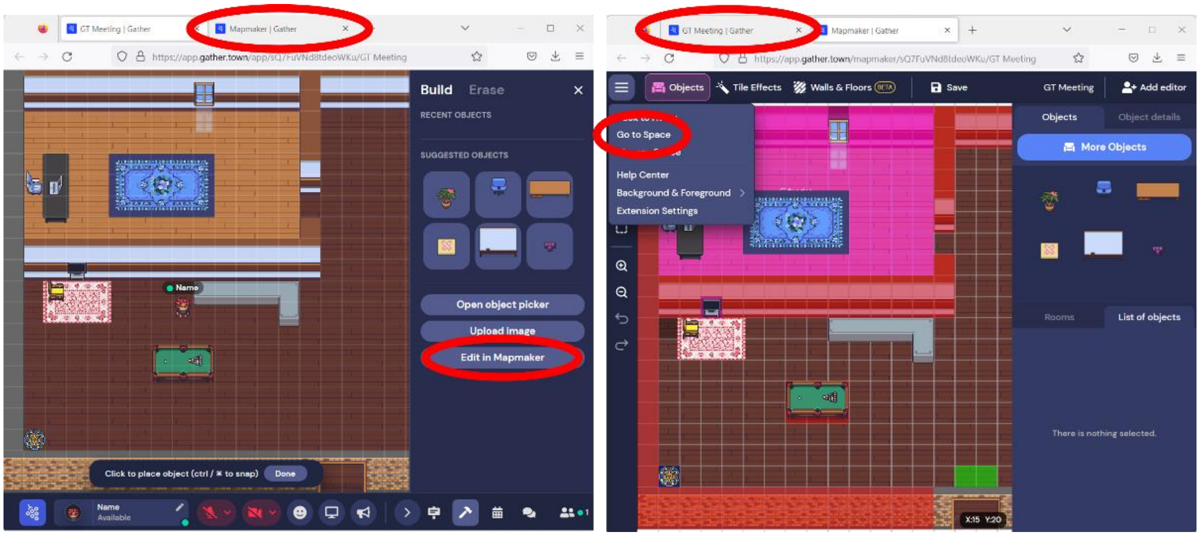


Fig. 3. Left screenshot: user is currently in a virtual room and can switch to GTM by clicking on "Edit in Mapmaker" in the right panel or clicking on the other tab if GTM is already open. Right screenshot: user is in GTM and can switch to the space by clicking on the "Go to Space" option in the top-left menu, or by clicking on the tab for GT.

3.2. Participants

User characteristics, such as their prior software expertise, play an essential role in the exploration process [7]. The focus of this thesis was on how novice older adults explore feature-rich software; therefore, we recruited dyads of participants who had zero prior experience using GTM, with at least one older adult (65+) in each dyad. We excluded participants who did not know how to use computers and the Internet for basic activities such as emailing. Also, to prevent the awkwardness of interaction with a stranger, we only accepted dyads of participants who knew each other (e.g., family members, friends, or colleagues). The study was advertised on social media, on the university campus, in the local community, and in the newsletters of some universities' retiree associations. Each participant was compensated with $45 CAD. We were able to recruit 16 older adults and 6 younger participants which formed 6 mixed-age and 5 same-age dyads. All but one participant were in Canada. We discuss participant demographics in Chapter 4.

3.3. Apparatus

We chose not to have participants co-located during the study to reduce the likelihood of one partner becoming dominant and doing all the work. Therefore, to maximize each participant's involvement in performing the tasks, each participant worked on a separate computer in a separate location. There was no need to install any software as GT and GTM are web-based applications that can be accessed using a browser. The fact that the participants were in a shared GT space eliminated the need to use an additional communication tool; the dyad could communicate with each other and the researcher (me) through GT. In addition, I asked participants to share their screens in GT throughout the study to allow their partner and me to see their actions in GTM. We gave participants the option to either participate in the study remotely or to come to our campus. Participants who came to campus were placed in separate study rooms. All but three participants participated remotely.

I was present throughout the whole study with three different GT accounts using three computers. As Fig. 4 demonstrates I used three computers so I could assign one device to each participant and monitor the whole study using a third computer. Having one computer for each participant enabled me to capture each participant's shared screen (interaction with the software) by screen-recording my computers. I also recorded the third computer screen to capture participants' conversations with each other.

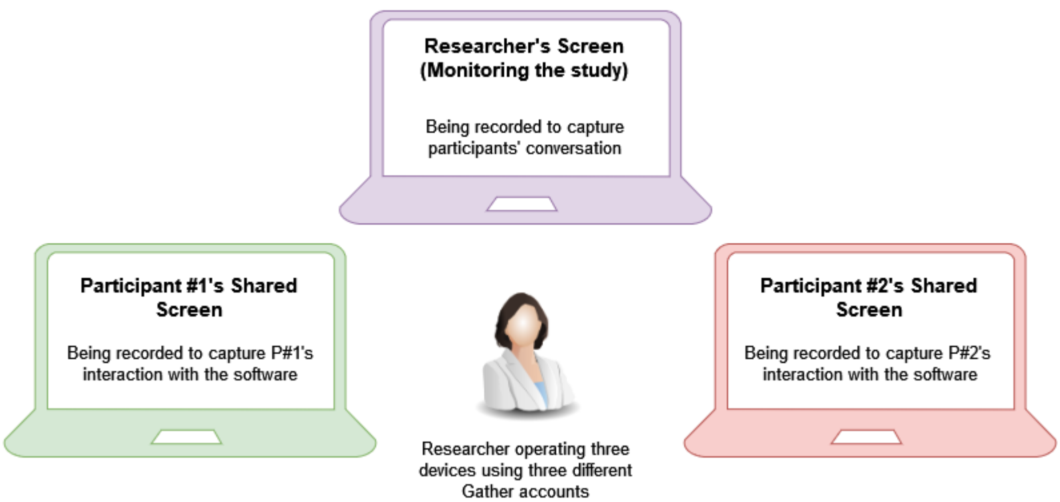


Fig. 4. Researcher monitoring the study with three different computers and Gather accounts.

3.4. Procedure

The study took place over two sessions. In the first session, *Contextual Orientation*, I introduced participants to the GT environment and allowed them to explore the space and get accustomed to the video-conferencing and screen-sharing capabilities of the platform. In the second session, *Design Tasks*, participants explored the GTM and used it to design a virtual room following a set of high-level task instructions. We elaborate on each of these sessions below.

3.4.1. Contextual Orientation Session

At the beginning of the *Contextual Orientation* session, I asked participants to fill out a background questionnaire (Appendix A) to gather information on demographics, education, and computer experience. Next, participants watched a 3-minute introduction video that explains fundamental GT concepts including: “proximity chat”, “impassable tiles”, “private areas” and “portals”. “Proximity chat” attempts to mimic real life by allowing users to only see and talk to others whose avatars are close to theirs in the virtual space. “Impassable tiles” refer to areas in GT that avatars cannot walk through, such as walls and tables. “Private areas” are defined areas within the space that are similar to breakout rooms, in that only users who are in the private area can see and hear each other, while people outside the private area cannot see the video or hear the audio of the people inside it. Avatars who step on a tile that is a “portal” will be transported to a virtual space/room at the other end of the portal. Participants had time to roam around in the sample cottage and find examples of the concepts introduced in the video. After explaining these concepts, and allowing the participants to experience each feature, I showed participants a virtual cottage as a sample of what they would be asked to design in the second session.

The first session ended by asking each participant to work with “interactive build mode” briefly. Interactive build mode is a feature in GT that can be used to decorate the virtual space by placing/erasing virtual objects. This feature provides a very simplified subset of what users can do in GTM and was meant to serve as scaffolding for the second session. Participants were asked to first remove two barrels and then place a fire pit and two benches similar to the provided sample (Fig. 5).

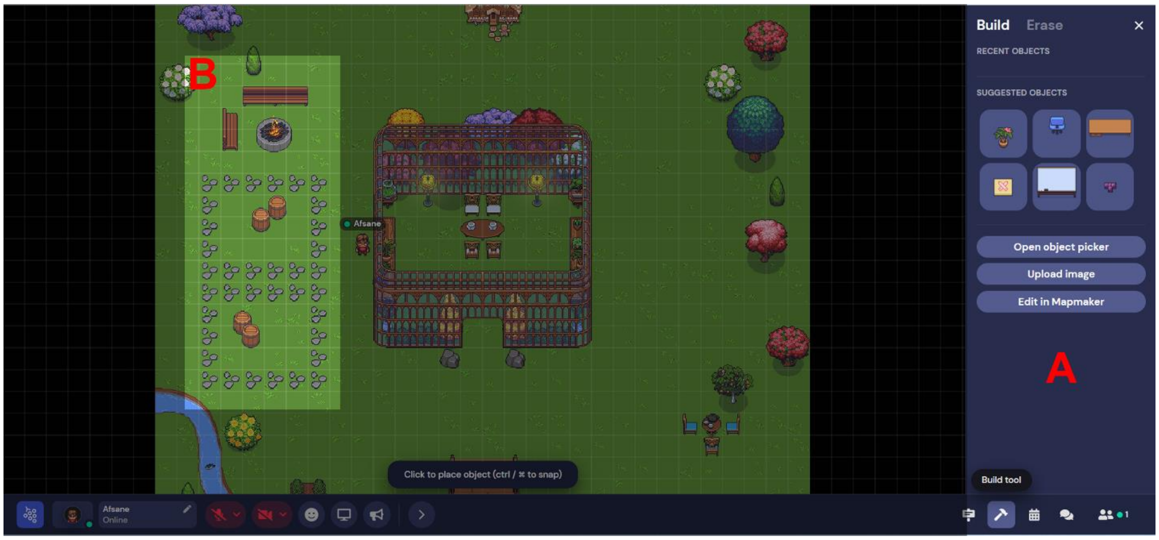


Fig. 5. “Interactive build mode” panel to manipulate objects in the space (A) – two squared areas marked with stones, one for each participant and the given sample which is two benches and a fire pit (B) participants had to erase the barrels and replicate the sample.

3.4.2. Design Tasks Session

I scheduled the second session, *Design Tasks*, in the same week as each dyad’s *Contextual Orientation* session. During this session, I first shared a 2-minute video about GTM to demonstrate how participants should open it in another tab and its main editing modes. Then, participants had one hour to perform tasks (described below) while collaborating. During the tasks, I asked participants to talk to each other. I prompted participants to talk after a silence of more than ~2 minutes. To avoid participants becoming overly frustrated, I also gave tips when it seemed like participants were unable to progress even with the help of their partner. After going through the tasks, participants filled out a post-study questionnaire (Appendix B) to collect information about their experience working with GTM and collaborating with their partner. The second session concluded with a separate semi-structured interview (Appendix C) with each participant (~15 minutes each) to follow up on questionnaire answers and to elicit further perceptions of their collaborative experience with GTM.

3.5. Tasks

Task-oriented exploration is more common in software learning than task-free exploration because users usually focus on performing a specific task when exploring software for the first time [59]. So, we assigned each participant a separate empty room in GT that they could decorate and design progressively by following prescribed tasks which increase in challenge level.

GTM has different navigation menus and editing panels that allow users to work on different aspects of their space: “walls and floors”, “objects”, and “tile effects” which we used to classify the three sets of tasks respectively. The “walls and floors” mode enables users to work with the bottom layer of a GT virtual space, which is floor patterns and walls. In GT, the smallest unit that can be changed by users is a tile. In this mode, users can place walls or change the floor pattern (set a tile to a particular wall or floor pattern). The next layer is associated with virtual objects which can be manipulated in “objects” mode. This mode includes an object selection dialog box and features that allow users to place, remove, and edit objects such as furniture, decoration, and interactive objects like whiteboards and video screens. The top layer is about tile effects where users can designate special attributes of tiles such as being impassable, being part of a private area, and being a portal to another room. Fig. 6 shows the virtual boards which contained instructions for each set of tasks.

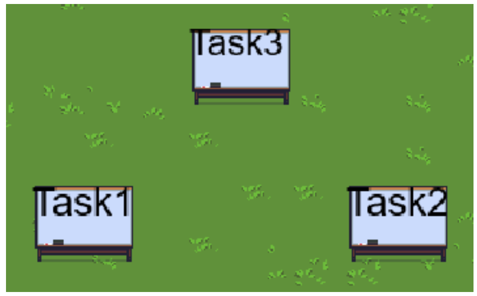
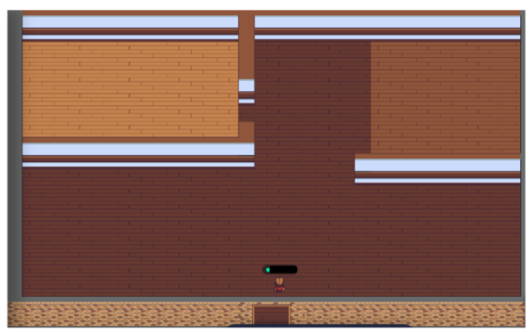


Fig. 6. Virtual boards containing instruction posters for each task set.

