@HOME: Exploring the Role of Ambient Computing for Older Adults

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Abstract. Building on results of a recent global study as well as additional exploratory research focused on *Aging in Place*, this paper reflects on the role that intelligent systems and ambient computing may play in future homes and cities, with a specific emphasis on populations aged 65 and beyond. This paper is divided into five sections. The first section provides an introductory background, which outlines context, vision, and implications around the development of ambient computing and smart home technologies for the 65 + population. The second part of the paper overviews the methodological approaches adopted during the research activity at the center of this paper. The third section summarizes pertinent findings and a discussion on the opportunities offered by intelligent, ambient systems for the 65+ population follows. While this fourth section will specifically focus on the smart home, it will also provide reflections on opportunities and applications in the context of autonomous vehicles and smart cities. The fifth and last section offers conclusive remarks, including implications for developers and designers that are shaping ambient computing usages and technologies for the 65+ population. The paper ultimately advocates for adopting Participatory Design [1] approaches, to ensure that intelligent and ambient technologies are developed **with** (instead of **for**) end users.

Keywords: Artificial intelligence · Ambient computing · User experience

1 Background

The research here discussed focuses on enabling and grounding the development of ambient computing and smart technologies for the 65+ population. An increasing number of older adults live in isolated conditions, without the opportunity of aging in place and in emotionally stable conditions. Grounded in this knowledge, the project here featured acknowledges the high economic, psychological and social burden caused by such a reality. *Aging in Place* means making a conscious decision to live in the residence of one's choice for as long as one can with comforts that the individual sees as important and with the ability to leverage supplementary services that facilitate living conditions and maintain quality of life. This section outlines context, vision, and implications around the development of ambient computing and smart home technologies for older adults.

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1.1 Context

The so-called *population ageing*, a phenomenon related to fertility decline and life expectancy rising, is occurring globally. The number of people aged 60 years and over is projected to more than double by 2050 and more than triple by 2100, rising from 962 m globally in 2017 to 2.1b in 2050 and 3.1b in 2100 – this population segment is growing at a faster rate than all younger age groups [2]. By 2050 hyper-ageing societies will represent a large part of the global population [3]. This data highlights an urgent need to focus on diverse technological means to cater to this fast growing segment.

In the US, AARP [4] reports that while 90% of seniors want to live at home as they age, many cannot do so suitably because homes and communities cannot accommodate their particular needs. In 2011, 5.6% of the US elderly, community-dwelling Medicare population was for instance completely or mostly homebound [5], with 75 as average age and 30% living alone. Semi-homebound would be an additional ~ 20%. Being homebound and living alone implies reduced opportunities for social interaction and research shows that mortality is higher among more socially isolated, lonely individuals and that social isolation had the most significant association with mortality [6]. It is urgent we address this segment's diverse needs and complexities.

Additionally, shifts in the *dependency ratio* (estimate of the pressure on productive population) and projections of further shifts [7], alongside a *Bean Pole effect* (family trees get taller, thin, with few people per generation, due to children decrease and life span increase) are impacting society's caregiving capabilities. Several societal changes are aggravating this situation: increase of divorce, re-partnering, and more complex family ties [8–12]; welfare state provision expansion (Europe) and decreased need for family support [13]; women's higher labor-force participation (Europe) and challenges for family caring [14–16]; and processes of individualization, secularization and emancipation, alongside greater emphasis on individual needs and personal happiness [17, 18].

The nature of caregiving has therefore changed and long-distance caregivers are emerging, with ~ 5–7 m long-distance caregivers (~15% of total) in the U.S., with numbers projected to double by 2020 [19]. Long-distance caregivers, however, represent higher annual expenses (compared to co-resident caregivers or those who care for a loved one nearby) [20], their distance from clients is 450 miles on average [21], and are more likely to report emotional distress [22]. Regardless of who provides caregiving support, research also shows that emotional support is a key role they typically fulfil [23]. These caregiving shifts imply a need to provide economically, practically and emotionally sustainable support structures and tools: smart technologies offer the opportunity to address some of these needs and urgencies.

Another important point to consider is that, while better health and quality of life often lowers societal burden and costs, technology can lower the cost of maintaining wellness. In the U.S. for instance, functional limitations such as difficulty to bathe, dress or walk are often reason behind older adults' institutionalization, and 1 in 3 older adults report having trouble using some feature of their home [24]. Long-term care costs keep increasing [25] and nursing homes and assisted living care costs are growing at rates higher than overall inflation [26]. Yet, home care technology can bring substantial cost savings over using human provided care [27]. There is an opportunity to favor, where applicable, home-based care and, since tech-enabled home care could help address many medical conditions [28], there is an opportunity to create a high-tech home health care market that leverages the use of sensor technology to lower elder care costs [29]. Additionally, technology is increasingly accepted and familiar to older adults and less of a barrier to a high-tech home health care market – internet use by 65 + individual for instance increased from 14% in 2001 to 66% in 2018 and during the same timeframe social media use increased from 14% to 37% [30].

