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ORIGINAL RESEARCH

# Analysis of human behavior in five healthcare centers for the development of new technologies and the improvement of life quality

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**Abstract**
The analysis of human behavior in everyday-life situations starts from the assumption that people who act on indoor devices too often are not entirely conscious of the functioning of these systems and cannot achieve well-being as intended, with non-negligible physical and cognitive efforts in weaker subjects. Is it possible to create the best comfort possible in an indoor environment with minimized activity by final users at any time? This study aims at understanding vulnerable human beings and their development through the lifespan, detecting their actions in order to design a smart indoor device able to provide seniors with the ideal comfort level, that cannot be achieved autonomously inside private and institutional environments. Five healthcare centers located in Italy took part in this project between 2016 and 2017 and a total of 75 field observations have been carried out in order to gather information about behaviors of people that live in. Findings highlighted that both men and women seem to act, physically react, and voice their discomfort more in relation to cold, and women appear extremely sensitive to the temperature and choose more carefully the right clothes based on indoor and outdoor temperatures. A huge gap seems to exist between the perceptions of senior people and those of their caregivers. This suggests that technological innovations should improve the quality of life of human beings through a process of customization to target response, especially in relation to vulnerable categories, and place themselves within an evolutionary framework all along the course of life.

**Keywords** Human behavior · Ambient Assisted Living (AAL) · Indoor Environmental Quality (IEQ) · Thermal-luminous comfort · Gender differences

## 1 Introduction

This study was developed within a Eureka Research Program funded by the Marche region, the University of Macerata, and the company MAC srl. The overall project included field observations in different indoor environments and healthcare facilities, in order to detect the different behaviors and physical reactions an end user has when feeling uncomfortable with the environment around him/her, in terms of temperature and lighting. In addition, interviews with health professionals were conducted and questionnaires to different age groups were administered for evaluating the validity of the observations in various indoor environments and gaining more information about observed people's perceptions.

The analysis of human behavior in real everyday-life situations starts from the assumption that people who act on *indoor devices* (related to temperature, lighting, sound, etc.), at home and in offices alike, all too often are not entirely conscious of the functioning of these systems and cannot achieve well-being as intended (Belda-Lois et al. 2010; Peffer et al. 2011). Actively interacting with a device in order to adapt technology to one's specific needs at a given time can result in non-negligible physical and cognitive efforts in weaker subjects. Precisely for this reason, such systems

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should "interpret" users' behaviors based on the latter's perceptions of thermal, luminous, acoustic, etc. comfort and/or discomfort in everyday-life indoor environments (Cook et al. 2009; Makonin et al. 2013).

Physical and environmental parameters such as temperature, relative humidity, acoustic quality, air quality, lighting and ventilation concur to defining *indoor environmental quality (IEQ)* (Brager and de Dear 1998; Buffoli et al. 2007; de Dear et al. 2013). These parameters are all interconnected with *comfort* being a combination of responses that the human brain provides to one's senses in relation to a set of environmental factors (physical environment and services) and individual physiological conditions, including but not limited to health, social relations, and economic status (Fransson et al. 2007). In its definition, a few factors play a crucial role in the occupants' perceptions: these are gender, age, outdoor climate conditions and season, behavioral adaptation, physiological adaptation, and psychological adaptation (or expectation), location and type of the building, and culture (Moschandreas and Chu 2002). The scope of IEQ lies in its impact on energy consumption in buildings and people's comfort, health and productivity. IEQ is deeply tied to cognitive functions, which considerably enhance wholesomeness of the building, and the notion of overall well-being, i.e., approval of sunlight and artificial lighting, room temperature (hot/cold) and air quality (dry/wet) (MacNaughton et al. 2017).

Occupants' behaviors are closely tied to multiple factors originating from various features at physical, social, cultural, psychological level among others (Lee et al. 2011, 2012). Relations between perceived indoor environment and occupants' comfort vary according to one's socio-cultural context, personal features (gender, age, and effort reward imbalance index) and characteristics of the building (e.g., type and location) (Frontczak and Wargocki 2011; Sakellaris et al. 2016). Links between the factors above can be extremely complex and have an impact on individuals in the short and long term (Babisch 2008; Fisk et al. 2007; Huizenga et al. 2001; Lewtas 2007). The term 'behavior' refers to any direct or indirect action implemented by a resident or occupant to achieve the best comfort possible according to his/her judgment in an indoor environment. The residents' behavior is not only a physical response, but also a psychological one in relation to environmental conditions (Veitch 2001). Understanding residents' behaviors can help foreseeing indoor energy consumption (Asadi et al. 2017). Habits can influence in their own right the residents' adaptive responses. Sometimes, inappropriate adaptive behaviors are put into place, which can influence the residents' subsequent coping with their environment (Liu et al. 2013). People feel happier and overall, more satisfied about the building they spend time in whenever they feel that they can exert a certain *degree of control over their environment*, with the notion of "control" pertaining to the perceptions of confidence self-efficacy and subjective well-being. Reduced capabilities or possibility to interact with one's environment, e.g., not being able to open a window, often triggers an increasing number of physiological reactions, including increased levels of temperature and skin hydration (Fountain et al. 1996; Schweiker et al. 2013).