3.5.1. Task Set 1

The first set of tasks was related to the "walls and floor" mode of GTM, and required participants to remove the boxes, place interior walls, and change the floor pattern in their own cottage. We also gave participants a picture of what their rooms should look like after performing the first task set (Fig. 7). We gave participants 15 minutes for task set 1.

1. Remove the boxes from the floor
2. Place the interior **walls**
   - the tiles are marked with yellow in your cottage
3. Change the **floor** pattern
   - feel free to choose the pattern and color based on your taste



Please visit your cottage in the Gather.town to make sure you completed the tasks correctly.

Fig. 7. Task set 1 poster; Design tasks session.

3.5.2. Task Set 2

In the second set of tasks which was related to the "objects" mode, participants were asked to choose one of the four areas shown in Fig. 8 and replicate the design. By providing four different spaces, we wanted to cover different tastes and give participants the opportunity to choose their favourite room of a cottage to increase their level of engagement in performing the task. To cover more options in the second task set, we picked objects which would force users to use the features of objects mode such as rotating objects and changing their colour. Also, each area had at least one object that is placed on top of another and an object that should be placed on the wall to see how participants would deal with one tile having more than one attribute. We gave participants 20 minutes for task set 2.

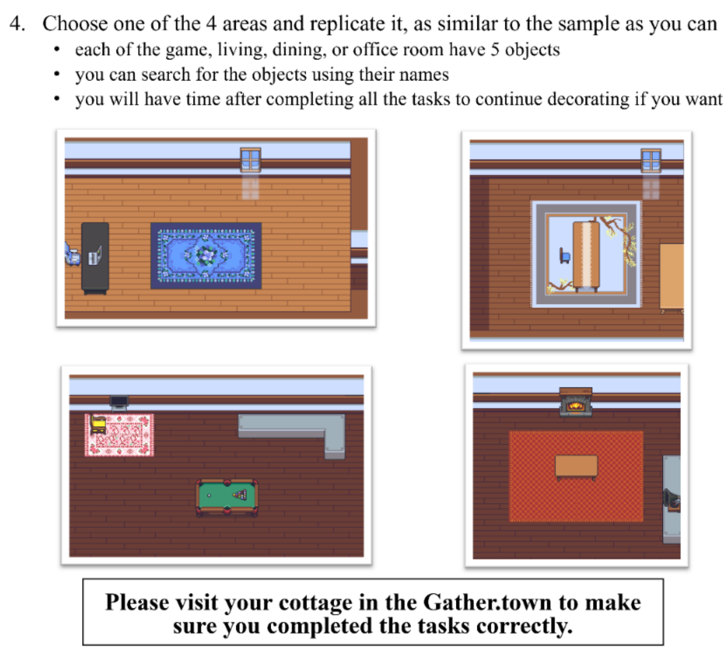
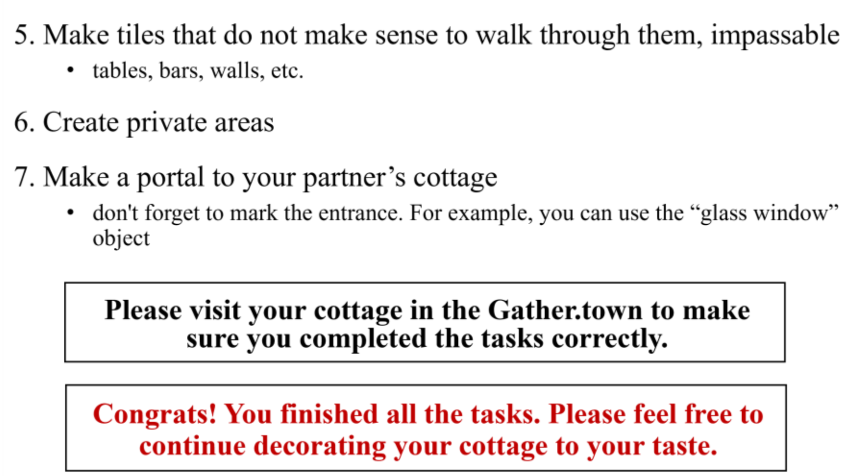


Fig. 8. Task set 2 poster; Design tasks session.

3.5.3. Task Set 3

The third set of tasks related to “tile effects” mode and consisted of making the walls “impassable”, creating “private areas”, and adding “portals” (Fig. 9). This was the most challenging task set as it required participants to do more steps and it involved setting IDs for private spaces and switching between rooms and spaces to set up both ends of a portal. These tasks involved setting “non-visible” properties of the map and are more abstract. We gave participants 25 minutes for task set 3.


5. Make tiles that do not make sense to walk through them, impassable
   - tables, bars, walls, etc.

6. Create private areas

7. Make a portal to your partner’s cottage
   - don't forget to mark the entrance. For example, you can use the “glass window” object

Please visit your cottage in the Gather.town to make sure you completed the tasks correctly.

Congrats! You finished all the tasks. Please feel free to continue decorating your cottage to your taste.

Fig. 9. Task set 3 poster; Design tasks session

3.6. Data Collection and Analysis

Our main source of data was participants’ interactions with each other and the software in the *Design Tasks* session. We also collected data through pre- and post-study questionnaires, and separate interviews with each learning partner. In the following paragraphs, we discuss each of these data sources and our analysis strategy.

As the participants were working on the tasks, I recorded their screen (participants shared their screen the whole time) along with their voice and video feed to capture both their interaction with GTM and with each other. To understand the interaction patterns that emerged between learning partners while they were working on the tasks collaboratively, we analysed their conversations in the *Design Tasks* session. First, I transcribed the video recordings of the *Design Tasks* session, then we used open coding [15] to code each interaction. I did multiple passes while consulting with my two advisors to revise the codes and their definitions. We discussed samples for each code over multiple meetings, and the final codes are described in Chapter 4. Next, we grouped the interactions by the parties involved and then conducted a thematic analysis [15] based on the coded data to detect themes and characterize the main dynamics that emerged between partners.

I audio and video recorded the interviews which took place at the end of the *Design Tasks* session. We followed the thematic approach of Corbin and Strauss [15] to analyse the interview transcripts. We focused this analysis on participants' perceptions of their partner and the collaboration in general.

We also collected data through the pre- and post-study questionnaires. The pre-study questionnaire captured participants' demographic information, their level of technology comfort [5] and self-efficacy [14] as well as their prior experience using various types of technology. For our post-study questionnaire, I modified a questionnaire from Rice et al. [58] to capture participants' perceptions about their performance and how they communicated in the *Design Tasks* session. When comparing data from older and younger adults, we used two-tailed t-test, considering results with p-value < 0.05 as significant and 0.1 > p-value > 0.05 as an indication of a trend.

3.7. Summary

In this chapter, we described our study design about older adults learning a feature-rich application while they are collaborating with a partner of the same versus different ages. We presented our rationale behind choosing GTM as the feature-rich software and described the characteristics of our participants such as the fact that they knew each other prior to the study as well as recruitment methods and compensation. We further described the study procedure which was conducted in two sessions. We also discussed our different sources of data and our analysis approach to answer the research questions. In the next chapter, we will present the results of the study.

Chapter 4

Results

In this chapter, we describe the main findings of our observational study. First, we report on participants' demographic data, their general level of comfort with technology, and their prior experience with various types of technology. Next, we look at the interaction dynamics that emerged between the partners and how elements of the different dynamics related to success on the tasks. Finally, we conclude with observations on key factors that appeared to influence the collaboration and exploration style of older adults in the context of learning a feature-rich application collaboratively.

Throughout the rest of this chapter, we use notation to specify participants according to their age range and dyad type. Table 1 shows examples to explain the notation format.

Table 1. Notation for participants, based on their age and dyad type.

Notation	Description
S1	Same-age dyad #1
M6	Mixed-age dyad #6
S1-O_1	Older adult partner #1 in same-age dyad #1
S1-O_2	Older adult partner #2 in same-age dyad #1
M6-Y	Younger partner in mixed-age dyad #6
M6-O	Older adult partner in mixed-age dyad #6
O >> Y	Older adult addressing their younger partner in a conversation

4.1. Participants' Demographic Data

We were able to recruit 22 participants forming 11 dyads. We considered 16 of the participants as older adults (1 aged 55-64, 12 aged 65-79, and 3 aged 80+), and 6 as younger participants (1 aged 15-17 and 5 aged 25-34). For analysis purposes, we considered the participant in the 55-64 age range as an older adult because they were close to the older adult demographic of 65+ and they were partnered with an older adult (65-79) who was a family member and close in age. Table 2 shows the gender distribution of participants, along with the relationship between learning partners in each dyad. "Other" refers to pairs in which the participants were colleagues or acquaintances. Participants' highest level of education ranged from middle school to graduate degree (Fig. 10).

Table 2. Dyad type by gender distribution and by partner relationship

	Gender distribution			Relationship		
	F-F	M-F	M-M	Family	Friend	Other
Mixed-age 6 dyads	2	4	0	3	2	1
Same-age 5 dyads	2	3	0	3	1	1

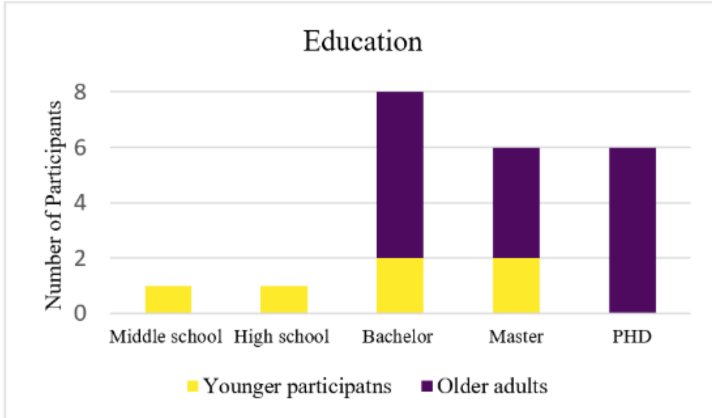


Fig. 10. Participants' education level

In terms of technology comfort, the pre-study questionnaire asked participants how comfortable they were performing various tasks with computers [5]. As Table 3 shows, most older adult participants responded with "Somewhat easily" or "Very easily" for "Keyboard and Mouse", "Email", "Finding Information Online", and "Entertainment" tasks, but reported less comfort with "Managing Appointments" and "Printer" tasks.

Table 3. Questions to assess tech comfort across 6 categories in the pre-study questionnaire. Participants answered "How easily can you …" on 5-point Likert scale (never tried=1 to very easily=5). Columns 3 and 4 show average (standard deviation) participant responses

Criteria	**Questions**	**Older adults**	**Younger participants**
Keyboard and Mouse	- Use a computer keyboard to type - Use a mouse	4.69 (0.54)	4.92 (0.29)
Printer	- Load ink into the printer - Fix the printer when paper jams	3.75 (1.27)	3.58 (1.31)
Email	- Open emails - Send emails	4.88 (0.34)	5 (0)
Finding information online	- Local community resources - Hobbies and interests	4.5 (0.72)	4.58 (0.67)
Managing appointments	- Enter events and appointments into a calendar - Check the date/time of upcoming/prior appointments	3.19 (1.65)	4.42 (1.16)
Entertainment	- Use a computer to watch movies and videos - Use a computer to listen to music	4.16 (1.17)	5 (0)

Older adult participants reported lower levels of technology self-efficacy [14] on a 3-point scale (mean=2.2, SD=0.49) than younger adult participants (mean=2.6, SD=0.16), a difference that was significant (t_{20} = 3.43; p=0.002).

Fig. 11 shows responses to a question about how frequently the participants use four types of computer applications. Almost all the older adult participants had zero experience using sandbox games and just a few used graphic software occasionally or frequently. On the other hand, 83% and 33% of younger participants were either occasional or frequent users of graphics software and sandbox game respectively.

