Seniors' expectations to adopt IoT technologies

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Abstract

A new computational paradigm called the Internet of Things (IoT) has allowed various objects in our routine to communicate with each other. We can also observe that the global number of seniors with the effective potential to be its users grows, mainly due to the increase in life expectancy. Then, seniors can benefit from IoT technologies to achieve a better quality of life and healthy ageing when these technologies consider accessibility and usability. This study aimed to understand better the seniors' main perceptions about using IoT technologies, especially to discover the users' expectations of dealing with them. Thus, 11 Brazilian seniors (over 60 years old) participated in interviews, and based on their responses, we conducted a thematic analysis. Besides revealing the expectations of the interviewees for adopting IoT, this study also presents the development and evaluation of an IoT application to support seniors based on the requirements identified in the interviews.

Keywords: Internet of Things, Seniors, Usability, Expectations

1 Introduction

Technologies with the Internet of Things (IoT) have reached different economic sectors due to the growing number of connected objects. Ashton [1] introduced this concept in 1999, and the basic idea of IoT is that several things can identify and interact with each other to achieve common goals [2]. IoT features are increasingly available in the consumer market and are gaining strength to be available in everyday objects. The number of IoT devices worldwide is forecast to almost triple and reach more than 25.4 billion IoT devices in 2030, as predicted by [3]. This rapid growth has accompanied population aging. The global number of seniors is increasing drastically and is expected to more than double, reaching more than 1.5 billion in 2050 [4]. An estimated condition is that the global population aged 65 and over will increase to 16.0 percent in 2050 [5].

Seniors can benefit from IoT technologies to achieve a better quality of life, well-being, and healthy aging [6]. For this, these applications need to be adequately designed to minimize problems such as high perceptual and cognitive demand due to increased interactivity and the infinity of devices in intelligent environments. Other benefits ensured by these new environments include the possibility of task delegation

to the environment and its agents, which can reduce physical and cognitive strain, as well as the breadth of applications and services that will be available, addressing a wide variety of domains that are critical for the disabled and older users [7]. Thus, it is required to understand the demands, preferences, feelings, and impact IoT solutions can have on those who have not grown up with technology in their lives.

According to Ashraf et al. [8], researchers have investigated elements that may affect the perception and attractiveness of widespread technology through a typical user. These studies have centered on encouraging acceptance via enhancing the usability of technology for older adults. Kowalski et al. [9] highlighted four key needs of seniors: (a) understanding technology and receiving feedback; (b) accessible design with a low barrier of entry, unlike regular computers; (c) seamless incorporation into everyday life, as the participants liked the idea of being able to accomplish specific tasks using only speech not only because they might have difficulties moving, and (d) control and assurance of security. We can also reinforce a need to investigate the development of IoT solutions considering older adults. Indeed, older adults can benefit from the potential of these solutions if they are user-friendly.

This article presents an extension of our previous study [10], in which it was discussed implications for the design of IoT technologies considering seniors' main concerns. In this study, our focus was to identify and analyze predictions and expectations related to using IoT technologies by seniors. Therefore, according to scientific research, we have defined the following Research Question:

"–*What are the expectations arising from the seniors' potential use of IoT technologies?*"

The remainder of the paper is organized as follows: section 2 presents the related research. Next, section 3 describes the method. section 4 outlines the discussion, and in section 5, we discuss future directions for IoT research in Human-Computer Interaction (HCI) area and our conclusions.

2 Related Work

Different studies have investigated predictions and expectations of final users considering the future use of IoT technologies. Erel et al. [11] state that smart-home and IoT technologies come a great opportunity to create a "digital bedroom culture". Then, to understand how children perceive their bedrooms and how they think smart-home technologies can be integrated into their rooms, they conducted interviews with 17 children in the context of their bedrooms. As result, children associated the "smart-room" technologies with practical needs and much less with emotional ones. The authors concluded that smart-home and IoT designers should consider this gap and explore the possibilities of designing IoT technologies that will augment children's emotional needs in the context of their bedroom.

Psychoula et al. [12] aimed to understand how and if contextual factors affect users' privacy perceptions of the IoT environment. They deployed a public online survey (N=236) and contacted interviews (N=41) to explore factors that could have an influence. As a result, the authors find that many participants would still decide to have the offered IoT service if they find it useful and practical for their daily lives despite the infringement on their privacy.

Considering the senior public, a survey performed by Stara et al. [13] investigated the factors that may influence the perceptions and expectations of 306 Italian older adults (average age = 74 years) regarding smart home technology. The results showed that about half of the respondents had a positive interest in technology. However, their attitudes towards technology were involved by practical means, such as utility, facility, security, and privacy. Aspects such as aesthetics, size, and weight were not crucial for participants. Researchers also highlight other issues, such as the relevance of gender and education in accepting technology.

Tsuchiya et al. [14] carry out a study to understand the needs and problems encountered by older users in computer systems familiar to them and, from there, implement new control systems for their homes. A focus group was performed with people over 60 who had experience with computers and smartphones. The main findings evidenced an interest in the use of technologies. However, they have reported some concerns about such applications' dependability, reliability, and cost.

Singh et al. [15] conducted an online survey with 234 participants to understand the attitudes and perceptions of future smart home users, followed by a detailed analysis of their responses. In general, the users agree that smart home technology would improve the quality of life to a greater extent and enhance the safety and security of residents. On the contrary, they raise several concerns, such as increased dependence on technology and monitoring private activities (drawbacks). The results show that older adults are more open to monitoring and sharing data, especially if it useful for their doctors and caregivers. In contrast, young adults are reluctant to share information.

Pradhan et al. [16] investigated how seniors who use technology infrequently perceive and use these voice assistants. They conducted a 3-week field deployment of the Amazon Echo Dot in the homes of seven older adults. The finding emphasized the need to revisit concerns about the credibility of information with

this new interaction medium. Although features to support memory (e.g., setting timers, reminders) were initially perceived as useful, the actual usage was unexpectedly low due to reliability concerns. Finally, the authors could discuss recommendations for future work on voice-user interfaces.

Additionally, Bolaños et al. [17] identified the intention of older adults to use smart virtual assistants. They held focus groups to gather precise, clear, and simple information. The results obtained indicate that older adults can potentially use virtual assistants for their daily personal, work-related, and recreational activities. Nevertheless, motivation and technology acceptance are key aspects to ensure the usability of technological systems by this group, and user requirements should be well defined in order to identify the characteristics that they expect to find in such technology products.

We have found few studies investigating seniors' predictions and expectations considering the future use of technologies. While authors considered methodologies such as questionnaires and focus groups, we considered interviews aiming to obtain detailed and rich information about preferences, restrictions, insecurity, and other factors. In general, our focus was to rescue respondents' emotions regarding the use of IoT.

