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Beyond digital privacy: Uncovering deeper attitudes toward privacy in cameras among older adults

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ABSTRACT

Fall detection cameras at home can detect emergencies of older adults and send timely life-saving alerts. However, the equilibrium between privacy protection and life safety remains a controversial issue when using cameras. In this study, we assessed the attitudes of older adults towards the privacy issue of cameras using surveys (N=389) and interviews (N=20). Furthermore, we conducted a co-design workshop (N=6) in which older adults and designers collaborated to develop a prototype of cameras. We found that for older adults, the disclosure of privacy not only involves a leakage of personal information, but also influences their dignity and control, which has rarely been expressed directly in the past. Our results expand the conceptualisation of privacy and provide novel design implications for smart product development on privacy for older adults.

1. Introduction

Ambient Assisted Living at home is a crucial solution to the increasing trend of ageing of the global population, assisted living technology ensures the safety and health of older adults by installing sensors in their physical or home environments (Cicirelli et al., 2021; Song and van der Cammen, 2019). Although these sensors provide real-time monitoring to ensure the well-being of older adults, they inevitably raise privacy concerns (VandeWeerd et al., 2020). Among environmental sensors, home fall detection cameras pose significant privacy issues because captured footage contains substantial private information (Badillo-Urquiola et al., 2018; Li et al., 2020a). In recent years, advances in artificial intelligence have integrated facial recognition and fall detection into home cameras, offering more support for independent living (Adjabi et al., 2020; De Miguel et al., 2017). However, despite the growing acceptance of home camera installations, the issue of privacy invasion by these cameras remains unresolved.

The alignment of privacy protection in human-related technologies is a significant legal and ethical issue (Holvast, 2007). As assistive technologies for the elderly, such as fall detection cameras, become more widespread, designing privacy protection for the elderly is increasingly emerging as a significant research issue. In the information society, researchers have linked privacy with human–computer interaction to require a more extensive examination of social, technological, and design factors to expand the limits of the definition of privacy and solve the issues it poses (McDonald et al., 2020). The scope of privacy discussed in this paper is defined in the context of smart homes, for home cameras with fall detection functions that compromise the privacy of older adults.

Current research on privacy for older adults primarily focuses on categorising individuals based on their varying privacy attitudes, using typology derived from general population privacy attitudes (Westin, 1968). For example, Elueze extended Westin's typology and classified older adults into five types: fundamentalist, intense pragmatist, relaxed pragmatist, marginally concerned, and cynical expert (Elueze and Quan-Haase, 2018). Additionally, most privacy design guidelines for the elderly emphasise how to better protect the privacy that needs safeguarding (McNeill et al., 2017; Duckert and Barkhuus, 2022; Yao et al., 2019). For instance, Yao et al. identified six key factors — data transparency and control, security, safety, usability and user experience, system intelligence, and system modality — that are essential for understanding privacy attitudes (Yao et al., 2019).

However, given the ambiguity and dynamic nature of privacy (Brandeis, 1890; Solove, 2002), it remains unclear what specific privacy concerns the older adults perceive as needing protection. Additionally,

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how can we effectively safeguard the privacy content that older adults particularly value? These questions are still unresolved.

To address these research gaps, our study employed a mixed-methods approach, incorporating questionnaires, interviews, and co-design workshops. This approach was used to explore in depth the specific privacy issues that are of particular concern to older adults in scenarios involving fall detection cameras, as well as to identify design strategies to protect these privacy concerns.

Our contribution lies in revealing that physical changes due to ageing and the use of digital technology are specific privacy concerns for older adults. In addition, we highlight the importance that older adults place on having control over such technologies and maintaining a sense of dignity in their use. We propose two privacy design recommendations: avoiding the stigmatisation of ageing and ensuring that older adults themselves have control over their privacy protection.

2. Background

Surveillance cameras are widely deployed in public places in China, such as roads and retail malls, to maintain order and reduce crime. The presence of these cameras is generally accepted by the public, and people are not particularly sensitive to them (Huang and Wu, 2019), as they are seen to be a useful tool to prevent unlawful behaviour. In recent years, home cameras have become increasingly prevalent in China and around the world. According to IDC's China Quarterly Smart Home Device Tracker, the home security/monitoring market shipped 8.17 million units in Q4, 2020, up 24.9% year on year, with sales approaching $ 600 million, up 43.4% year on year.[1]

This trend is not limited to China, as a survey conducted by Strategy Analytics has shown that the penetration rate of intelligent home surveillance cameras in the United States, the United Kingdom, Germany, and France is close to 33%, indicating that one in three households is equipped with intelligent surveillance devices. Among many smart home products, intelligent surveillance devices have become the second most popular.[2] The increasing adoption of cameras in homes can be attributed to the advantages that these features bring to people's daily lives (Cheng et al., 2019). Gradually, older adults living alone adopt cameras so that their family members, who do not reside with them, are aware of their safety in case of an emergency.

However, users typically have little understanding of what data these fall detection cameras collect, how the data are used, and where they go (Jakobi et al., 2018; Tabassum et al., 2019). They assume that their privacy is secure under the protection of camera manufacturers, but verifying this protection is often challenging (Zheng et al., 2018). As the ubiquity of home fall detection cameras increases, there is a growing demand to improve technological transparency to better ensure the safety and privacy of the use of these products (Norval and Singh, 2023).

The use of home cameras raises privacy concerns but offers older adults better living conditions with enhanced security. Investigating older adults' perspectives on privacy and balancing the benefits of cameras against potential concerns is crucial. Some older adults prioritise safety over privacy, especially those who live independently. Our study introduces a fall detection camera that uses image recognition algorithms to identify falls. When a fall is detected, the camera can notify guardians or call for emergency assistance according to a pre-defined procedure. The underlying algorithm and stakeholder collaboration are key to ensuring immediate assistance for older adults. Considering privacy concerns and perspectives when designing such cameras is essential to balancing privacy and security (Ray, 2022; Ray et al., 2019). In this article, we use the term "camera" to refer to the fall detection camera. our aim is to explore two questions:

(1) RQ1: What unique privacy concerns do older adults care about when they use cameras?

(2) RQ2: What potential privacy by design strategies can address these specific privacy issues?

3. Related work

Our work lies at the intersection of the following principal research areas: (i) Older adults' attitudes toward privacy; (ii) Current privacy by design frameworks for older adults; (iii) privacy-preserving mechanisms on fall detection cameras for older adults in the home.

3.1. Attitudes of older people to privacy

The definition and scope of privacy have been changing with the development of society and technology. Initially, privacy comes from the natural need of individuals to distinguish themselves from the outside world (Brandeis, 1890), and then gradually evolved and expanded to include the right to be alone, limited access to self, secrecy, control of personal information, personhood and intimacy (Solove, 2002). The proliferation of digital technologies has expanded the scope of privacy to include data privacy, Nitin Agrawal et al. discuss preserving privacy while also obtaining the benefits of computational analysis (Agrawal et al., 2021).