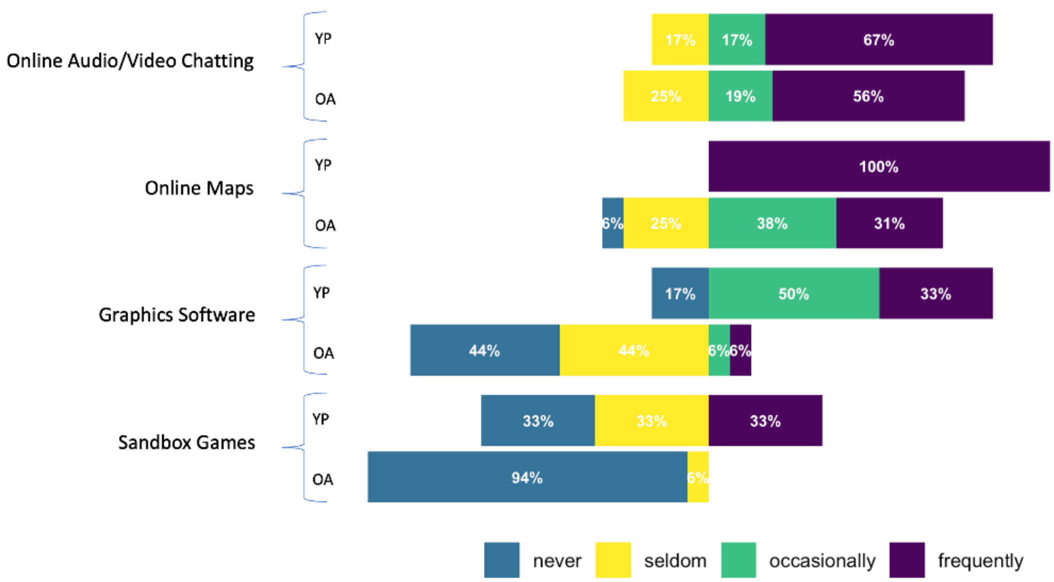


Fig. 11. Participants' prior experience using different types of technology, separated by older adults (OA) and younger participants (YP). Example: 56% of older adult participants use video/audio chat frequently.

4.2. Coding the Dyadic Interaction

Our open coding process for dyadic interactions (see Section 3.6) resulted in 17 unique codes (Appendix D). Of these codes, we found the 7 codes listed in Table 4 to be most useful in differentiating collaboration dynamics.

Table 4. Examples of codes developed through the open coding method. Column 5 and 6 shows average and standard deviation of frequency for each code divided by participants involved in each interaction. In the Parties column, for mixed-age dyads, P1 refers to the older participant and P2 refers to the younger participant. In the case of same-age dyads, we randomly assigned P1 and P2 to the two older adults.

Code	Description of code	Example of code	Parties	Avg frequency	STDEV
Discussion	Both partners bring their own thoughts and ideas to do a task.	"Is portal an object?" (M6-O) "Maybe they are tile effect." (M6-Y) "if you go to objects and type portals you get portals" (M6-O)	P1>>P2	2.44	2.74
			P2>>P1	2.44	2.74
Question	Question that was related to how to do a task or about concepts of the GT.	"Can you tell me where private area is?" (S1-O_1)	P1>>P2	46.22	14
			P2>>P1	6.11	9.17
Correct Answers	Answers to a question that were correct, even if they were not understood by the asker.	"You first go on the wall, right?" (M7-O) "Yes, first click on stamp then click on the wall" (M7-Y)	P1>>P2	3.2	2.95
			P2>>P1	33.56	14.28
Correct Tips	Unsolicited (but correct) advice about how to do a task.	"Below impassable there [are] spawn portal and then private area. And then you need to select or type a new name" (M9-Y)	P1>>P2	5.22	3.73
			P2>>P1	31.55	28.31
Incorrect Tips	Unsolicited (incorrect) advice about how to do a task.	"Just go to the laptop area. Move your mouse to that. Try to click, so it's only making the laptop thing private" (M11-Y) [Wrong assertion]	P1>>P2	3	2.55
			P2>>P1	3.33	2.55
Busy Answers	Answers that indicated one's reluctance to respond to their partners' questions.	"How do you change the object? Do you remember that? (S3-O_1)" "No, no. I'm having trouble, I had a rug and I erased it and now I cannot get it again." (S3-O_2)	P1>>P2	2.55	3.94
			P2>>P1	5.89	6.39
Current Stage	A partner informing the other about what they are doing.	"This time I drag it over here. And leave it there. Ok. Wait, I got two rugs here now." (S4-O_1)	P1>>P2	35.11	22.65
			P2>>P1	19.56	12.68

These 7 codes also had the highest standard deviations in frequency across dyads, indicating their utility in differentiation.

After counting the occurrences of the seven codes for each dyad, including who was involved in each interaction, we realized that in the S1 and S2 dyads, the interactions were mostly between the researcher (me) and the participants as opposed to being between the partners. The average number of interactions between partners in these two dyads was less than half of the average interactions for all other dyads (93 vs. 194), and the average number of times they interacted with me was more than three times that of other dyads (171 vs. 52). Due to the significant amount of aid provided by me to enable the four participants in these two dyads to progress with the tasks, we excluded them from further analysis.

For the remaining dyads, we graphed the frequency of each code, excluding those involving interactions with me. These graphs suggested four different collaboration dynamics: *dominant-follower*, *equal collaboration*, *on demand*, and *individual exploration*. We classified each dyad according to the most repetitive and prevailing dynamic type between partners, as dyads often exhibited patterns of different dynamics. Table 5 lists our classifications, and we elaborate on the nature of the dynamics below.

Table 5. Clustering dyads based on the dominant dynamic between partners.

Dynamic Types	**Dyads**
dominant-follower	M8, M9, M11
equal collaboration	M6, S4
on demand	M7, M10
individual exploration	S3, S5

4.2.1. Dominant-Follower – Collaboration Dynamic

The most distinct attributes of this dynamic are unidirectional help giving and lack of discussion. As the example in Fig. 12 shows, the dominant partner gave constant tips to the follower partner and almost all the questions came from the follower partner.

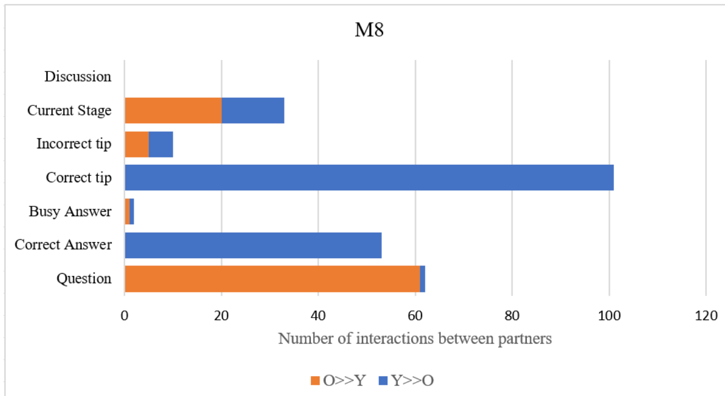


Fig. 12. Frequency of occurrence of each code of interaction in M8
(example of dominant-follower collaboration dynamic).

This dynamic characterized mixed-age dyads where the older adult acted as the follower and their younger partner played a dominant role. In cases where partners were family members (M8 and M11), the dominant partner would often ask the follower to wait for them to complete the tasks first and then give step-by-step instructions to them, as the following quote illustrates:

> *M8-Y >> M8-O: "So you're done here. Now I'm gonna do my task. You need to have patience and wait for a while."*

In rare cases where the older adult partner wanted to express their thoughts and opinions, their partner seemed reluctant to engage in discussion. In the example dialog that follows, the older adult partner in M11 wanted to correctly draw the younger partner's attention to the fact that they need to name the private area (i.e., give it an ID), but the younger partner was reluctant to listen:

M11-Y: "Now just go to the laptop area. Move your mouse to that and try to click. [...] We're done, click save."

M11-O: "[...] you can give the name laptop area." [This is a correct assertion/suggestion]

M11-Y: "It's not about naming anything." [This is incorrect – a name/ID is required for private areas]

M11-O: "Ok, then save?"

M11-Y: "Save it, it should be fine."

4.2.2. Equal Collaboration – Collaboration Dynamic

In the *equal collaboration* dynamic, we observed both partners discussing their thoughts and opinions regarding how to do each task by providing tips and answers instead of one telling the other what to do (Fig. 13).

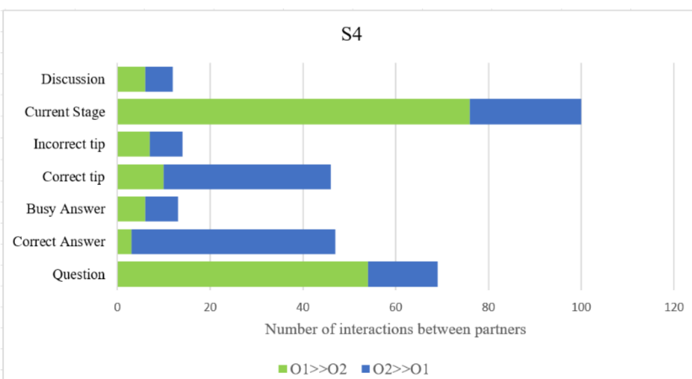


Fig. 13. Frequency of occurrence of each code of interaction in S4 (example of equal collaboration dynamic).

Here is an example of a discussion that occurred between partners in S4 around how to make a portal (task step #7):

S4-O$_1$*: "Pick portal type, portal to a room, portal to another space. That's what I should have?"*

S4-O_2: "[…] I put one to my cottage and one to your and I pressed confirms and nothing happened."

S4-O_1: "input space to portal to [S4-O_2]'s cottage."

S4-O_2: "well, I did that, and I press confirm and nothing happened."

S4-O_1: "you should put my name"

S4-O_2: "[…] maybe it doesn't like being called that." [they continued discussing]

4.2.3. On Demand – Collaboration Dynamic

This dynamic was mostly observed in mixed-age dyads. Unlike the *dominant-follower* dynamic in which the older adults were mostly passive in terms of exploring the software, in the *on demand* dynamic, older adults explored the software actively and asked questions only when they could not find the answer themselves first. As Fig. 14 shows, in contrast to the *equal collaboration* dynamic, there was less discussion surrounding issues, with the younger partner typically providing the answer quite directly by switching to the older adult's screen to get additional context and then telling their partner what to do. Here is an example of a help giving/seeking interaction between partners in M7:

M7-O: "Can these objects be rotated or not?"

M7-Y: "Which one? [switched to their partner's screen]"

M7-O: "I have to select a bar."

M7-Y: "Oh yeah, I think they can be rotated. If you go back to the object details, and it says bar right hook. I think if you press those circles, it rotates it."

M7-O: "OK. Oh perfect, thank you. [M7-Y switched back to their own screen]"

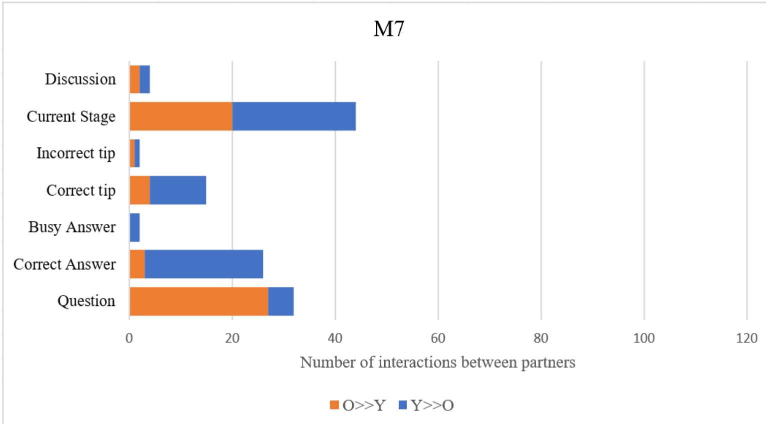


Fig. 14. Frequency of occurrence of each code of interaction in M7 (example of on demand collaboration dynamic).

Younger partners were typically ahead of the older adults in task completion. We observed differences in how the younger partner reacted to this. In M7 (where the partners were friends), we observed that the younger participant tried to stay in sync with the older adult such as by continuing to decorate their cottage while waiting for their partner to move to the next task. In contrast, in M10 (where the partners were family), the younger participant tended to express the fact that they were ahead, as illustrates by the following excerpt:

M10-O: "OK, now we need a computer."
M10-Y: "OMG, [they are] still at the computer. [laugh]"
M10-O: "oh, you have the computer already?"
M10-Y: "I finished my room."
M10-O: "[...] well, hang up a picture or something."

4.2.4. Individual Exploration – Collaboration Dynamic

In the *individual exploration* dynamic, which characterized two same-age dyads, participants seemed more focused on individual task success rather than collaboration, which led to “busy answers” to questions (Fig. 15).