3 Method

We developed a qualitative exploratory study to address our research question (see Section 1). This study involved interviews with seniors to identify usage perceptions and the gathering of requirements for the development of an IoT application. Figure 1 shows an overview of the four phases of this research methodology, including the inputs and outputs, the methods applied, and the responsibility for performing the activities in each phase. Initially, we performed a literature mapping of the studies related to IoT, and the relevant findings were fundamental to proceed to the other phases [18], [19],[10]. Subsequently, we conduct interviews to investigate expectations about IoT technologies and collect requirements for developing an IoT application. Below, we detail the other phases, such as interview design, characteristics of participants, the materials, the procedure used to collect and analyze data, and the IoT application development process.

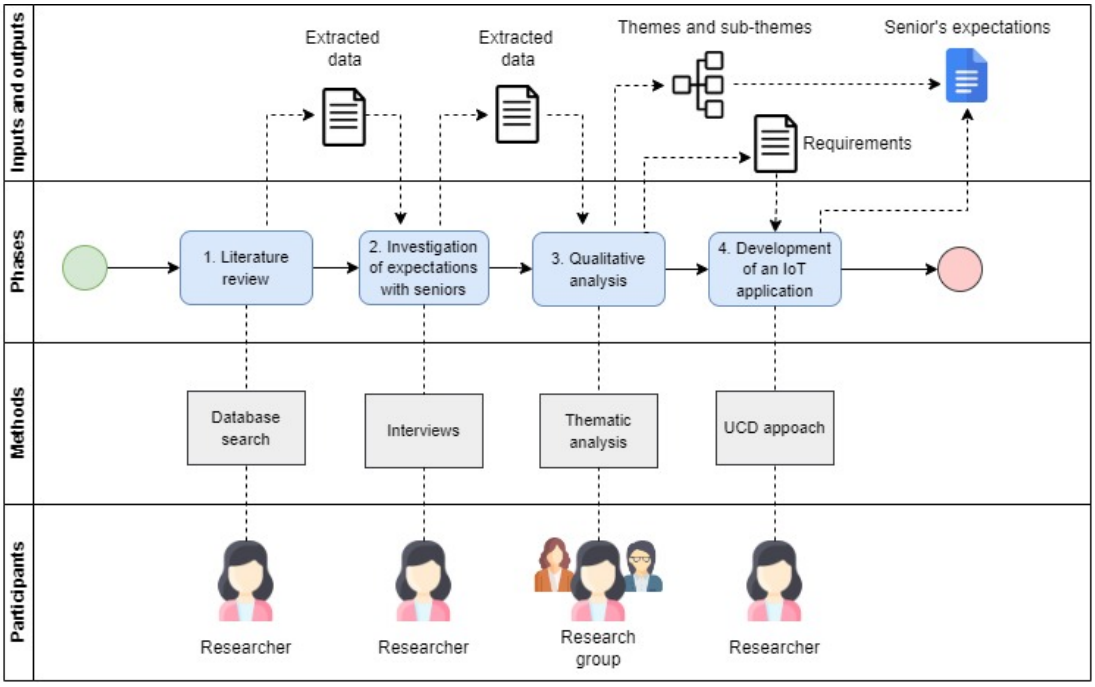

Figure 1: Overview of the stages of the research methodology

3.1 Interviews

This study's primary objective was to understand better seniors' perceptions, concerns, needs, and reactions to IoT applications. For this, we conducted interviews and engaged participants in a speculative inquiry exercise to understand their expectations of the potential use of these technologies. In addition, this study allowed the identification of requirements for developing an IoT application, which will be further detailed in subsection 3.3.

The interview script was elaborated by two researchers in the HCI area and was made in two parts. First, we created a preliminary version and invited two participants to a pilot study. Next, we developed an

improved version of the issues pointed out by these participants. The interview was then semi-structured, and it included closed and open-ended questions. The questions were dedicated to getting the demographics data, Internet use, use of smart devices, and feedback on a proposed scenario.

To exemplify the application of IoT technologies in people's daily lives, we presented the following fictional scenario to the participants:

> *Imagine the following scene in your everyday life - At night, you put your alarm clock to ring at 6 am to go to your doctor's appointment, and you go to sleep. While you are sleeping, your alarm clock accesses the Internet and finds that there will be a gasoline strike and gas stations until 9 am, and then your appointment should be postponed by your doctor. So your alarm clock lets you sleep a little bit, changing the time to ring at 8 am. As you had programmed the coffee maker to make the coffee at 6 am, the alarm clock warns the coffee maker that you will have breakfast only at 8 am. You get up at 8:00 am, drink your coffee warm, and your smart refrigerator starts blinking because she found that the milk you need to take your medicine, which was in it, is running out. The refrigerator sends a message to your smartphone telling you about the milk and indicates the supermarkets near you where this item is in the promotion. In this scene, we have intelligent objects: cell phone, alarm clock, coffee maker, and refrigerator. These objects are intelligent because they can "reason a little". They connect to the Internet, communicate with each other, and make decisions to improve people's lives.*

Next, we asked some questions to the participants, such as:

1. From this scenario, can you identify other things in your everyday life that could be intelligent too, that would connect to the Internet, and that could help in your routine? Observe what you perform routinely.
2. What are these objects?
3. How could they help you? How?
4. Do you have any proposals that you find useful or of interest? Why?

Interviews were audio-recorded and later transcribed. In addition, the research received ethics approval from the university's Research Ethical Committee, study protocol 02896318.2.0000.5390. All the data collection for this research proceeded with the participants' consent for using their answers, and the complete anonymity of participants was assured. Also, participants in our study were 60 years or older, in conformity with article 1 of the Statute of the Elderly (Brazilian Law 10.741). According to the Law, the Brazilian seniors are aged 60 years or over [20].

3.1.1 Participants

Eleven participants aged 60 or older participated in the study. They were six men and five women, with an average age of 66.5 years. Seniors were recruited from the University of the Third Age educational program at the University of São Paulo (UATI/USP) in São Carlos, São Paulo, Brazil. We randomly recruited seniors who attended the educational program and had experience with the internet, smartphones and computers. Participants were assigned an anonymous identifier (PX) in the order they spoke.

All participants had some experience with the Internet, smartphones, and computers. When asked to indicate their education level, 45.4% of the respondents reported having an undergraduate degree. Most participants reported having Wi-Fi Internet access in their homes. Almost two-thirds of the participants (63.6%) said that the frequency of Internet use per day was between 1 hour and 4 hours. Table 1 shows a summary of this data.

3.1.2 Procedure

The interviews were individually conducted face-to-face at the Institute of Mathematics and Computer Sciences laboratory at the University of São Paulo (ICMC/USP). Participation was voluntary, and all participants were asked to read and sign the informed consent form before starting the research. After a short description of the purpose of the study, the interview was divided into the following parts: demographic data, Internet usage, and familiarity with IoT devices. We provided the participants with questions and a fictional scenario. We asked them to identify smart things that could help their routines and expectations of using these technologies. The interview period was approximately four weeks (October to November 2018). We registered all the interviews with written notes and audio recordings. They totaled 5.12 hours, and the average time spent in each session was 28.2 minutes (SD=7.04 minutes).