Finally, given the substantial shift in educational attainment over the past several decades [31], there is an opportunity to introduce high-tech care tools that, by utilizing and nurturing older adults' existing competencies, provide a platform to share their skills, knowledge, experience and wisdom with their communities. This thinking is central to recent initiatives, such as *The Amazings* [32] or initiatives where students and older adults share facilities in retirement homes [33].

The above discussion and details not only point out a global urgency: they point out a need for products, services, infrastructure and systems with a clear focus on and understanding of aging populations. As cities worldwide devise their smart city plans, it is clear that not addressing the needs and realities of this growing segment would have fatal consequences, with cross-segment repercussions. Because of that, many cities are designing or adjusting their comprehensive plans to address their aging populations.

1.2 Vision and Implications

Given the context outlined in the previous sections, my research endeavors in this space advocate for the use of unobtrusive home-based sensors technologies to (1) support older adults' emotional, intellectual, social wellness, (2) enabling them to live safely in their homes for as long as possible and (3) retaining their sense of independence and self-confidence longer. My hypothesis is that intelligent systems and technologies can help creating social connections and communities that leverage the skills and intellectual capital of homebound seniors, hence promoting their emotional, intellectual, social wellness (Table 1), and therefore addressing their overall wellness while lowering burden and costs.

Table 1. Dimensions of wellness [34, adapted from 35].

Dimensions of wellness	Definition
Occupational	Ability to contribute unique skills to personally meaningful and rewarding paid or unpaid work
Social	Ability to form and maintain positive personal and community relationships
Intellectual	Commitment to lifelong leaning through continual acquisition of skills and knowledge
Physical	Commitment to self-care through regular participation in physical activity, healthy eating, and appropriate health care utilization
Emotional	Ability to acknowledge personal responsibility for life decisions and their outcomes with emotional stability and positivity
Spiritual	Acquiring purpose in life and a value system

Existing literature grounded the decision to focus specifically on emotional, intellectual, and social wellness. Firstly, research not only shows a connection between physical activity and quality of life in older adults [36], but also that physical and emotional wellness are intertwined [37–39] and that positive emotions initiate upward spirals toward enhanced emotional wellbeing [40]. Secondly, while there are correlations between social support and physical health [41], social support, companionship, and control/regulation [42] impact health and can be provided by diverse social partners. Thirdly, cognitive decline may be prevented, slowed or reversed when engaged in creative, challenging, stimulating activities [43]. While having few social ties, poor integration and social disengagement are risk factors for cognitive decline [44, 45], those receiving more emotional support have better baseline cognitive performance [45]. Finally, there are correlations between emotional wellness and social behavior [46] as well as between social support and emotional wellbeing [47, 48].

In light of the above, investigations and developments I here report focused on using intelligent systems and technologies to provide to older adults the opportunity to: be - and feel - connected on their own terms; feel independent, enabled and valued; and be intellectually active. Specifically, experimentations focused on leveraging sensing technology, sensor fusion, emotion understanding and activity recognition to:

- Facilitate connections benefiting older adults by leveraging their own knowledge, past history, preferences, emotional state or patterns, needs, and capabilities;
- Act as emotional and intellectual companions (when others are not around, needed or wanted) by tracking and building on vocal and behavioral cues; and
- Recommend activities or trigger context-centric actions that do not burden to overcome social isolation or downward emotional spirals.

While the vision outlined in this section represents my ultimate goal of the project, the research effort is still in progress. The next sections discuss progress to date.

2 Methodological Approach

The effort at the center of this paper focuses on the use of unobtrusive sensor technologies in domestic environments, to detect older adults' behavioral patterns and then automate voice-based and screen-based interventions when pattern changes are detected. To achieve this, my work incorporates diverse techniques:

- Secondary research, global surveys, interviews and participatory workshops;
- Development of ad-hoc unobtrusive sensor-based systems and technologies and identification of off-the-shelf options;
- Analysis of existing datasets, to identify patterns and correlations, utilizing literature-derived inferences;
- In-home data collection with unobtrusive sensors and technologies, alongside user experience research (e.g. interviews and surveys) and telemetry from users' PCs;
- In-lab data collection with unobtrusive sensors and technologies while users engage in scripted or unscripted tasks and/or to ensure prototypes' usability, functionality, durability and overall value proposition.

This paper overviews data from secondary research (market analysis), global surveys (in US, PRC and Germany) preliminary interviews and workshops (in US), which focused on: perspectives of intelligent systems, with emphasis on smart home, autonomous vehicles (AV) and smart workspaces; the role of Ambient Computing [49] and Affective Computing [50] in everyday contexts; and participants' routines.

The market analysis, which grounded the decision to focus subsequent phases on smart home, AV and smart workspaces, looked at on AI through the lens of diverse verticals (home, office, factory, retail, entertainment, public transport, automotive, classroom, learning) and vectors (players, products, academic research, investments, partnerships, associations, mergers and acquisitions, policies, events).