Meanwhile, individual perceptions and attitudes toward privacy have always been a focal point of research. Westin's typology of privacy attitudes categorises individuals into three main groups based on their approach to privacy (Westin, 2000). Privacy Fundamentalists means highly protective of their personal information and typically resist sharing it; Privacy Pragmatists weigh the benefits and risks of sharing personal information and make decisions based on specific situations, and the Privacy Unconcerned are generally indifferent to privacy issues.

This categorisation of populations helps to develop personalised privacy protection strategies and design frameworks. Older adults are not homogeneous and have different definitions of privacy due to physical conditions, such as technological familiarity. Elueze extended Westin's Typology and classified older adults into five types: fundamentalist, intense pragmatist, relaxed pragmatist, marginally concerned, and cynical expert (Elueze and Quan-Haase, 2018).

However, only categorising older adults does not fully understand their attitudes toward privacy (Kim and Kwan, 2021), some studies have indicated that healthy older adults are more concerned about data privacy, while unhealthy people are willing to sacrifice more privacy to ensure their safety (Bullek et al., 2017). The complex influences behind these attitudes are an important basis for developing privacy policies and design approaches, and this understanding of older adults' attitudes toward privacy and the factors that influence them has not been adequately researched. This lack of information makes it difficult to be very accurate with privacy strategies when designing for older adults.

3.2. Principles on privacy by design for older adults

In the HCI community, the principles and frameworks for privacy-by-design (PBD) have garnered significant attention from researchers. An important concept is to incorporate privacy protections into the initial design phase of products rather than incorporating them later (Wong and Mulligan, 2019). Ann Cavoukian introduced seven privacy-by-design principles from a design thinking perspective. These principles, such as Privacy as the default and visibility and transparency, serve as crucial reference standards for privacy design (Cavoukian

[1] China Quarterly Smart Home Device Tracker: Product segmentation (Q4, 2020), IDC, https://www.idc.com/getdoc.jsp?containerId=IDC_P38322.

[2] Smart Home Survey-Surveillance Cameras-April 2020, Strategy Analytics, https://www.strategyanalytics.com/access-services/devices/connected-home/smart-home/reports/report-detail/smart-home-survey-surveillance-cameras-april-2020?slid=247704I&spg=4.

et al., 2009). Although these principles are applicable to any population, there are still inaccuracies and missing details when it comes to specific groups, such as those of older adults.

Research focussing on privacy by design for older adults centres on scenarios such as social media use and ageing in place, particularly the protection of personal and health information (McNeill et al., 2017; Duckert and Barkhuus, 2022). Hirak Ray et al. explored the mental models of privacy of older adults, which include both digital and non-digital environments (Ray et al., 2019). Alan Newell's research also emphasised the importance of considering psychological factors in technology design (Edwards, 1995). This concept was later applied to the privacy design for older adults, expanding the definition of privacy beyond information disclosure. Now, it also includes the psychological impact of privacy breaches and changes in older adults' privacy perceptions. For example, Yao et al. demonstrated that these six key factors: data transparency and control, security, safety, usability and user experience, system intelligence, and system modality are essential for privacy attitudes (Yao et al., 2019).

It can be noticed that privacy is an important topic in HCI's research. However, discussions around privacy protection principles often focus on how to better protect already identified privacy content; this leads to some undefined privacy issues for older adults being easily overlooked in the privacy design process. As a direct result, the content and types of privacy that are of particular concern to older people are not yet the subject of targeted design protection strategies.

3.3. Privacy by design for fall detection cameras

As technology has advanced, home health monitoring has been increasingly applied to support older adults living independently at home (Wang et al., 2019). Camera-based fall detection technology, because of its low cost and high accuracy, has been widely used in the homes of older adults. However, privacy issues raised have been difficult to address satisfactorily (Knight et al., 2024). Currently, common privacy protection solutions include generating blurred images from cameras and developing algorithms for encrypted images (Merrouche and Baha, 2016; Ricciuti et al., 2018).

It is important to note that these privacy designs focus on image privacy, neglecting other concerns older adults may have other privacy concerns. Research by Tamara Mujirishvili et al. found that older adults prefer highly anonymous video monitoring modes, such as avatar filters (Mujirishvili et al., 2024). This indicates that older adults do not want others to know that they are using such technologies and services.

Older people have different abilities and technological knowledge, leading to different perceptions and attitudes towards privacy issues (Wang and Lin, 2024). The privacy of information such as images is one of their privacy concerns. However, ageing due to physical deterioration and the need to use assistive technology as a result of ageing are particular privacy concerns for older people that have not been adequately explored in current research.

In general, current research has not adequately addressed the privacy-specific concerns of older adults, leading to a lack of targeted design strategies for privacy-preserving frameworks. This gap is particularly evident in fall detection camera scenarios, where most strategies focus on image information. Therefore, in this study, the co-design approach was used to involve older adults in a fall detection scenario, allowing them to express their privacy concerns during the design process. The study explores the unique elements that older adults care about regarding privacy and possible design strategies to address these specific concerns.

4. Methods and data analysis

Using a mixed research methodology, we conducted a series of studies to gain insight into older people's perceptions of fall detection cameras. Surveys and interviews helped us to understand which privacy issues are most relevant, while co-design workshops helped us to explore what privacy design principles are important to designing cameras and were clear for an exploratory research study. Our study was approved by the IRB of the university prior to starting the experiment.

To address RQ 1, which focusses on privacy issues related to camera design, we employed a structured approach. Survey: A questionnaire survey was conducted to identify the range of privacy concerns older adults have with cameras; Interview: Subsequently, 20 older adults were recruited to explore the underlying reasons that shape their attitudes toward privacy. Using insights from the initial findings, a co-design workshop was organised to tackle RQ2. This workshop aims to provide information on possible solutions for privacy settings from the perspective of older adults, through which researchers inspire the principles of total privacy design.

4.1. Survey

To assess the attitudes of older adults towards fall detection cameras, focussing on their privacy concerns and design preferences, we conducted a survey. This survey was completed by 409 older adults residing in five different cities, selected for their geographical spread to ensure a broad representation of the participants. We reached out to social worker organisations to help recruit participants from different cities. These individuals must be at least 55 years old and meet at least one of the following criteria: have experience with falls; have experience with cameras; or demonstrate a willingness to use cameras. Following the exclusion of respondents below the age of 55 years, the data from 389 participants (134 male, 255 female) were considered for the final analysis. The age of these participants ranged from 55 to 94 years (mean = 67.84, SD = 9.53). This demographic spread allowed for a comprehensive understanding of older adults' perspectives across a wide age range.

To ensure the quality of the survey, all participants were completed in the company of their familiar social worker the time to complete the questionnaire is around 15 minutes. We established specific behavioural guidelines for the social workers participating in the project, requiring them to review a preparatory handbook in advance. The handbook made it clear that they were only supposed to objectively explain the questions if older adults did not understand the question and were not involved in the process of filling out the questionnaire or discussing the questionnaire with them during that time. Each older adult who completed the research was paid approximately 8 dollars. After collecting the questionnaire, 20 participants were randomly selected for a telephone call to confirm that they had completed the questionnaire independently. Participants who returned phone calls reported completing the questionnaire autonomously.