People with special needs, most notably senior people and people with disabilities, can benefit from an aptly structured home environment. An assisted living space aims at improving life for everyone on the long-term. It does so (a) providing devices that can make life easier and empower individuals to remain relatively autonomous; (b) enhancing the capabilities of users with special needs regarding their integration into work and community life; (c) compensating for functional limitations, be it mobility, sight, sound, intelligence or speech and language impairment, and facilitating home care.

The theoretical framework that underpins it is known as *lifespan psychology*, whereby "lifespan" refers to an individual's cycle of development over time, as well as his/her family's and his/her surrounding environment's respective developments (Baltes 1978, 1987).

Lifespan psychology puts forward *a vision of humans as ever-changing beings*, both in what is referred to as the age of development and during later stages. It investigates changes occurring all along one's life course, from birth to death (Elder 1998). It ushered in *a new vision of older people and ageing*, moving away from an imagery of decay, decline and loss to embrace old age as a phase in which re-structuring and change are still possible. During senior age, psychological decline and progress go hand in hand: "precisely the conditions of loss and constriction can push for new forward-looking strategies and loss-control strategies to be learned" (Canestrari and Godino 1985; Castelli and Sbattella 2008). The works of Baltes et al. (1998) were based on the observation of various cases of older people within society. It is shown that cognitive decline is not inescapable, but rather linked to a set of living conditions at domestic, social, and professional level. Based on these results and acknowledging that individual and social culture can compensate for reduced biological functions, Baltes and Baltes (1990) promoted a positive culture of old age: ageing is regarded as a heterogeneous process (both within single people and across people of the same age) implying decay of fluid intelligence (i.e., speed of perception, memory capacity, problem-solving) in which, conversely, crystallized intelligence-based skills (including cultural intelligence, language and social skills based on experience and expertise) can be enhanced all along one's lifespan. Older people consequently act by making use of mechanisms of *selective optimization with compensation*, i.e., they select where to invest new energies to discover or investigate a new domain, striving for self-improvement, and counterbalance some skill loss by re-adjusting some of their goals, using already acquired and consolidated strategies and looking for new resources. Cristini

et al. (2012) pointed out that this narrative does not reject age-induced involutions, but rather testifies to the presence of enhancement and upgrades, also in senior people experiencing serious physical and mental decline.

Considering this scenario, the overall project attempted to answer the following research question: is it possible to create the best comfort possible (at thermal, luminous, and acoustic level) in an indoor environment with minimized activity by final users at any time? The present study aims at understanding vulnerable human beings and their development through the lifespan, detecting and assessing their actions and physical reactions in order to make the human–machine relation as simple and effective as possible so that users can feel at ease and can attain a high level of comfort in their everyday-life indoor environments. The goal is to use the collected data to design a flexible, smart, and multifunctional indoor system able to provide people with special needs with the ideal comfort level, that for a few reasons cannot be achieved autonomously inside private and institutional environments.

## 2 The healthcare facilities

Five healthcare centers—more specifically, nursing homes and rehabilitation centers—located in the Italian region Marche took part in this project. Selection took place based on geographical proximity and availability to join the project.

Table 1 lists the healthcare centers that participated in the present research, together with their respective location, healthcare categories and number of residents.

## 3 Data collection

The analysis of human behavior is achieved by using naturalistic observation in daily contexts, where human actions normally occur, and the researcher exerts a minimum level of control on his/her object of study. Naturalistic observation is defined as a "systematic description of events, behaviors and artifacts" within an investigated social context (Marshall and Rossman 1995). Over the course of field observations, a strive for systematic assessment of a few features of human behaviors in their natural environment, i.e., daily real-life situations, in the least intrusive way possible. Non-intrusiveness implies that observers remain neutral and do not manipulate variables to pursue their own interests.

At the early stage of observations, knowing the environments through explorative tours was important: the researcher was able to get to know the context that was about to be observed. The first meeting in all facilities helped to identify reference professionals and to negotiate times and places of observations based on each facility's management and specific times of the day in which care and treatment procedures are administered.

To detect several behaviors (directed towards oneself and one's environment), physical reactions and occurrences of verbal communication that can be interpreted as a display of some sort of *discomfort at thermal (hot/cold) and/or luminous (lighting) level* perceived by senior residents, two checklists have been devised ad hoc. One on the matter of temperature and another on the topic of lighting. The first one is made up of two lists of potential behaviors, the first list on the sensation of heat and the second on the sensation of cold. The first part of the second checklist pertained to insufficient illumination, the second one to excessive illumination.

In addition to the detected behaviors, data and place of observations, time of the day, age and gender of monitored subjects as well as indoor and outdoor temperatures of the environments were all recorded.

Inside the healthcare centers, a total of *75 field observations* (15 for each center) have been carried out in relation to mainly temperature and lighting. Observations took place from October 26th, 2016 to July 4th, 2017, spanning all four seasons.

