

Exploring tangible user interface for social interaction and quality of life: The experiences of home-dwelling older adults

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Abstract

Background: Social relationships are an important element in our quality of life, and good social interaction can contribute to flourishing social relationships. Information and communications technology (ICT) has been developed to enhance our social interaction, but older adults encounter challenges in connection with its use. Some older adults might find it challenging to use small icons and buttons on touch screen devices, mouse and keyboard that require hand-eye coordination and touch screens that require sensitive fingers etc. Tangible user interface (TUI) enables users to interact with digital information through everyday physical objects. Hence, TUI can be a more intuitive user interface for older adults. However, little is known about the potential of TUI in relation to social interaction and quality of life in older home-dwelling adults.

Objective: In this study, we aim to investigate home-dwelling older adults' experience of using a TUI application with respect to social interaction and quality of life.

Methods: The TUI application, Tangible Cup, was used by 20 older participants in a 12-week pilot study. The study design was based on a semi-structured interview and the interview data were analysed using a hermeneutic interpretation approach.

Results: The results show that some participants managed to have enjoyable conversations with others despite the challenges in using Tangible Cup. The participants reflected on reasons for and against using Tangible Cup, and there is a mismatch between the participants' attitudes and behaviour in relation to using Tangible Cup and its design.

Conclusion: Based on the results, the characteristics of older adults who can benefit the most from using TUI and TUI designs that are suitable for them are summarised. By providing a better understanding of how older people use TUI, the findings from this study could inform better TUI design for older people's social interaction and quality of life.

Keywords: Tangible user interface, older adults, social interaction, quality of life

INTRODUCTION

With an ageing population, many studies have focused on the quality of life of older adults (Bergland et al., 2016; Boz & Karatas, 2015; Gerino, Rollè, Sechi, & Brustia, 2017). In accordance with the World Health Organization (WHO), quality of life is defined as 'an individual's perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations standards and concerns' (Group, 1993). The social aspect is an essential element in older adults' quality of life and healthy ageing (Corner, Brittain, & Bond, 2006). Older adults' social interaction can promote healthy ageing by acting as a buffer against the negative effects of ageing, regardless of whether they interact with friends or family members (Huxhold, Miche, & Schüz, 2013). People with more social networks tend to be more optimistic, feel better, and are therefore healthier (An-

tonucci, 2001; Cohen & Janicki-Deverts, 2009).

Research has shown that Information and communications technology (ICT) could contribute to enhancing our social interaction. Technologies such as mobile apps, smart phones, tablets etc. have been designed to support social networks between friends and family, and enhance the social interaction between them. However, due to the diversity in older adults, not all ICT solutions are suitable for older adults (Author1 & Author2, 2019; Chen & Schulz, 2016). Many of our current ICT solutions use a graphical user interface (GUI). GUI is a type of user interface that enables users to interact with their electronic devices through graphical elements, icons, and symbols, e.g. visual keyboards on smartphones and tablets, icons in mobile apps, and computer-based software. Although GUI has made the interaction between humans and electronic device-

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Figure 1. Tangible Cup

es easier by eliminating the need for text-based user interfaces such as command lines, it is not always intuitive and user-friendly, especially for older adults. Usability issues such as understanding icons and the size of buttons and icons were identified in a study evaluating six mobile launchers for older adults (Al-Razgan, Al-Khalifa, & Al-Shahrani, 2014). Existing mobile instant messaging apps were evaluated and some GUI elements did not appear to be intuitive for older ICT users (Bong & Chen, 2015).

In 1997, Ishii and Ullmer (1997) introduced tangible user interface (TUI). Their aim was to make the digital world truly invisible and ubiquitous by coupling digital information to our everyday physical objects and environments. Through TUI, older adults can interact with digital information by using familiar physical objects instead of graphical elements. This could minimise the difficulties they encounter interacting with GUI, as suggested by Davidoff, Bloomberg, Li, Mankoff, and Fussell (2005) and Spreicer (2011), thus enabling TUI to contribute to more intuitive and effortless use of ICT. When the use of ICT is enhanced, more frequent use could improve the quality of life (Boz & Karatas, 2015; Christophorou et al., 2016; Gustafson et al., 2015). Although TUI has been adopted in many studies, our review shows there is limited summarised evidence of its effects on enhancing older adults' social interaction (Bong, Chen, & Berg-

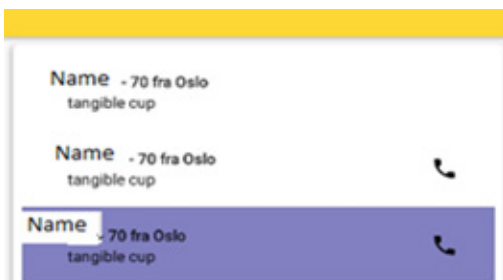


Figure 2. Interface of Tangible Cup app on tablet

land, 2018).

There is currently limited knowledge of older adults' experience of using TUI and the perceived barriers that may hinder their use of TUI for social interaction and quality of life. To address these gaps in the literature, we conducted a pilot study using a qualitative approach to investigate how home-dwelling older adults experience a TUI application in relation to their social interaction and quality of life in a 12-week TUI intervention. By exploring older adults' use of a TUI application, we hope to provide a better understanding of the ways they use TUI. The findings could provide useful information for reducing amendable barriers to using TUI, and thus inform better design for older people's social interaction and quality of life.

Tangible Cup

Using a user-centered and co-design approach, a TUI application, Tangible Cup, has previously been designed for older adults' social interaction and quality of life (Bong & Chen, 2019). The main feature of Tangible Cup is to make calls. The participants did not know each other at the beginning of the intervention.

The idea of Tangible Cup was inspired by the Norwegian coffee drinking culture where a coffee cup was identified as a familiar everyday physical object for older adults. It consists of a cup attachment (under the cup), five cup coasters (from left to right: log out, log in, search contacts, call and end call), and a tablet (Figure 1). There is a calling app on the tablet displaying the name and age of the users, the city the users live in and the status (logged in or logged out) (Figure 2).

There are RFID tags attached under all cup coasters, and a RFID reader is placed inside the cup attachment. By placing the cup with the cup attachment on the cup coasters, the RFID reader inside the cup attachment will read the RFID tag number on the cup coasters. The RFID reader will inform the calling app installed inside the tablet of the action to be performed.