We analyse data using the online platform where questionnaires were collected and the data presented in this study are the results of descriptive statistics.

4.2. Interviews

The survey conducted in this study provided insight into the attitudes of older adults toward fall detection cameras. To dig deeper into the underlying reasons and behavioural preferences associated with these attitudes, we employed a more nuanced approach through semi-structured interviews. The interview framework facilitated a comprehensive exploration of several key areas. These areas included the participants' personal experiences and responses to falls, their views on privacy in the context of using home fall detection cameras, and their

perspectives on achieving an equilibrium between preserving life and protecting privacy.

Before conducting formal interviews, a pre-experiment was carried out with 3 older adults. This step involved presenting them with the questions, and based on their feedback, adjustments were made to the phrasing and structure of these questions. This process was carried out to ensure that the questions were understandable to the participants, ensuring the effectiveness and clarity of the subsequent formal interviews.

The recruitment of older adult participants was done using the snowball sampling method. Initially, four older adults, who had prior use experience with the fall detection camera, were identified through community referrals. Through them, 13 older adults who also had experience using or were interested in fall detection cameras were invited as participants. The ages of 20 participants ranged from 58 to 89 (mean = 66, SD = 7), including 4 male and 16 female, the interviews lasted on average about 40 minutes. These participants had not joined the survey before, we screened their living conditions and expected using scenarios as well, detailed information on table Table 1. P1-P20 joined the interviews, and it lasted about one hour and each participant was paid about 14 dollars and two packages of disposable masks.

To analyse the interview data, we used thematic analysis, and 6 researchers participated in the coding process, working in pairs to cross-verify each other's coding efforts. This collaborative approach ensured a rigorous examination of the data and helped maintain the reliability of the coding process. Throughout the coding phase, the six researchers convened for three meetings. These sessions were crucial for discussing emerging themes, resolving any discrepancies in coding, and finalising the themes that accurately represented the data.

4.3. Co-design workshop

The survey and interviews focused on older adults' views on privacy concerns associated with cameras, particularly the role of exterior design in privacy protection. These insights revealed that older adults have unique wisdom and potential solutions to these problems. However, their limited technical vocabulary and the absence of design knowledge obstructed their ability to communicate their ideas clearly. To facilitate a more comprehensive and detailed expression of older adults' solutions, we organised a co-design workshop employing participatory design methods. This approach aims to involve participants in the design process and articulate their ideas more effectively using professional collaborative design tools.

Participants for the workshop were recruited through a dual approach: posting announcements in community centres and directly contacting older adults who had participated in our previous studies. Of the people who expressed interest, a representative group of 6 older adults was selected, including P3 and P9 who had previously joined the interview. This selection process considered their living conditions, including people living with partners and people in multigenerational co-housing situations. In addition, we took into account their level of acceptance towards camera technology, ensuring that the group included both positive and conditional recipients of the technology. This strategy aimed to capture a diverse range of perspectives and experiences regarding the use of camera technology in their daily lives. The ages of the participants ranged from 61 to 73 (Mean=65.83, SD=3.76), and details of the participants can be found in Table 1. P3, P9 and P21-P24 were joined the workshop, it lasted about 2 hours. All the research process was recorded by voice and video with their agreement.

Before starting the co-design workshop, we grounded our approach in the design thinking process and leveraged insights from previous co-design experiences with older adults (Yang and Moody, 2022; Yao et al., 2019). This preparation involved setting up the necessary tools and planning the processes to follow during the workshop.

For the co-design workshop tools:

Whiteboard: A large hard board paper divided into five sections for different activities: understanding scenarios, functionality, privacy, referencing appearance, material cards, and participating in the collaborative design area (see typography and case in Fig. 1).

Cards: Scenario cards from video screenshots showing typical scenarios for easy reference; Material cards on picture schematics of different materials for hands-on exploration.

Video: We created 4 videos within real home environments to effectively illustrate the functionality and interaction of camera-based fall detection systems. These videos showcased two key scenarios; see Fig. 2: the automatic initiation of a help call following a fall that results in unconsciousness, and the manual activation of a help request by individuals who are awake after a fall. Each scenario was recorded in two distinct settings within the home: the living room and the bedroom. This approach provided a comprehensive demonstration of how the fall detection system operates in different environments and situations.

For the co-design workshop process:

The co-design workshop was structured into two distinct phases, following the overarching design thinking. In the first phase, participants delved into examining the interplay between camera functionality and privacy concerns. The second phase was dedicated to the actual design and presentation of their ideas. Throughout the workshop, designers were present to assist older adults in materialising their concepts into sketches (Hirsch et al., 2000). However, these designers acted merely as instruments or "brushes", enabling older participants to directly shape their desired designs. This approach facilitated the swift realisation of the older adults' design visions, ensuring that their ideas were accurately and efficiently brought to life.

In the first phase of the workshop, older adults were presented with videos that demonstrated the camera's functionality and its interaction form. This visual introduction helped set the context for their design considerations. Subsequently, they were encouraged to identify and list features that they deemed crucial for the home camera design, with a particular focus on ensuring that these features could be implemented without infringing on privacy.

In the next phase of the workshop, participants then consolidated their ideas using pre-prepared cards, which served as tangible prompts for brainstorming and discussion. After assembling their thoughts, they communicated their concepts to a designer's assistant. This assistant played a key role in translating the older adults' verbal and card-based ideas into visual representations, creating hand-drawn sketches of the proposed designs. Finally, each participant presented their design concepts. These presentations not only showcased the functional aspects of their proposed camera systems, but also highlighted their innovative approaches to preserving privacy within the design.

The Co-Design Workshop produced an extensive collection of video, audio, and graphic materials. After the workshop, all designers and researchers who participated shared the insights and inspirations they had gained from older adults. We focus on the working process of the fall detection camera in data analysis, using the co-design manuscripts from older adults to explore how privacy concerns were addressed before and after the fall. By analysing these contributions step by step, we gain insight into the privacy-orientated design decisions made during the process.

We systematically organised and analysed the textual data collected in the interview and co-design workshop, employing thematic analysis to synthesise the findings together. These findings are further bolstered by descriptive statistics from the additional questionnaires, providing a comprehensive overview of the study results.

5. Findings

Through thematic analysis, we categorised privacy concerns and solutions related to camera use among older adults, which were identified in our co-design process. The analysis is presented from three distinct

Table 1
Detailed information of participants in interview.