**Table 1** Healthcare facilities joining the project

| Name | Town | Healthcare category | N. of residents |
|---|---|---|---|
| I.R.C.E.R. Foundation | Recanati | Care home<br>Nursing home | 65 |
| Villa Letizia | Civitanova Marche | Care home<br>Temporary relief facility | 57 |
| Santo Stefano | Porto Potenza Picena | Long-term care facility | 40 |
| | | A3 ward | 33 |
| Casa Hermes | Loreto | Care home<br>Nursing home | 72 |
| Casa di Ospitalità | Castelraimondo | Care home<br>Nursing home<br>Day care center | 40 |

## 4 Data analysis

A descriptive analysis of the 75 observation sheets collected in five healthcare centers has been carried out.

### 4.1 Observations at I.R.C.E.R. Foundation—Assunta of Recanati

From October 26th, 2016 to February 15th 2017, 15 observations took place at this facility. The residents sample consists of 0 male and 15 female subjects. The average age of the subjects displaying any of the detected behaviors is 89.3 years.

Table 2 shows both heat- and cold-related behaviors recorded at I.R.C.E.R Foundation sorted by gender, with their respective frequencies.

Only actions directed towards oneself (as opposed to one's environment) have been recorded, as displayed by women only. The single most frequent heat-related behavior is taking off one's clothes (5), whereas putting on one's clothes ranks highest among cold-related behaviors (3). Two female frequencies have been detected inside the canteen (#14 and #15), where indoor temperature was high; it is however unclear whether the two women in question pulled up their sweater sleeves because of their perception of heat or rather because they were simply about to start eating.

This is the only facility where the largest number of behaviors has been recorded in relation to heat, although observations took place in the colder part of the year (autumn/winter). Probably, the heater is set at a rather high temperature inside this facility, and the temperature is perceived as hot by residents themselves. Additionally, the least variety of behaviors among all facilities has been recorded here.

**Table 2** Frequencies sorted by gender of behaviors detected at I.R.C.E.R. Foundation

| Behaviors | M | F | Total |
|---|---|---|---|
| Heat | | | |
| Taking off one's clothes | 0 | 5 | 5 |
| Pulling up one's sleeves | 0 | 3 | 3 |
| Wiping off one's sweat with hand/handkerchief | 0 | 1 | 1 |
| Subtotal | 0 | 9 | 9 |
| Cold | | | |
| Putting on ones' clothes (also on shoulders only) | 0 | 3 | 3 |
| Pulling down one's jumper sleeves | 0 | 2 | 2 |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 1 | 1 |
| Subtotal | 0 | 6 | 6 |
| Total | 0 | 15 | 15 |

### 4.2 Observations at Villa Letizia

15 observations took place at this facility from January 24th to March 3rd, 2017. The residents sample consists of 2 male and 13 female subjects. The average age of the subjects who displayed any of the detected behaviors is 83.9 years.

Table 3 shows the behaviors recorded at Villa Letizia sorted by gender, with their respective frequencies.

Occurrences of verbal communication, actions directed towards oneself and physical reactions have been detected, most of them being displayed by women. The only three male behaviors are "Unbuttoning/unzipping one's coat", "Sipping from a hot drink" and "Getting closer to the heater (also on wheelchair)". The single most frequent heat-related behavior is voicing one's perception of heat (3), whereas the single most frequent cold-related behavior is rubbing/cleaning one's nose with a handkerchief or tissue (2). The most frequent behavior related to the lighting is putting on one's spectacles (1). Two cold-related physical reactions have been detected, namely sneezing and coughing. One of

**Table 3** Frequencies sorted by gender of behaviors detected at Villa Letizia

| Behaviors | M | F | Total |
|---|---|---|---|
| Heat | | | |
| Verbal communication occurring | 0 | 3 | 3 |
| Taking off one's clothes | 0 | 2 | 2 |
| Unbuttoning/unzipping one's coat | 1 | 0 | 1 |
| Taking off lap blanket | 0 | 1 | 1 |
| Subtotal | 1 | 6 | 7 |
| Cold | | | |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 2 | 2 |
| Putting on ones' clothes (also on one's shoulders only) | 0 | 1 | 1 |
| Sipping from a hot drink | 1 | 0 | 1 |
| Getting closer to the heater (also on wheelchair) | 1 | 0 | 1 |
| Verbal communication occurring | 0 | 1 | 1 |
| Sneezing | 0 | 1 | 1 |
| Coughing | 0 | 1 | 1 |
| Subtotal | 2 | 6 | 8 |
| Lighting | | | |
| Putting on one's spectacles | 0 | 1 | 1 |
| Subtotal | 0 | 1 | 1 |
| Various | | | |
| Wiping off/rubbing one's eyes with handkerchief/hands | 0 | 1 | 1 |
| Subtotal | 0 | 1 | 1 |
| Total | 3 | 14 | 17 |

the detected behaviors does not fit into either the temperature or the lighting category, namely cleaning/rubbing one's eyes with a tissue/one's hands.

Table 4 lists the heat- and cold-related sentences uttered by the residents of Villa Letizia during observations.

A total of 4 female occurrences of verbal communication have been detected, 3 in relation to heat and 1 in relation to cold. They have been divided into impersonal statements, those using or implying the pronoun 'it', and first-person statements. Interestingly, in the middle of winter, three women voiced their perception of heat, probably because the indoor heating system is set at a rather high temperature with consequences in the residents' perceptions. It is important to stress that for observation #11 as the senior patient exclaimed "It's cold" and put her blanket on her shoulders, a healthcare worker argued: "It's not cold at all! It's hot!". As this episode indicates, *perceptions differ greatly between senior people and their caregivers*.