Survey ($\sim$600 participants, of which $\sim$200 were 65+) and 18 initial in-home interviews focused on two key areas: perceptions, attitudes, thresholds and expectations of intelligent systems; and perspectives toward specific applications in home, AV, and workspace contexts. It should be noted that this first part of the research was used to develop design criteria for those that develop intelligent systems [51]. The screener used to recruit participants focused on diverse criteria (e.g. age; gender; device ownership; purchase intention) and had soft quotas (e.g. family composition; income) as well as a natural fallout for intelligent system knowledge and Intel's segmentation. Through jargon-free descriptions and specific usage examples, I engaged participants in a series of activities: general discussion on intelligent systems and assessment of their comfort level with AI in four contexts (i.e. home; car; workspace; classroom); clustering exercise of AI usages in four areas (i.e. must have; nice to have; do not want; not sure); and assessment of their comfort level with and comparative evaluations of specific home, AV and workspace usages.

For each tested item, I collected a series of metrics to facilitate comparative analysis:

- One to five ratings to identify comfort levels or assess concepts on seven parameters (relevance, uniqueness, appeal, quality, comfort, excitement, trustworthiness);
- Word-based criteria, to gather associative feedback by selecting three items from a list of value-centric adjectives (e.g. exciting; creepy); and
- Emotion-based criteria, to gather emotional feedback by selecting three items from a list of emotions (e.g. love/desire; worried/fearful).

In-home interviews (two hours/participant) I mixed observational techniques (e.g. home tour) with a semi-scripted interview approach that mirrored the survey's protocol and criteria. After survey and in-home interviews, I invited some interviewees to a workshop, to explore key themes and co-create a manifesto to regulate intelligent systems futures. I then co-conducted similar workshops in conference settings, to gather expert input [52, 53].

Subsequent exploratory research on *Aging in Place* leveraged data from additional interviews (still in progress) and in-lab data collection using distributed sensors. This second round of interviews focuses on gaining a high-level understanding of participants' preferences, routines and attitudes toward smart home systems as well as an in-depth knowledge of each participants' daily routines, including discussions on home care (e.g. ironing; cleaning; storing; etc.), pets or garden care, sleeping habits, hygiene, cooking and eating habits, entertainment activities and hobbies, and social habits. In additional ethnographic sessions, I will also include a home tour and routine simulations within participants' everyday environments. In-lab data collection focused on a series of scripted usages and leveraged a number of distributed technologies installed in a laboratory setup to simulate kitchen and living room areas. The setup included point cloud cameras, RGB HD resolution cameras, low resolution and ultra-low resolution thermal cameras, microphones, pressure array mat, and several networking and storage devices. Additionally, during some interviews, we experimented with live or post-production sketching as additional research tool. This last technique will be discussed in future publications.

3 Key Findings to Date

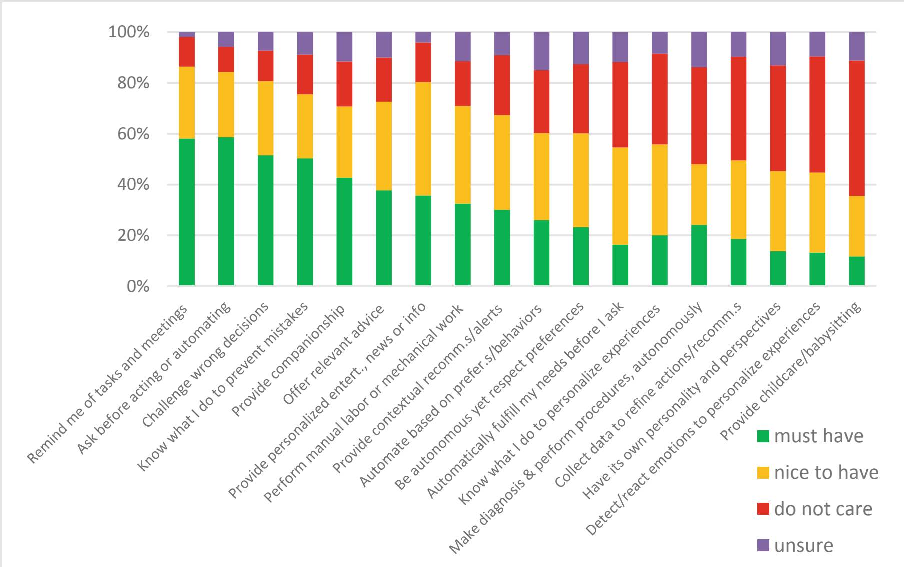
While key findings from all users engaged in survey and initial home interviews are included in a previous publication [51], this section provides a summary of finding from all to-date activities that relate to older adults.