No.	Age	Gender	Living conditions	Key characteristics
P1	58	M	Long-term living alone while the last 6 months with nephew	Still employed; prefers electronic products, but rejects the camera monitoring; may install home cameras in the future, mainly for theft prevention.
P2	59	F	Living with her partner, children, and grandchildren	Has experience installing cameras outside the room and is also considering installing cameras inside the house in the future.
P3*	73	F	Living with her partner	Was a physician before retirement, experienced two falls at home, wishes to install cameras, and does not worry about privacy issues.
P4	75	F	Living with her partner	Children are settled abroad, and in case of an emergency, they contact the neighbors. Prepared to install a camera at home to call the emergency services in case of an accident.
P5	67	F	Living with her partner and two cats	Need to take care of her grandchildren so the camera can help look out for her partner when she is out; does lots of housework and hopes for robots can help her.
P6	67	F	Living with her partner	Very resistant to invasion of privacy by cameras; children work in the medical industry and visits them regularly; might use cameras in the future following the advice of the children.
P7	66	F	Living alone	Unmarried, has been taking care of parents for 20 years; often participated in community activities; satisfied with the voice assistant sent by the community; might install home cameras in the future.
P8	64	F	Living with her partner	Has a father over 90 years old with mobility problems and unable to care for himself, so a nanny and her brother take care of him, and therefore, cameras were not needed.
P9*	61	F	Living with her mother	An 84-year-old mother who has experienced falls is in a semi-dementia state after a brain attack; sensitive to changes in her mother's voice in abnormal situations, so she hopes to use a camera to monitor and communicate with her.
P10	55	F	Living with her partner and 93-year-old father	Previously worked handling petitions for older adults; her mother had a sudden coma at home in 2015, and also has experienced falls in the house herself; need for a camera at home mainly for reminders and social functions.
P11	59	M	Living alone	Using home cameras for 5–6 years; his mother had fallen at home and wasn't discovered until he came home from work; except for the kitchen and bathroom, the entire house has cameras installed, and he would like to install one in the bathroom.
P12	72	F	Living with her partner	Worked in an education-related field before retirement, familiar with smartphone applications, and needs to care for her partner with Parkinson's disease.
P13	67	F	Living with her 91-year-old mother	Her mother always forgets to turn off the tap and had fallen twice; keen to install cameras at home, but strongly opposed by her mother as disrespectful.
P14	68	F	Living with her 40-year-old son and two cats	Good health conditions; Her son works in their community, able to provide prompt care to her, so don't need home camera.
P15	80	F	Living alone	Was a doctor; children often come to visit; hoped for a small, easy-to-use and high accuracy in fall detection device.
P16	80	F	Living alone	Well health conditions; passive attitude towards cameras depending on her children's wishes; left her home key to neighbours in case of emergency.
P17	82	F	Living alone	Was a nurse; in good health conditions, but has a high demand for home cameras as she lives alone and values self-safety; left her home key with neighbors in case of emergency; concerned about the after-sales service of home cameras.
P18	89	M	Living alone	Was a doctor; had a pacemaker in the heart; hopes the camera can have full coverage of the house.
P19	86	M	Living with the youngest son	His partner was in nursing home, so he always checks the status of her by smartphone; hopes the camera can have full coverage of the house and comprehensive functions.
P20	82	F	Living alone	Not really familiar with smartphones, the only use is for socialising; her partner was gone 10 years ago and seldom has contacts with children.
P21*	67	F	Living with her son's family	Disciplined, shares willingly, swims thrice weekly, focusses on health, reads news on history and politics, cares for pets and plants, prefers discreet cameras.
P22*	66	M	Living with his partner, son and daughter-in-law	Daily use smartphone for social and entertainment, especially noticing WeRun's ranking on WeChat; has a voice assistant purchased by his son at home.
P23*	63	M	Living with his partner and children	Regular and monotonous lifestyle; occasionally enjoys photographing birds with cameras and regularly using a smartphone;prefers the appearance of relaxing and soothing camera.
P24*	65	F	Living with her partner	Actively volunteers in the community and loves to play croquet; visits and takes care of her father every Thursday to Sunday.

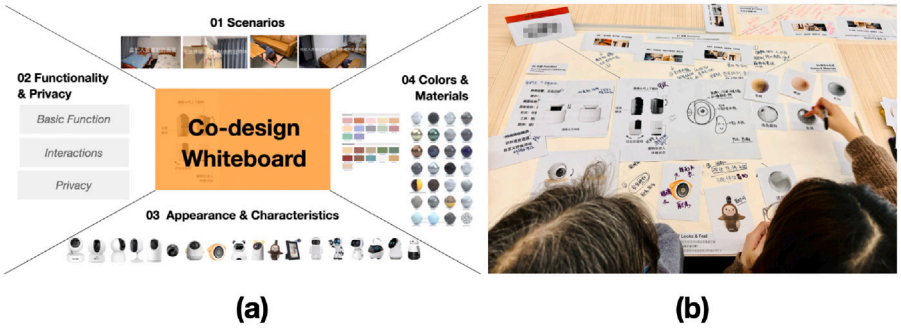

Fig. 1. Co-design workshop presents: (a) an exemplar of design whiteboard; (b) older adults are co-designing the list of priorities and functionalities for cameras with researchers.

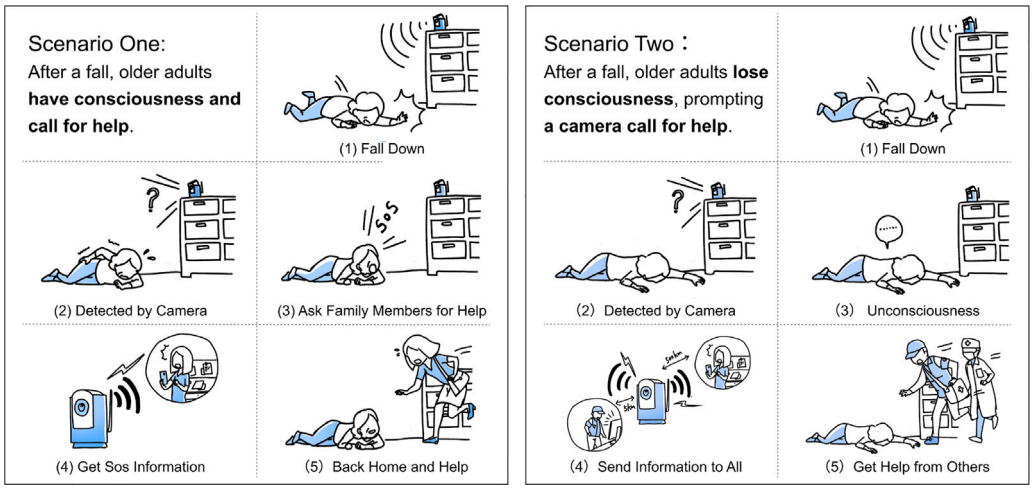

Fig. 2. Storyboards for Video Shooting.