### 4.3 Observations at "Santo Stefano" rehabilitation Institute

From February 1st to March 30th, 2017, 15 observations took place at this facility. The residents sample consists of 3 male and 12 female subjects. The average age of all people displaying any of the detected behaviors is 81.3 years.

Table 5 shows the behaviors recorded at "Santo Stefano" sorted by gender, with their respective frequencies.

At "Santo Stefano", the lowest average age among all facilities has been recorded, probably since rehabilitation wards accommodate patients of all age groups, from young adults to older seniors. Actions directed towards oneself, occurrences of verbal communication and physical reactions have been recorded, most of them being displayed by female subjects. One of the wards where observations took place accommodates mostly male patients; nevertheless, the only three behaviors displayed by male subjects are "Unbuttoning one's shirt/sweater", "Coughing" and "Putting on ones' clothes". The most frequent heat-related behaviors are taking off one's clothes (2) and fanning oneself with one's hand/piece of paper (2). The most frequent among cold-related behaviors is coughing (5). Two of the detected behaviors do not fit into the temperature category, namely yawning and snoring. Compared to all other facilities, the greatest variety of behaviors has been recorded here, probably also because two different wards have been taken into account.

Two significant episodes occurred during observations: (1) one social educator said to a patient while touching him: "You're wearing your shirt under your jumper; don't you feel hot?!". The patient answered back with emphasis: "No!". This episode suggests how *senior patients' perceptions can differ from those of their caregivers*; (2) one physiotherapist asked a patient who had suffered from a

**Table 5** Frequencies sorted by gender of behaviors detected at "Santo Stefano"

| Behaviors | M | F | Total |
|---|---|---|---|
| Heat | | | |
| Taking off one's clothes | 0 | 2 | 2 |
| Fanning oneself with one's hand/piece of paper | 0 | 2 | 2 |
| Unbuttoning one's shirt/sweater | 1 | 0 | 1 |
| Pulling one's collar | 0 | 1 | 1 |
| Pulling up one's sleeves | 0 | 1 | 1 |
| Verbal communication occurring | 0 | 1 | 1 |
| Subtotal | 1 | 7 | 8 |
| Cold | | | |
| Coughing | 1 | 4 | 5 |
| Sneezing | 0 | 1 | 1 |
| Putting on ones' clothes (also on one's shoulders only) | 1 | 0 | 1 |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 1 | 1 |
| Getting closer to the heater (also on wheelchair) | 0 | 1 | 1 |
| Subtotal | 2 | 7 | 9 |
| Various | | | |
| Yawning | 0 | 2 | 2 |
| Snoring | 0 | 1 | 1 |
| Subtotal | 0 | 3 | 3 |
| Total | 3 | 17 | 20 |

**Table 4** Villa Letizia: sentences uttered in relation to heat and cold

| Category | Frequencies | N. of observation | Quote |
|---|---|---|---|
| Heat | | | |
| Impersonal statements | 2 | 12 | "Oggi è caldo, ieri era freddo, c'avevo questo, e questo, e la sciarpa" [It is hot today, yesterday it was cold, I had this and this on, and my scarf too] (resident pointing at her clothes) |
| | | 15 | "Madonna, che caldo!" [My God, it's so hot!] |
| First-person statements | 1 | 1 | "Sento caldo!" [I am feeling hot!] |
| Cold | | | |
| Impersonal statements | 1 | 11 | "È freddo" [It's cold] |

**Table 6** "Santo Stefano": sentence uttered in relation to heat

| Category | Frequencies | N. of observation | Quote |
|---|---|---|---|
| Heat | | | |
| First-person statements | 1 | 3 | "Sento caldo oggi" [I'm feeling hot today] |

**Table 7** Frequencies sorted by gender of behaviors detected at Casa Hermes

| Behaviors | M | F | Total |
|---|---|---|---|
| Cold | | | |
| Coughing | 0 | 6 | 6 |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 4 | 4 |
| Verbal communication occurring | 0 | 2 | 2 |
| Getting away from the door/window | 0 | 1 | 1 |
| Subtotal | 0 | 13 | 13 |
| Lighting | | | |
| Putting on one's spectacles | 0 | 1 | 1 |
| Subtotal | 0 | 1 | 1 |
| Various | | | |
| Rubbing/scratching one's chest | 0 | 1 | 1 |
| Yawning | 0 | 1 | 1 |
| Subtotal | 0 | 2 | 2 |
| Total | 0 | 16 | 16 |

stroke: "Do you feel hot? Do you feel cold?". The patient answered no to both questions. This episode suggests how comfort and/or discomfort in those patients whose health is more seriously affected is for the most part filtered by healthcare workers' questions and own perceptions.

Table 6 shows the single sentence uttered by one resident at "Santo Stefano" in relation to her perception of heat as recorded during observations.

