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Environmental design for SHAFE approach

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Abstract. The *World report on ageing and health* highlighted the need to ensure age-friendly environments to foster active and healthy ageing because, as the *World Health Organization* has estimated, the number of people over 60 is set to double by 2050. Recently, SHAFE (Smart, Healthy, Age-Friendly Environments) has been proposed as a design approach to face the challenge of ageing. SHAFE model is focused on two goals: the promotion of smart and inclusive solutions to improve the independent life throughout the life course, regardless of age, gender, disabilities, cultural differences and personal choices; the optimization of social and physical environments, supported by digital tools and services. Nevertheless, studies on how to apply integrated principles of SHAFE to architectural design are still lacking, even if the interdisciplinary network NET4Age-Friendly is the most recent application of SHAFE model and aims to implement its practice and deployment. Based on a literature review, the paper discusses the contribution of environmental design for improving SHAFE approach on architecture, to build living spaces really responding to the changing needs of people from the ageing in place to the long-life approach.

1 Introduction

Population ageing are changing our lives and the United Nations member states have proclaimed 2021-2030 as the *UN Decade of Healthy Ageing*, and its call to leave no one behind [1]. The *World report on ageing and health* also highlighted the need to ensure age-friendly environments to foster active and healthy ageing [2] because the rise in the number of elderly, coupled with a lack of suitable for existing houses, poses the dilemma of adequate housing provision that will allow the elderly to age in the right place, protecting their autonomy and independence [3]. The themes explored in the *World report on ageing and health* range from strategies to deliver comprehensive and person-centred services to older populations and to policies that enable older people to live comfortably and safely. The report aims to move the debate about the most appropriate public health response to population ageing and emphasizes that healthy ageing is more than just the absence of disease.
The aim of this paper is to review the various existing studies that examine the role of environmental design that aspires to enhance the smart, healthy, age-friendly (SHAFE) approach to architecture, for living spaces that are truly responsive to people's changing needs in a long-life perspective.

2 Conceptual Framework

2.1 Trajectories for ageing in place

Urbanization and population ageing are transformative trends that are changing the way we live, work, and experience our urban environments throughout our lives and into older age. Age-friendly environments, such as in the home and in the community, foster healthy and active ageing by building and maintaining intrinsic capacity across the life-course and enabling greater functional ability in someone with a given level of capacity. Working to create cities and communities that are sustainable and accessible to all requires a process across the life-course that progressively improves the fit between people's needs and the environments in which they live. Creating environments that are truly age-friendly requires action in many sectors – community support and health services, long-term care, transport, housing, outdoor spaces and buildings, energy efficience, labour, information and communication technologies, social participation and protection– by many actors – government, service providers, civil society, older people and their organizations, families and friends [2].

2.2 Smart technologies for ageing in place

The framework of the home environment for ageing in place and the smart home modification process show that both home modification and smart technologies can support older adults' independent living [4]. Recently, the word "smart" has become an umbrella term for innovative technologies, including partial assistive technologies (AT), ambient intelligence (AmI), ambient assisted living (AAL), Internet of Things (IoT),

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information and communication technology (ICT), smart home, and artificial intelligence [5]. The smart technologies or devices designed for older people are also called "gerontechnology", combining gerontology and technology, as an interdisciplinary field of science for creating health, comfort and safe living spaces [6].
The recent pandemic scenario has had a major impact on the elderly population and the dimension of housing discomfort has amplified. So, the construction sector, through the analysis of case studies and pilot projects, investigates the key role of ICT in the management of space, both physical and virtual, in which relational and social-assistance dynamics are enabled to support innovative housing models [7].