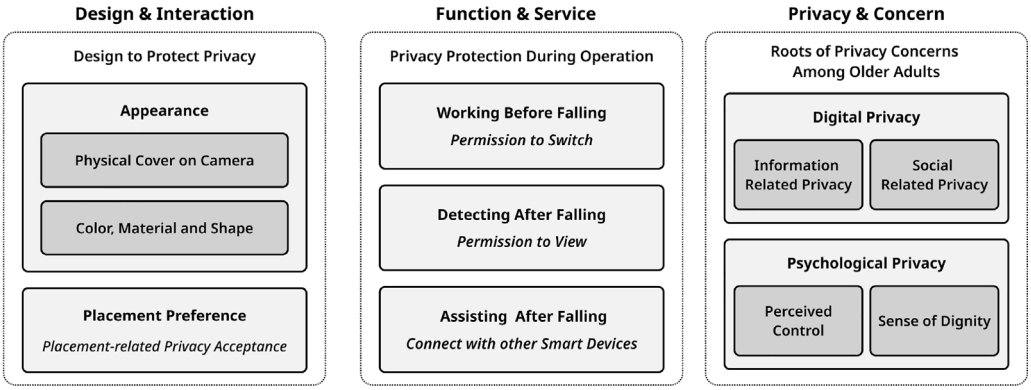

Fig. 3. Thematic analysis.

perspectives, thematic was shown in Fig. 3. Initially, from a design point of view, we explore several privacy issues that are important to older adults. Next, we explore solutions that navigate the delicate balance between privacy preservation and life safety, particularly within the operational framework of fall detection cameras. Lastly, we explore the psychological factors that affected older adults' perceptions of privacy.

5.1. Design to protect privacy suggested by older adults

5.1.1. Appearance

During the co-design workshop, older adults expressed a desire for cameras in their homes to be unobtrusive and to provide them a more sense of control in appearance, considering privacy issues. To achieve this, two dimensions of design ideas were proposed, including physical occlusion and colour, material, and shape.

(1) Physical cover on camera. Older adults expressed a desire for cameras to be turned off during daily activities and activated only upon detection of abnormal sounds when they fall down at home. Cameras equipped with switches and shields were perceived to provide a greater sense of control and peace of mind. The participants emphasised the importance of intuitive indicators that clearly communicate whether the camera was actively recording. For example, P3 mentioned:

"I would feel more comfortable if the camera remained closed and only started recording when the alarm is triggered." [P3]

(2) Colour, material and shape. In terms of colour, material, and shape, participants preferred cameras that seamlessly blended into their

home environment, making them virtually unobtrusive. Most older adults wanted the camera to be unobtrusive in colour, such as white or light grey, similar to the style of home decoration. Although some participants mentioned an affinity for bright colours, the general consensus leaned toward unobtrusive and subtle camera appearances. P9 mentioned: *"I prefer a discreet white plastic camera that blends seamlessly and does not draw attention." [P9]* Furthermore, some older adults proposed that wood grain material or white plastic also allowed the camera to integrate well with the home.

Interestingly, 3 out of 6 participants in the co-design workshop also proposed the concept of an anthropomorphic or anthropocentric camera that did not resemble a traditional camera. Furthermore, in the survey, 17.07% of older adults prefer an anthropocentric design style, while 14.63% prefer an anthropomorphic design style. Since they are more likely to be recognised as a small decoration in the home, they would reduce the psychological burden on older adults. In addition, anthropomorphic cameras could provide comfort and companionship to older adults in addition to functional fall detection. For example, P3 mentioned that *"I want the camera to look like a little penguin, creative, and not like a camera, which makes for a better psychological state. [P3]"* Furthermore, P24 claimed that *"The appearance of the camera is expected to give people a sense of security. It can be used as a small decoration in the home, making outsiders not treat it as a camera." [P24]*

5.1.2. Placement preference

In terms of the older adults' preference for the location of the cameras, the survey showed that the majority (77.56%) expressed a preference for cameras to be placed in the living room, followed by the bedroom (28.78%) and kitchen (19.51%), while the bathroom was the place where the older adults least wanted the cameras to appear (14.15%).

Older adults have different opinions about whether cameras should be placed in private spaces such as bedrooms and bathrooms. Some participants believed that these areas pose potential risks, particularly when they lived alone or during periods of vulnerability. Consequently, they considered it necessary to have cameras in these spaces to ensure their safety. For example, P24 mentioned some potential dangers when in the bathroom. *"I think it is necessary to install cameras in the toilets. It is easy to cause sudden death when squatting in the toilet to defecate force. Furthermore, older adults are likely to have vertigo after squatting for a long time." [P24]* Also, P4 pointed out the need to have cameras in the bedroom: *"When the older woman and her husband fall asleep, the older man's breathing is unusually rapid and loud, indicating a potential danger or health concern. If we put a camera in the bedroom like this, we could detect it." [P4]*

Others were unwilling to have cameras in these private spaces considering their family's privacy, but when balancing their security and privacy, they offered certain terms of acceptance. They expect alternative methods of surveillance that do not rely solely on visual images. *"The toilet cannot be filmed by a camera but can be monitored by sound." [P21]* This approach allows the collection of critical data while also maintaining a level of respect for the privacy of individuals.

5.2. Privacy protection during operation

5.2.1. Working before falling: Permission to switch

The control permission of camera switches has emerged as a topic of discussion among the participants. Older adults expressed their desire for cameras installed in their homes to be easily operable and with the ability to control their functionality. A key concern voiced by the participants was the desire to avoid constant surveillance and have mechanisms in place to trigger the camera switch. This approach allows for privacy preservation while ensuring the camera is activated when necessary.

> *"I don't want to be watched 24/7, and it's better to have a mechanism to trigger the switch. Normally, just turn its head away from me, and if there is an unexpected sound, it can be switched on automatically, but normally it is in the off position." [P9]*

It was also recommended that the camera be turned off when many people were home. Many older adults believed that when there were people in the house, the probability of danger was low because falls among older adults can be easily detected and promptly addressed. Therefore, they perceived keeping the camera on as potentially jeopardising their privacy. Similarly, older adults who cared for their parents expressed the need to turn on the camera remotely when they were away from home, and the camera turned off automatically when they were at home, providing reassurance and peace of mind, just as P12 suggested:

> *"When only the older adults are at home, the camera typically faces them, but once others return home, it needs to be covered to avoid making them uncomfortable." [P12]*

Older adults were also concerned about whether the camera was on and how it interacted with them. In the survey study, 65.04% of the seniors expressed a desire to operate the camera, turning it on and off by voice. Furthermore, 49.87% of seniors preferred to connect with their mobile phones for camera control, while 31.36% of seniors preferred to be on alert for light. P12 mentioned that *"it will feel a bit more at ease if it tells you that it is off right now, or if it notifies you of the state it is on or off"*.

The on/off switch is the focal point of older adults' privacy concerns regarding the camera in everyday life. Customisation options for activating and deactivating the switch as well as the ability to control the camera were emphasised as important considerations. Furthermore, older adults expressed a preference for visible indications of the camera's switching status to ensure transparency and reinforce their privacy preferences.

5.2.2. Detecting after falling: Permission to view

When it comes to permission to watch the camera content after a fall, the opinions vary greatly among the participants.

Although some participants prioritise their safety and advocate for widespread dissemination of distress messages, they also require high-resolution cameras for medical professionals to accurately diagnose the cause or type of fall. For example, a participant said that the urgency of an emergency makes privacy concerns irrelevant, stating that life-saving devices should be prioritised over privacy considerations.