One heat-related occurrence of verbal communication by one female resident has been recorded. The woman in question had suffered from a stroke five months prior to this observation, and had difficulties speaking. This episode seems to suggest that *communicating one's need prevails over one person's mental and physical difficulties*.

### 4.4 Observations at Casa Hermes

From March 2nd to June 22nd, 2017, 15 observations were carried out at this faculty. The residents sample consists of 0 male and 15 female subjects. The average age of residents displaying any of the detected behaviors is 85.8 years.

Table 7 shows the behaviors recorded at Casa Hermes sorted by gender, with their respective frequencies.

Casa Hermes has a larger number of female residents compared to their male counterparts. No heat-related actions have been recorded, even though observations took place in the warmer time of the year (spring/summer). A possible explanation is that this facility is equipped with air conditioning systems. Overall, physical reactions, actions directed towards oneself and occurrences of verbal communication have been detected, most being displayed by female subjects. One cold-related physical reaction has been recorded, namely coughing (6), two actions directed towards oneself, namely "Rubbing/cleaning one's nose with a handkerchief/tissue" (4) and "Moving away from the door/window" (1) and finally two occurrences of verbal communication. In this regard, scholarly sources indicate that the thermoregulatory system is altered with age. Senior people generally experience a decrease in their own body temperature without even being aware of it, as their bodies are not capable of boosting heat production and reducing dispersion. More in details, their capability of generating heat after a decrease of lean body max is compromised. Reduced mobility, unhealthy eating habits, cold-induced chills and reduced vasoconstriction are all consequences (Bragagni et al. 2012). One behavior in relation to lighting has been detected, namely putting on ones' spectacles. Two behaviors do not fit into either the temperature category nor the lighting category, namely rubbing/scratching one's upper body and yawning.

Table 8 lists those remarks uttered by residents of Casa Hermes in relation to cold as detected during observations.

**Table 8** Casa Hermes: sentences uttered in relation to cold

| Category | Frequencies | N. of observation | Quote |
|---|---|---|---|
| Cold | | | |
| Impersonal statements | 1 | 12 | "Qui c'è corrente" [There's a draft here!] |
| Action-related sentences | 1 | 13 | "Mi chiudi questa finestra che sono piena di raffreddore?! [Will you close this window here? 'cause I've got a bad cold!] (to a healthcare worker) |

Two occurrences of cold-related verbal communication by female subjects have been detected: one is an impersonal statement, while the other is an action-related sentence. Impersonal statements use or imply the pronoun 'it', whereas action-related sentences refer to actions that need to be implemented by the speaker him/herself or someone else in relation to the temperature.

### 4.5 Observations at Casa di Ospitalità

From March 7th to July 4th, 2017, 15 observations were carried out at this facility. The residents sample consists of 2 male and 13 female subjects. The average age of senior residents displaying any of the detected behaviors is 89.4 years.

Table 9 shows the behaviors recorded at Casa di Ospitalità sorted by gender, with their respective frequencies.

At Casa di Ospitalità there are more female residents than male residents. Only occurrences of verbal communication and actions directed towards oneself have been detected, most of them by female subjects. The only three behaviors displayed by men are "Touching one's face", "Verbal communication occurring" (in relation to cold) and "Cleaning/rubbing one's eyes with tissue/one's hands". Verbal communication occurrences are more frequent than any other behaviors, in relation to heat (2), cold (7) and lighting (1). The largest number of verbal communication occurrences among all facilities has been recorded here (10), and also the average age of monitored residents is the highest. One of the detected behaviors does not fit into either the temperature or lighting category, namely cleaning or rubbing one's eyes with a tissue or with one's hands. As concerns observation #11, it is questionable whether touching one's face is mainly due to the senior person's perception of heat or any other factor.

**Table 9** Frequencies sorted by gender of behaviors detected at Casa di Ospitalità

| Behaviors | M | F | Total |
|---|---|---|---|
| Heat | | | |
| Verbal communication occurring | 0 | 2 | 2 |
| Pulling up one's trouser legs | 0 | 1 | 1 |
| Touching one's face | 1 | 0 | 1 |
| Subtotal | 1 | 3 | 4 |
| Cold | | | |
| Verbal communication occurring | 1 | 6 | 7 |
| Putting on ones' clothes (also on one's shoulders only) | 0 | 1 | 1 |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 1 | 1 |
| Subtotal | 1 | 8 | 9 |
| Lighting | | | |
| Verbal communication occurring | 0 | 1 | 1 |
| Subtotal | 0 | 1 | 1 |
| Various | | | |
| Wiping off/rubbing one's eyes with handkerchief/hands | 1 | 0 | 1 |
| Subtotal | 1 | 0 | 1 |
| Total | 3 | 12 | 15 |

Table 10 shows the sentences uttered in relation to temperature and lighting by residents of Casa di Ospitalità as recorded during observations.