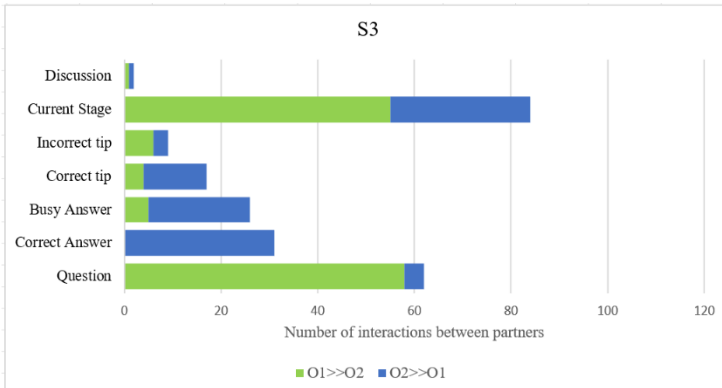


Fig. 15. Frequency of occurrence of each code of interaction in S3 (example of individual exploration collaboration dynamic).

As an example, S5-O_2 was having difficulty placing the walls while their partner (S5-O_1) had already completed this step and was currently experiencing a new problem with the “eraser” mode. When S5-O_2 asked a question about placing walls, S5-O_1 responded with their own problem, essentially ignoring their partner’s question:

> *S5-O_2: “[…] Did you go to small too?”*
>
> *S5-O_1: “I don't seem to have anything here. I got my bottom, my one wall and I had the other wall. And then I lost it […]”*
>
> *S5-O_2: “Uh-huh, how did you rotate your walls? The arrows?”*
>
> *S5-O_1: “I can't remember where to find those [they are looking for a way to put walls again for themself]”*

Note that in a similar situation in the *on demand* dynamic, the younger partner would quickly switch to the older adult’s screen to help them. By contrast, in *individual exploration*, the partners seemed too busy with their own problems to help each other.

4.3. Task Performance

To examine potential relationships between each dyad's collaboration dynamic and their overall success in performing the study tasks, we needed to assess task success. To do so, I counted the number of task steps correctly completed, either partially or fully, by reviewing the screen-recordings and final cottage designs. Fig. 16 depicts task success (horizontal axis) plotted according to each dyad's dominant dynamic (vertical axis). Each shape represents one participant and partners in a dyad have the same colour. Participants who continued to decorate their cottages while their partners were being interviewed are highlighted with a star.

All the participants in the *equal collaboration* and *on demand* dynamics achieved moderate or high levels of success in doing the tasks as they were able to complete more than 6 of the 7 tasks fully or partially. Note that the only mistake that M7-O (*on demand*) made was when their younger partner was not available to answer their question, otherwise they likely also would have achieved a high level of success. On the other hand, some of the older adults in the *dominant-follower* and *individual exploration* dynamics were less successful. A notable property of the *equal collaboration* dynamic is that partners tended to achieve a similar level of task success, whereas we tended to observe larger gaps between partners in other dynamics. All but one of the participants who continued designing their spaces after the session ended were in a mixed-age dyad. We suspect these participants likely achieved a better understanding of the software or at least enjoyed working with the software.

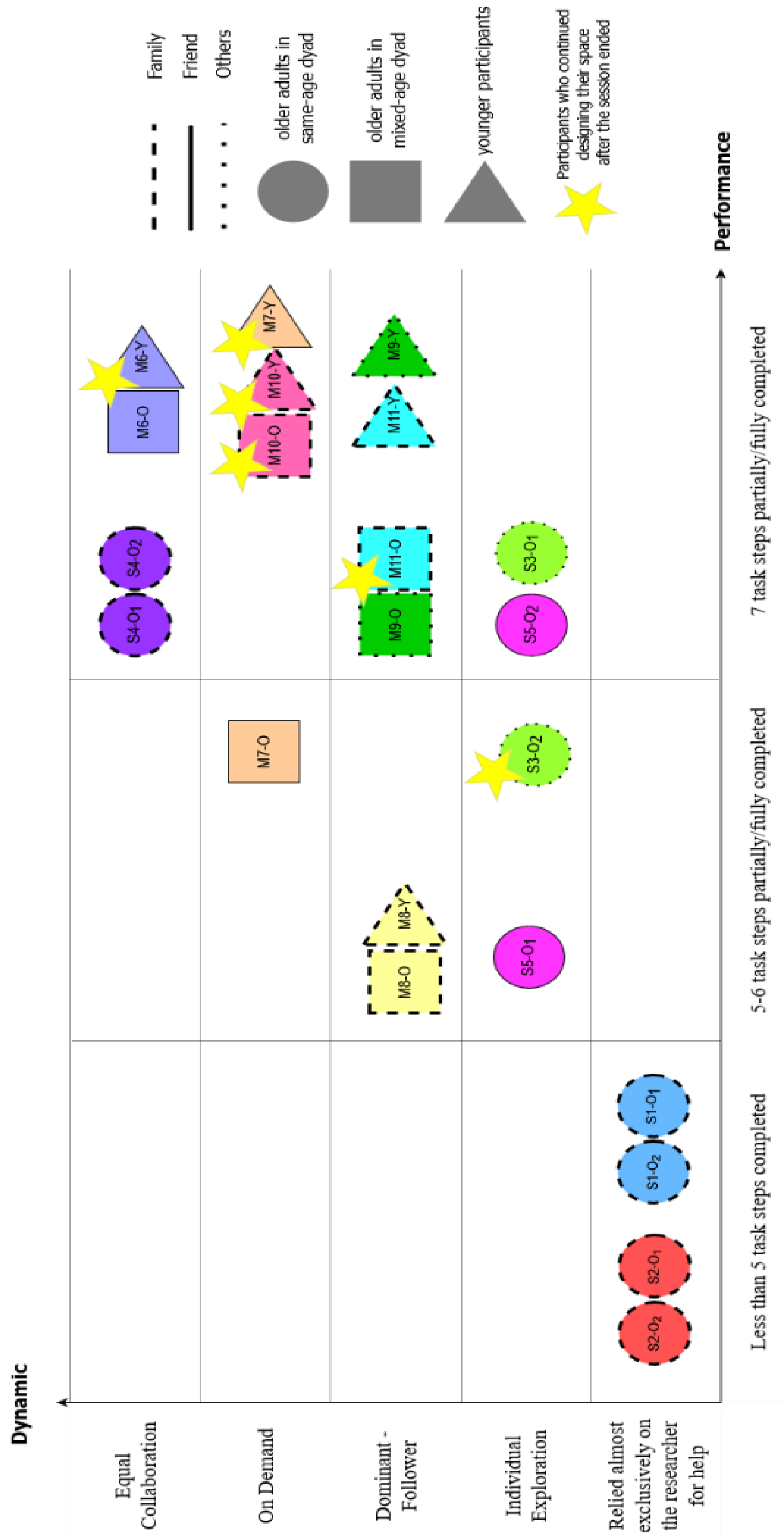


Fig. 16. Participants' task success (x-axis) plotted based on the collaboration dynamic (y-axis). "Others" refers to pairs in which the participants were colleagues or acquaintance.

With only 2-3 dyads per dynamic, we acknowledge that these observations are based on sparse data and this link between collaboration dynamic and task success needs to be verified with larger sample sizes in future studies.

4.4. Participants' Perceptions of Collaborative Learning

We analysed data from the post-study questionnaires to get a sense of how participants viewed their collaboration experience. We clustered questions into three different constructs: communication, co-operation, and competence (Table 6).

Table 6. Questions on participants' perceptions of the collaboration and their partner; divided into three constructs. "*" indicates negative statements which were reversed in the analysis process.

Constructs	Questions
Co-operation	1. My partner and I worked well together 2. Learning how to use mapmaker was easier when I cooperated with my partner compared to when I was doing the tasks on my own 3. My partner and I shared knowledge as we were learning 4. My partner and I faced similar issues while exploring the mapmaker *5. I would have felt more comfortable learning by myself (without a partner)
Communication	1. It was easy to communicate with my partner 2. I was comfortable asking questions from my partner 3. I was comfortable answering my partners' questions *4. Communicating with my partner was distracting
Competence	1. I was good at designing my space *2. It was difficult to reach the goals *3. I could have done better if I was given more time *4. I felt frustrated during the experience 5. I felt good whenever I finished a task successfully and wanted to do more

For each of the three constructs in the post-study questionnaire, we reversed the answers for the negative statements and then calculated the average and standard deviations for each construct based on participants' age and their pair types (Table 7).

Table 7. The average (standard deviation) of participants' answers to post-study questionnaire grouped by the three constructs.

Construct/ participants	Younger participants	OA participants	OA in mixed age pairs	OA in same age pairs	Overall
Co-operation	3.57 (0.99)	4.3 (0.50)	4.47 (0.33)	4.2 (0.57)	4.1 (0.72)
Communication	4 (0.71)	4.41 (0.52)	4.75 (0.32)	4.2 (0.51)	4.3 (0.59)
Competence	3.83 (0.53)	3.24 (0.65)	3.27 (0.69)	3.22 (0.66)	3.4 (0.66)

We observed differences in the average of younger participants' perception compared to older adults in mixed-age pairs. Also, there were differences in the average of older adults' opinions in same-age versus mixed-age dyads. Therefore, we ran two-tailed t-tests on participants' answers based on their age and dyad type to assess the significance of these differences. Here we describe the significant differences and trends that are shown in Table 8. We use data from the interviews and interaction coding to provide further context for these results.

Table 8. P-value of t-test on how different participants in different types of pairs perceived interactions / * for significance / ** indication of a trend

Construct/participants	Younger participant VS OA in mixed-age pairs	OA in mixed-age pairs VS OA in same-age pairs
Co-operation	0.0791 **	0.2558
Communication	0.0494 *	0.0186 *
Competence	0.1442	0.8964

Older adults assessed the communication with their partners more positively (mean=4.75, SD=0.32) than younger participants (mean=4, SD=0.71) in mixed-age dyads, a difference that was significant (t_7 = -2.37; p=0.049). We also observed a trend (t_6 = -2.11; p=0.079) suggesting that older adults had a more positive perception of the co-operation (mean=4.47, SD=0.33) than the younger participants (mean=3.57, SD=0.99). These differences may be related to the fact that almost all the younger participants claimed to be ahead of their partner and felt that they provided more help than they received. An example quote from the younger partner in M8 illustrates this perception:

> *M8-Y: "[…] I wasn't really benefited from my [partner], but I was helping [them]. So, it was OK for [them] but not OK for me […]"*

This sentiment aligns with both the older adults' perceptions of the interactions and the results of our open coding. Most of the older adults in mixed-age dyads expressed that they asked more questions of their partner compared to the other way around and they found their younger partners very helpful.

> *M9-O: "My second option [for solving a problem] was when I know that I'm stuck or I can't go further. I know that I can ask [them] and [they] will help me."*

Our coding revealed that older adults in mixed-age dyads asked 50 questions on average of their younger partners while younger participants asked 1 question on average of their older partner. A similar trend is observed for correct answers and tips in mixed-age dyads, as younger participants gave 74 tips or correct answers, compared to 7 for older adults.

Older adults in mixed-age dyads assessed the communication with their partners more positively (mean=4.75, SD=0.32) compared to those in same-age dyads (mean=4.2, SD=0.51), a difference that was significant ($t_{14} = 2.66$; $p = 0.019$). One reason might be that 12 out of the 16 older adult participants expressed that they preferred working with someone who knows more than they do. Having a partner with a similar level of knowledge about the software (in same-age dyads) was distracting and frustrating for some as they had to listen to their partner talking about their own issues rather than providing help.

> *S3-O2: "I would say [collaboration with my partner] was frustrating for me at times, because I was also having the same challenges, but I felt like I had to answer what [they were] looking for, before I can go on with my own."*

> *S5-O1: "I think it comes back to the knowledge of the person. I think it would work better to work with somebody that knows more about it than I, and they're sharing the knowledge. But in this case we were both trying to learn about the program at the same time, and you know, coming from a background of nothing almost like basic, really really basic computer skills [made the collaboration not working]."*

However, some of the older adults appreciated being at the same level as their partner:

> *S2-O1: "It was nice to work with my partner because I knew both of us has some limitations."*

Also, some of the older adults were worried about being a burden on the more knowledgeable partner or not being able to keep up with their fast pace:

> *M7-O: "I guess the only [concern with collaborative learning is], because with [M7-Y], knowing a lot more than I do, I feel a little bit like I maybe make it more frustrating for [them] because I'm always needing more help."*

> *M8-O: "[I prefer a same-age partner] because in the similar age, we can discuss more. Because the younger [partner] go very fast. Sometimes it is difficult to follow the younger group because they are faster than me, but I'm slow."*

In summary, our findings illustrate an interesting tension: older adults struggled when working with a same-age partner with a similar skill level and stated a preference for working with younger partners whom they believed are more skilful and knowledgeable. However, older adults also worried about being a burden to younger partners and we observed that having a knowledgeable partner did not always lead to successful interaction or exploration.