> *"It doesn't really matter. At this moment, life is still the most important thing; it's an emergency, and I don't need to worry about privacy; you're sick and dying, so why think about it? Isn't it a life-saving device?" [P3]*

In contrast, some participants emphasise their privacy rights, advocating for the implementation of order and conditions in emergency response software, such as giving precedence to notifying their children, followed by people close to them, such as social workers. They would also like to see laws and regulations that limit the behaviour of those engaged, so that privacy may be legally protected, as P24 said, *"if social workers or unknown individuals want to examine some emergency footage from the camera, they should sign an agreement ahead of time to ensure legal protection." [P24]* Furthermore, older adults have requested that authorised photographs be masked to maintain some level of privacy while transmitting rescue signals to additional parties.

5.2.3. Assisting after falling: Connect with other smart devices

Some older adults noted that other smart technology, in addition to camera, could address certain privacy concerns. Smart bracelets and

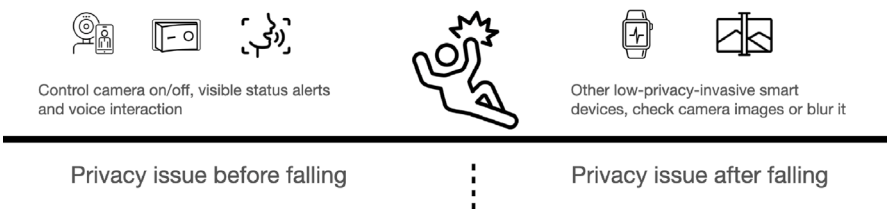

Fig. 4. Privacy concerns before and after falling.

stereos were the most frequently mentioned, as they do not collect image data. There are already smart bracelets and watches that support fall detection, but the issue of false alarms remains a concern for older adults due to the high sensitivity of the detection mechanism. These devices primarily serve the purpose of facilitating emergency contact and offer a privacy-friendly alternative, particularly in areas such as bedrooms and bathrooms where individuals are reluctant to install cameras.

> *"It is preferable to wear a bracelet on your hand so that the camera can detect any unexpected vibrations. Alternately, it can be worn on the right hand, where your pulse is located. On the one hand, this can assist in calling for help through the bracelet button and camera if the camera cannot detect it. In addition, the bracelet placed on the pulse area can also monitor the pulse fluctuations at any time to prevent a situation in which the heart stops beating when the individual falls asleep." [P3]*

It should be noted that this valuable insight was shared by P3, drawing on her experience as an emergency physician before retiring. Fig. 4 provides an illustration of the privacy concerns of older adults before and after a fall has occurred and some of the solutions that they have suggested.

5.3. Roots of privacy concerns among older adults

5.3.1. Digital privacy

Cameras can potentially trigger many privacy issues, particularly when they are installed at home, which is a private zone for everyone. From the perspective of older adults, the installation of cameras raises two main concerns: information-related privacy and social-related privacy.

(1) Information related privacy. It is intolerable for older adults to be monitored everywhere in daily life. When there are specific safety protections and strict regulations, being watched is acceptable. P3 mentioned that

> *"There should be regulations that specify who and where the notifications from this remote monitoring will go, and it's not just released to the public, right? If I want my children or community to be informed, it should be possible. However, it's not appropriate to see it without my permission. Therefore, I think it's important to comply with regulations and to follow laws on the protection of personal information. I believe that as researcher working on this project, you will not break the rules, but if you do, you must be prepared to face the legal consequences." [P3]*

Cameras are acceptable for older people with health concerns, but it is important to recognise the need for privacy in certain areas of the home. Specifically, the bathroom and bedroom are considered highly personal spaces where cameras should not be installed. P1 claimed that *"It (camera) spies on the house but not on me. It cannot intrude on my privacy. There is no way cameras are installed in the bathroom, and if one were to operate my camera and release my bathroom scene, my personal privacy would be completely disclosed". [P1]* It is crucial to respect the privacy of older adults and to ensure that their personal spaces are not monitored by cameras without their explicit consent.

Digital privacy concerns extend beyond mere data protection; the ubiquitous presence of cameras in domestic space can lead to the erosion of informational privacy, potentially resulting in social pressures. P12 underscored the importance of preserving privacy in vulnerable moments, such as during episodes of distress or embarrassment, highlighting that individuals have personal secrets they wish to keep confidential. P13 proposed using sound detection as a solution to this problem. *"In fact, sound detection is necessary in the bathroom. One's fall must make some noise, and if the sound is unusual, then it (camera) can call the police; otherwise, installing a camera in the bathroom would definitely invade one's privacy." [P13]* Therefore, older adults supported the idea of only using sound detection or emergency buttons in the bathroom.

(2) Social related privacy. Installing cameras at home will inevitably have an impact not only on older adults themselves but also on family members and visitors. In addition, many people are resistant to installing cameras in their homes because it is supposed to be a place of comfort and relaxation. However, if there is a "big eye" staring at them, it can make them feel uneasy and insecure, especially in the psychological aspect.

For family members living with older adults, the main role of cameras is to care for older adults during periods when they are alone at home. However, when family members are present with older adults, cameras are no longer needed. In contrast, older adults are typically concerned that their visiting friends and acquaintances may notice the installation of cameras, which could cause discomfort or suspicion. This reluctance can be attributed to the fact that cameras are relatively rare at home, leading to the potential stigmatisation of older adults who install them. P10 shared:

> *"The most serious concern is I don't want anyone else to know that I have a camera in my house. You know, if our friends and neighbors find out, they might spread rumors in the neighborhood." [P10]*

Therefore, older adults prefer the use of unobtrusive cameras to avoid drawing attention from others, enhancing their sense of security and comfort.

5.3.2. Psychological privacy

(1) Perceived control. The aforementioned findings reveal that the challenges of privacy extend beyond the traditional concerns of digital privacy regarding the image captured by the camera and also include the psychological privacy concerns of older adults. What P23 said has inspired the authors to reconsider the definition and scope of privacy.

> *"I wanted the camera to be under my control, and that if the camera was visible to outsiders, it would cause them to believe that I was too old to live on my own and make them laugh at me, so it would be preferable if it were not too obvious. Most importantly, I hope it won't offend me." [P23]*

The perspective of "don't offend me" has prompted researchers to investigate the boundaries of privacy and to consider whether certain smart technologies that enhance the lives of older adults are psychologically burdensome for them to use. Many studies in the field of assistive technology generally emphasise functionality and usability (Edwards,