As shown in Figure 2, the logged-in status is indicated by a telephone icon behind the name while the logged out status is without the telephone icon. The users who were logged in were expected to make calls to the other logged-in users and the users who received calls could either accept or reject the calls (we address them as the 'caller' and the 'recipient' in the rest of the article). We hoped that by making calls to people they did not know in the calling group, the users could make new friends and enhance their social well-being.

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Table 1. Participants' demographic information

Participant	Age	Gender	ICT skills	Education (years)	Relationship status
P1	79	F	Average	12	Widow
P2	74	F	Average	11	Widow
P3	82	F	Average	21	Widow
P4	77	F	Average	10	Widow
P5	76	F	Very advanced	14	Widow
P6	81	F	Average	15	Widow
P7	82	F	Advanced	10	Widow
P8	72	F	Advanced	12	Widow
P9	82	F	Average	13	Widow
P10	81	F	Average	14	In a relationship
P11	81	F	Advanced	19	Widow
P12	89	M	Advanced	17	Widower
P13	77	F	Advanced	11	Widow
P14	83	M	Advanced	14	Married
P15	83	F	Advanced	12	Widow
P16	79	F	Advanced	12	Widow
P17*	77	F	Advanced	11	Widow
P18*	81	F	Average	8	Widow
P19*	76	F	Very advanced	13	Widow
P20*	79	F	Average	10	Widow

*Indicates the participants who withdrew after four weeks of the study. Their withdrawal from the study is discussed in detail in the 'Results' section.

METHODS

Study design

A qualitative approach was adopted in this study, with the aim of exploring and describing the participants' views on and experience of using TUI. Semi-structured interviews were conducted to collect qualitative data. According to Bottorff (2015), qualitative inquiry has unique advantages that contribute to the exploration of the complex process of research translation. Our qualitative approach explores the participants' communication, expectations, opinions, attitudes, process, and, most importantly, interaction and relations. These are the core components of clinical knowledge (K. Malterud, 2001).

Interview

The main focus of the interview was to explore the 20 participants' views and experiences, and how they used Tangible Cup. Thus, after introducing them to Tangible Cup and demonstrating its use, the participants were given a user guide to refer to and were assured they could contact us whenever they faced problems. A semi-structured interview guide was used. We conducted three rounds of interviews, i.e. pre-study, mid-study, and post-study. In the pre-study interview,

the participants were asked about their use of ICT, their social interaction and social life, their perception of a good life (quality of life), and their expectations of using Tangible Cup. In the mid-study interview, we asked them about their experience of using Tangible Cup and the ways they used it. Finally, the post-study interview focused on their feelings about and experiences of using Tangible Cup, changes in their lives after using it and their opinions about using it. Examples of interview questions were: 'Tell me your experience of using ICT/Tangible Cup?', 'What is the best/worst part of your social life?', 'How do you think the conversations you have had contribute to your quality of life (i.e. a better life)?',

'How do you feel after using Tangible Cup?' and 'How has ICT/Tangible Cup contributed to your social life?' Follow-up questions were asked when necessary to clarify and elaborate on their answers.

Recruitment and participants

We recruited a total of 20 older adults (2 men and 18 women) to participate in the study (Table 1). The potential participants were identified based on a previous project related to the quality of life, nutritional status, physical condition and pain, and mental and social function of senior centre users in Oslo. They were briefed about the project during a phone call and asked whether they were interested in taking part. We aimed to recruit all the participants for the 12-week Tangible Cup intervention, with the aim of reaching data saturation (Creswell & Poth, 2017; Fusch & Ness, 2015). We recruited 20 participants, which is more than the number suggested by Guest, Bunce, and Johnson (2006) to achieve data saturation. Our participants' ages ranged from 72 to 89 and their education from 8 to 21 years.

We originally only included people who lived alone, but due to the difficulty of recruiting

male participants who lived alone, we included one man who was still living with his wife (P14). Other inclusion criteria were being 70 years or over and being able to walk independently with or without an assistive device indoors. Their ICT skills and how they used ICT, such as smartphones and tablets, on a daily basis were observed and assessed during our visits. 'Average' IT skills indicates that they could use ICT with some problems; 'advanced' describes those who use ICT with minor problems; while 'very advanced' users face almost no problems using ICT on a daily basis.

Ethical considerations

The study was pre-approved and registered by the Norwegian Centre for Research Data (NSD), reference number 253545. After receiving written and oral information, all the participants gave their written and informed consent. This included the assurance that they could withdraw their consent without consequences at any time and that they were guaranteed confidentiality.

Procedure and data collection

A Tangible Cup set was given to the participants during the first visit to their home. We briefed them about the project and demonstrated how to use Tangible Cup. The original intention was for the users to attach the cup attachment to the bottom of their own cup. However, with the safety of using Tangible Cup in mind, we asked the participants to just use the cup attachment without a cup. They had to move the cup attachment and place it on the corresponding cup coasters to perform desired actions. Once they agreed to participate in the study, they were asked to give their informed consent and we asked them to use Tangible Cup whenever they wanted to. They were then interviewed.

We conducted the mid-study visit after six weeks. Before the mid-study visit, some participants needed extra visits because they were having problems using Tangible Cup. During this visit, we discovered that most of them were experiencing problems contacting the other Tangible Cup users. Some participants did not get an answer when they called the other online users. In addition, only a few of them were logging in and using Tangible Cup at the same time. To address this issue immediately, we suggested the participants could try to use Tangible Cup during two time slots, i.e. 3 pm to 5 pm and 7.30 pm to 9.30 pm. The post-study visit was conducted after another six weeks, which was 12 weeks after the pre-study visit.

Data were collected from 9 January to 3 May 2019. A total of 56 individual interviews were conducted. Four post-study interviews were not

conducted due to four participants withdrawing from the study after the mid-study visit. They were however interviewed prior to their withdrawal. The interviews were conducted at the participants' homes with only the interviewer and the participant present. All the interviews lasted less than an hour.

It is important to mention that during these visits, all the participants were observed using Tangible Cup and these observations were noted down. Based on these observations, follow-up questions were asked during the semi-structured interview when necessary, which were also used to help us understand and interpret the qualitative data.