Table 1: Participant demographic data and Internet usage

Participant (P)	Age	Gender	Highest level of education	Wi-fi at home	Daily time of Internet Usage
1	78	Male	Undergraduate	Yes	$1 \leq t \leq 4$ hours
2	65	Male	Undergraduate	Yes	$t > 4$ hours
3	61	Male	High school	Yes	$1 \leq t \leq 4$ hours
4	62	Male	Undergraduate	Yes	$1 \leq t \leq 4$ hours
5	66	Male	Elementary school	No	$1 \leq t \leq 4$ hours
6	70	Male	High school	Yes	$t < 1$ hour
7	73	Female	Undergraduate	Yes	$1 \leq t \leq 4$ hours
8	67	Female	Undergraduate	Yes	$1 \leq t \leq 4$ hours
9	64	Female	Elementary school	Yes	$1 \leq t \leq 4$ hours
10	63	Female	Graduate degree	Yes	$t > 4$ hours
11	62	Female	Postgraduate	Yes	$t > 4$ hours

We considered all responses valid answers by the end of the interview period. We transcribed the audio recordings using the oTranscribe [1] tool. Next, all transcripts of records were entered in ATLAS.ti tool version 22.0.10.0 [2] for analysis. We analyzed the transcriptions according to Braun and Clarke's [21] procedure for conducting the thematic analysis.

3.2 Thematic analysis of the interviews

The qualitative data were analyzed using an inductive thematic analysis approach to identify patterns in the interview transcripts [21]. Three researchers conducted the six phases of thematic analysis to increase reliability and reduce misinterpretations and biases. The analysis began with the researchers individually reading and rereading the transcripts to familiarize themselves with the data, seeking preliminary ideas and interesting features. This phase consumed a significant amount of time considering the number of participants in the study and the profile of users, who, because they are seniors, like to report their experiences in detail.

Sequentially, the initial code production phase was conducted, focusing on the research question. Each researcher independently coded the responses using separate documents in ATLAS.ti, as illustrated in Figure 2. Then they created a list of codes and grouped them into potential themes, gathering all the data relevant to each potential theme. Based on discussions among the researchers, the analysis continued to iterative refine and revise the themes until reaching a final consensus on the thematic map prepared.

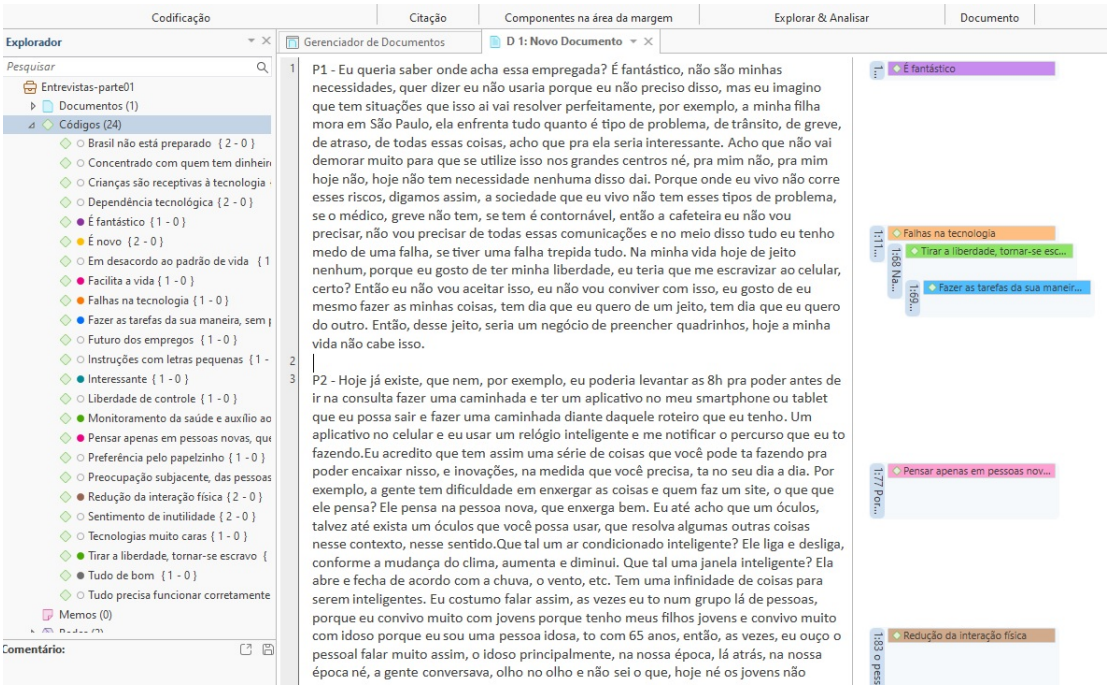

Figure 2: Example of document (in Portuguese) with codes from ATLAS.ti

[1] http://https://otranscribe.com
[2] https://atlasti.com

The analysis resulted in two high-level themes reflecting the expectations of the potential use of IoT technologies: (1) **positive assertions** and (2) **negative assertions**. Participants expressed several sentences which indicated expectations for or against the potential future use of IoT technologies. After several rounds of analyses and coding of the original participants' statements, these two expectations were generalized in the two themes. The iterative process was performed in a bottom-up manner since we examined each participant's speech. In this way, we could see that after careful analysis, we obtained from the 11 respondents an indication of the distribution of their answers in the two identified themes, as shown in Figure 3.

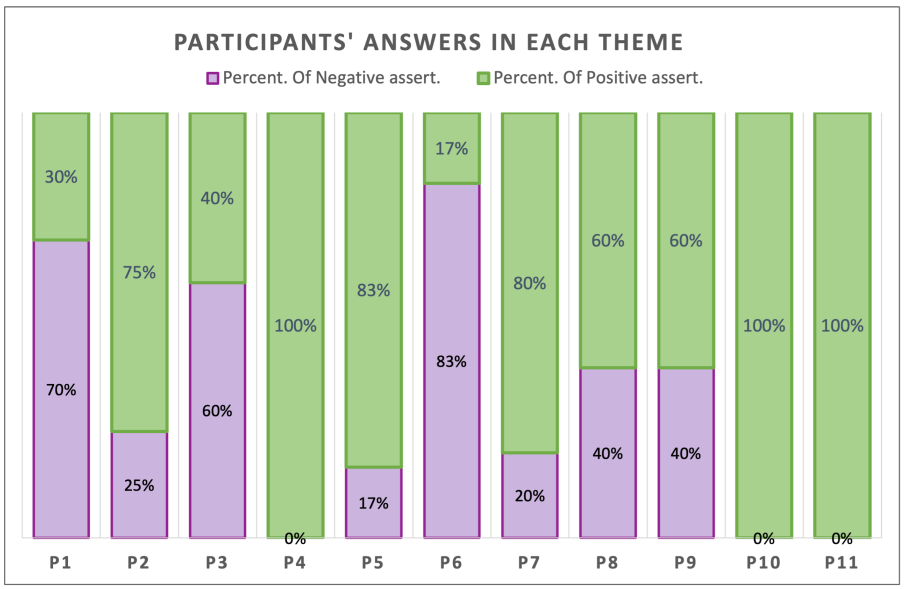

Figure 3: An overview of the participants' answers in each themes

We defined a set of sub-themes for each theme, as shown in Figure 4, which will be detailed below. Due to our small sample size, we do not quantitatively report findings yet indicate whether patterns were identified by one or multiple participants. Future work could apply our themes with a larger sample size for a quantitative indication of their relevance.