Two heat-related occurrences of verbal communication have been detected, while 7 of them have been detected in relation to cold, and 1 in relation to lighting. They have been divided into impersonal statements and action-related sentences. Impersonal statements use or imply the pronoun 'it', whereas action-related sentences contain references to actions that need to be implemented by the speaker him/herself or by somebody else. Remark #1 is the only cold-related occurrence of verbal communication by a man, whereas remark #6 has been made by a 100-year-old woman who, despite her old age, felt the need to voice her perception of cold. Finally, it is interesting to notice that all 7 cold-related occurrences verbal communication took place during the warmer time of the year (spring/summer) and inside a healthcare facility equipped with ceiling fans. Here again, *impaired thermoregulation linked with advanced age had an impact on the residents' perception of temperature*.

### 4.6 Analysis of the overall data

Table 11 is an overview of all behaviors detected in the five healthcare facilities and related to heat, cold, lighting, and various factors. Their respective frequencies have been sorted by gender and weighted since the number of women (68) is much higher than that of men (7).

The percentages were calculated based on the total of women and men respectively, and not on the total behaviors. The comparison between males and females would be of little significance, since the number of men is extremely low and the difference between the number of men and that of women is remarkably high.

The detected behaviors amount to a total of 83. Female residents are much more than their male counterparts inside these healthcare facilities and most detected behaviors are female ones (74). Actions directed towards oneself are more frequent than physical reactions and occurrences of verbal communication. *No action directed towards one's environment has been detected*. The single heat-related behavior with the highest frequency is taking off one's clothes (9/13.2%), with coughing ranking highest among cold-related behaviors (12). In relation to lighting, putting on one's spectacles ranks highest (2/2.9%), whereas the category "various" is dominated by yawning (3/4.4%). *Coughing* (12) is the single reaction with the highest frequency. Most occurrences of verbal communication are

**Table 10** Casa di Ospitalità: sentences uttered in relation to temperature and lighting

| Category | Frequencies | N. of observation | Quote |
|---|---|---|---|
| Heat | | | |
| Impersonal statements | 1 | 5 | "Qui c'è caldo adesso" [It is hot in here right now] |
| Action-related sentences | 1 | 10 | "Mi sono spogliata, perché era caldo. Adesso sì che si sta bene!" [I took my clothes off 'cause it was hot. Now it feels much better!] (to a healthcare worker) |
| Cold | | | |
| Impersonal statements | 4 | 2 | "Qua dentro è freddo, io c'ho pure la maglia leggera" [This place is cold, and I'm wearing a light jumper too] |
| | | 6 | "È freddo, eh!" [It's cold, isn't it?] |
| | | 9 | "È freddo qua dentro!" [This place is cold!] |
| | | 15 | "C'è corrente!" [There's an air draft!] |
| Action-related sentences | 3 | 1 | "Chiudi la porta che è freddo!" [Close the door, it is cold!] (to a healthcare worker) |
| | | 8 | "Chiudi questa porta! Senti quanta aria c'è!" [Close that door! Can't you feel the drafts?] (to a healthcare worker) |
| | | 14 | "Chiudi la porta, per favore!" [Close the door, please] (to a healthcare worker) |
| Lighting | | | |
| Action-related sentences | 1 | 12 | "Mi sposti che c'ho tutta la luce negli occhi?!" [Will you get me away from here? The light's blinding me!] (to a healthcare worker) |

related to the sensation of cold (10); among these, there is also one male occurrence. *Third-person statements* display the highest frequency compared to other categories, in relation to both heat (3) and cold (6). As shown in chart 11, *both men and women seem to act and react to and voice their perceptions more in relation to cold than heat (45).* Inside these healthcare facilities, cold-related behaviors are more than heat-related ones, the ratio being 4 to 1. The one and only facility where most detected behaviors are related to heat is I.R.C.E.R. Foundation even though observations took place during the colder part of the year (autumn/winter). It is safe to say that the indoor heating system there is probably set at an extremely high temperature, as reflected in the perceptions of senior residents. Moreover, at I.R.C.E.R. Foundation the lower variety of behaviors has been recorded, with the larger variety being at "Santo Stefano". At "Santo Stefano" the largest number of behaviors has been detected compared to all other healthcare facilities (20), presumably because two different wards have been monitored. The highest average age among residents has been recorded at Casa di Ospitalità (89.4 years), while the lowest has been recorded at "Santo Stefano" (81.3 years), probably since generally people from all age groups enter rehabilitation centers like this one, from young adult to older seniors.

## 5 Discussion

The present paper outlined data resulting from field observations about ageing which took place in five healthcare facilities (nursing homes and rehabilitation centers) in the Marche region (Italy), in order to detect behaviors (directed towards oneself and one's environment), physical reactions and occurrences of verbal communication that can be interpreted as display of any discomfort at thermal (hot/cold) and luminous level as perceived by senior residents inside these facilities. The following step was a descriptive analysis of all behaviors detected in the five healthcare facilities in relation to both temperature and lighting, with attention given also to gender differences. Additionally, the sentences uttered by the subjects in relation to their perception of heat/cold/lighting were recorded during observations and later analyzed. These have been divided into impersonal statements, first-person statements, and action-related sentences. Impersonal statements display the highest frequency compared to all other categories, both in relation to heat (3) and cold (6). Lastly, a global analysis of all behaviors detected in all five facilities in relation to temperature, lighting and other categories followed, with attention given to gender too.