Methodology for analysis

All the interviews were audio-recorded and transcribed verbatim. A hermeneutic interpretation approach, i.e. an approach that seeks to understand the meaning of the text, over and above how it was created, was used to analyse the transcripts (Birkeland & Natvig, 2009; Lindwall, von Post, & Eriksson, 2010). Ricœur's theory of hermeneutic interpretation was referred to, which is closely connected to the concept of the text, and the principal features of the theory can be derived from the characteristics of written discourse (Ricœur, 1981, p. 14). Important background information for the hermeneutic interpretation is that a user-centered design approach was used to design Tangible Cup, based on input from a focus group consisting of older adult volunteers, and it was subsequently co-designed and tested by older adult volunteers (Bong & Chen, 2019). However, the final version of Tangible Cup has never been used and tested by a group of users over a long period of time. Since the older participants had very little knowledge of using TUI, using Ricœur's hermeneutic interpretation allows 'more interpretation and guessing' in our analysis. As explained by Ricœur (1981, p. 14), 'the construal of meaning may indeed result in more than one interpretation of a text, in which case the imminent conflict must be subsumed to a process of argumentation; but this is a process...'. Thus, by using a hermeneutic interpretation approach, we were able to make interpretations while gaining a broader understanding and meaning of the researched phenomenon (Alvesson & Sköldböck, 2017, pp. 122-132), in this case the impact of Tangible Cup on older adults' social interaction and quality of life.

All the transcripts were read five times using hermeneutic text interpretation (Lindwall et al., 2010). The first reading was to integrate the text with the reader and 'Let the text itself speak' (Gadamer, 1989). Any interpretation or analysis was avoided during this reading, as the focus was to understand the text and ask what the text had to say. In

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Table 2. Summary of themes

Primary themes	Secondary themes	Basic themes
Reasons to use	Experienced good conversations	Willing to open up Good at talking
	Motivating factors	Potential friendship Hope for more calls TUI object - interesting Use with family/Little time with family Interests-based Dating
Reasons not to use	Difficulty in making contact	Called but no answer Not answering due to not hearing the device ringing
	Suitability Experienced bad conversations Withdrawal	Passive use Only want to be the listener Busy enough – social life Difficult to be logged in at the same time, different schedules Bad at talking to strangers Too little information about the other users Not willing to open up Health problems
The mismatch between the attitude and behaviour of older adults using ICT and the design of the technology	Forget easily	Thought that they had logged out but had not
	Usability issues Need motivation	Accidentally turned down/switched off the volume Misunderstood the use of the coasters (order, search contacts) Intuitive – Need instructions, reminders, suggestions No ring tone when calling No missed call indication No battery level indicator on cup attachment Less human Do not take initiative by themselves Affected by other users Like follow-up Gender difference

depth, detailed and descriptive analysis of the data and by quoting participants' responses to substantiate the findings. To achieve dependability, the transcriptions were reviewed several times, and they were checked and coded by the first author and validated by the co-authors. Additional interpretations were arrived at based on consensus among all the authors. Confirmability was obtained by substantiating each emergent theme with rich quotes that were extracted from the participants' responses.

Berger (2015), stated that the position and reflexivity of the qualitative researcher are of paramount im-

our second reading (the fusion of horizons), interpretations and more questions were raised. The aim of the third reading was to understand the text and to answer questions that could lead to another element of understanding. Primary, secondary and basic themes were summarised in the fourth reading. In the fifth reading, we read the text once again to compare all the themes from the previous reading to the text as a whole, so that a new understanding could be formed.

The steps in the analysis process and the generated themes are exemplified in Table 2. To ensure the rigour of the analysis, all the authors read the final version of the analysis and the themes. In addition, quotations are used to illustrate the findings to show the validity of our interpretations. To try to secure trustworthiness and reduce potential threats to validity, we used the 'trustworthiness' criteria described by Lincoln and Guba (1985): credibility, transferability, dependability and confirmability. Credibility is achieved through open-ended questioning, prolonged engagement with the data and articulation of a detailed description of the methods. Transferability was performed by providing an in-

portance at all stages of the research process. The researchers' professional background and professional experience may have affected the data collection and analytic procedures. Specifically, the researcher who conducted the interviews was familiar with the 'language' of the research context and could, therefore, address certain topics or ask follow-up questions during the interviews. This could have influenced both the quantity and quality of the data in a positive manner (i.e. enrichment of the data). However, there is a risk that the researcher might have overestimated the between-participants similarities and consequently overlooked individual differences in experiences; this may have impeded the discovery and construction of new knowledge (Enosh & Ben-Ari, 2016). To avoid this, the researchers maintained a constant sense of awareness about how their preconceived notions may affect the study findings both during the interviews and analysis.

RESULTS

The five-reading hermeneutic interpretation (Table 2) resulted in three primary themes. The three primary themes are presented as the fol-

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lowing three sub-sections, and the selected quotations from the interviews are illustrated to show the validity of the interpretation of our findings.

After the first month, four participants (P17, P18, P19 and P20) withdrew from the study. All four of them stated clearly that they did not see the need to use Tangible Cup. Their withdrawal is described in detail under the theme 'Reasons not to use'.

Reasons to use

The greatest positive outcome of using Tangible cup is that some participants had good conversations. Together with this primary positive outcome, there are other motivating factors that contribute to the reasons why some participants wanted to use Tangible Cup. These participants faced similar challenges in using Tangible Cup, which is mentioned in the next section. However, they had better experiences, and we describe these in detail in this section.

We noticed that those who were more open were more likely to enjoy the conversations via Tangible Cup. Some of them were already naturally good at talking. Once they managed to talk about more than just the project, they enjoyed the conversations.

"I wanted to know what her name was. I said, "Do you mind telling me what your last name is?". I told her mine first, and she told me her name and last name, and what she has been doing, and so on... And she talked a lot about how she was living in a big house, and yes, that kind of everyday thing. And we laughed a bit, because we thought that it was nice that we were both suddenly younger than we were. She was 70 and I was 70 (referring to the age displayed in Tangible Cup)!" (P4)

Since it was difficult to make contact with the other participants, finally managing to get to talk to each other was especially exciting!

"I think it was fun! So great! So nice finally! And then the other lady said, finally, yes now I've succeeded!" (P9)

Furthermore, we are pleased to see that some of these enjoyable conversations could lead to potential friendships. Due to the difficulty of being online at the same time, some of them even thought of making an appointment with the person they were talking to after their first conversation.