At a high level, 65+ participants expressed concerns with the potential for AI-based systems to impact their privacy (*Not opposed, but cautious about how information that is collected will be used*. Jim 65), security (*These things can be hacked so I expect them to be designed so they are safe.* Sonia 66) and sense of autonomy (*If it's the way it works, fine. However, I still want to make my own choices*. Carla 66). When reviewing usages that leverage Affective Computing [50], they saw benefits yet expressed great skepticism (*The issue is not with discomfort with the action but doubts that it can do it properly and reliably.* Sheila 69) as well as irritation (*Too personal, too close. Here is a (new) device to get mad at for checking out my emotions.* Carla, 66). To the notion of systems with their own personality and autonomy, participants provided negative (*Too much control. It's trying to act like a person and I do not want a machine to do that.* Jane, 65), annoyed (*Maybe it would assume things that are not true… maybe I am not that predictable.* Jim, 65) and entertaining commentary (*Have enough personalities in my life, thank you very much!* Monica 79). Again, these usages greatly challenged their sense of autonomy (*I do not want this as then it is no longer a helper.* Sonia 66) and self-worth (*I do not want a machine to do what I am capable of doing.* Sheila, 69).

When surveying older adults' comfort levels with the presence of AI systems in different locations (home, workspace, classroom and car) on a 1 to 5 scale, about a third expressed very high comfort with home and car-based applications (32% and 31% respectively). In response to specific (yet location-agnostic) usages, participants had very clear preferences (Table 2).

As depicted in Table 2, participants for instance negatively reacted to usages implying machine-autonomy in contexts where the end user may not have self-determination (e.g. provide childcare/babysitting) and to usages that referred to emotion (e.g. detect/react to emotions to personalize experiences) or that alluded to machines with their own agency (e.g. have its own personality and perspectives). On the other hand, they responded positively to usages implying a clear power relationship structure, where machines are subordinates (e.g. remind me of tasks and meetings) and where the human is in full charge (e.g. ask before acting or automating). At the same time, participants were clearly willing and open to embrace and leverage an intelligent machine's recommendations and abilities, to prevent issues (e.g. know what I do to prevent mistakes) or even be challenged to avoid them (e.g. challenge wrong decisions).

Table 2. Usage clustering (N = 200; ages 60 + ; usage descriptions shortened).



Interestingly, a high number of 60 + participants responded very positively to the notion of leveraging artificially intelligent technologies and services to provide companionship, specifically in the context of elder care and care of other adults in need. In fact, 74% of respondents aged 60–69 (n = 100) labelled the companionship usage as "must have" or "nice to have" and 67.5% of respondents aged 70+ (n = 77) labelled the same usage as "must have" or "nice to have". Interviews clearly confirmed this specific data point, because, as Jane (65), who takes care of her aging mother, pointed out: *There are so many people that do not have ability or family to stay with or have around… people get ill faster because of that.*

Additionally, older adults that participated in the research had much to say in relation to specific usages that leveraged AI in home and autonomous vehicle (AV) contexts. From an AV context, I identified for instance a series of concerns and preferences:

- **Reliability** – *What about reliability? How does it keep up to date?* (Carla 66); *I need it to be as bulletproof as possible in a car that drives itself* (Dante, 69)
- **Societal impact** – *What is this contributing to with regard to society? what happens to drivers? will they be displaced?* (Carla, 66); *I think it's going to be hard… in the US people equate themselves to their cars* (Jim, 65)

- **Practicalities** – *How can it take into account all passengers preferences? I do not have something to hide but it could take away my individuality. Is the system transferred to the new car or you keep it in the car?* (Nadia, 65)
- **Purpose** – *That seems unnecessary with all the things that need to be done in the world* (Monica, 79); *I can see you enjoying more what is in and out of the car* (Sheila, 69); *Not driving to do something else… valuable time saving* (Dante, 69)
- **Ownership** – *I understand the fleet thing (…) I prefer to have my own vehicle* (Dante, 69); *I like the idea of carpooling better than being an individual owner with this type of car* (Jane, 65)
- **Control** – *If the tech is right, I'd consider it but I'd want to be able to take over when and if I want* (…) *for now I rather have a smart car that I drive but that makes smart decisions for me* (Dante, 69).

While these concerns and preferences are similar to those expressed in relation to AI in a home context, interviews not only provided depth of how such concerns would specifically apply to the home, but also highlighted what specific usages felt most convenient and welcome to them.

In the smart home context, participants articulated strong expectations for intelligent systems to be secure, and highlighted clear needs for hands-on evidence that such systems should be trusted. Brand, data storage location and, as previously articulated, a strong sense of predictability and control (*I still want to make my own choices. It's My Choice.* Carla, 66) all played key roles. Interesting, 60 + participants felt particularly attracted to usages focused on distance monitoring and that implied opportunities to save money, energy, time and frustrations (*What appeals to me more about the smart home is that it can help me do things from afar.* Jim, 65). From this perspective, they provided openness and excitement toward usages that would enable them to better maintain, upgrade, and protect their homes.