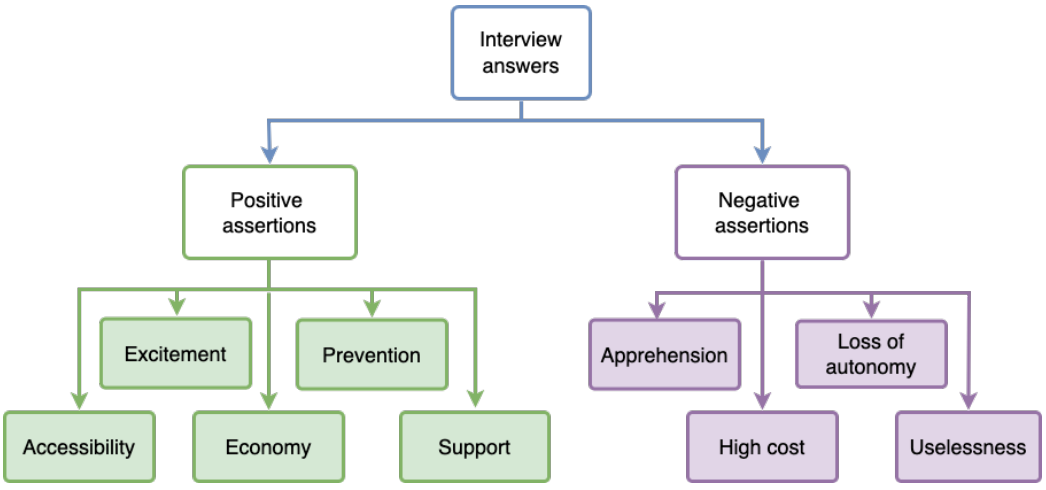

Figure 4: Thematic analysis: themes and sub-themes

An overview of the frequencies of the sub-themes in the two themes that were identified during our analysis can be seen in Figure 5. It is worth noticing that these accounts just summed the number of times certain sub-theme appeared in the Inverviewed' answers. In section 4, we present a discussion about these numbers to envision the concerns and suggestions regarding the future of IoT technologies aiming to attend to senior people.

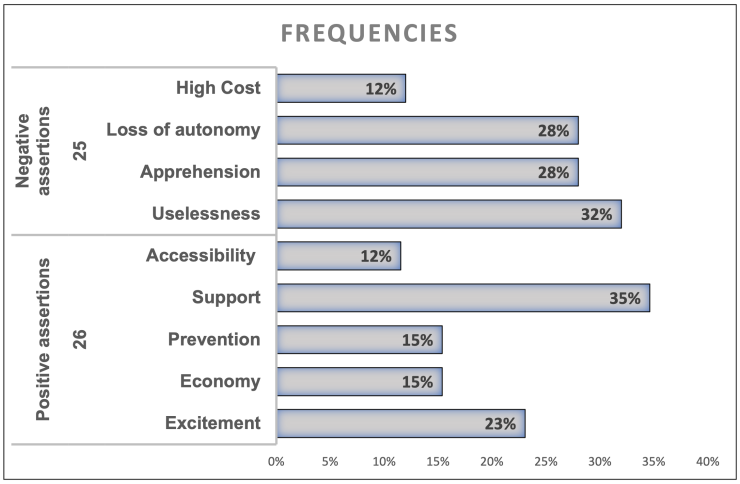

Figure 5: Frequency of the sub-themes observed during the Thematic analysis

3.2.1 Positive assertions

All seniors (11/11) mentioned any positive assertions. The frequency of these assertions was, on average, 67.7% across seniors, SD=0.278. Some participants, such as P4, P10, and P11, reported positive aspects exclusively. As described in the following, the positive assertions were discussed and organized in five contexts/themes (summarized from their original answers), such as (1) accessibility, (2) economy, (3) excitement, (4) prevention, and (5) support.

(i) Accessibility

Seniors (3/11) emphasized considering accessibility in IoT application designs. They mentioned that developers have usually developed the applications focusing on younger people that own greater ease and receptivity to technology, such as children. In addition, the seniors highlighted the carelessness with the font size of the user manuals. They are still small and represent barriers to accessibility to use/read. The seniors face limitations due to the aging process, making interaction with technologies difficult. Three participants discussed the need for a design that considers the elderly and their limitations in the interviews. Some comments/answers on this subject:

> *"We have trouble seeing things, and who makes a website, what does he think? He thinks of the young, who sees well." (P2)*
>
> *"I think these technologies would be very good for the elderly. But the instructions must be written or spoken, because nowadays you want to learn but the letters are tiny." (P11)*

(ii) Economy

Most seniors (7/11) identified opportunities to use IoT technologies to provide economy and avoid wasting time and money, such as greater agility in obtaining information using technology than searching through traditional means, such as books and newspapers:

> *"I can even read a book, but some things make you more up-to-date than reading alone: the smartphone, the tablet, the social network, and such, so I think we have reached a stage where we can't go back any further." (P2)*

Participants mentioned the application of IoT technologies in home appliances to configure themselves according to the perception of the context of use. We see some evidence of this in our participants' responses, for example:

> *"An intelligent shower that adapts to the water pressure, the temperature you like [...] something that tells you to take things out because it's going to rain [...] if there was something smart that did its job, but the house itself, not an app, that said: it's going to rain." (P4)*

In addition, the participants associated the application of these technologies to aid in the organization of supermarket purchases that demand significant time. A few comments about this:

"Let's imagine that you have food in the fridge and it's running out; then she warns you: oh, there's so much of it, and then you already know how long it will last, then you could make the fridge already make the purchase at the supermarket and come." (P5)

"If my fridge told me what was missing inside, supermarket issues, I get lost a lot, I buy things I don't need, so I stop buying what I need. This situation is boring. I have to go back; time is short, and I get stressed. So something in that sense, supervising, shopping, especially supermarkets [...] for me it would be fundamental, I'm very disorganized in this matter" (P8)