"I said, 'is there a suitable time that I can call you? Like a specific time that I can contact you in the evening or during the day'. She's busy during the day, and so am I. So we agreed that if I was going to contact her it should be in the evening, but not after 9, 10..." (P9)

The hope of receiving more calls might have motivated the participants to use Tangible Cup more. Most of the participants hoped to receive more calls, but for different reasons. Those who just wanted to be the listeners hoped to receive more calls as they wanted to help others who were feeling lonely and wanted to talk.

"Yes, I have been logged in all the time. And yes the people have had the chance to call me the whole time if they wanted to, but none of them have. You could say it's a bit disappointing. It would have been nice if someone had called!" (P15)

While the others who had enjoyed their conversations also hoped for more calls.

"I would like to talk more to (name of P5). I thought that was... I thought about it afterwards, that it was very pleasant actually. It was also very pleasant to talk to (name of P12)! So then it was like I almost suggested that we could meet (referring to P5)." (P3)

And lastly, the group of passive users (who did not call the others) but who perhaps felt lonely at times, also wished to receive more calls. Although they were disappointed, hoping for more calls was seen as a positive feeling. In the future, when Tangible Cup is used by the right user group, it could benefit those in need.

"And when I used it, I sat down here and hoped that I would get to have a conversation." (P12)

Since Tangible Cup adopts TUI, the interaction between the TUI object and tablet appeared to be intuitive to the participants. All the participants easily grasped the idea of using Tangible Cup. Furthermore, they found the interaction with a real physical object interesting and fun.

"I think the positive thing is the design, absolutely. And it's a bit fun too. It's almost like a board game, where you move the cup here and there. ... And once you start using it you think it's easy." (P3)

In terms of functionalities that can motivate the older adults' use of Tangible Cup, the participants would like to extend the use of Tangible Cup to their family members. Some of them have contact with their children, but they are busy most of the time. Their children use other ICT tools or social media that their parents do not use. Only a few of the participants use social media such as snapchat and Facebook.

"It would be very fine to have something like that as a family contact tool, and also for contacting friends so that you can chat two, three days a week, or something like that. My kids know about this project. They have not commented much. They think it looks interesting, but otherwise nothing else." (P12)

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The older adults are afraid of making mistakes when using social media. Thus, the simplicity of Tangible Cup made them feel safe.

"I am not on social media like Facebook or Twitter or whatever like this, and I do not want to. I have been actually been warned... I went to a workshop for many years ago, and there was a young man and he said No to Facebook (referring to complexity and functionalities on Facebook)" (P3)

Tangible Cup offers no other functionality than just calling and conversing with other people. Besides, using cup attachment to control the calling app on the tablet was seen as simple interaction. Although anonymity has been an issue for some of the participants, more than half of them actually thought it was totally fine to talk to strangers. P7 even changed her opinion about talking to strangers. She found it awkward before the study started, but not as difficult by the end of the study. She had nice conversations since the people she had talked to were nice and friendly. To ensure that the users can have good conversations, we can add an interests-based feature to Tangible Cup. The users can choose to talk to people who have the same interests as they do. The interests can be used as a topic for their conversations as well.

"Maybe it can be based on interests. Like if someone is interested in going to the cinema with me, or if someone wants to go for a walk." (P5)

Many older adults go to the nearby senior centre where there are other older adults with the same interests. The participants therefore expressed that more older adults could be motivated to use Tangible Cup if it was introduced to them via a senior centre.

"Yes, or tell people about this at a senior centre. Sit there and say that we now need people who don't use a smartphone and don't have a computer or anything. But it's just a case of having it (referring to Tangible Cup) there and of just pressing it and having those cup coasters. And show them visually. Perhaps you will get two or three people that would like to join, who are feeling isolated, who would like to have a friend through ICT." (P9)

Another possibility that Tangible Cup can offer is dating. P12 who has been single, was actually hoping that he might have a chance to get to know someone new. However, due to the above-mentioned challenges in using Tangible Cup, he did not succeed.

"No, I am only shocked that as a single man, no women are interested in calling me." (P12)

Tangible Cup was not designed as a dating tool. Its aim was to improve older adults' social interaction. However, we were glad to see that it

opened up dating opportunities for a few participants. If it had been designed as a dating tool, the older adults might have had second thoughts about using it.

"The only negative thing I thought about was men, because I have had bad experiences with men. And I thought that I had no interest in that. When there was a woman in the picture I answered them. But I have not called the only man there... so I have been a bit funny then, think if he, that man called then I would have accepted the call happily! It's funny, it is like on a date you know!" (P9)

Reasons not to use

During the study, the biggest challenge all the participants faced was the difficulty of getting other participants to contact them. Many of them had very few conversations even though they actively used the TUI application. The callers attempted to call the others who were logged in to Tangible Cup, but they rarely got an answer. We found out that the main reason for this situation was that some of them did not log out properly from their Tangible Cup, which resulted in the callers calling users who were not actually using the application. When we asked how they logged out, some of them demonstrated this by turning off their tablet's screen. Tangible Cup would still be running in the background as long as it was not logged out by placing the cup attachment on the log out coaster. To resolve the situation, we had to manually log some of the participants out from the server side.

"They never managed to reach me because I never answered, even though I was always logged in. They must have tried to call me when I wasn't at home. I understood then that I had to log out (Tangible Cup) when I wasn't at home." (P5)

We also observed that P12 did not answer incoming calls due to not hearing the ring tone. We saw that he was logged in, so we tried to call him several times. We eventually had to send him a SMS to verify that he was actually present and using Tangible Cup. He informed us that there was no sound when someone called. We noticed that some participants had mistakenly pressed the volume button instead of the power button. This mistake was made by other participants as well.

"It was used wrongly and switched off with the big one (the power button). They probably thought they were logged out (by pressing the volume button)." (P1)

Many of the participants were frustrated by the above situations where incoming calls were not answered. They subsequently gave up calling the logged in participants.

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The 'suitability' of the participant is an issue in this study. Many of the participants were actually passive users, which can be explained by many reasons. Firstly, some of them were more interested in playing the role of the recipient rather than the caller. They were willing to answer calls from whoever needed to talk but rarely took the initiative to call someone.