More in relation to their specific age bracket, older participants positively remarked on usages with focus on use of audio, light switches or projections to help them find items; activity monitoring to prevent or address accidents; tracking of valuable data with automatic inclusion to their health chart; and tracking of physical activity to detect early sign of disease. On the other hand, older participants provided rather negative responses to home usages focused on monitoring or facilitating kids' play or school activities without parental supervision.

When comparing the global survey's pre- and post-ratings for AV and smart home on a scale 1 to 5, data shows interesting differences. Table 3 outlines ratings shifts, by age groups, when we asked the same question on purchase likelihood (*how likely are you to consider purchasing something like that in future?)* twice: at start (based on existing knowledge) and end of the survey (based on knowledge accumulated through the research).

While we anticipated a decline in ratings in relation to age brackets, we somehow expected higher margins. Besides interesting granularity seen by comparing the 60–69 versus the 70+ bracket, there are interesting differences in how older adults responded to AV versus smart home and in their higher openness to embrace smart home systems, which have arguably a higher potential to be perceived as intrusive.

Table 3. Pre and Post ratings for AV and smart home (<50 Yrs. n = 328; 50–59 Yrs. n = 102; 60–69 Yrs. n = 100; >70 Yrs. n = 77)

	<50 (A) Pre:	<50 (A) Post:	50-59 (B) Pre:	50-59 (B) Post:	60-69 (C) Pre:	60-69 (C) Post:	>70 (D) Pre:	>70 (D) Post:
AV Likely to Purchase *(Would consider definitely/probably)*	78% [CD]	74% [CD]	75% [CD]	68% [D]	53%	57%	60%	45%
Smart Home Likely to Purchase *(Would consider definitely/probably)*	81% [BCD]	77% [D]	71% [D]	73% [D]	61%	69% [D]	55%	53%

4 Opportunities

As stated earlier, the hypothesis at the center of my research is that intelligent systems and technologies can help creating social connections and communities that leverage the skills and intellectual capital of homebound seniors, hence promoting their emotional, intellectual, social wellness (Table 3), and therefore addressing their overall wellness while lowering burden and costs. Insights outlined in Sect. 3, alongside ongoing research activities, are not only deepening and reiterating the reasons why (and how) intelligent systems should and could bring value to older adults, but also appear to support the offered hypothesis.

Given identified insights and existing literature, I propose that ambient computing opportunities for this population segment have ramifications in three entwined areas, all fundamental in the contest of future urban life and smart cities.

The first area, which I call *Community and Companionship*, is about leveraging distributed sensing, contextual understanding and Affective Computing [50] to equip older adults with opportunities to reach out, participate, belong, contribute – ultimately feeling connected, empowered and supported. This approach would help break down social isolation and increase older adults' sense of agencyand self-worth, while enabling them to contribute to society and their communities and promoting the sentiment that one's skills are recognized, cherished and valuable. Imagine an ambient system that:

- Enables sharing and co-management of resources with neighbors, through crowd-sourced local sensor data;
- Detects social isolation to provide recommendations and enable social and community interactions by integrating real-time emotion status, contextual details, local services, and knowledge of one's history and preferences;
- Detects emotional or social distress to prompt communication with loved ones;
- Uses humor and multi-modal techniques and tools to deflate argument or aid distressing social situations;
- Auto-records family memories when user-defined trigger words are used;
- Provides transparent user data in community living spaces; or
- Connectsone's skills and superpowers with local needs (for instance, an ex-mathematician may become the perfect tutor for a struggling teen that lives nearby).

The second area, *Wellness and Care*, focuses on leveraging ambient intelligence, context analytics and Affective Computing [50] to advance older adults' ability to self-care and be cared for, on their terms. This means using distributed intelligence to scaffold (vs direct) their ability to nurture their physical as well as emotional, social and intellectual wellness and independence. Imagine an ambient system that:

- Tracks everyday activity to detect early signs and symptoms of cognitive decline;
- Tracks diverse sets of valuable data and automatically adds it to one's health chart;
- Tracks activities and provides practical support such as health prompts, assistance calls, incident alerts or even service ordering;
- Leverages vision and voice activation to leverage and access private (e.g. in home or care facility) and public (e.g. transportation, shared facilities) services;
- Detects anomalies in everyday patterns to automate behaviors, recommendations and interventions that focus on nurturing and enabling personal wellness;
- Leverages multi-modal means (e.g. audio, visual, haptic, projected) to coach and provide instructions to self-care, address concerns or cope with distress; or
- Leverages voice, text, or visuals to promote cognitive wellness, delay cognitive deterioration or complement post-trauma therapy.