These technologies aim specifically at enhancing personal safety, health monitoring, living environment control, improving social interaction for older adults living independently [8]. Technically, a complete smart home system consists of four components: external device, control system, communication system and the database [6,9]. Sensors, as one type of external devices, have hundreds of classifications by functions and use patterns. From the viewpoint of the relation between sensors and housing infrastructure, Ding and her colleagues determined three main categories: wearable sensors, direct environment sensors which are distributed in the environment, and infrastructure mediate sensors installed on the housing infrastructure [10]. In addition, Lee and Kim highlighted that smart technology should be customised according to changes in people's lifestyles and housing structures. Although several theoretical studies on home adaptations exist, the benefits of custom home adaptations remain poorly evaluated. So far, the real-life smart home projects designed or renovated for older people are limited [11]. In a systematic review, Pal and colleagues reported that most application scenarios were conducted in ideal environments, such as laboratories or academic institutions [12]. Thus, the knowledge of combining smart technologies with architectural design is lacking, especially when it comes to retrofitting [10, 13].

Most of the smart technologies are non-structural and which are placed on the surface of architectural components or installed inside the infrastructure and furniture, such as indoor climate sensors on walls or ceilings, pressure sensors under mattresses, water meters on taps, and contact sensors on doors [4, 14, 15, 16, 17].

Non-structural technologies make a minimum change of homes and are easier to be deployed. On the contrary, structural technologies require retrofitting the existing housing structure for some specific purposes, such as using fall detection floor to replace slippery floor tiles in risky areas. Indeed, falls are the leading cause of injury and deaths in people over age 65, and the risk is higher following age [4, 18].

The hazards synthesised by the WHO that encourage slips, trips and falls that could result in injuries include: uneven floor surfaces; inadequate or inappropriate lighting; steep stairs, stairs of varied height, stairs without handrails or in disrepair; lack of guarding of stairs, landings and balconies; lack of grab-rails or handles to baths and showers [19].

Actually, the starting point of the smart home modification process for ageing in place usually begins after older people realise that their living environment is unsuitable. The modification consists of four phases: home assessment, technology selection, design strategy, and user evaluation. Therefore, an assessment tool is required to evaluate the compatibility of smart technologies with existing housing structures before modification design and construction.

Nowadays, there are different research projects where recognised systems for evaluating the modified living environment of older people were developed or tested.

Moussaoui et al. proposed experimental research using virtual reality technology for a personalised assessment of the accessibility to a dwelling. They tested the accessibility of mobility, reaching and grasping by modelling a person moved in a wheelchair or with a walker. Using VR technology, they visualised the possible state after modifying the environment and the ability of older adults to control their living spaces. Their research provided an approach to use VR technology as a supplementary method of architectural design. For smart home modification, it is essential to simulate and validate technology application scenarios in the design stage [20].

Renaut and colleagues investigated French residences for seniors through semi-structured interviews. The study focused on how they construct the space in their home environments and how to fit new devices with the evaluated housing condition. They considered the importance of involving older people in the design and construction phase of home modification and the advantages of small repairs and minor changes [21].

Linner et al. developed the concept and prototyped "robotic micro-rooms" (RmRs), which do not require refurbishment of the existing interior. The concept is based on the "terminal-wall" approach that pre-embed assistive devices into modular elements as integrated furniture. Base on the size of the three-dimensional space surrounded by the ceiling panel, wall panels and the floor panel, the adjustable smart components can be easily inserted into existing rooms and enables a "plug-n-play" installation [22].

A recent study of Schorderet et al., aimed to explore older adults' expectations and needs regarding home adaptations and evaluate the impact of individualized home adaptations on quality of life, fear of falling, independence, and difficulties using adapted rooms. Its secondary aim was to describe the barriers and the facilitators of home adaptation. The method focused on 15 homes adapted using an inclusive, interdisciplinary approach. An architect and a health professional visited each home twice to assess the older adult's expectations and needs, evaluate the home's technical aspects, and co-create an adaptation plan with that study participant. The results were that most homes had their bathroom adapted. Participants reported improved safety, independence, ease of use, positive feelings, and comfort. They also reported lower perceived levels of difficulties during the activities of daily living in the adapted rooms (reductions of 93.4% of bathrooms and

100% of kitchens), an improvement in quality of life of 9.8%, and a reduction in fear of falling of 12.5% [23].