"I'm not in the target group so I'm not seeking contact, but I have tried to use it with the hope that it could help someone to get started (to use Tangible Cup). ... I put it on a couple of times during the day to see if anyone is online." (P14)

Another type of passive use is due to the busy life of the participants. They had enough to do every day so did not have time to use Tangible Cup. P5 went to a gym, met friends, took care of her grandchildren etc. She was so busy that she did not even remember that she was logged in to Tangible Cup. As a result, her Tangible Cup remained logged in without her being present. Most of the participants are healthy older adults who are fully mobile, so they are active in many different activities. This explains why they were not online at the same time. They were busy at different times of the day.

"I have not got into a routine with it, because I never have any idea if I'm going to make contact with other people. The woman I talked to yesterday evening, or yesterday night, is away a lot during the day and at home in the evening. And that is the same as me. I'm not sitting here crying about being alone." (P4)

Many of the participants stated that they did not fit into this study, where they were required to talk to strangers. They were not good at talking to people who they did not know. This characteristic made them passive users. P7 usually goes to a senior centre near where she lives. However, she goes there to drink coffee and read. She said that she does not go there to talk to people.

"So I found out that talking to strangers is not for me.... I'm not very good at it, and I don't like it either, actually. So I know people through others." (P7)

Some participants commented that not knowing more about the other participants restricted their conversations with them. Tangible Cup only displayed the name and age of the participant and where they lived. All the participants were shown as being 70 years old. The age was not displayed 'accurately' in order to make the participants as anonymous as possible. Some of the participants disliked this feature. In addition, most of the participants were reserved when it came to talking with the others. They felt they had nothing to talk about apart from this project, as it was the only thing they had in common.

None of them opened up to talk about things other than the project.

"It's not that easy when you have no idea about them, if they have any education, if they have had a career, you don't know anything. You just talk about the sun shining. Do you understand? It just hangs in mid-air. ... I think it's just absolutely hopeless, certainly. ... We only talked about the project, what we thought about it. ... No matter how nice the people are and they were nice conversations. But it wasn't that... there was none of us who... should you just continue talking on the phone with each other then? Or like what was the point?" (P11)

P9 who enjoyed using Tangible Cup and had good conversations, commented that other participants could have asked more if they wanted to expand the conversation. She always enjoyed talking to people but it was difficult to get other participants to open up.

"Yes, I think I chatter the most, but I have a tendency to talk more so maybe that's why. And then there are many older adults, when they don't know who they're talking to they're very reserved, very cautious, I think." (P9)

Four participants withdrew from the study after four weeks of using Tangible Cup, i.e. P17, P18, P19, and P20. They are advanced users of ICT and are adept at using a touch screen on their smartphones and tablets. Tangible Cup, which requires using a cup attachment to control the calling app on the tablet, therefore seemed to be more difficult and troublesome for them. The experience of using the cup attachment was described as frustrating by P19, who has many friends overseas who she is in regular contact with. She is active and good at using social media on her smartphone. Hence, she commented that she found using a TUI object, the cup attachment, old-fashioned.

P19 and P20 had health problems that meant they were unable to use Tangible Cup often. During the first four weeks of the study period, P19 traveled overseas and had a serious fall and had to be admitted to the hospital. She underwent an operation on her return, and thus did not have much time to use Tangible Cup. P20's health problems meant that she wanted to be alone some days when she was not feeling good. Her children and grandchildren live nearby so there are enough people in her social circle.

Same as the other participants, both P18 and P19 experienced bad conversations. Both of them only had one conversation while testing Tangible Cup, and they both withdrew.

"I understand that (name of P18) wanted to talk about her own interests, i.e. knitting, which is

not my kind of thing. She wanted to have a nice conversation. I think that (name of P18) and I understand that we didn't have that much to talk to each other about." (P19)

All the participants who withdrew expressed that talking to strangers was not suitable for them. This same problem was faced by many of the participants, and has been discussed earlier. P18 mentioned the lack of male participants in the study. During the recruitment process, we found that men were not as interested in trying new ICT tools as women. This made it harder for us to recruit men. Despite their withdrawal, all four of the participants who withdrew from the study agreed that Tangible Cup would be suitable for people who feel lonely and want to make new friends and talk to someone new.

The mismatch between the attitude and behaviour of older adults using ICT and the design of the technology

Over this study, we managed to identify the challenges the participants faced in using Tangible Cup. These challenges were related to their personal characteristics and the ways they used Tangible Cup, as well as the design of Tangible Cup itself. Combining observation with the interviews, some general patterns and behaviours in participants' use of ICT in general were observed. We generalise these findings and present them as a mismatch between the attitude and behaviour of older adults with respect to using ICT and the technology's design.

Firstly, this user group tends to be forgetful, which also means they get confused easily. This has led to some of them having issues using Tangible Cup, such as not logging out properly and accidentally turning down or switching off the volume on the tablet, which we have discussed in the previous section.

Since they can be forgetful, they like to refer to a user guide. They commented that the user guide is too simple and should include detailed steps. The user guide did not list all the steps from logging in Tangible Cup to logging it out. Instead, we only demonstrated how Tangible cup was used to the participants when we visited them the first time. Although they seemed to understand, we realised during the second visit that many of them were not using Tangible Cup correctly. For instance, some of them misunderstood that the search contacts was a group chat function (Figure 1). They thought that placing the cup attachment there meant they were automatically assigned to a group chat. Others did not remember to place the cup attachment on the search contacts coaster after logging in.

"It's irritating when I don't manage to get in, and it won't go any further. It stops at this lady (referring to login screen) and nothing more. It irritates me!" (P9)

Thus, older adults need clear instructions and guidance when it comes to using ICT. The older adults could always refer to the user guide when they did not remember the steps. P6 did not remember how Tangible Cup worked and always remembered incorrectly that phone numbers were required to call the other participants even though it had been explained to her several times.

"No, I think it certainly was just me that didn't manage to understand, and I didn't understand how I could find those phone numbers. No...I'm a bit slow yes...." (P6)

Some of them also misunderstood that the cup coasters had to be placed in a certain order. The actions can be performed as long as the cup attachment is placed on the right coaster, regardless of the order of the cup coasters.