The third area, *Independency and Management*, focuses on leveraging ambient intelligence and natural user interfaces (UIs) to address key areas such as mobility, and life management. Here voice and other natural modalities can facilitate hands-free usages that are engaging and do not overwhelm less tech savvy users. Imagine, for instance, an ambient system that:

- Keeps track of and finds common objects such as keys, glasses or remote controls;
- Controls and manages one's property, providing alerts and instructions when maintenance or repairs are required, should be considered or are imminent;
- Understands who is giving commands and context to personalize actions;
- Adapts to feedback to refine future behaviors;
- Supports coordination and sense of control in diverse contexts and life stages;
- Offsets tasks through home automation and smart devices based on past behaviors or preferences;
- Provides context-appropriate reminders leveraging rich dialog capabilities;
- Contextually adjusts interaction and dialogue styles (e.g. adjusts speech calibration) to facilitate desired outcomes, based on real-time feedback, preference settings or tracking of behavioral patterns;
- Automatically provides to drivers or smart vehicles (including autonomous and shared) key details to facilitate or customize a transportation event.

5 Conclusive Remarks

In this paper, I shared insights from an ongoing research endeavor focused on the opportunities offered by distributed sensing and ambient computing in support of growing aging populations. Reflecting on data gathered to date, I proposed that ambient computing opportunities for this population segment have ramifications in three entwined areas, all fundamental in the contest of future urban life and smart cities: Community and Companionship; Wellness and Care; and Independency and Management.

Given the discussed context, it is clear that there is a global urgency to design and develop products, services, infrastructure and systems with a clear focus on and understanding of aging populations. As cities worldwide devise their smart city plans, many are focusing on addressing the needs and realities of this growing segment.

In the US for instance, following guidance from AARP's Network of Age-Friendly Communities [54], many cities launched comprehensive plans in 2017 with focus on *aging in place*. Equipping one to successfully age in place is not an easy task, as it requires focus on multiple, diverse needs (e.g. home, community or city supporting mobility) and barriers (e.g. reduced mobility). Equipping one to successfully age in place through ambient technologies comes with additional complications. If we just focus on health-related technologies, for instance, a number of challenges arise. Dishman, Matthews and Dunbar-Jacob [55] articulated this very well when they pointed at six key challenges: going beyond contemporary clinical and computing models (imagination); finding and prioritizing problems to pursue (identification); concept testing and refinement (iteration); deep dives on enabling technologies (infrastructure); exploration of human-machine interaction (interfaces); and testing whole systems in situ (integration).

Putting challenges aside and inspired by existing literature (e.g. [28, 29, 55–57]), this paper argues that ambient computing could play a key role in scaffolding *aging in place* in multiple contexts, from the home to the city. Moreover, insights from current research analysis show that older adults are open to embrace ambient computing in diverse contexts provided that ambient intelligent systems:

- Have clear purpose and no societal impact;
- Respect older adults' sense of and need for autonomy and equip them with a strong sense of predictability and control;
- Are designed to be and remain subordinates that ask before acting;
- Do not have autonomy, especially when the user does not have self-determination;
- Do not have their own personality, as this implies that they may have autonomy;
- Focus on assisting (versus controlling, deciding, or dictating) and providing recommendations to enable or prevent issues;
- Fully meet their stringent expectations in terms of privacy, security and reliability;
- Provide *helper* usages to save money, energy, time and frustrations, to maintain, upgrade, protect their assets, and to provide companionship to those in need; and
- Are clear on how emotion recognition is utilized, and why.

I argue that the need for intelligent products, services, infrastructure and systems for aging populations goes alongside the need for developers and designers that have the ability to shape ambient computing usages and technologies in ways that are respectful of and grounded in an understanding of older adults' everyday life – their practices, desires, expectations, and thresholds.

In a previous publication [51], I discussed ten guidelines for intelligent futures and offered them to designers and developers as practical people-centric recommendations to "spark a healthy debate on the processes used to develop intelligent systems and the agency that designers and developers have and should have in such processes". While I do not go in details on such guidelines in this paper, at a high level they are as follows:

1. Take a firm, unambiguous ethic stand – be a trusted brand;
2. Adopt the minimize intrusion mantra and a less-is-more approach;
3. Design socially trusted & trustworthy platforms;
4. Do not make systems human, but capable of helping humans;
5. Prioritize usages that matter – helper usages;
6. Design systems with consistent behaviors, yet design for serendipity;
7. Make people feel unique and empower their unique goals;
8. Create multiple and diverse educating tools;
9. Design on-boarding mechanisms that grow and evolve; and
10. Create families of products.

While these ten guidelines apply to any intelligent system for any end user type, I propose that, in light of research insights discussed earlier, some guidelines may be particularly critical when designing ambient systems for aging populations. Specifically, I suggest that five of the ten guidelines are key. While open to ambient computing opportunities, older adults shared stringent expectations in terms of privacy, security and reliability – because of this, I suggest great emphasis on guidelines 2 (*Adopt the minimize intrusion mantra and a less-is-more approach*) and 3 (*Design socially trusted & trustworthy platforms*). Secondly, this population segment clearly expressed a need for intelligent systems to respect their autonomy and to remain subordinates without personality, while equipping them with a strong sense of predictability and control – due to this, guidelines 4 (*Do not make systems human, but capable of helping human*) and 6 (*Design systems with consistent behaviors, yet design for serendipity*) are of key interest. Finally, specific discussions of what value and scenarios older adults wish to see, it is clear that they see value in practical directions, to help them minimize (cost, energy consumption, time loss or frustrations) and protect (as well as maintain and upgrade). Guideline 5 (*Prioritize usages that matter – helper usages*) is consequently another key parameter to consider. As mentioned, details and a discussion on each of the 5 recommended guidelines are available in a previous publication [51].