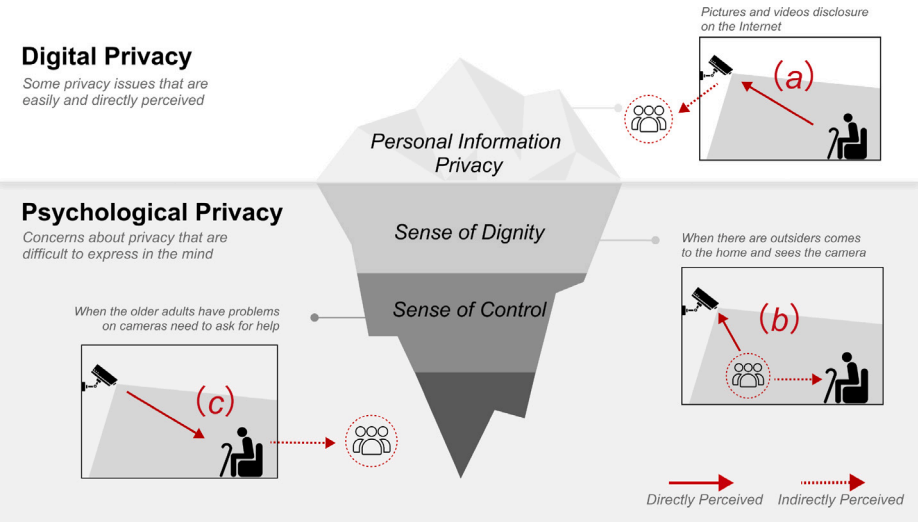

Fig. 5. Psychological privacy and the way camera compromise privacy.

1995). However, the use of such technologies is influenced not only by technical attributes but also by personal preferences in social contexts (Shinohara and Tenenberg, 2009). Specifically, ageism within the design process could pose an impediment to the acceptance of these technologies among older adults (Mannheim et al., 2019). Therefore, in the design and research process of assistive technology products for older adults, it becomes imperative to broaden the scope beyond mere functionality, incorporating considerations of aesthetics and social acceptance. This holistic approach aims to optimise the efficacy and adoption of assistive technologies among older adults (Edwards, 1995; Shinohara and Wobbrock, 2011) At the psychological level, older adults want a camera that does not offend them, which means that psychological privacy is not only related to whether the camera takes and discloses images, but also whether it respects their wishes, reduces their sense of control, and is easy to learn, thus preventing them from feeling useless.

Our findings are summarised in Fig. 5. As shown in Fig. 5(a), digital privacy is obviously important, as the image information captured from older adults is exposed to other people, which invades their personal privacy, and this has also been the focus of many research studies. Furthermore, our study emphasises the privacy demands about dignity that are difficult for older adults to express.

(2) Sense of dignity. The first underlying psychological concern for privacy is **the sense of dignity**, as shown in Fig. 5(b). The opinions of older adults demonstrate their concern about how others perceive them. They fear that using cameras may create an impression of diminished independence and capability, as we discussed in Section 5.2.1. Almost all of the participants expressed a preference for unobtrusive cameras. These sentiments are also reflected in the physical appearance of cameras. Traditional camera designs can help older adults perceive themselves as ageing, weak, and lacking independence, while also subjecting them to stigmatisation and reinforcing stereotypes that can directly undermine their sense of dignity. As a result, older adults may actively resist the use of cameras as a means of preserving their dignity. Therefore, it is crucial for the design of cameras to take into account the desires of older adults and avoid perpetuating such prejudiced notions in others. Privacy design must carefully consider these complex needs, which are difficult to articulate directly. The second underlying psychological privacy concern is **the sense of control**, as shown in Fig. 5(c). Older adults consider autonomy and independence when evaluating privacy invasion. As discussed in Section 5.1.1(1), older adults expressed a desire to determine camera status using switches or physical occlusion. They can adjust the camera's activation status and receive immediate feedback, fostering a sense of control and independence. This serves to further diminish their perception of privacy intrusion. During the co-design workshop, P3 mentioned:

"I believe that the switch control of the camera is crucial. It provides an intuitive sense, allowing me to turn off the camera when I don't need it, reducing the feeling of being watched".

If they cannot actively participate in controlling the camera and are merely subjected to constant "monitoring", they are more likely to perceive the camera as an invasion of privacy, just as P12 mentioned in the interview.

> *"I don't really care about the presence of additional functions attached to the camera because, even if they exist, I will still perceive it as an operating camera. My major concern is the issue of privacy invasion, and I hope to have complete control over its operation." [P12]*

In addition, smart device operation has consistently presented challenges for older adults. According to our survey, When there is a camera problem, such as fear of complicated functions (54.24%) or lack of knowledge about how to fix the camera if it had problems (44.73%), this is also the biggest concern of older adults. When older adults are unable to handle a situation, they must seek the help of family members or others. However, during the process of seeking help, older adults fear being viewed as incapable of handling such simple issues. These feelings further undermine their self-efficacy and elicit negative emotional responses. Poor interactive design and user experience cause older adults to be unable to properly operate smart devices and require assistance. On the level of privacy, the belief that older adults cannot effectively use smart devices is an unspoken desire to preserve dignity.

6. Discussion

Many studies have looked at new ways to detect falls and protect older adults' privacy. However, most of this research has focused more on technology and less on what older adults think about privacy. This means that there has been little detailed study on older adults' privacy concerns or how to include their views in designing these technologies. Our study looks at how older adults understand privacy at the psychological privacy level and suggests design ideas based on their opinions.

6.1. Foundational privacy issues among older adults

This study explores what older adults consider to be private from their point of view, as well as what they consider to be potential privacy solutions, including them in the design research process. We found that there is a correlation between the perceived privacy of older adults and their dignity.

6.1.1. Privacy in perceived control

From the perspective of a significant portion of older adults, their physical ageing is considered a private matter, especially in public settings. Research has found that people with limited mobility often use shopping carts instead of canes because they do not want to be perceived as part of the disabled community (Li et al., 2021). Studies have consistently shown that, unless absolutely necessary, older adults avoid using medical assistive devices to demonstrate that they can still control their bodies (Li et al., 2020b). They often forget to wear devices like wristbands that track physical changes, but do not forget to carry meaningful items. In their view, "wheelchairs represent illness, while scooters represent vitality". Using a scooter or shopping cart symbolises being "strong" or "independent", whereas assistive devices might signify being "old" or "frail".

In our study, we found that the ability of older adults to autonomously control their cameras can influence their feelings of privacy. Many older adults feel that their privacy is being invaded because the camera can view their lives at any time, and very often the authority to switch the camera on and off is not just on the older adults but on the side of their children and caregivers. This makes them feel like they are losing their independence and autonomy, which deepens their privacy concerns.

Several older adults mentioned the importance of being able to take control of the camera on/off for their own privacy. In addition to not wanting their lives to be monitored, there was also the issue of not wanting to repeatedly ask for help when they encountered problems with the camera, as this process could also lead to others thinking that "this older person doesn't know how to do anything". This lack of digital competence is also an issue of privacy that older people do not want to reveal. This kind of privacy is hidden underneath digital and physical privacy, and it is difficult to understand by designers in a short period of time.

6.1.2. Privacy in dignity

We found that older adults concerned about their dignity felt challenged by the installation of cameras at home. They perceived cameras as a symbol of ageing and disability rather than mere violations of digital privacy. This is because the technology-assisted living scenario can make older adults feel that they are unable to live independently, repeatedly reminding them that they need outside help. In addition, older adults perceive smart aids to be closely associated with negative labels such as disability and vulnerability, and fear of stigmatisation is one of the main reasons they are reluctant to use or acknowledge their need for smart aids (Astell et al., 2020; xin Chen, 2020; Park and Kim, 2024).