"And sometimes I was a bit impatient. So I put it on calling (referring to call coaster) but I forgot to put in on conversation (referring to search contacts coaster) first. And so I sat down and mixed things up, and it was like "oh". And then I became very irritated, and suddenly slid one of them into another. So I thought, which order should I put them in so that it becomes slightly easier and I can do it a bit faster?" (P13)

We noticed that many of the participants said that Tangible Cup was easy to use but demonstrated it incorrectly when we asked them to show us how they used it. Thus, it is crucial to make Tangible Cup more intuitive and user-friendly. For example, in addition to the instructions in the user guide, we can include instructions, reminders, and/or suggestions inside the app itself. When the expected actions are not being performed by the older adults, the app could prompt guiding messages.

Usability issues are another factor to be considered. The participants found it problematic that there was a ring tone on the recipient's end but not on the caller's end. This made them feel unsure about whether they were doing the right thing when they put the cup attachment on the call cup coaster. There was a text indicating that they were calling but no ring tone, and it was thus not intuitive and informative enough.

"I think that it's a bit strange when I have moved it (cup attachment) to the call tone (referring to the call coaster), I haven't heard a ring tone, even though there is a telephone behind those I have called (referring to logged in users)." (P16)

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The participants knew they might have missed some incoming calls. However, missed calls were not indicated in Tangible Cup. This is an important feature for the users, because it could indicate who was interested in talking to them and thus possibly motivate them to call them back.

"It should be developed in a way that if someone tries to make contact with somebody else, it sends a message that the person has called. So that you can see when you log in that someone has tried to contact you. Then I can try to contact the person back....and there should be a function where you can leave a message that you have tried to call but there was no answer, so that you understand that it works." (P6)

In addition, there was no battery level and charging indication shown on the cup attachment. The cup attachment can last for 7 to 8 hours once it is fully charged and we have informed the participants about this in written instruction. Some participants had problems charging the cup attachment due to the charging port being too loose. In addition to this, many of them were unsure if the cup attachment was charging or fully charged because, unlike the tablet, there was no indication of battery level.

"But then I had everything on the floor, right...because it was meant to be in the charging port. Because I didn't know how long it was supposed to charge, I had no idea. So I wish that the cup attachment could be...in a way I could tell when it was charging. I was missing that." (P7)

Some of them also felt that Tangible Cup did not offer them human interaction. Although Tangible Cup enabled them to talk to a real human being, some of them preferred face-to-face conversations, while others wanted to meet up in person at a café or senior centre for example.

"I read that it was supposed to help people not to feel lonely, but you don't feel less lonely by sitting and looking at this thing. It's human contact that counts.... Away from your home!" (P1)

This attitude discouraged them from using Tangible Cup and, in the future, we hope to change their attitude to using ICT. Using ICT to make new friends can be a good start that leads to meeting each other in person.

"We talked about the ideal aspect of this, that you shouldn't sit alone and feel isolated, you should make friends! And I'm interested in that point. So I see that this is a good idea, if it can lead to the elderly getting up from their chairs. Maybe meeting someone, or talking to someone in the evening." (P9)

The participants did not always take the initiative to use Tangible Cup, or to make the first move

and call the other logged in users. The older adults need motivation when it comes to using ICT, and one of their main sources of motivation is the other users. These reasons not to use demonstrated how some of the participants were demotivated by the use of Tangible Cup. They thus started to give it up, and as more and more of them gave it up, fewer and fewer participants were online. This resulted in demotivating those who were initially active.

"Uncertainty about how I should do it when I didn't make any contact. The fact that I didn't make any contact made me lose confidence and faith in it." (P1)

Also, the participants liked to be followed up. P6 had not started using Tangible cup when we visited her during the mid-study.

"I haven't used it because I have yet to figure out which cup coasters I should put it (the cup attachment) on. So it was nice that you could show me again." (P6)

She actually wanted us to visit her more often so that we could follow her up in terms of her use of Tangible Cup. It can be argued that in addition to older ICT users requiring motivation, many of them also need regular follow-up. A reminder and suggestion feature can be added to Tangible Cup in the future. Older people can thus receive reminders and suggestions to call the other users, since they do not generally take the initiative on their own.

Last but not least, we notice a gender difference in terms of the attitude and behaviour of older adults using ICT. Most of the older men wanted to be seen as tough and independent, and thus denied that they needed ICT to improve their social lives. This resulted in our recruitment process not succeeding in recruiting more male participants.

"I was so disappointed, especially in the men at the centre (referring to the senior centre), they never join anything! And then they say "there are so many women at the training parties (referring to activities at the senior centre) that I feel like I am lost (not connected)". So there is a very big difference between the genders. And you see that when we have these social evenings with dinners and things like that. There might be around 40 ladies and 3 men, at a rough estimate. And then we dance with each other, because there is live music and they have set it up to be a bit fun. ...but why can't these men stand up and do a waltz or something like that? I say, listen you're not a poor walker, why don't you take a lady up for a dance?" (P13)

DISCUSSION

To the best of our knowledge, this study is the first to investigate older adults' experience of us-

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ing TUI for their social interaction and quality of life. The findings show that the use of Tangible Cup had both positive and negative impacts on the participants' social interaction. Several participants expressed their enjoyment of using Tangible Cup. A total of six participants would consider further developing friendships with the call recipients they had talked to. This is a clear indication that Tangible Cup had an impact on their social interaction. They told us that the conversations went well when both the caller and the recipient opened up and talked about more personal matters. Some of them would even consider meeting each other in person. As found in a study using an accessible iPad-based app to support older adults' asynchronous communication with family and friends (Barbosa Neves, Franz, Judges, Beermann, & Baecker, 2019), the use of Tangible Cup can open up possibilities for improving older adults' social interaction.

The positive impacts on these participants' social interactions are believed to have some positive impacts on their quality of life as well. Previous studies have shown that the social aspect plays an important role in older adults' quality of life (Bowling, 2009; Bowling, Banister, Sutton, Evans, & Windsor, 2002; Gerino et al., 2017). When older adults have better social interaction and social relationships, they tend to feel more positive and therefore, have better quality of life (Bergland et al., 2016; Boz & Karatas, 2015; Corner et al., 2006; Gustafson et al., 2015; Scocco & Nasuato, 2017; Theeke & Mallow, 2013).