Regardless of guidelines and because of the specific target segment, designers and developers tackling *Aging in Place* contexts not only have the moral and ethical responsibility to engage with how intelligent systems and ambient computing futures are being (and will be) shaped: they must equip themselves with a deep understanding of older adults and with appreciation for the many nuances that categorize their realities. Only by deepening one's knowledge on older adults' everyday life – practices, desires, expectations, and thresholds – and by grounding design and development in such an understanding, truly meaningful and life-changing futures for this growing population segment will be achievable. Given this, I strongly advocate for adopting Participatory Design [1] approaches as a mean to ensure that intelligent and ambient technologies are developed **with** (instead of **for**) end users. A participatory approach will provide unbeatable opportunities to cater to the diverse, complex, nuanced realities of older adults' everyday life.

References

1. Schuler, D., Namioka, A.: Participatory Design: Principles and Practices. Erlbaum, Hillsdale (1993)
2. United Nations, Department of Economic and Social Affairs (UNDESA), Population Division: World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248. United Nations, New York (2017)
3. UNDESA Population Division: World Population Prospects: The 2015 Revision, DVD Edition. United Nations, New York (2015)
4. Farber, N., Shinkle, D., Lynott, J., Harrell, R.: AARP public policy institute and national conference of state legislatures research report. 2011–13. Washington, DC (2011)
5. Ornstein, K., et al.: Epidemiology of the Homebound Population in the United States. JAMA Int. Med. **175**(7), 1180–1186 (2015)
6. Steptoe, A., Shankar, A., Demakakos, P., Wardle, J.: Social isolation, loneliness, and all-cause mortality in older men and women. PNAS **110**(15), 5797–5801 (2013)
7. U.S. Census Bureau: 2010 Census Summary, Census of Population and Housing (2012)
8. Dykstra, P., Fokkema. T.: Relationships between parents and their adult children: a West European typology of late-life families. In: Ageing and Society, pp. 1–25. Cambridge University Press (2010)
9. Bengtson, V.L.: Beyond the nuclear family: the increasing importance of multigenerational bonds. J. Marriage Family **63**(1), 1–16 (2001)
10. Hagestad, G.: The aging society as a context for family life. Daedalus **115**(1), 119–139 (1998)
11. Matthews, S., Sun, R.: Incidence of four-generation family lineages: is timing of fertility or mortality a better explanation? J. Gerontol. Soc. Sci. **61B**(2), S99–S106 (2006)
12. Seltzer, J., et al.: Explaining family change and variation: challenges for family demographers. J. Marriage Family **67**(4), 908–925 (2005)
13. Esping-Andersen, G.: Social Foundations of Postindustrial Economies. Oxford University Press, Oxford (1999)
14. Blossfeld, H.: The New Role of Women: Family Formation in Modern Societies. Westview, Boulder (1995)
15. Blossfeld, H., Huinink, J.: Human capital investments or norms of role transition? How women's schooling and career affect the process of family formation. Am. J. Sociol. **97**(1), 143–168 (1991)
16. Hakim, C.: Work-Lifestyle Choices in the 21st Century: Preference Theory. Oxford University Press, Oxford (2000)
17. Hareven, T.: Historical perspectives on the family and aging. In Blieszner, R., Bedford, V. (eds.), Handbook of Aging and the Family, pp. 13–31, Greenwood, Westport CN, (1995)
18. Lewis, J.: The End of Marriage?. Individualism and Intimate Relations. Edward Elgar, Cheltenham (2001)
19. National Council on Aging: Nearly 7 Million Long-Distance Caregivers Make Work and Personal Sacrifices (2006)
20. AARP Public Policy Institute: Valuing the Invaluable: The Economic Value of Family Caregiving (2008)
21. National Alliance for Caregiving and the MetLife Mature Market Institute: Miles Away: The MetLife Study of Long-Distance Caregiving (2004)
22. National Alliance for Caregiving and AARP: Caregiving in the U.S. (2004)
23. Taylor, P., Parker, K., Patten, E., Motel, S.: The Sandwich Generation: Rising Financial Burdens for Middle-Aged Americans. Pew Res. Center, Washington DC (2013)