4.5. Open vs. Judgmental Communication Impacts

The communication styles that we observed across the four different collaboration dynamics appeared to strongly impact older adults' ability to explore the software, and some interview responses support this. One attribute of a learning partner that seemed to encourage active collaboration from the older adult participants in mixed-age dyads was the younger partner's openness to the older adult's opinions. As an example, when participants in M6 (*equal collaboration*) discussed how to add a "portal", M6-Y took the time to look at the problem from their older adult partner's perspective and then they determined a solution together. A contrasting example occurred with M11 (*dominant-follower*) when they were creating a "private area". M11-O tried to draw their partner's attention to the need to name the private area, but their partner ignored them and just gave them step-by-step instructions instead. This type of behaviour appeared to discourage older adults from expressing their thoughts, and we observed older participants in these situations becoming quieter and more passive. On the other hand, in the M6 case, the younger partner's responsiveness seemed to encourage the older adult partner to continue exploring and expressing their opinions.

An additional important communication element was the younger participants' reaction to their older adult partner's (possible) mistakes. As the following quote illustrates, some younger partners reacted negatively when their older partner would make a mistake:

M8-Y >> M8-O: “no no no no, [don’t click] on that one”, “hold on let me figure out. wait, don’t do anything” (dominant-follower; family)

These types of negative reactions appeared to discourage older adults from expressing their opinions and made them more dependent on their partner. Note that we did not observe similar reactions from older adults towards either their younger or older partners. In addition to making communication challenging, judgmental partners seemed to make the older adults hesitant to explore the software. The older adults in the M8 and M11 dyads (*dominant-follower*) were trying to explore the software at the beginning of the *Design Tasks* session but gradually seeing their younger partner’s impatient reactions led them to just sit and wait for their partner to tell them what to do and to seek approval before doing anything.

We also observed some older adults in same-age dyads having difficulty trusting that their partner could help them, particularly at the start of sessions. For example, in S5 (*individual exploration*), S5-O_1 had difficulty placing the walls but was not discussing the issue with their partner. At first, this dyad only relied on self-exploration but could not find any solution. Finally, I encouraged them to talk to each other, at which point S5-O_1 asked their partner about the walls, was able to apply their partner’s tip, and was surprised to find it helpful. After that, we observed more questions and discussions between the two participants in this pair as S5-O_1 realized their partner’s helpfulness.

In the interview, S3-O_2 (*individual exploration*), mentioned that their low expectations of their partner’s knowledge deterred them from asking questions:

$S3\text{-}O_2$: "I think just trial and error [was my way of learning], or asking finally saying ok no I can't figure this out right now [...] [and I mean] asking you, I didn't feel like I was getting any help from [$S3\text{-}O_1$] or was going to get any help from [$S3\text{-}O_1$]. Just by the way [they were] talking about what [they were] doing."

4.6. Complex Task Assessment Observations

One way that feature-rich software applications differ from simpler software is that they often enable users to engage in complex, open-ended tasks. While this is often positive, it introduces complexity in that users must be able to navigate all the steps necessary and be able to determine if the set of steps they have taken has resulted in the desired outcome. In coding the *Design Tasks* session interactions, we observed that many participants did not easily engage in assessing whether they had correctly completed some of the more abstract or complex tasks in the study. Even though the instructions for each task set indicated that participants should visit their own cottage in GT to make sure their changes had their intended effects, only one of the older adults did so without prompting.

Table 9 shows that all the younger participants tried to check their work and fix mistakes, while only 5/16 older adults did so. Older adults did not appear to intuitively switch to GT to check whether their GTM actions had the desired results. The screen-recordings revealed two major obstacles to task assessment for older adults: navigation issues and difficulties knowing how to determine if they had done the task correctly.

Table 9. Number of participants who visited their cottages and subsequent error testing by age and dyad type.

Participants' age and dyad type	Older adults (Same-age dyads)	Older adult (Mixed-age dyads)	Younger participants
# Participants who did not visit their cottages at all	2/10	0/6	0/6
# Participants who visited the cottages for the first time without prompting	0/10	1/6	3/6
# Participants who visited the cottages for the first time after being prompted	8/10	5/6	3/6
# Participants who attempted to test and then fix mistakes after visiting cottages	2/10	3/6	6/6

This study involved three different levels of navigation and effective testing required comfort with all three. As the first step, participants needed to visit their cottages to assess their progress, which required them to navigate from GTM to the GT tab (see Fig. 3). After that, they needed to navigate in the GT environment to get to their cottages by first closing the task instruction poster (which occluded the Gather map when being viewed) and then moving their avatar to their cottages. Finally, after visiting their cottages and finding mistakes, they needed to switch back to the GTM tab and navigate between different modes and dialog boxes to correct their mistakes. Five out of 16 older adult participants were uncomfortable using their arrow keys to move their avatar in GT. Other older adults struggled with other navigation levels, such as switching between tabs and/or views. What is particularly relevant is that these navigation issues also made communication with their partner difficult for older adults as navigation was also needed to switch to the GT tab and then change the view to their partner's shared screen to see the partner's interaction with the software. This meant that it was difficult for older adults to check their progress against their partners' progress, or to get help from their partner in assessing correct task completion.

In terms of assessment, 7 out of 16 older participants did not know how to test if they had done a task correctly, even though they were able to navigate to their cottages. For example, they would ask me how to check if the portal was working. On the other hand, only one of the younger participants (in only one task step) could not assess their progress and asked me for help. Most of our older adult participants had very little experience with sandbox games and graphics software (see Fig. 11), applications that could enable transfer learning [36,55] about virtual world interactions, and complex object editing. These participants did not know how to assess whether they had correctly added effects such as impassable walls, private areas, and portals between rooms. For most older adults, their first solution to this assessment uncertainty was to ask me instead of checking their cottages themselves. This lack of transfer learning was described in a few interview responses:

> *M10-Y: "[M10-O] is very just not used to this sort of stuff [and this made it challenging]. This is in a way similar to games. My friends and I would play like Animal Crossing [...] this is sort of similar in the way that you're placing things and creating spaces and [M10-O] just doesn't have that sort of experience [...]"*

> *M9-O: "[...] I have never played computer games at all, so I was pretty unaware of couple of things. So, I depended on [M9-Y] a lot."*

4.7. Older Adults' Exploration Style of Feature-Rich Software

Most of the older adult participants achieved a high level of success in performing the tasks, however, from observing older adults' interaction with the software, we noticed actions that indicated some challenges with exploration as a method of learning a new feature-rich application. In the following paragraphs, we discuss some of these observations.

We noticed that older adults were more cautious in clicking on the options and menus, especially in mixed-age pairs compared to younger participants. They would first ask for approval from their partner if they wanted to click on something new. As mentioned in Section 4.5 this phenomenon might have been a result of younger participants' reaction to older adults' possible mistakes. While on the other hand, younger participants were more open to clicking rapidly on options in GTM to view the result. In the interviews, all the younger participants mentioned that they dealt with the tasks in the *Design Tasks* session by exploring GTM while only 4/16 of older adults mentioned that as their first solution in the interviews. Also, some older adults (S1-O_1, S1-O_2, S2-O_1, S2-O_2, M8-O) mostly relied on me or their partner instead of exploring GTM themselves to do the tasks. All the other older adults either mixed exploration with asking questions from me or their partner.

> *M9-Y: "[…] when I go after a new software, I just like to push all the buttons and kind of try every option and just see where it goes. […] Usually when I go through, I'm just trying things and seeing what works and what doesn't, and kind of adjusting as I go"*

> *M7-O: "Sometimes I would try things myself, but quite frequently I asked [M7-Y]. Because I'm always afraid to put [or] hit the wrong button, you know? So, I mostly asked [them]"*

A second issue that we observed was that sometimes older adults would repeat a certain sequence of actions expecting different outcomes. Fig. 17 shows an example where S3-O_1 tried to make a portal compared with the shortest set of steps needed to do so. They essentially tried the same sequence four times before finally giving up and asked for a hint.

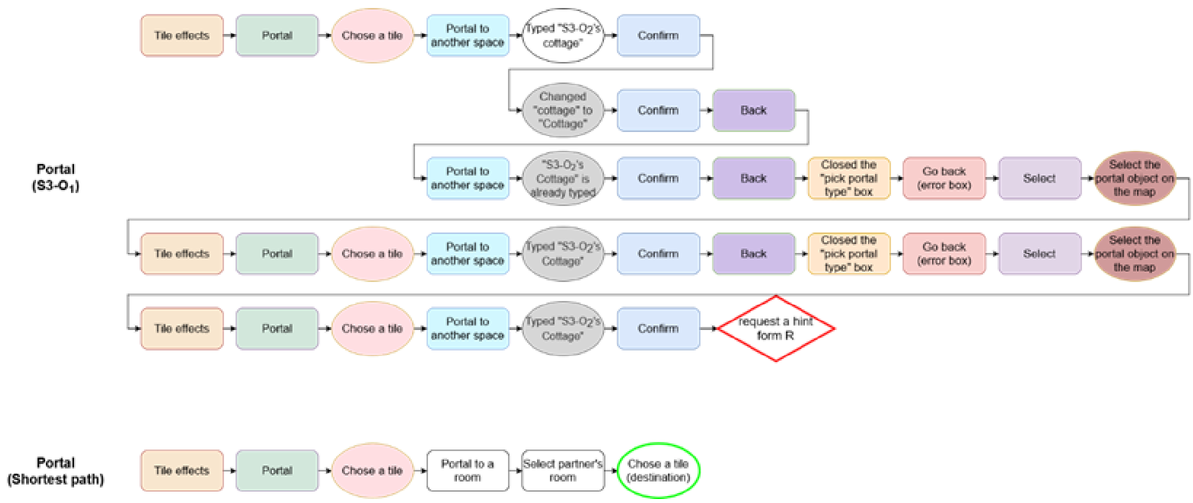


Fig. 17. Comparison between the shortest path to create a portal and how S3-O2 tried to do it while repeating a wrong sequence of actions.

Note that they were aware of this repetition as they mentioned it while doing the task:

S3-O$_1$: "what is the definition of crazy, is it doing same thing over and over again?"
S3-O$_2$: "yeah, exactly exactly [laugh]"
S3-O$_1$: "That's exactly what I am now [laugh]"

On the other hand, younger participants would try different steps to do a task and they would usually examine the outcome of their actions to observe the changes and adjust their choices accordingly.

In general, GTM having different modes for deleting and putting objects/effects was not clear for all the participants and especially for older adults. For example, they would select "eraser" and then would not realize that they needed to change the mode to "stamp" or "select" to stop deleting whatever they click on.

Another issue was the fact that rooms are shown from a bird's-eye view in both the GT and GTM which impacted how participants perceived objects and walls in the space. For example, the difference in the appearance of horizontal and vertical walls was confusing to a few older adult participants (Fig. 18). The conversation between participants in M10 illustrates this type of confusion.

M10-O: "And what's going on over there? Is that part of the wall or is that weird? I guess I'll just leave it."

M10-Y: "I don't know what part you're talking about."

M10-O: "This part, up here, which is such a long brown area."

M10-Y: "That's the wall"

Fig. 18. Different representation of horizonal (A) and vertical (B) wall because of the bird's-eye view of the GT and GTM

4.8. Summary

In this chapter, we reported the main findings of our study that helped answer our research questions. Here we summarize the main findings with respect to our three research questions.

Our first research question asked how older adults experience collaborative learning in the context of feature-rich software. Our findings indicate four different dynamics between older adults and their learning partners when exploring a new feature-rich application. By comparing the distinct attributes of the dynamics, we found that effective communication between partners and an initial ability to explore the software independently led to successful dynamics in which older adults were able to achieve moderate to a high level of task success. Our results also show some challenges associated with feature-rich software that hindered older adults' exploration, such as different modes of GTM and different steps to assess error or task progress.

Our second research question asked about the differences between the same-age and mixed-age dyads. Our findings suggest that older adults prefer someone who knows more than them which was typically expressed by wanting a younger partner but at the same time, they had fear of being a burden on the more knowledgeable younger partner. On the other hand, older adults in the same-age dyads sometimes got frustrated by their older adult partner's questions but also liked the fact that they have similar limitations. Also, analyzing the attributes of the four dynamics uncovered other impactful characteristics of the partnership than a partner's age. For example, the relationship between partners impacted the dyadic interactions which led to different impacts on older adults' learning behaviour.

Our third research question asked about the impact of collaborative learning on older adults' learning behaviour and exploration style. We found that partners' positive reactions to older adults' possible mistakes, such as being patient, and their openness to listen to their older adult partner's thoughts and opinions encouraged older adults to participate in discussions and ultimately led to effective communication and exploration. In the next chapter, we will elaborate on these findings and discuss implications for design.