However, the use of Tangible Cup did not go as smoothly as expected due to some challenges that occurred during the study. Although Tangible Cup has been tested throughout the design and development process (Bong & Chen, 2019), this study is the first time Tangible Cup was used and tested with all its functionalities over a long period of time at the participants' homes, which is the most natural setting for them to use ICT without any supervision. Several usability issues and unforeseen user behaviour were identified that resulted in challenges in using Tangible Cup.

Heinz et al. (2013) investigated older adults' perception of technology and 'frustrations, limitations and usability concerns' emerged as one of their main themes. Our main theme 'the mismatch between the attitude and behaviour of older adults using ICT and the design of the technology' illustrates a similar concern. The participants in a study by Heinz et al. (2013) disliked that the technology might lead to reducing human contact; while the participants commented that the communication through Tangible Cup was slightly 'less-human'. It is important to teach older adults that using ICT is intended to en-

hance their social interaction with other human beings, and not to replace it. This could motivate them to accept and use ICT.

Barbosa Neves et al. (2019) identified five feasibility elements to be considered in an accessible app to enhance older adults' social connectedness. Our findings supplement some of these feasibility elements. Firstly, 'the active involvement of one tie' was considered important when the older participants needed to learn and use Tangible Cup. Some of them mentioned that they would use Tangible Cup more if someone they already knew was also using it. According to Wood and Bandura (1989), the behaviour of an individual relies on his or her environment, cognitive, and other personal factors. In this context, the other users using Tangible Cup constitute the individual's environment. We have found that older adults need motivation from their surroundings when it comes to using ICT, and one of their main sources of motivation is other users. The participants would also use it more actively if they were able to make more new friends through the use of Tangible Cup. This is another feasibility element, 'perceived usefulness and functionality' that influenced the ways the participants used their Tangible Cup.

Our study pointed out the importance of follow-up and feedback to older adults. Vaportzis, Giatsi Clausen, and Gow (2017) investigated older adults' use of tablets and found that a lack of instructions and guidance was a major barrier to older adults using technologies and tablets. Our findings supplement this study. Most of the participants did not always remember the steps and the right way to use Tangible Cup. They liked us visiting them often and demonstrating the use of Tangible Cup to them. It is worth mentioning that some of the participants received more visits from us due to the use of Tangible Cup. This may have contributed to their social interaction and relationships. Dickinson and Gregor (2006) argue the same in their study, i.e. that the effects of training/support may have contributed to the well-being of older adults and not the use of a computer.

The participants' use of Tangible Cup has revealed some general characteristics in older adults using ICT, i.e. they tend to forget things easily and need motivation. When designing ICT for older adults, it is important to pay attention to these characteristics and address their needs accordingly. As pointed out by Hallewell Haslwantner, Fitzpatrick, and Miesenberger (2018), older adults are very diverse. Our findings indicate the same, and there is no single solution for older adults' use of ICT. In their systematic review, Chen and Schulz (2016) propose identifying older adults whose social isolation can be reduced

by using ICT. On the background of this 12-week intervention involving 20 older participants using Tangible Cup, we propose characteristics in older adults for whom TUI is most suitable, and what kind of TUI design is appropriate for them.

Target user group

All of the participants in this study are average and advanced ICT users, and our results show that they were not the target user group for using Tangible Cup. As suggested by most of the participants, **older adults with low or no ICT literacy** should be the main target user group. ICT literacy is associated with many factors. A study conducted by Olsson, Samuelsson, and Viscovi (2019) including 796 Swedish respondents aged 65 to 85 shows that age has a negative correlation with ICT skills. Older adults need more time and effort to learn new technologies. While our application is inspired by a cup, Davidoff et al. (2005) used a book as a TUI object for older adults to send messages. Similar to our findings, their results suggest that TUI can appear more intuitive and familiar to older adults because it uses an everyday physical object as part of the user interface. This can help older adults with low ICT skills to learn new technologies because they can easily relate the new technologies to everyday life.

Some **older adults face challenges in using tablet devices**. Previous studies investigating older adults' use of tablets highlighted some negative features of tablets (Barnard, Bradley, Hodgson, & Lloyd, 2013; Vaportzis et al., 2017) and our findings support these studies. Some older adults have problems understanding touch screen technology and user interfaces in tablets compared to laptops and personal computers (UISEL, 2015). Vaportzis et al. (2017) revealed in their study that older adults found the buttons on a tablet cumbersome. The participants in our study made the same comment. Without labels and names, the participants made mistakes and confused the power button for the volume button.

TUI can appear to be more intuitive than interface elements on tablets and touch screens. For older adults who have **restricted physical abilities**, for instance weaker muscle control in fingers, touch screen buttons and icons can be problematic, especially when they are small (Xiong & Muraki, 2016). Instead of interacting with small buttons and icons on a tablet, TUI provides a bigger physical interface for older adults to interact with. Some of the participants commented that the use of Tangible Cup can help older adults with restricted physical abilities to control the tablet better.

TUI designs

Some usability issues identified that should be addressed to resolve the mismatches, are presented in the results section. By addressing these issues, TUI designs are also developed to be more suitable for the older adults. Through the process of designing Tangible Cup, a list of lessons has been learned about what to consider when designing TUI for older adults, i.e. **using familiar physical objects, integrating TUI into their daily life, having minimal functionality, avoiding crowded interfaces, considering older adults' physical abilities, providing necessary instructions and making the use of TUI practical to older adults** (Bong & Chen, 2019). Some of the lessons learned are applicable in addressing the usability issues identified in this study and improving Tangible Cup in the future. For instance, the cup attachment could have a battery level indicator (making the use of TUI practical to older adults). In addition, alert message can be prompted on the tablet when the user accidentally turns down or switches off the volume, or has any missed calls (providing necessary instructions). The calling app is the main digital feature which the older adults use the cup attachment to interact with. So providing such alert message is necessary. While designing a TUI application, it is crucial to be mindful of the designs of all components, both the tangible representation (the cup attachment and cup coasters) and the digital representation (the calling app).