Even more so, seniors reported that there would be more time to devote to other daily activities if they adopted IoT technologies in their routines, as evidenced by the following comments:

" In an ideal scenario, it would be interesting because then, if the person lives in a situation like this, he would have more time to dedicate himself to other things, and things would be arranged automatically." (P6)

"The good part is not having to do almost anything; the good part is taking care of other things, washing clothes, and ironing clothes, huh?!" (P9)

(iii) Excitement

More than half of the respondents (7/11) expressed enthusiasm and receptivity when imagining the use of IoT technologies in their daily lives. They used words such as "fantastic", "interesting", and "very good", for example:

"It's fantastic [...] I imagine there are situations that this will solve perfectly." (P1)

"It's a fascinating thing, right!?" (P9)

"Everything you said is all good in our lives." (P10)

Seniors perceived that technologies could improve or make their lives easier, especially for those who live alone at home, monitoring their health and sending information for the follow-up to their doctors and family members, as the comments show:

" I think a smart bracelet is fantastic because you are sleeping and suddenly you feel sick; This situation of yours has someone or a doctor, or your family who is far away will be following up; this is a fantastic thing for me today, [...] I live alone, in a big house and this is for me [...] it would be ideal for me today." (P2)

"Things to make life easier, it's all good." (P5)

Some participants also associated IoT technologies with something new, and that provokes interest in using them, for example:

"Everything that is new, I am in favor of a lot of things, everything that can help us." (P4)

"In general, everything that is new like this, I think it is very valid [...] I think that these technologies would be very good for the seniors." (P11)

(iv) Prevention

Participants (6/11) were able to cite reasons for the potential use of IoT technologies to provide prevention. Seniors identified the application of these technologies to alert them about the right time to carry out inspections on their cars and thus prevent incidents. We see some evidence of this in our participants' responses, for example:

"A smart car would be attractive, one that warns about a part that is about to cause problems." (P3)

"An intelligent car that warns when the part is wearing out is time to change the oil. You will save a lot of things; sometimes it's some adjustment, it's prevention." (P4)

"The car could be smart and help me [...] it could pass you behind a panel or radio and remember the time for the service" (P11).

Seniors also reported other opportunities for use that refer to precaution, such as helping to check the state of things at home and the validity of products:

> *"A system to check the light bulbs in the house and when they are almost gone and let you know because at some point you need it, and then it ends." (P5)*
>
> *"The validity of food sometimes goes unnoticed, and when you see it, it's gone. An intelligent system that helps us to guide us to buy the amount we use would be excellent, right, so there is no waste because sometimes we buy a lot of things thinking we are going to use them and end up not using them, especially people who are alone." (P7)*
>
> *"A closet that would see the products expiring in the pantry would be a dream. I have the habit of checking the expiration date once a month, but if you had something to look at this. Like I said about my niece, an intelligent home is fantastic and saves a lot; you can spend to put it on, but it's quite an economy, and it's all good; you don't run the risk of leaving it on, leaving it open." (P10)*

(v) Support

Just over half of the respondents (8/11) indicated other possibilities of using IoT solutions according to their needs and interests. In addition, to solutions provide savings and prevention, the seniors also identified other possibilities for using these technologies to support their routine. Some respondents reported it as a support for entertainment in their daily lives, for example:

> *"I'm at home alone, I spend the whole day fighting with the Internet, looking for things that if I didn't have a smartphone or tablet to research, I would have gone crazy [...] because I worked my whole life, I stopped working, and I need a company." (P2)*

Participants mentioned other possibilities of use, such as support in managing medication and appointments, forgetting their belongings, and helping with checking their home when leaving, such as closing doors and windows, as the comments show:

> *"Something that reminds me to take and manage my medicines is difficult, I even have medicines at home that are stopped, that I bought, vitamins that I have to take and I forget, and then you will see, did I take them? Didn't I?" (P2)*
>
> *"I could have everything scheduled and have an intelligent agenda; an agenda would be interesting that would help me organize my appointments." (P3)*
>
> *"Something that reminds you would be interesting: are you carrying your wallet?" (P4)*
>
> *"If I had something smart that would wake me up five days earlier to remind me of something that would communicate with the bus company and check if there was a ticket available." (P5)*
>
> *"When I had walked about 10km by bus from home, then I remembered, Oh my God, did I turn off the stove?! [...] Then I got off the bus and took it back, I hadn't left the stove on, but I came back, and I was tidy [...] because sometimes every silly accident happens, sometimes it's not even because the person wants, but there are so many tasks, carelessness and it happens more with the housewife." (P9)*
>
> *"I have this habit of leaving the house, and I go back to check if everything is ok, if I turned off the stove." (P10)*
>
> *"I have trouble remembering to take things, something that tells me what I don't need to carry in my bag." (P11)*

3.2.2 Negative assertions

Even though the number of positive assertions was more significant than the negative ones, most seniors (8/11) also associated their expectations about using IoT technologies with any negative aspects. The frequency of these negative assertions was, on average, 32.3% across seniors, SD=0.278. Just three participants did not report negative aspects, only positive ones. In short, the comments pointed out four main issues regarding a low acceptance of these technologies such as (1) fear of failure, (2) high cost, (3) loss of autonomy, and (4) uselessness. In the following, we present a description for each of the four negative assertions/ themes and transcribe some exciting comments to assist in the comprehension.

(i) Apprehension

Participants (6/11) reported feeling insecurity, discomfort, and fear of these technologies failing. They point out that if a failure happens in the middle of a process, it will be compromised and were able to cite reasons for not trusting IoT technologies across the board. One participant also reported that Brazil has some problems and is not yet prepared for these technologies; for example,

> *"I'm afraid of failure, and if I have a fault, it compromises everything." (P1)*
>
> *"because for things to work, everything needs to work. [...] I think Brazil is not ready for this yet, because things still do not work at this rate. [...] in Brazil, we are not yet organized to live in a world with this technology, it is wonderful in theory, but it does not work in practice. [...] It is necessary that the whole process works, that the logistics work." (P6)*
>
> *"But I think that we are still in the process of transition, things do not always happen as they should." (P11)*

Other concerns that also afflict the elderly were the reduction of physical interaction, the digital exclusion, and the fear of the future with IoT, of these technologies causing unemployment, as can be verified by comments:

> *"Guys, what are we going to do, nothing? It's the future, right ?! Guys, I'll ask you, how are you going to get the jobs? I'm afraid of this future." (P8)*
>
> *"If you've never had these technologies, you can, but you're out of touch with a lot of things [...] the elderly talk like this, in our time, back then, we used to talk, eye to eye, today young people don't do that, but why? Because of the tablet, because of the smartphone, and this social network, the technologies." (P2)*
>
> *"Technology is changing. Everything is changing. Today you go to the doctor's office, and the nurse asks you to tell her everything, and you can't even talk to the doctor anymore; some people want to talk and tell the doctor in their way." (P3)*