24. U.S. Census Bureau: American Community Survey (2011–2015) and American Housing Survey (2011)
25. Gurnon, E.: The staggering prices of long-term care (2017). https://www.forbes.com/sites/nextavenue/2017/09/26/the-staggering-prices-of-long-term-care-2017/#294d318f2ee2. Accessed 30 Jan 2019
26. Moeller, P.: Long-term care costs favor home-based treatment. https://money.usnews.com/money/blogs/the-best-life/2013/04/09/long-term-care-costs-favor-home-based-treatment. Accessed 30 Jan 2019
27. Caring, LLC: Technologies to reduce care costs and allow safe aging at home (2016)
28. Kayyali, B., Kimmel, Z., Van Kuiken, S.: Spurring the market for high-tech home health care. McKinsey (2011)
29. Deloitte: Using sensors technology to lower elder care costs. Wall Street Journal (2014)
30. Per Research Center: Internet and social media use by age. http://www.pewinternet.org/
31. U.S. Census Bureau and Census and Community Survey 1-year estimates: Educational Attainment by age and sex: 1970, 2010, and 2040 (1973, 2012, 2010)
32. Cargo Collective: The Amazings. https://cargocollective.com/cookie/The-Amazings. Accessed 30 Jan 2019
33. Thielking, M.: Baked fish, chair yoga, and life lessons: to learn to care for elderly, students move into retirement home. Stat News, 28 April (2017)
34. National Wellness Institute: Six dimension of wellness, https://www.nationalwellness.org/page/Six_Dimensions. Accessed 30 Jan 2019
35. Hettler, W.: The six dimension of wellness (1976), http://www.hettler.com/sixdimen.htm. Accessed 30 Jan 2019
36. Acree, L., et al.: Physical activity is related to quality of life in older adults. Health Q. Life Outcomes 4(37) (2006)
37. Fredrickson, B.L.: What good are positive emotions? Review of general psychology. J. Div. 1 Am. Psychol. Assoc. **2**(3), 300–319 (1998)
38. Fredrickson, B.L.: Cultivating Positive Emotions to Optimize Health and Well-Being. Prev. Treat. **3**(1), 1a (2000)
39. Stegeman, M.: The relations between health and wellbeing. Thesis, Twente University (2014)
40. Fredrickson, B., Joiner, T.: Positive emotions trigger upward spirals toward emotional well-being. Psychol. Sci. **13**(2), 172–175 (2002)
41. Clark, C.: Relations Between Social Support and Physical Health. http://www.personalityresearch.org/papers/clark.html. Accessed 30 Jan 2019
42. Rook, K., August, K., Sorkin, D.: Social network functions and health. In: Contrada, R., Baum, A. (eds.) The Handbook of Stress Science: Biology, Psychology, and Health. Springer, New York (2011)
43. Strout, K., Howard, E.: Five dimensions of wellness and predictors of cognitive health protection in community-dwelling older adults. J. Holist. Nurs. **33**(1), 6–18 (2015)
44. Zunzunegui, M., Alvarado, B., Del Ser, T., Otero, A.: Social networks, social integration, and social engagement determine cognitive decline in community-dwelling spanish older adults. J. Gerontol. Ser. B **58**(2), S93–S100 (2003)
45. Seeman, T., Lusignolo, T., Albert, M., Berkman, L.: Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. Health Psychol. **20**(4), 243–255 (2001)
46. Isen, A.: Positive affect, cognitive processes, and social behavior. Adv. Exp. Soc. Psychol. **20**, 203–253 (1987)
47. Abbey, A., Abramis, D., Caplan, R.: Effects of different sources of social support and social conflict on emotional well-being. Basic Appl. Soc. Psychol. **6**(2), 111–129 (1985)

48. Blazer, D.: Social support and mortality in an elderly population. Am. J. Epidemiol. **115**, 684–694 (1982)
49. Gunnarsdottir, K., Arribas-Ayllon, M.: Ambient intelligence: a narrative in search of users. Discussion Paper. Lancaster University (2011)
50. Picard, R.: Affective Computing. MIT Press, Cambridge (1997)
51. Loi, D.: Ten Guidelines for intelligent systems futures. In: FTC2018 Future Technologies Conference 2018, Vancouver BC, Canada (2018)
52. Loi, D., Raffa, G., Arslan Esme, A.: Design for affective intelligence. In: 7th Affective Computing and Intelligent Interaction conference, San Antonio, TX (2017)
53. Loi, D., Lodato, T., Wolf, C., Arar, R., Blomberg, J.: PD manifesto for AI futures. In: Proceedings of the 15th Participatory Design Conference2, Belgium (2018)
54. AARP: The AARP Network of Age-Friendly Communities. https://www.aarp.org/livable-communities/
55. Dishman, E., Matthews, J., Dunbar-Jacob, J.: Technologies for Adaptive Aging. National Academies Press, Washington (2004)
56. Kaye, J.: Making pervasive computing technology pervasive for health & wellness in aging. Pub. Policy Aging Report **27**(2), 53–61 (2017)
57. Kaye, J., et al.: Methodology for establishing a community-wide life laboratory for capturing unobtrusive and continuous remote activity and health data. J. Vis. Exp. **137**, e56942 (2018)