In these facilities the number of female residents is much larger than that of men and more female behaviors have been recorded (74). *Actions directed towards oneself are more frequent than physical reactions and occurrences of verbal communication, and no action directed towards one's environment has been recorded.* The single heat-related behavior with the highest frequency is taking off one's clothes (9/13.2%), while the single cold-related behavior with the highest frequency is coughing (12). The single most frequently detected behavior in relation to lighting is putting on one's spectacles (2/2.9%), whereas the category "various" is dominated by yawning (3/4.4%). Coughing (12) is the single

**Table 11** Overview of all detected behaviors: frequencies are sorted by gender

| Healthcare facilities | IRCER Foundation | | Villa Letizia | | Santo Stefano | | Casa Hermes | | Casa Ospitalità | | Tot M | Weighted value | % | Tot F | Weighted value | % | Tot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F | | | | | | | |
| Behaviors | | | | | | | | | | | | | | | | | |
| Heat | | | | | | | | | | | | | | | | | |
| Taking off one's clothes | 0 | 5 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0.132 | 13.2 | 9 |
| Verbal communication occurring | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 6 | 0.088 | 8.8 | 6 |
| Pulling up one's sleeves | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.059 | 5.9 | 4 |
| Fanning oneself with one's hand/piece of paper | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.029 | 2.9 | 2 |
| Wiping off one's sweat with hand/handkerchief | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Unbuttoning/unzipping one's coat | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.143 | 14.3 | 0 | 0 | 0 | 1 |
| Taking off lap blanket | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Unbuttoning one's shirt/sweater | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.143 | 14.3 | 0 | 0 | 0 | 1 |
| Pulling one's collar | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Pulling up one's trouser legs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Touching one's face | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.143 | 14.3 | 0 | 0 | 0 | 1 |
| Subtotal | 0 | 9 | 1 | 6 | 1 | 7 | 0 | 0 | 1 | 3 | 3 | 0.429 | 42.9 | 25 | 0.368 | 36.8 | 28 |
| Cold | | | | | | | | | | | | | | | | | |
| Coughing | 0 | 0 | 0 | 1 | 1 | 4 | 0 | 6 | 0 | 0 | 1 | 0.143 | 14.3 | 11 | 0.162 | 16.2 | 12 |
| Verbal communication occurring | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 6 | 1 | 0.143 | 14.3 | 9 | 0.132 | 13.2 | 10 |
| Rubbing/cleaning one's nose with handkerchief/tissue | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 9 | 0.132 | 13.2 | 9 |
| Putting on ones' clothes (also on shoulders only) | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0.143 | 14.3 | 5 | 0.073 | 7.3 | 6 |
| Pulling down one's jumper sleeves | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.029 | 2.9 | 2 |
| Getting closer to the heater (also on wheelchair) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.143 | 14.3 | 1 | 0.015 | 1.5 | 2 |
| Sneezing | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.029 | 2.9 | 2 |
| Sipping from a hot drink | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.143 | 14.3 | 0 | 0 | 0 | 1 |
| Getting away from the door/window | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Subtotal | 0 | 6 | 2 | 6 | 2 | 7 | 0 | 13 | 1 | 8 | 5 | 0.715 | 71.5 | 40 | 0.587 | 58.7 | 45 |
| Lighting | | | | | | | | | | | | | | | | | |
| Putting on one's spectacles | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0.029 | 2.9 | 2 |
| Verbal communication occurring | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| Subtotal | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0.044 | 4.4 | 3 |
| Various | | | | | | | | | | | | | | | | | |
| Yawning | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0.044 | 4.4 | 3 |
| Wiping off/rubbing one's eyes with handkerchief/hands | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.143 | 14.3 | 1 | 0.015 | 1.5 | 2 |
| Snoring | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |

**Table 11** (continued)

| Healthcare facilities | | IRCER Foundation | | Villa Letizia | | Santo Stefano | | Casa Hermes | | Casa Ospitalità | | Tot M | Weighted value | % | Tot F | Weighted value | % | Tot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | F | M | F | M | F | M | F | M | F | | | | | | | |
| | Rubbing/scratching one's upper body | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.015 | 1.5 | 1 |
| | Subtotal | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 2 | 1 | 0 | 1 | 0.143 | 14.3 | 6 | 0.089 | 8.9 | 7 |
| | Total | 0 | 15 | 3 | 14 | 3 | 17 | 0 | 16 | 3 | 12 | 9 | – | – | 74 | – | – | 83 |

reaction with the highest frequency. Most occurrences of verbal communication are linked to the sensation of cold (10); they include a male occurrence. Moreover, *both men and women seem to act, physically react, and voice their discomfort more in relation to cold (45).* Women additionally seem to act much more than men, they appear extremely sensitive to temperature and choose more carefully the right clothes based on indoor and outdoor temperatures (Choi et al. 2003; Jeong 1999; Schellen et al. 2013).