(ii) High cost

The interviews (3/11) highlighted a concern with the costs of implementing and acquiring IoT technologies. Participants recognize and are interested in the ease and convenience that IoT applications can provide in their lives. However, they report the high costs of these technologies and still make them unfeasible in their life context. Following, we transcribe some interesting comments, which show their consciousness regarding the high cost:

> *"[...] that's interesting, but it's a high cost, right? For my standard of living, it does not." (P3)*
>
> *"It would be great a system to check when the house lamps are almost finished, and let me know because when you need it, it ends. But these technologies are still costly." (P5)*
>
> *"for example, [...], it may even be that there are some devices in our country, but they are with those who have lots of money." (P9)*

(iii) Loss of autonomy

Another negative aspect frequently addressed by the participants was the loss of autonomy. Seniors (7/11) mentioned that IoT solutions could reduce their freedom. They emphasized that they like to be in control of their lives and believe that this technology could cause dominance. According to one participant, people who have their lives dominated by technology are not happy. It all bothered a portion of our participants:

> *"In my life today, no way, because I like to have my freedom, I would have to enslave myself on the cell phone. So I will not accept this, I will not live with it, I like to do my things myself." (P1)*
>
> *"These are stages of life; the first thing I don't have an alarm clock, I don't use a watch, I'm not controlled by business hours; my biological clock controls me; when he says I have to wake up, I'll wake up, whenever I'm sleepy I'm going to sleep [...] and the people who work at this hectic pace are not happy, do not live, and are driven by technology [...]. Where is the self-mastery? From that, I gave my domain to technology; no, I want it to stay with me; I decide how and when to do it." (P6)*
>
> *"People, and what are we going to do? Nothing? It's the future, right?!" (P8)*

Two participants questioned whether they would be useless in a world with connected things. They reported that there is a need for a limit to life with the technologies to not cause certain idleness and a sense of worthlessness in people's lives, as can be seen in the comments:

> *"I think everything has to have a limit; otherwise, you are without utility; you must have a parameter [...] anyway, our head will be useless, right, because for us, the fewer tasks, the less our brain will want to work." (P7)*
>
> *"Wow, I do not need to do anything else? It's risky for my body to stop like this." (P9)*

(iv) Uselessness

The final expectation presented by some seniors (3/11) refers to the absence of adequate functionalities so that they can do what they need or want. Participants expressed not identifying the usefulness of IoT technologies. They believe that the potential of these technologies is not interesting for them, mainly because they are elderly and have a slower pace of life. A few comments about this issue:

> *"Are not my need, I mean I wouldn't use it because I don't need it, but I imagine that there are situations that this will solve perfectly, for example, my daughter lives in São Paulo, she faces all kinds of problems, traffic, strikes, delays, all these things, I think it would be interesting for her." (P1)*
>
> *"Not for me, not for me today, today there is no need for that then [...] I won't need all these communications [...] today my life doesn't fit that." (P1)*
>
> *"My life is simple, there's not much that changes [...] in my day today, there's none of that, but I have to think that one day." (P3)*
>
> *"Intelligent equipment is terrific, but I think our population still doesn't need it." (P6)*

3.3 Development of an IoT application

We developed an IoT application in this research, aiming to observe potential senior's perceptions and receptivity to the new forms of interaction with this technology. For the development of this app, we adopted the Human-Centred Design (HCD) approach, which aims to "carry out the design and development of systems to make them more usable, focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques" [22]. Thus, the procedures adopted were: we elaborated interviews (subsection 3.1), a scenario of use, architecture proposal, prototype, and evaluation. A more detailed description of these procedures is available in literature [10]. It is worth noting that all these procedures, briefly described below, focused on the senior's needs.

3.3.1 Getting the Requirements

Interviews with senior people to identify their needs and requirements were carried out (see subsection 3.1). From the results, we have designed a scenario of use to assist in developing the prototype. Based on their remarks, we monitored that older adults are interested in things to help them not forget anything.

In fact, the aging process affects the ability to remember facts and tasks [23]. Older adults face more difficulty concentrating and keeping attention on activities for extended periods [24].

From the results of the interviews, we started to develop an IoT application prototype to help older users with their forgetting complaints. We defined a use scenario in which an old widow (Maria) lives alone in a condominium far from downtown, and she spends a lot of time alone at home. Maria takes advantage of the various activities offered by her condominiums. Still, she has recently begun to face the decline of some cognitive skills, such as altered memory, attention, and concentration, due to the aging process. The forgetfulness causes problems for Maria and leaves her in unpleasant situations. This kind of situation causes emotional problems in older adults, reinforcing the sense of worthlessness.

Based on this scenario, we figure out the possibility of applying IoT technologies to help these users to remind themselves of these objects. Therefore, an IoT application can alert the seniors when they forget any item at home, such as keys and wallets, among others. This IoT app can track objects that have been registered through a beacon. Thus, the system can identify objects that are out of reach.

3.3.2 Designing and prototyping

The results of the interviews and usage scenarios served as the basis for designing two architectural ideas. Three researchers in the HCI area held meetings to discuss which the most suitable architecture would be implemented, and they refined a final architecture based on the discussions. The proposed IoT architecture (shown in Figure 6) has three layers: presentation, communication and services.

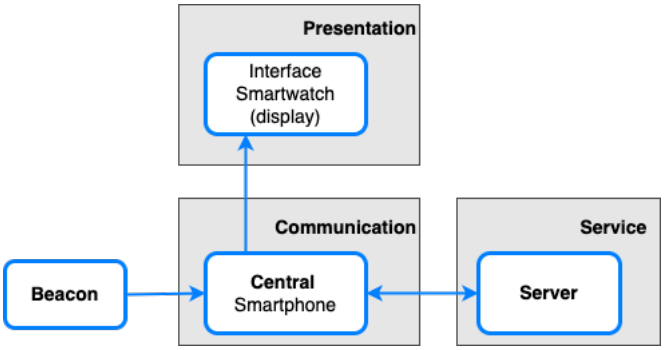

Figure 6: Architecture proposed

Figure 6 presents the components of the architecture. The components, in the three layers and respective functionalities are summarized as follows:

1. **Presentation** Smartwatch: it presents all the resources available to the user, such as interface, notifications, Beacon information, and beacon manager. Beacon information is related to all the device information available in the application. It also relates to the Beacon manager, responsible for managing everything connected to the application.

2. **Communication** Smartphone: it retrieves the signal from the beacon and identifies it. If it is a known beacon, obtain information from it with the Beacon Physical Entity (BPE). Once the BPE has the answer, it sends a request to the Service Component. All the beacons used must be previously registered. The central component is responsible for the communication between the other parts, enabling interaction between the things: personal objects with beacons and smartwatches. Thus, the essential software and the central modules of the application are installed on the smartphone.