Chapter 5

Discussion

This study investigated how older adults explore a feature-rich software application for the first time when working with a learning partner from their social circle. In this chapter, we discuss our main results along with implications for technology designers aiming to support older adults' exploration of new applications.

Our results indicated how older adults experienced collaborative learning in the context of a feature-rich application. Detailed coding of the dyadic interactions between partners showed older adults had positive experiences of collaborative learning when there was effective communication, and they had an initial ability to explore the software independently. Our findings also shed light on the characteristics of older adults' learning partner that empowered both effective communication and exploration. For example, trust between partners was a main driver of effective communication and influenced the exploration behaviours of older adults. Also, the results suggest other characteristics besides the age of the learning partner, that affected older adults' learning behavior such as the younger partner's patience and expertise. Our results also shed light on aspects of the software that impact older adults' learning behaviour. We found that progress checking or error testing, which is a common process when engaging in complex tasks using feature-rich software, was particularly challenging for older adults. This was particularly true for older adults who did not benefit from transfer learning or had issues with navigation. In the following paragraphs, we elaborate on these findings and suggest implications for design to improve older adults' learning experience of feature-rich software both individually and collaboratively.

5.1. Mutual Trust Between Learning Partners Facilitates Collaboration and Exploration

The results of this thesis suggest that some younger participants' reluctance to listen to their older adult partner might have decreased older adults' willingness to participate actively in discussions. At first glance, one might suspect that this type of behaviour originated from the common stereotype that younger generations hold towards older adults, i.e., that older adults are not capable of learning new technology [58]. We did not, however, uniformly observe this stereotype manifest itself across our mixed-age partners. While 3/6 mixed-age pairs assumed a *dominant-follower* dynamic, 3/6 exhibited dynamics with much more discussion (*equal collaboration* and *on-demand*). In looking at the different relationships between the partners, we observed more use of patronizing language towards older adults in pairs who were family members (mostly parent-child) compared to dyads who identified as friends. This may be due to younger family members having pre-existing assumptions about their older relative's inability to learn new technologies or having pre-existing patterns of taking over and fixing technology for their older relatives instead of taking the time to teach them how to use the technology and deal with issues that come up. This observation aligns with prior research regarding younger family members providing technology support for their older adult relatives. Some older adults in these studies reported disempowering and ageist practices from younger family members towards them, which resulted in an unequal power relationship and made the older adults wait for help and support [11,34,65,71].

One solution for building trust between older adults and younger learning partners might involve considering methods to educate family members on the importance of avoiding stereotypes. For example, a 2017 study suggested teaching teenagers in school how to tutor older adults [65]. Also, since we observed slightly more positive interactions in the mixed-age dyads who were not family members, it might be worth considering using people in an older adult's *outer* social circle to provide collaborative learning support, rather than *close* family members. While research has shown that partner familiarity does not affect outcomes while learning a puzzle [16], we are not aware of prior work that indicates how partner familiarity and relationship type impact older adults' exploration of complex technologies, which is a promising direction for future work.

Our observations of some younger participants not trusting their older adult partner's opinions align with prior research that has identified older adults as "untapped resources", as the false assumption is that older adults cannot provide support regarding technology issues [31]. This phenomenon not only hurt the quality of communication in some mixed-age dyads, but also appeared to impede older adults' self-efficacy with respect to software exploration. In some cases, younger participants infused fear in older adults which led to the older adults seeking approval before performing actions. Unfortunately, this seemed to create a negative cycle: Some younger participants did not trust their older adult partners because of their inability to explore. This lack of trust led to patronizing language, which reduced their partner's independent exploration even further. We suspect this cycle can be broken if the younger generation attempts to use more supportive and encouraging language towards older adults [64], however, some younger partners might need more awareness of the implications of their reactions. We also observed some trust issues within same-age dyads, with some older adult participants expressing expectations that their same-age partners would be unable to help them, which potentially reflects internalized ageism [3,34].

5.2. Beyond Age: Salient Partner Characteristics

Initially, we hypothesized that the age of the learning partner might impact the quality of the collaboration and older adults' learning process. The results uncovered some nuances on this matter. Consistent with the past investigation we observed a range of benefits from both younger and same-age partners [35,58], but somewhat contrary to previous research we could not propose an ideal partner solely based on the learning partners' age for supporting older adults [41,71]. In other words, there were advantages and disadvantages with both age groups of partners, suggesting that other characteristics or combinations of characteristics are more salient. For example, their partner's experience and knowledge seemed more important to the older adults than age, and this could be misinterpreted as a preference towards younger partners due to younger people typically having more technology experience. Therefore, it seems that older adults can learn from people of any age as long as there is a useful expertise match.

Nevertheless, our participants' interview responses were more nuanced than just wanting a partner who knows more. Older adults preferred someone who can provide help and expertise, but at the same time, they worried about their ability to keep up with a learning partner who is much more knowledgeable and tech-savvy. Older adult participants also worried about being a burden on their partner. This aligns with prior research claiming that children and grandchildren might not be the best source of technology support for older adults as they often act impatiently which can imply older adults being a burden [65,71]. However, we observed successful dynamics in some of the mixed-age pairs in which the younger partners were patient and understanding towards their older adult partner and tried to stay synced with them. These instances showed the importance of mutual respect, patience, and understanding towards older adults in order to have a successful collaboration. Previous research has shown that one of the benefits of co-playing videogames is enhancing intergenerational relationships and breaking down stereotypes [13,58]. Programs that provide an opportunity for different generations to learn complex software together could have similar effects.

The impatience acts were not exclusive to younger participants. We observed frustration from older adults towards their older adult peers. This adds to the results of previous research that suggested teenagers are impatient towards older adults when providing technology support [34], as our findings indicated younger adults and older adults can also act impatient towards older adult partners. For example, while our older adult participants (in same-age dyads) appreciated a partner who was at their level because they knew their partner had similar limitations, they sometimes found it frustrating because they had to help their partners while they were struggling themselves. This might have been related to older adults' lower ability to recover from interruption while performing tasks [49]. In other words, older adults might have found stopping to give help to their partners distracting, therefore would become frustrated by their partner's questions.

In conclusion, we observed contrasting opinions from older adults about who makes an ideal learning partner. While older adults appreciated a partner who knows more, they also worried they might not keep up with their younger partner's fast pace or be a burden on them. On the other hand, while older adults enjoyed having a partner with similar limitations they sometimes got frustrated or distracted by their older adult partner. The above two ends of the spectrum open interesting future research questions about the ideal partner for an older adult learning a new feature-rich application: is it better to have a partner who is far ahead in knowing the software or someone who only knows a bit more? For example, a learning partner who is just a few steps ahead might struggle to balance learning the software themselves and helping their partner. On the other hand, a very advanced partner might be in a better position to provide answers, but also less understanding and relatable.

5.3. Support Progress Checking/Error Testing to Enhance Exploration

We observed many older adult participants achieving substantial task success, and some even chose to continue working on their cottage designs while I interviewed their partner (see Fig. 16). Other older adults appeared to struggle with assessing their work and fixing mistakes and this appeared to limit how far they could get in exploring and learning the software. This issue is likely particularly prominent in CSTs, but could also be relevant to other feature-rich applications that involve complex multi-step tasks, for example, trip planners, where the user has to test the impacts of their selections on other constraints. We observed that explicitly taking action to evaluate their work on complex tasks was not initially intuitive to participants, especially for older adults. This may be due to the task not being natural or familiar, however, younger participants tended to pick up on the idea of testing their work after reminders from the task instructions or me. This confirms the results of prior work that showed older adults struggled in understanding system feedback while exploring a feature-rich software individually [42]. To mitigate this issue, Mahmud et al. [42] suggested showing the sequence of actions to older adults so they know they are in repetition. However, our observation indicated older adults' awareness of this mistake. Going further into our findings enabled us to identify two primary challenges to task assessment or error testing with the older adults that we did not observe with the younger participants.

The first was difficulty navigating through the application. In GT and GTM, this involved issues using the keyboard for spatial navigation and a lack of comfort in switching tabs and screens. One might suspect that some of the navigation issues can be mitigated by using other modes of interaction such as touch screens instead of keyboards or mouse [48]. While keyboard and mouse are classified as indirect input devices, touch screens are known for being direct and more natural as the users' actions are mapped directly to the outcome in the system. Touch screens have been suggested as a better option for older adults compared to a mouse while interacting with the computer and doing tasks such as pointing, selecting, or dragging [32]. The spatial mapping required when working with indirect input devices decreases the naturalness of the interaction [32]. As the ideal input device is varied based on the applications, the user's age, and the goal, such as performance vs accuracy [32], it is worth investigating other modes of interaction with less cognitive load to enhance older adults' navigation in virtual environments. Alternatively, it might be that more clearly labeled interface components could help alleviate some of these navigation challenges. For example, in the case of GTM, tab labels such as "go to gather" or "go to mapmaker" might have helped with navigation between tabs.

We also observed older adults struggling to understand how to assess their progress when visiting their cottages, which we suspect is largely related to them having little to no prior experience with similar software. Most of the younger participants were able to transfer their prior knowledge with similar software (such as games and graphics software) to GT and GTM. For example, the fact that GT and GTM use a bird's-eye view affected the representation of objects and materials which was more familiar for younger participants compared to older adults. Also changing modes was more obvious for younger participants in GTM while for some older adults it was not as intuitive. In addition, younger participants would change their actions or subset of them and examine the outcome while older adults sometimes repeated an ineffective sequence. Prior research suggested using skeuomorphic design to leverage older adults' experience with real-life objects to enhance technology learning in the context of online banking [22]. The main idea of such design is to stimulate interaction with a physical object so that the user can refer to aspects of design that they are already familiar with while interacting with the interface [22]. However, it seems in the case of virtual spaces this idea did not work properly as GT and GTM are attempting to mimic real-life aspects in their design but still were not completely intuitive for older adults.

5.4. Implications for Design

The findings of this thesis suggest several implications for technology that aims to support older adults in exploring feature-rich software, both individually and with a learning partner. That we observed very different collaborative dynamics and differing levels of success in terms of both perceptions of the interaction and task performance has interesting implications for systems that aim to match people with others for collaborative software learning experiences. For example, application expertise is one potentially important factor, but how the partners perceive each other's competencies, and their assumptions of an older adult's capabilities may also be salient.

The findings also suggest opportunities for systems to consider ways to communicate partner competencies both before a match is made and during the partnership. For the latter, systems that have a notion of task progress could display task steps completed so that the learning partner can see if their partner is ahead and therefore in a position to provide help. When partners are working on a task not known to the system, there might be opportunities to display command usage information for task-agnostic "over-the-shoulder" learning [28].

The findings also indicate the need for feature-rich software to support older users with checking their task progress or testing and fixing their mistakes. One of the obstacles we identified was the high number of steps required to assess progress. This obstacle could potentially be lessened with easier ways to test output, such as through easy-to-access preview modes. We also observed older adults having more difficulty leveraging their prior software experiences given that they had less familiarity with 2D spatial applications than their younger partners. Prior work has proposed techniques to help users with transfer learning in complex software [36,55]. Our findings suggest value in pursuing personalized approaches that adapt to user's familiarity with general classes of applications. There is a wide body of work on providing users with in-context help, including social mechanisms that involve other software users (e.g., [10,37]). One interesting question is if this content could be tailored to older adults' needs. For example, might older adults benefit more from explanations and demonstrations from other older adults, as a way of increasing relatedness and acting as a form of encouragement? This type of social support from other older adults was shown to be effective for simple IT skill learning [41], but has not been investigated in the context of complex tasks within feature-rich software.

Our results also indicated that an initial ability to explore the software independently enabled older adults to participate in discussions, which was one of the main drivers of the more successful collaboration dynamics (e.g., *equal collaboration* and *on demand).* However, there are challenges that hinder the independent exploration, which can heavily depend on the type of software. For example, in the case of our study, where older adults explored GTM, we observed that skills related to spatial navigation and modal interactions impacted how well the older adults could explore the software. It is worth investigating ways to help older adults bring this type of initial pre-requisite knowledge to a collaborative experience. One solution might be that feature-rich software developers provide a notice indicating the pre-requisite skills to start learning a software application. The challenge, however, would be avoid discouraging older adults who are not familiar with the pre-requisites. Therefore, one might consider tutorials targeting the set of particular skills to help older adults to reach a comfortable level of domain knowledge to start collaboratively learning the software.