Smart products are intended to promote independent living among older adults; however, certain evident "ageing" features or stigmatising design elements can compromise their sense of dignity. Consequently, some older adults may refrain from actively exploring the use of smart products due to these concerns. For example, Seaborn et al. revealed that older adults avoid using powered wheelchairs in quiet public places. They felt embarrassed as the wheelchair made really loud noises that drew the attention of other people (Seaborn et al., 2016).

Moreover, loss of privacy occurs not just when images of family activities are captured and transmitted, but more importantly when they lose their independence and sense of dignity in the process (Sas et al., 2017). As we note in our findings, older adults want independence and dignity. They want cameras with switches and shields, so they have more control over whether they are being watched.*"Cameras with switches are better because they are intuitive and can easily control them".* They prefer the appearance of the camera that looks like a decoration or a small pet that can save lives at crucial moments. It can also reduce the discomfort caused by "watching" and can play a role in emotional companionship (Urban, 2017). *"I want it (the camera) to be a companion that records my happy moments, giving me warmth when I live alone".*

In traditional East Asian cultures, the values of autonomy and dignity are significant. However, specific design elements, which are perceived as strongly associated with ageing, can create cognitive burdens for older adults when using them. For instance, they may worry that using a fall detection camera will lead others to perceive them as "incapable" due to their age, even though the majority of people do not share such a perception. These psychological layers of privacy concerns are difficult to discover directly in the design research process due to cultural and environmental influences. Some older adults may avoid such discussions because of their dignity, leading researchers to focus only on digital privacy. However, there is more than that.

6.2. Privacy by design implication for older adults

For designers, understanding and addressing the need to preserve the dignity of older adults living independently is more challenging than addressing apparent privacy concerns. In current research on privacy design, some researchers have touched on privacy and dignity-related scenarios. However, most of these scenarios have focused primarily on palliative care and hospice care, with less emphasis on the broader use of digital technology by older adults (Bagnasco et al., 2020).

6.2.1. Avoiding emphasis on "ageing" as a privacy strategy

Tt is critical for designers to raise awareness of avoiding stigmatisation. Older adults are aware of protecting their privacy with respect to age and technological proficiency, considering that disclosing such information constitutes an invasion of their privacy. They do not wish to be subjected to stereotypes such as being labelled as "elderly" or "digital refugees". Age-friendly designs, albeit well intentioned, can inadvertently highlight these aspects, leading older individuals to feel that their use of such designs inadvertently discloses sensitive information.

The design language that stigmatises may originate from placing too much emphasis on "fall detection", which can inadvertently highlight their dependence rather than independence. Older adults prioritise autonomy and dignity, expressing a preference for the camera to serve as a supportive companion rather than an intrusive monitor that restricts their activities out of fear of falling. Consequently, they desire the cameras to blend seamlessly into their living environment, either by being discreet in appearance and placement or by incorporating the camera into a decorative item to minimise stigmatisation.

When it comes to the design of a camera, it is important to weaken the concept of "old age". Designers need to give the camera a non-intrusive appearance from the perspective of preserving older adults' dignity. Let older adults feel that they can control the camera to help them rather than being restricted by the camera in their lives. For example, the camera can look like a decorative object at home, invisibly present in the living environment (Hirsch et al., 2000). shared similar design ideas, using scooters instead of wheelchairs or walkers for assisting older adults to walk independently can avoid being stigmatised and empowering older adults.

Older adults are often stereotyped as a vulnerable population with cognitive decline and in need of social support in earlier studies of assistive technologies. In fact, Dudek found that resistance to AT can be decreased by rejecting and shattering negative assumptions about older adults (Dudek et al., 2021). Scott et al. mentioned that excessive concern for older adults would lead to a "slippery slope", forcing them to pay the price of independence and skill degradation for so-called

safety (Scott et al., 2022). Instead, they advocate ratchet-wise rehabilitation, which uses ATs to empower older adults and give them dignity, for example, using technologies to make exercise and fall prevention training a part of everyday life for older people rather than just an approach to dealing with emergency (Ogonowski et al., 2016).

6.2.2. Permission to ensure privacy controlled by older adults themselves

Cameras for older adults should ensure that they themselves have privacy-related control permissions. Permissions in this context refer to the ability of older adults to feel in control of their lives during use. Some privacy-transparency-related discussions focus on the delivery of privacy information rather than the design of privacy permissions (Siljee, 2015). And many of the rights to information and control do not take into account the needs of older adults in their use, leading to older adults relying on their family members or other younger people to help them take control. And this approach hurts older adults' sense of control and psychological privacy.

When standards for privacy exposure are established, it is crucial that older adults are fully informed about how their information might be shared. Furthermore, the discussion should extend to the reallocation of control over private information, ensuring that older adults have complete authority over the disclosure of their data (Yang and Moody, 2022). Designers play a key role in making this process transparent, helping older adults understand the implications of their private information being exposed. It is important that this process is presented neutrally, empowering older adults to make informed decisions without feeling coerced or persuaded by the design.

Most older adults do not want to be a burden on others, keeping independence is a key factor in their decision to use cameras at home. They feel respected when they can operate the devices themselves, as it reflects their capability. This study shifts the focus from the technical usability of control, previously discussed in design research, to exploring the psychological aspect of control. It emphasises that the sense of responsibility of older adults in managing their own lives is a concern for privacy. This sense of control extends to their perception of privacy, particularly by ensuring that they do not feel monitored or restricted when taking actions, thus safeguarding their dignity.

7. Limitation

Our study has some limitations; as an exploratory research effort, the recruitment and selection process of participants led to a sample size that may not be sufficiently comprehensive. Furthermore, due to the nature of our study that involves interpretation of techniques and interactions, the participation of social workers and designers, despite their training, might have subtly influenced the responses of older adults. Consequently, our findings might not be universally applicable to all older adults but are representative of our specific sample group. In future work, our aim is to expand upon this exploratory study by conducting quantitative research to assess the generalisability of our results.

8. Conclusion

This study aims to understand the perspectives of older adults on privacy by investigating their attitudes toward using fall detection cameras. Through a co-design approach, we involved older adults in the privacy-by-design process. We found that, beyond data privacy, older adults consider ageing and their ability to use digital technology as part of their privacy concerns. Crucially, these privacy issues are closely tied to their sense of dignity, a factor previously underemphasised in research. We also propose two privacy design implication: avoid the stigmatisation of ageing and ensure privacy transparency, providing valuable information for designing privacy solutions for older adults.

CRediT authorship contribution statement

Weiwei Zhang: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jianing Yin:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Ka I Chan:** Writing – review & editing, Writing – original draft, Investigation, Data curation, Conceptualization. **Tongxin Sun:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation. **Tongtong Jin:** Writing – review & editing, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Jihong Jeung:** Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Jiangtao Gong:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

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Data availability

The data that has been used is confidential.

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