3. **Service**: it acts as a back-end. Consequently, all Database and Web Service features are located on it. Once the beacon information is available, it will be stored in the database. The beacon manager can access the Web Service to add or delete any information.

All three components are divided by the devices used in the application. At least one beacon, smartphone, and smartwatch in this architecture are required. The smartwatch is fully connected to the smartphone. Thus, there is a central component where all data is collected and used. If something is lost, the smartwatch must send a notification.

Prototype

The conceived architecture has oriented the development of the prototype using the Justinmind tool. In this prototype, the smartphone and smartwatch work in a particular way. Two devices were included for interactions simulation, a smartphone, and a smartwatch, each with its interface and functionalities, as described as follows.

- Smartphone: It works as a central component. The user can see and edit all the monitored things. On the "main" screen, all the available features are shown. A "List screen" shows all the monitored things, and in the "Add screen", the user can add a thing.

- Smartwatch: It works as an extension of the smartphone. The user can activate notifications.

3.3.3 Evaluation and refinement

For evaluating the prototype, we considered two criteria of software quality [22]: accessibility and usability. The prototype aims to help older people avoid forgetting their personal belongings. So, it was necessary to

check its ease of use and how accessible it was for these target users. We provide the necessary files for the prototype simulation in the Justinmind tool for evaluations.

Four experts conducted the **Heuristic Evaluation** (HE) [25] to identify usability problems in the prototype that involved the interfaces of two devices, the smartphone and the smartwatch. One senior undergraduate student, one master's student, one Ph.D. candidate, and one post-doctoral researcher have more than three years of usability knowledge. The undergrad student had previous training guided by the Ph.D. candidate about usability evaluations. The experts used ten of Nielsen's Heuristics described in Table 2 to guide user interface inspections. Table 2 also presents the final number of usability violations found by the experts.

During inspections, each participant was asked to individually perform a predefined set of tasks that we provided them. The tasks were defined in a sequence as shown in Figure 7.

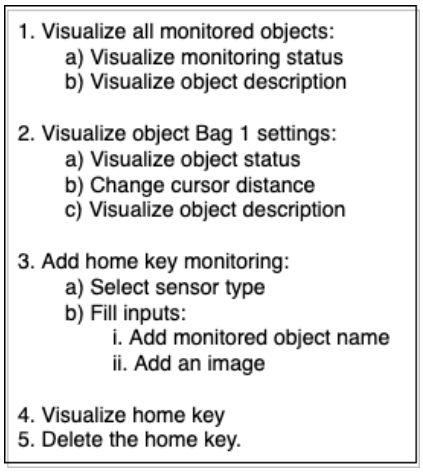

Figure 7: The tasks defined for inspecting usability of the prototype

Each expert pointed out each problem found and its location on the interface, assigned a severity level, and described the violated heuristics and possible solutions. The evaluation lasted about 40 minutes each. They recorded all the information in spreadsheets. All experts met remotely, reviewed the individual evaluations' problems, and created a consolidated report about this consensus. The period of evaluations lasted a week. After that, the data were grouped according to the evaluated interface. We have grouped into problems related to Smartphone screens and those related to Smartwatch screens. Then, the analysis consisted of verifying the relationship between the number of problems found and their levels of severity. Next, it was possible to analyze which problems were more recurrent, their levels of severity, and the heuristics violated.

They reported 29 usability problems in the prototype, and most of the problems were related to Task 3 ("add home key monitoring"). The experts complained about the organization of the information, using the term sensor, problems in the exclusion message, and some simulation failures. Another common complaint was the lack of a "back button", although the Android button is functional. Table 2 shows the number of violations in each heuristic. The three most violated heuristics were H1, H2, and H5.

Table 2: The number of violations of ten Nielsen's heuristics found in the prototype

Nielsen's heuristics	**Number of violations**
H1 -Visibility of system status	5
H2 - Match between system and the real world	8
H3 - User control and freedom	2
H4 - Consistency and standards	4
H5 - Error prevention	9
H6 - Recognition rather than recall	3
H7 - Flexibility and efficiency of use	1
H8 - Aesthetic and minimalist design	1
H9 - Help users recognize, diagnose, and recover from errors	0
H10 - Help and documentation	0

For an **Accessibility Evaluation** of the prototype, a conformance review was conducted. The objective was to find the accessibility problems in the prototype. Three experts, two master's students, and one Ph.D. candidate, all with more than three years of accessibility knowledge, performed the conformance review with

WCAG 2.1 success criteria [26]. We have selected some WCAG success criteria for this review, only those that apply to mobile apps and older users. We elaborated a checklist with the success criteria chosen to guide the specialists in evaluating the prototype.

In the end, six of the eight considered success criteria were violated (75%), as shown in Table 3. In addition, we observed that the prototype does not satisfy the Level A Success Criteria (the minimum level of conformance) due to violations of Success Criteria 1.1.1, 1.4.1, and 2.4.2. Therefore, the evaluation showed that the prototype does not conform to WCAG 2.1.

Table 3: WCAG 2.1 success criteria violated in prototype, according to conformance review.

WCAG 2.1 success criteria applied in the evaluation	**Violation**
Success Criterion 1.1.1 – Non-text Content	**x**
Success Criterion 1.4.1 – Use of Color	**x**
Success Criterion 1.4.3 – Contrast (Minimum)	**x**
Success Criterion 1.4.5 – Images of Text	**x**
Success Criterion 1.4.8 – Visual Presentation	–
Success Criterion 2.4.2 – Page Titled	**x**
Success Criterion 3.1.3 – Unusual Words	**x**
Success Criterion 3.1.4 – Abbreviations	–

The main problems identified were inappropriate contrast between text and background colors, inadequate font size, absence of alternative text for non-textual content, and language challenging to understand. The application prototype does not use other visual means besides colors to show the information, and finally, the prototype does not have titles that describe the topic or purpose. These issues should be seriously addressed to evolve the development of a proposed application. Based on the HE and accessibility evaluation results, we made a refinement and improvements to the prototype. We have developed the application following the proposed architecture (Figure 6), and what do we name "Perdi?" (In Portuguese). We developed an open-source application whose source code is hosted in the GitHub repository[3] A technical report documenting the "Perdi?" application is also available[4]. Although evaluations with specialists are necessary to identify problems, conducting tests with seniors users using this application should be essential.

4 Discussion

In this work we aimed to find and discuss the main expectations of the seniors about the potential adoption and use of IoT technologies. To discover these expectations, we interviewed random senior Brazilian people. All the interview' participants have experience with computers and smartphones and use the Internet every day. In addition, there was a gender balance, and most of the participants were undergraduates. The seniors involved in the studies had cultural differences, especially concerning education level, professional experiences, and others. We have limited our inferences to our participants noting that theirs are not necessarily a wholly representative sample. When seniors discussed expectations of the potential use of IoT technologies, they mentioned several issues.