5.5. Summary

In this chapter, we reflected on the main findings from our observational study. We discussed that not having mutual trust hindered effective communication between partners. Also, we elaborated on other partner's characteristics than age that might be worth considering for older adults' ideal partner when exploring a new feature-rich application collaboratively. We also discussed error testing being important, especially for older adults in terms of effective exploration of the software. Thus, feature-rich software designers can consider making this evaluation less difficult for older adults by making the outcome more accessible for them. Also, to improve older adults' experience of exploring feature-rich applications collaboratively, we suggested that a matching system for collaborative learning might want to consider a partner's competencies before partner matching. Also, it might encourage older adults to communicate and seek help if the system shows each partner's progress to each other.

Chapter 6

Conclusions

With the long-term objective of making the exploration of feature-rich applications a pleasant and effective experience for older adults, we examined how older adults experience exploring a new feature-rich application. We chose collaborative learning as a supporting mechanism while exploring the software. Prior research suggests collaborative learning as a promising approach in the context of learning basic IT/ICT applications and videogames. We observed the interactions of 6 mixed-age and 5 same-age dyads while they explored a new feature-rich application for the first time. By comparing the distinct attributes of four different collaboration dynamics that emerged between partners, we found factors that contributed to successful collaboration and exploration. This thesis is an initial step towards understanding older adults' exploratory learning of feature-rich software and how collaborative learning can support this experience. This chapter discusses the contributions of this work, the limitations of the study, and directions for future research.

6.1. Summary and Contributions

This thesis was an attempt to reflect on the increase in older adults' use of more complex software and the fact that their technology use is no longer limited to only basic IT/ICT applications. Feature-rich software provides many options through complex structures and is typically associated with a difficult learning process [42,46]. We examined how older adults experience learning a new feature-rich application for the first time while they are collaborating with a partner of the same age versus a younger partner.

Our first research question asked how older adults experience collaborative learning in the context of feature-rich software. Our study results suggest that good communication, enabled by trust between the two partners, helped to create a successful exploratory learning collaboration. We also identified features of GTM that introduced some exploration challenges for older adults, which affected the collaboration experience. Performing complex tasks while working with GTM requires participants to navigate through different modes of the software and be able to determine if the set of steps they have taken has resulted in the desired outcome. We noticed that assessing whether they had completed a study task was particularly challenging for some older adult participants. In other words, task progress assessment or error testing in complex feature-rich software needs more attention regarding novice older adult users.

Our second research question was about differences between same-age and mixed-age dyads. Our results indicated that age was potentially less influential than other dimensions of the partnership. For example, older adults preferred learning partners with more expertise in the software regardless of their age. Also, we found the relationship between partners and other characteristics such as the partners' patience and understanding of each other's limitations might be more influential than their ages.

Our third research question asked how collaboration dynamics impact older adults' exploratory learning behaviours. The findings illustrate the nature of dyadic interactions through the four types of collaboration dynamics that emerged from our detailed coding: *dominant-follower*, *equal collaboration*, *on demand*, and *individual exploration*. The description of these dynamics shows the different ways that collaboration manifested in the context of using a new feature-rich software application and provides a lens through which to examine potential influence factors. We found that the initial ability to navigate and explore the software can impact the collaboration and a lack of such skill can lead to a lack of trust by a learning partner that hinders communication and creates a negative cycle.

This thesis is a step towards an understanding of how older adults learn and explore feature-rich software when working collaboratively with a partner. Our work was inspired by prior research that investigated social support in the context of learning basic IT/ICT skills and videogames. While this prior work mostly emphasized on quantitative methods [48], we applied a detailed qualitative approach through open coding to understand the collaboration dynamics that emerged between learning partners while learning a new feature-rich application. Using this approach, we detected impactful characteristics of learning partners that affected older adults' learning behaviour. Further, the results highlight skills that are beneficial for the effective exploration of feature-rich software, such as the ability to validate progress on a task and fix errors. The findings also point to design implications to enhance older adults' exploration of feature-rich software both individually and collaboratively.

6.2. Limitations and Future Research Directions

While this observational study allowed us to document collaboration dynamics and exploration challenges, we were limited in our ability to measure the effectiveness of collaborative learning beyond assessing individual performance on a single task. Other approaches, which might be more comprehensive, would be evaluating the group performance or whether the collaborators develop skills that they can reuse in other settings [19]. For example, future longitudinal studies can investigate how different dynamics might impact longer-term software learning experiences.

Future studies should also investigate the generalizability of the findings to other types of software and different collaboration scenarios. For example, in this study, the learning partners were remote. While many older adults are remote from potential learning partners, remote communication (e.g., viewing each other's screens) introduced communication difficulties that would not be an issue in a co-located setting. Also, it has been reported that older adults prefer giving/receiving support in person compared to over the phone, which shows the importance of investigating co-located collaboration [31].

The two-session study only briefly introduced participants to GT and GTM before asking them to engage in a variety of map design tasks ranging from simple to complex. A longitudinal study could generate different results by allowing participants to practice some simpler tasks over time to gain more familiarity with a feature-rich application before attempting more complex tasks with a collaborative partner.

Finally, we were able to recruit only a relatively small number of participants (n=22), which led to a small number of each type of dyad (5 same-age and 6 mixed-age). A study with a greater number of participants would help to achieve a more robust understanding of the collaboration dynamics that were detected in this study. Also, the diversity of the participants was limited as one of the main recruitment sources used was through universities' retiree associations, which led to us having a well-educated pool of older adult participants. Less educated older adults may have different experiences with collaborative learning of feature-rich software.

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Appendix A – Pre-study Questionnaire

The survey will take approximately 15 minutes to complete.
Please read the questions carefully and answer them.

1. Please enter the ID that the researcher gave you.

2. How do you describe your gender identity?

- Woman
- Man
- Non-binary
- Prefer not to say
- Other

3. How old are you?

- 15-17
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-79
- 80+

4. What is your highest educational attainment?

- Primary
- Middle school
- High school
- Bachelor
- Master
- PhD

5. What is your current occupation?

6. What was your last occupation (if you are retired)?

7. What type of software/applications you use/ed the most while working?

8. What's the most difficult or challenging computer application you have ever learned how to use? What was challenging about it?

9. Please indicate how easy it is for you to work and perform the following. (modified from [5])
(Never tried, Not at all, Not very easily, Somewhat easily, Very easily)

- Use a computer keyboard to type
- Use a mouse

- Load ink into the printer
- Fix the printer when paper jams
- Open emails
- Send emails
- Find information about local community resources on the Internet
- Find information about my hobbies and interests on the Internet
- Use a computer to enter events and appointments into a calendar
- Check the date and time of upcoming and prior appointments
- Use a computer to watch movies and videos
- Use a computer to listen to music

10. How often do you use the following software applications?

(Never, Seldom (less than per month), Occasionally (about once per week), Frequently (more than once per week))

- Video/audio chatting (e.g., Zoom)
- Online Maps (e.g., Google map)
- Graphics software (e.g., Microsoft Paint, Adobe Photoshop)
- “Sandbox” games (e.g., Minecraft, Roblox)

11. Do you find technology/software beneficial in terms of:
(Strongly agree, Agree, Neutral, Disagree, Strongly disagree)

- Contributing to stay in touch with people
- Facilitating everyday tasks
- Helping do your job
- Helping you educate yourself (getting information)
- Filling your leisure time (Fun/creative activities)

12. Imagine that you were required to learn a new software to help you with some aspects of your work. It seems that the software has many features and a complex interface. For each of the following statements, please indicate how confident you are that you would be able to complete your job tasks? (modified from [14])

(Not at all confident, Moderately confident, totally confident)

- If there was someone giving me step by step instructions
- If there was no one around to tell me what to do as I go
- If I had never used a software like it before
- If I had only the software manuals for reference
- If I had seen someone else using it before trying it myself
- If I could call someone for help if I got stuck
- If someone else had helped me get started
- If I had a lot of time to complete the job for which the software was provided
- If I had just the built-in help facilities for assistance
- If had access to online tutorial (e.g., Youtube videos)
- If I had used similar software before this one to do the same job
- If I was learning it with another person collaboratively

Appendix B – Post-study Questionnaire

The survey will take approximately 5 minutes to complete.
Please read the questions carefully and answer as many questions as you can.

1. Please enter the ID that the researcher gave you.

2. Please select the option that describe you the best.

(Strongly agree, Agree, Neutral, Disagree, Strongly disagree)

1. My partner and I worked well together
2. Learning how to use mapmaker was easier when I cooperated with my partner compared to when I was doing the tasks on my own
3. My partner and I shared knowledge as we were learning
4. My partner and I faced similar issues while exploring the mapmaker
5. I would have felt more comfortable learning by myself (without a partner)
6. I would have felt more comfortable learning with a partner with similar age to mine
7. It was easy to communicate with my partner
8. I was comfortable asking questions from my partner
9. I was comfortable answering my partners' questions
10. Communicating with my partner was distracting
11. I was good at designing my space
12. It was difficult to reach the goals
13. I could have done better if I was given more time
14. I felt frustrated during the experience
15. I felt good whenever I finished a task successfully and wanted to do more

3. Please rank the following alternatives to learn a new software based on your prior experiences, 1 to 6 for most to less favourite. You can use the arrows on each option to move them.

- Reading/Watching tutorials
- Exploring it yourself
- Reading manual and instructions
- Asking someone for help (tutor or some one you know might be familiar with it)
- Going to class/workshops
- Learning it with someone collaboratively

Appendix C – Interview

1. Can you please tell me how you felt about exploring Gather.Town mapmaker with another person collaboratively?
2. Can you please tell me about your interaction with your learning partner? How do you describe it?
3. When you had difficulty progressing with your task, how did you get help? Why did you decide to get help in that way?
4. Can you please explain why you chose “learning software with/without partner” as your preferred learning method in the pre-study questionnaire? Now that you have had this experience, has your opinion changed?
5. Can you please explain why you preferred a partner with similar age as you indicated in the post-study questionnaire? (If they had chosen that option)
6. Can you please provide your reasoning for why you ordered different ways of learning software in the post study questionnaire in this way?
7. Are you interested in learning more about Gather.Town? (If yes) How do you want to continue your learning journey? Would you want to do it individually? Would you want to do it with your learning partner? or with another partner?
8. Do you think your communication with your learning partner would have been different if you had been together in the same room? How so?
9. If you had to pick one advantage and one disadvantage of learning software with a partner, what would they be?
10. Was the Gather.Town mapmaker harder than X (The software they mentioned in the pre-study questionnaire)? Why/Why not?

Appendix D – Codes of open coding, dyadic interaction

Table 10. 17 codes developed through the open coding method with description and example, Column 5 and 6 shows average and standard deviation of frequency for each code divided by parties involved in each interaction.

Code	Description of code	Example of code	Parties	Avg frequency	STDEV
Discussion	Both partners bring their own thoughts and ideas to do a task.	"Is portal an object?" (M6-O) "Maybe they are tile effect." (M6-Y) "if you go to objects and type portals you get portals" (M6-O)	P1 >> P2	2.44	2.74
			P2 >> P1	2.44	2.74
Question	Question that was related to how to do a task or concepts of the GT.	"Can you tell me where private area is?" (S1-O1)	P1 >> P2	46.22	14
			P2 >> P1	6.11	9.17
Correct Answers	Answers to a question that were correct, even if they were not understood by the asker.	"You first go on the wall, right?" (M7-O) "Yes, first click on stamp then click on the wall and then where you want it on the yellow" (M7-Y)	P1 >> P2	3.2	2.95
			P2 >> P1	33.56	14.28
Correct Tips	Unsolicited (but correct) advice about how to do a task.	"You can go all the way over to the right. Yeah, and below impassable there [are] spawn portal and then private area. And then you need to select or type a new name" (M9-Y)	P1 >> P2	5.22	3.73
			P2 >> P1	31.55	28.31
Incorrect Tips	Unsolicited (incorrect) advice about how to do a task.	"So now just go to the laptop area. Move your mouse to that. Try to click, so it's only making the laptop thing private" [Wrong assertion] (M11-Y)	P1 >> P2	3	2.55
			P2 >> P1	3.33	2.55
Busy Answers	Answers that indicated one's reluctance to respond to their partners' questions.	"How do you change the object? Do you remember that? (S3-O1)"	P1 >> P2	2.55	3.94
			P2 >> P1	5.89	6.39