During the study, we observed two important features that may be useful to older TUI users. The first is **automation**. Some older adults suffer from age-related memory decline and tend to forget things (Craik, 1994). Automation has been used in other ICT tools to assist older adults, such as tele-homecare (Nourizadeh, Deroussent, Song, & Thomesse, 2009). Automating a feature such as automatic log out of users after a long period of inactivity, can eliminate the chance of the users forgetting and/or not logging out properly. Some of the participants did not log out by placing the cup attachment on the log out coaster. They thought that they could simply log out by pressing the power button and turning off the screen. However, the app was actually still running in the background and their status was shown as logged in to the other users. This resulted in callers not receiving answers to calls, which made them frustrated.

Some of the participants felt that too little information was displayed about the other users in the app, while others appreciated that minimal information was shared and that they could then ask more personal questions in the conversations. Such information can be customised on the app, so that the users can decide how much they

want to see, and how much they want the others to see. **Customisation** can address the different needs of diverse older adults (Camarinha-Matos, Afsarmanesh, Ferrada, Oliveira, & Rosas, 2013), and this applies to TUI design as well. According to the participants, Tangible Cup has to be more accessible and intuitive to adapt to older adults' use of TUI. Customisation shall not be limited to the design of TUI, but also cover the use of TUI. Chen and Schulz (2016) suggested that customised training should be organised for older adults when ICT is used to address their social isolation problem. Older adults can benefit from customised training material, settings, procedures and the instructor customising his/her style and attitude. Customised training and follow-up are necessary to ensure the maximum impact of TUI on the social interaction of older adults.

Strengths and limitations

To assure the transferability and generalisability of our qualitative data, we presented rich and detailed descriptions of the participants' 12-week experiences of using Tangible Cup on their social interaction and quality of life, as suggested by Lincoln and Guba (1985). Despite the strengths of the presented results, the main limitation of this study is clear. Our intervention period of 12 weeks could be too short. According to the study by Woodward et al. (2011), which examined the relationship between providing ICT-related training to older adults and their ICT use, the older adults' ICT use and the number of people in their social network increased over time. The impacts of using Tangible Cup on the participants' social interaction and quality of life could be more significant if we had conducted this pilot study over a longer period.

In addition, with only 20 participants, it was very hard for them to be online at the same time. Although we might have achieved data saturation (Fusch & Ness, 2015; Guest et al., 2006), the concept of 'information power' (Kirsti Malterud, Siersma, & Guassora, 2016) was neglected. 'Information power' relies on (a) the aim of the study, (b) sample specificity, (c) use of established theory, (d) quality of dialogue, and (e) analysis strategy. Our study did not have enough sample specificity. Prior to recruiting the participants, we had no knowledge of their ICT skills and social life. As discussed earlier in this paper, the participants had above average ICT skills for older adults. Tangible Cup is not suitable for this group of older adults. Most of the participants reported an active social life so they had little time to use Tangible Cup. After four weeks, four participants withdrew from the study. After the mid-study visit, the remaining 16 participants were told to use Tangible Cup during certain time slots. This strategy helped to a certain extent as most of

them finally managed to talk to someone using Tangible Cup.

Same as the study investigating older adults' use of tablets (Vaportzis et al., 2017), the majority of the participants are women. Out of the 20 participants who we managed to recruit, only two were men. The original inclusion criteria were that the participant had to live alone. However, since so few older men were interested in joining our study, we had to include one man who was still living with his wife. One of the reasons for this could be that more women tend to feel lonely and therefore agree to participate in such studies (Chen & Schulz, 2016). Vaportzis et al. (2017) commented that women might be keener to help and participate in such research studies, which is also our experience. Some participants considered Tangible Cup a potential platform for making new friends of the opposite gender. The significant imbalance in the number of each gender could lead to some participants losing their motivation to use the application. P18 even stated this as one of the reasons why she withdrew from the study.

The authors of this study are researchers working on human-computer interaction and health sciences. Thus, our study design, data collection, analysis and interpretation have been influenced by our backgrounds and preconceptions. A strength of this study is that it demonstrates interdisciplinary collaboration where the authors discussed and reflected on the interdisciplinary nature of the work throughout the research process (Polit & Beck, 2017). Our paper might be of importance when customising education for health, social, technological professionals along with those providing health services for older people. The study might contribute important knowledge to facilitating older people's use of TUI to enhance their social interaction and quality of life, as well as contributing to enhancing a broader understanding of older adults' everyday life situations.

Using the cup attachment to control the calling app on the tablet is a TUI while the calling app on the tablet is a GUI. Therefore, the design of Tangible Cup is actually a combination of a TUI and a GUI. This makes it challenging to investigate the participants' use of TUI precisely. To address this limitation, in the interviews and analysis we emphasized on the participants' use of cup attachment to interact with the calling app on the tablet, instead of the touch gesture app and the calling app use on the tablet. Although some of the identified issues are related to the calling app itself, i.e. the lack of missed call indications and suggestions to call online users, the use of TUI has the potential to enhance the older adults'

interaction with the GUI elements. For instance, cup attachment can be placed onto a missed call indicator cup coaster to see the missed calls.

CONCLUSION

Our pilot study explores the use of a TUI application, Tangible Cup, by 20 older adults over 12 weeks with respect to quality of life and social interaction. The findings indicate that those who were motivated to use Tangible Cup were more open in their conversations and had positive experiences of having good conversations. The challenges of using Tangible Cup were related to the difficulty of making contact with other users as well as the use and design of Tangible Cup, which were not suitable for the participants in our study. Notwithstanding the study's limitations and the participants' challenges in using Tangible Cup, all the participants agreed that Tangible Cup had the potential for further development and use by a certain target user group. Based on the results, we first recommend the characteristics of older adults who could benefit

more from using TUI. Older adults who have no or low ICT literacy and struggle with touch screen technology are the target user group for TUI. We then propose TUI designs that are appropriate for older target users of TUI. Automation and customisation are helpful designs that could enhance older adults' experience of using TUI. This study provides useful information about making TUI a more intuitive and usable user interface for older adults. TUI's ability to contribute to improving older adults' social interaction and quality of life as a whole is thus promising. In terms of the implications of the study, the findings may contribute to facilitating the delineation of improved strategies, which can inform policy makers, educators, clinicians, future researchers and older adults. In the future, based on the feedback received, we hope to improve Tangible Cup, reach out to the target user group that will benefit from using TUI, and further investigate the impacts of Tangible Cup with a bigger group of home-dwelling older adults.

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