Scholarly sources (Franceschi et al. 2011; Smolander 2002; Stocks et al. 2004) suggested that older people display a reduced thermoregulatory capability, which is linked—together with additional changes of one's body composition—to a decrease of the total of water in the human body. Body temperature is therefore lower in senior people, *their perception of cold being one symptom of ageing, especially in bedridden and non-self-sufficient subjects*. Also, in relation to temperature, men and women dress differently. Women have a lower metabolic rate than men during sedentary activities, and their regulatory hormones affect their reactions about their thermal comfort, thermoregulation, and thermogenic thresholds, as women have different hormone levels as compared to men (Golja et al. 2003; Kim et al. 2013). Additionally, as the outcomes of other studies (Choi et al. 2010; Karjalainen 2007, 2012; Kcomt Ché et al. 2010; Parsons 2002; Zalejska-Jonsson and Wilhelmsson 2013) carried out in various indoor environments indicate, *women are less satisfied with room temperatures and generally prefer higher temperatures than men, with discomfort in relation to both heat and cold being reported much more frequently in women than men*.

Based on observations, the behaviors displayed by senior people residing in healthcare facilities seem to indicate their discomfort in relation to both temperature and lighting. *A huge gap seems to exist between the perceptions of senior people and those of the healthcare workers that take care of them*. Two occurrences of verbal communication, namely by the woman who suffered from a stroke and the 100-year-old woman, respectively, indicate that the need to communicate one's need transcends physical and mental conditions and age alike. This shows that also those seniors whose health is most heavily affected try—insofar as possible—to continue voicing their discomfort.

Subsequent data analysis provided for an insight into frequent displays of thermal and luminous discomfort experienced by senior people in their everyday-life environments, that they are not always able to communicate to the healthcare staff who takes care of them. These data could be used to plan devices that can effectively ensure comfort and improve the quality of life of individuals, including more vulnerable categories such as non-self-sufficient senior people. In this regard, while planning these devices, it will be crucial to consider what a number of scholarly sources

(Baldewijns et al. 2013; Coughlin et al. 2007; Demiris et al. 2004; Dohr et al. 2010; Kleinberger et al. 2007; Krafft and Coskun 2009; Losardo 2014; Hamal Mishra 2015; Mohammadi 2010; Motta 2015; Portet et al. 2013; Sun et al. 2009) cited as the most important characteristics of smart devices for senior people: these are reliability, user-friendliness, emergency detection, reduced user's input, low maintenance costs, low invasiveness (privacy) and voice interface technology (audio input). Their underlying needs are safety and proactivity, health monitoring and user's confidence. *Acceptance* by senior users is reportedly a key factor in integrating new technologies into already existing houses. The success of new technological devices lies not only in the tools per se, but also in the assistance and training that is provided (Stara et al. 2020, 2021). This feeds into the notion of *Ageing in Place*, by which senior people can exert control over their own environment and daily activities to improve their perceived autonomy, health, wellbeing, and dignity.

Investigation of indoor everyday-life environments took place with the aim of providing a picture of reality as accurate as possible, with particular focus on population groups that are normally regarded as more vulnerable.

Despite the benefits of collecting and analyzing data about real behaviors in everyday life and using the information obtained for the design of smart devices, the gender imbalance could be seen as a limitation that do not allow for the generalization of results. In addition, a bias in research data interpretation may be present, as the first researcher is a woman and may be more likely to detect women's behaviors more easily. However, it is not excluded that women may be more sensitive to temperature and therefore react more clearly. Seasonal dependence on the detection of behaviors within the different healthcare facilities could also be seen as a limitation, especially about the comparison of data since the detection times are not homogeneous. In this regard, the actual temperature, relative humidity, and other environmental measurements of healthcare centers during observations are not available and this appears to be a bias and a significant limitation since these data could really be an added value in the interpretation of the collected behaviors and residents' relative perceptions. Despite these limitations, our study offers several research directions which may take the existing debates to the next level.

## 6 Conclusions

By analyzing data resulting from field observations about ageing which took place in five healthcare facilities, in order to detect behaviors that could be interpreted as display of any discomfort at thermal and luminous level as perceived by senior residents, this study shows that both men and women seem to act, physically react, and voice their discomfort more in relation to cold, women appear extremely sensitive to the temperature and choose more carefully the right clothes based on indoor and outdoor temperatures, so interesting differences between men and women should be further studied and deepened. Moreover, a huge gap seems to exist between the perceptions of older people and those of their caregivers, and some seniors whose health is most heavily affected try to continue voicing their discomfort, although they cannot always do it. Consequently, the collected data and their further improvement could be used to design smart devices that can really ensure comfort and improve the quality of life of individuals, including non-self-sufficient senior people. Therefore, a culture of technology is advocated in which technological innovations: (a) improve the quality of life of human beings and other living beings through a process of customization to target response in relation to someone's needs; (b) are positioned within an evolutionary framework all along the course of life; (c) are meant and implemented to serve everybody, especially most vulnerable categories, with the value in mind of reducing the digital divide.

**Author contributions** All authors contributed to the study design. Conception: LM. Material preparation, data collection and analysis: MR. Supervision: PN. The first draft of the manuscript was written by MR and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Availability of data and material** All data and material used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Consent to participate/to publish** All the healthcare facilities had been previously notified in writing on the purposes of the observation, the research project and the use of the collected data. The authors have had facilities committee's approval. Moreover, participants signed a written document giving their informed consent for the processing of their data, in accordance with the GDPR 2018 and national legislation on privacy and data protection.

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