		"No, no. I'm having trouble, I had a rug and I erased it and now I cannot get it again." (S3-O2)			
Current stage	A partner informing the other about what they are doing.	"This time I drag it over here. And leave it there. Ok. Wait, I got two rugs here now." (S4-O1)	P1 >> P2	35.11	22.65
			P2 >> P1	19.56	12.68
Question-Study Logistic	Question that was related to how to participate in the study.	"There is a button here, stop sharing [should I click?]" (S5-O1)	P1 >> P2	3.56	2.79
			P2 >> P1	0.56	0.73
Question-Verification	Question that was related to assessing participants' success in doing the tasks.	"Now, is it a private area?" (M11-O)	P1 >> P2	0.63	0.92
			P2 >> P1	0.11	0.33
Correct Answers-Study&Verification	Answers to questions about study logistic and verification that were helpful and correct.	"Share button, it should be a blue button at the bottom of the window." (R >> O2-O2)	P1 >> P2	0.11	0.33
			P2 >> P1	2.56	2.67
Incorrect Answers	Answers to all three types of questions that were unhelpful or incorrect.	"Make a longer line, like a rectangle I think." [Wrong assertion] (M8-Y)	P1 >> P2	0.89	1.45
			P2 >> P1	5.33	3
Tips-Gather	Unsolicited advice about how to participate in the study using Gather.town.	"Click escape on your keyboard because I believe you are seeing [M10-Y]'s screen now." (R >> M10-O)	P1 >> P2	0.22	0.44
			P2 >> P1	3	4.82
Checking on	Follow up on an unsolved problem or asking about participant's current stage.	"So are you doing the portal" (M7-O)	P1 >> P2	2.56	2.92
			P2 >> P1	2.22	1.72
Visit cottage	Prompting participants by the researcher or partner to visit their cottage.	"You can also go visit your cottage if you want" (R >> M7-O)	P1 >> P2	0.78	1.72
			P2 >> P1	1.89	2.42
			P1 >> P2	0.11	0.33

Task Clarification	Participants asking questions about the meaning of the tasks.	"Choose one of the four area, ok, replicate. 5 objects to be replicated. So, what do you mean by one of the four area, one of the four area shown here?" (S4-O1)	P2 >> P1	0.44	0.53
Prompt to talk	The researcher encouraging participants to talk to each other.	"I encourage you to talk to each other" (R >> O3-O1 and O3-O2)	P1 >> P2	0	0
			P2 >> P1	0.11	0.33
Other	Any other interaction that did not fall into the other 16 codes, such as participants talking about how to decorate their cottage or talking about their own daily lives.	"Maybe we need an antique screen to divide the idiots from the smart ones. [all laugh] cause they don't like to look at each other too much." (S2-O2)	P1 >> P2	11.11	5.18
			P2 >> P1	6.78	2.39

Appendix E – Research Ethics Board Approval

University of Manitoba | Research Ethics and Compliance

Human Ethics - Fort Garry
208-194 Dafoe Road
Winnipeg, MB R3T 2N2
T: 204 474 8872
humanethics@umanitoba.ca

PROTOCOL APPROVAL

Effective: April 21, 2022 | Expiry: April 20, 2023

Principal Investigator: Celine Latulipe
Protocol Number:
Protocol Title: *Older Adults Collaboratively Learning Feature-Rich Software*

Andrea L Szwajcer, Chair, REB2

Research Ethics Board 2 has reviewed and approved the above research. The Human Ethics Office (HEO) is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*- TCPS 2 (2018).

This approval is subject to the following conditions:

i. Approval is granted for the research and purposes described in the protocol only.

ii. Any changes to the protocol or research materials must be approved by the HEO before implementation.

iii. Any deviations to the research or adverse events must be reported to the HEO immediately through an REB Event.

iv. This approval is valid for one year only. A Renewal Request must be submitted and approved prior to the above expiry date.

v. A Protocol Closure must be submitted to the HEO when the research is complete or if the research is terminated.

vi. The University of Manitoba may request to audit your research documentation to confirm compliance with this approved protocol, and with the UM *Ethics of Research Involving Humans*Ethics of Research Involving Humans policies and procedures.

Appendix F – Research Ethics Board Approval (Amendment)

University of Manitoba | Research Ethics and Compliance

Human Ethics - Fort Garry
208-194 Dafoe Road
Winnipeg, MB R3T 2N2
T: 204 474 8872
humanethics@umanitoba.ca

AMENDMENT APPROVAL

June 27, 2022

Principal Investigator: Celine Latulipe
Protocol Number:
Protocol Title: *Older Adults Collaboratively Learning Feature-Rich Software*

Andrea L Szwajcer, Chair, REB2

Research Ethics Board 2 has reviewed and approved your Amendment Request submitted on June 24, 2022 to the above-noted protocol. The Human Ethics Office (HEO) is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*- TCPS 2 (2018).

This approval is subject to the following conditions:

i. Approval is granted for this amendment only.

ii. Any further changes to the protocol require subsequent amendment approvals from the HEO before implementation.

iii. Any deviations to the research or adverse events must be reported to the HEO immediately through an REB Event.

iv. Amendment Approvals do not change the protocol expiry date. Please refer to the original Protocol Approval or subsequent Renewal Approvals for the protocol expiry date.

Appendix G – TCP2: CORE Certificate

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Afsane Baghestani

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **23 January, 2021**

Appendix H – Recruitment Poster

Appendix I - Consent Form

Research Project Title: Evaluating the impact of mixed-age and same-age collaborative learning on older adults' exploration pattern of feature-rich software

Principal Investigator: Dr. Celine Latulipe (Celine.Latulipe@umanitoba.ca)

Co-Principal Investigator: Dr. Andrea Bunt (Andrea.Bunt@umanitoba.ca)

Co-Investigator (Master's student): Afsane Baghestani baghesta@myumanitoba.ca

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the research:

You and your learning partner are invited to participate in a research study on the topic of investigating older adults (65+ years old) collaboratively learning feature-rich software. You and your learning partner must already know each other, be at least 15 years old and one person should be at least 65 years old. Both participants must be able to use computers and the Internet independently. Participants must have an email address for correspondence and scheduling. Also, both participants must have no/little experience with Gather.Town. The goal is to evaluate the impact of collaboration on how older adults learn feature-rich software. Our long-term goal is to improve software design such that it aligns with older adults' exploration styles.

Study Procedure:

This study will take place online, in a video conferencing platform called Gather.Town. Therefore, your computer must have a working webcam and built-in microphone and be connected to the Internet to be eligible to participate in this study. Your participation in this research study involves filling out a pre-study questionnaire (up to 12 questions) and post-study questionnaire (up to 3 questions). Both the pre- and post-study questionnaires will be administrated via Microsoft Forms authorized under a UofM server and will take approximately 15 and 5 minutes to fill out respectively. Your participation also involves participating in an orientation session about Gather.Town, co-exploring the Gather.Town mapmaker in another session, and later answering interview questions. Baghestani will conduct the interviews with each participant independently in Gather.Town for approximately 15 minutes. Interviews will be audio and video recorded by

Baghestani. You can turn off your camera during the interview, but your voice will still be recorded. If you have any questions or concerns, please feel free to contact the researcher (Baghestani) at the above email address or phone number.

Your participation in the first and second sessions will take at most 60 and 120 minutes respectively. Before the first session, you must sign this consent form. This form will be administrated via Microsoft Forms authorized under a UofM server. After signing this consent form, we will send you a link to Gather.Town via email.

Here is what will happen in the first session:

- After joining the meeting, you will be asked to answer a pre-study questionnaire.

- Next, the researcher will give you a brief overview of the study's objectives.

- Then, we will show you a demonstration video about Gather.Town and you and your partner will have a chance to explore Gather.Town.

After the first session ends, we will contact you via email to schedule a suitable time for you to participate in the second session, preferably in the same week. We will send you another link to Gather.Town to participate in the second session on the settled date.

Here is what will happen in the second session:

- After joining the session, the researcher will ask you and your learning partner to design separate rooms for a friendly gathering using Gather.Town mapmaker. While performing the tasks we encourage you to talk to your learning partner, to ask questions and share tips. You can also ask questions of the researcher if you and your partner are stuck.

- At the end of the second session, each participant will be asked to fill out the post-study questionnaire.

- Then each participant will participate in a separate interview with the researcher.

Recording:

Both sessions will be recorded (audio and video), so that we can analyze the recording to understand your exploration patterns and how you communicated with your learning partner while exploring mapmaker. You can turn off your video during the interview session if you wish. As the researcher will be present throughout both sessions, they will record the audio and video using a screen capturing application. In addition, you will be asked to share your screen (only the Gather.Town window) throughout the whole sessions, so we can screen capture your interaction with the mapmaker. Our goal is to analyze your exploration style while you learn how to use the mapmaker with your partner.

Benefits:

The benefit of participating in this research is that the participants will learn about a video conferencing tool and how to design virtual spaces for gathering. The knowledge participants contributed to in this study will be used to suggest design implications to facilitate older adults learning feature-rich software. Also, participants will get to have a collaborative learning experience with a partner who is a friend or family member, which may alleviate boredom during pandemic social isolation.

Risks:

Participation in this study is voluntary and we will ask the participants to keep everything that happens in the sessions private, and to not share with anyone to protect the privacy of the other participant. Please be aware that there is a possibility that your learning partner may share details about the sessions. It is possible that you will feel frustrated while completing the tasks. It should be noted that the researcher will provide tips to help you progress with the tasks and you can also ask questions. You and your learning partner must provide a safe and respectful environment for each other. The researcher will end the session if they feel that the environment is not safe or respectful.

Other than these, the risks to this study are no greater than in everyday life.

Confidentiality:

All information you provide is considered completely confidential; your name will not be included, or in any other way associated, with the data collected in the study. Your answers to the questionnaires and interview and researcher’s note from the sessions will be anonymized. All the anonymized information along with directly identifiable data will be stored on a password protected computer of the researcher. Only researchers of this study will have access to the data. A copy of the data will be stored in the investigators' MS Teams project on the University of Manitoba servers. Only the researchers have access to this project.

Video and audio recordings of the two sessions and interview session are essential to the research analysis. Data collected during this study will be used for data analysis purposes only. We may use anonymized quotes from your conversion with your learning partner or from interview for purposes of public presentation; however, we will not present video, screenshots, or audio. Each participant and pair will be assigned IDs that will be used to present anonymized quotes (e.g., OA3, P4). That is, your image and voice will not be used in papers, presentations, put on the internet, etc.

If we think (from the video and audio recordings or during the sessions) a child under 18 years of age is being abused, we have the legal duty to report our concern to local child and family services (CFS) agency. (For a list of CFS designated intake agencies, go to: Manitoba.ca/intakeagencies. If you do not know the number of your local CFS agency, or if it is after working hours, you can call the province-wide intake and emergency, after-hours child, and family services line toll free at 1-866-345-9241). If we think the child is in immediate danger, we will call 911 or local police station. We will also notify the Research Ethics Board at the University of Manitoba.

Compensation:

In appreciation for your time and participation in this study, you and your learning partner will each be compensated $15 CAD and $30 CAD for attending the first and second online session respectively. We will give the compensation at the beginning of each session using e-transfer or PayPal, or any acceptable way you wish at your choosing. Please let us know your preferred way of receiving the compensation along with one of your preferred email addresses or phone number where we can send the e-transfer if that is your choice. You can email this information to baghesta@myumanitoba.ca

Withdrawal:

Participation in this study is voluntary and if you wish to withdraw from the study, you are free to do so at any time throughout the study and you will still receive the full compensation of each session that you started to attend ($15 CAD and $30 CAD for first and second session respectively). If either one of the pair wants to withdraw from the study at any point, the research team will end participation for both participants and delete all data obtained at any point prior to the point of withdrawing. After one week from the end of the second session participants will no longer be able to withdraw from the study as analysis will begin then.

Result Dissemination:

The results of this study will be reported in a Master's thesis and will be available in MSpace (https://mspace.lib.umanitoba.ca). Once published (in journals, conferences, MSpace, or thesis of the student), results of the study will be made available to the public for free at hci.cs.umanitoba.ca. Again, no personal information about your involvement will be included. Please note that the University of Manitoba may look at the research records to see that the research is being done in a safe and proper way.

Brief Summary of results:

Summary of the research will be available by approximately December 31, 2022, on Dr. Latulipe's website at celinelatulipe.net.

Data destruction:

All the data (Anonymized and directly identifiable) will be retained for a maximum period of three years and will be destroyed by April 2025.

Consent:

Please initial your response below.

I CONSENT to be recorded while being interviewed by Baghestani at the end of the second session and am aware my audio and video (you can turn off your camera) will be captured. _______

I CONSENT to be recorded via online conference software during both first and second session of the study and am aware my audio, video, and my computer's screen (only the Gather.Town window) will be captured. _______

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.
The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.
This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. If you have any concerns or complaints about this project, you may contact any of the above-named persons or the Human Ethics Officer at 204-474-7122 or HumanEthics@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Having read the provided information and after all my questions were answered to my satisfaction, I understand that I will participate with my learning partner whom I know prior to this study (e.g., friend, relative, etc.) and understand what I am freely consenting to.

Participant's Printed Name and Signature: ______________________________
Date: _____________

Participant's learning partner name and relation (e.g., friend, relative, etc.):
____

Researcher and/or Delegate's Signature: _________________ Date: _____________