Our research question guided a Thematic Analysis to clarify their main expectations. As a result of this process, we observed a set of positive assertions expressed by all participants, which were closely related to different ways of taking advantage of this technology to help with their daily activities. All the seniors perceived the Internet of Things as a powerful tool. They mentioned that IoT can save time and money, prevent incidents, check the status and validity of things, organize activities and appointments, besides support seniors living alone. They also showed enthusiasm and positive interest in these technologies, which reaffirms the results of Stara et al. [13] and Tsuchiya et al. [14]. We observed that three participants were more optimistic than the others and said only positive aspects envisioning their next future with available IoT systems (see Figure 3).

On the other hand, we observed several negative assertions. From 51 assertions 11 senior participants answered, we found 25 manifestations disapproving of IoT technologies (see Figure 5). We categorized the negative assertions into four sub-themes: the feeling of uselessness, apprehension, loss of autonomy, and high cost. Participants pointed out a low acceptance of IoT technologies, and eight of eleven participants pointed out negative aspects. They mentioned that they would not want to be controlled because they are senior or retired, a perspective also discussed by [14]. Among their comments, we could observe the following sub-themes regarding unfavorable situations that lead them not to want technologies that reduce their autonomy. Also, they mentioned that IoT solutions could reduce their freedom, causing dominance

[3] "Perdi?" - `https://github.com/abe2602/Beacon_Application`.

[4] `https://repositorio.usp.br/item/002981232`

and a feeling of uselessness. The high cost of these technologies was another expectation seen as a barrier to their subsequent acquisition and use.

Participants reported insecurity, discomfort, and fear of IoT technologies failing in the middle of a process. In addition, the Brazilian seniors believe that Brazil is not yet suitable for the Internet of Things. It is a country that faces many problems in different sectors. Another concern related to this expectation is the fear of the future with IoT. Seniors are afraid that IoT devices cause unemployment and idleness in people's lives because they know the things would do more and people would think less. In contrast to previous work ([13]), Brazilian seniors expressed fear of the Internet of Things. Therefore, it may be the case that this variation occurs in the Brazilian context due to cultural differences, education level, and lack of experience. It is, therefore, necessary for more studies to confirm this.

Accessibility was another essential expectation mentioned by participants. They recognize that designers and developers do not consider the age-related limitations in their projects. Senior users face a decline in their sensory, physical, and cognitive abilities that demand a design that is accessible and usable [27, 7, 28].

All the themes were identified from the 11 interviewed seniors. All seniors mentioned positive and negative assertions (Figure 3 and Figure 5). A total of nine assertions were identified (Figure 4). All participants expressed positive statements, and seven of them reported positive aspects exclusively. The positive assertions were discussed and organized in five sub-themes:

1. Accessibility (12%),
2. Economy (15%),
3. Excitement (23%),
4. Prevention (15%), and
5. Support (35%).

Most seniors (eight of them) also associated their expectations of the potential use of IoT technologies with negative aspects. Their comments pointed out a low acceptance of these technologies. The negative assertions were discussed and organized in four sub-themes:

1. Fear of failure / Apprehension (28%),
2. High cost (12%),
3. Loss of autonomy (28%), and
4. Uselessness (32%).

Although our sample of answers is not representative, it is possible to figure out some issues that could be prioritized according to the frequencies of incidences in each sub-theme. We can see that among all assertions, the frequency of positive ones is more significant than negative assertions. The most cited among the positive assertions is "Support", and we can suppose that senior people take it as an essential issue in their lives. On the other hand, the most cited among the negative assertions is "Uselessness", and we can suppose that senior people take it as a very relevant concern in their lives.

Even with the evolution to improve the resources (devices and the Internet) and uses of technology in favor of people's needs, senior people still have less comfort and efficacy toward technologies [29], and based on our studies, these effects have kept stable. It is crucial to investigate the senior' concerns around IoT technologies [30], given the projections of the aging of the world population [31, 5] and the exponential increase in the number of devices connected to IoT in the coming years [3]. Given the rapid aging of the population, the most significant proportion of future users of smart applications will be seniors. These users usually face difficulties in using and perceiving the technologies evolving due to the limitations caused by the aging process. The interaction with various devices simultaneously, the complex interfaces, and the sensors can introduce a considerable mental workload and generate a complicated, illogical, and nonsense, then frustrating experience for these users.

Based on these findings, we encourage interaction designers and HCI researchers to explore the potential of addressing senior expectations in the design of the IoT technologies by promoting improving the quality of the requirements engineering phase of the software development and enabling these users to perceive the benefits and satisfaction of adopting new technologies. These insights point out the need to investigate strategies to promote confidence in IoT devices among seniors.

5 Conclusion and Future Work

With the advancement of IoT technologies, intelligent applications are being developed worldwide, transforming people's daily lives and the way they interact with technologies. This technology can provide support and assistance to seniors. However, if IoT solutions are not designed to consider these users' expectations, concerns, and perceptions, they may not be adopted by this rapidly growing population.

This paper presented an investigation of the main expectations arising from the seniors' potential use of IoT technologies to find implications for the design and quality of use of these technologies. The study involved interviews with 11 Brazilian seniors (60+), and some results reinforced previous studies identifying interest in IoT technologies use, concerns about the loss of autonomy, accessibility, apprehension, and high costs of these applications.

We performed the qualitative analysis of the data based on the thematic analysis approach, which allowed the organization and description of our dataset in detail. This method contributed to the generation of an interpretative analysis of the data based on the patterns identified in them. Thematic analysis is widely used and is an approach created by researchers in the field of Psychology [21]. The data analysis showed that most of these people has a significant interest in things to help them not forget anything, paying particular attention to tasks based on day-to-day experiences. We could also analyze the narrations from the interviewed speeches, and their comments suggested positive and negative expectations considering the use of IoT technologies by seniors. As a result of our work, we identified nine sub-themes categorized in two themes (presented in Figure 4).

IoT technology industries can consider the themes and sub-themes identified in this study to support decision-making about which is the most appropriate project to serve users, especially the seniors. Despite the limitations of this study, we believe that our findings can contribute to research on seniors and the IoT.

Our sample size is small. However, we highlight how this study is a starting point to understanding expectations arising from the seniors' potential use of IoT technologies. We recruited random seniors who attended the educational program and already had experience with the Internet, smartphones, and computers. Therefore, interviews may have captured seniors with more experience and interest in technology than the general population. Additionally, we only interviewed participants from a specific region of Brazil in an urban center. Our participants' experiences may differ from those living in other country regions and rural areas. We recommend that future studies include focus groups with a more representative sample of seniors from other regions who are inexperienced with the Internet. In another future work, we will conduct user tests with seniors to investigate the usability and acceptance of the application "Perdi?".

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