2.3 Built environment: behavioural and psychological determinants

The built environment plays a central role in the quality of human performance because it is the physical context in which human activities take place. In a combined qualitative study of senior housing, Cohen and Allweil employed home space design to analyse the importance of social ideals such as autonomy, affordability, equality, inclusion, and community values. The authors observed everyday behaviours and innovative methods for sharing living space with elders and caregivers [24, 25]. In the framework of the smart home modification process for ageing in place, measures include the reconstruction of the building structure for a building functional improvement, the rearrangement of the housing layout to increase usability and the safety of indoor features, and now also contains the installation of smart technology devices to support activities [4]. There is an important proposal of the user interface design principles for older people for helping the evaluation of the usability of smart devices in the homes. These ones should be reliable, user-friendly, suitable for everyday use [4, 26]. So, a prior examination of the usability and user-friendliness is an essential prerequisite for the purchase and subsequent integration of smart home solutions in the households of the users [27]. By examining articles in the architectural field, Shon et al. discovered that investigations into smart houses often concentrate on utilitarian aspects, such as usability, physical experience monitoring, and energy efficiency modelling. Psychological wellness was frequently neglected. So, they built an evaluation framework by analysing smart environment components, using contextual analysis and factor extraction, to create enjoyable experiences in intelligent surroundings that enable the elderly to live independently and improve their general well-being. [24, 28]. Also Shu and Liu in their collaborative research on psychology and ergonomics, explained the utilisation of living space to create interior settings that, by addressing functionality, impact psychological and behavioural changes in the elderly [24, 29]. With a better knowledge of ageing behaviour and preferences, housing developments can be made more age-friendly, including the local home environment [24, 30]. Finally, another aspect not to be underestimated concerns a study of Choi et al. [24, 31] that used a survey to analyse the house colours of senior citizens in Korea and found that a warm colour series was preferred over a cold colour series. There was also a high preference for colours that had clear tones. The elderly also preferred high colours with bright and vibrant tones over low-saturation colours.

2.4 SHAFE model and built environment

Recently, SHAFE (Smart, Healthy, Age-Friendly Environments) has been proposed as an innovative design approach to face the challenge of ageing. The meaning and notion of Smart, Healthy, Age-Friendly Environments deal with the serious challenges, especially those related to the demographic change and the COVID-19 pandemic. SHAFE began a Thematic Network in 2018, approved by the European Commission and evolved to a European stakeholders network, which currently has over 170 partner organisations and is coordinated by Carina Dantas and Willeke van Staalduinen. The network is working to build capacity and to achieve better cooperation and implementation, as stated in the Position Paper released in 2020, with recommendations that aim to promote healthier environments for all citizens and make environments accessible, sustainable and reachable for all, with the support of ICT. The model of SHAFE is focused on two goals: the promotion of smart and inclusive solutions to improve the independent life throughout the life course, regardless of age, gender, disabilities, cultural differences and personal choices; the optimization of social and physical environments, supported by digital tools and services. Nevertheless, studies on how to apply integrated principles of SHAFE to architectural design are still lacking [32].

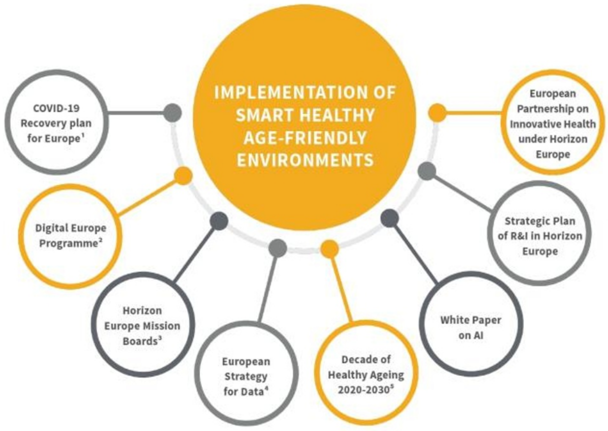

Fig. 1. The approach of SHAFE (*SHAFE Position Paper 2020*)

The network NET4Age-Friendly is the most recent application of SHAFE model and aims to develop an international ecosystem based on a network of researchers and stakeholders that enables the practice and deployment of SHAFE. NET4Age-Friendly is a COST Action, composed by five working groups, that aims to establish an international and interdisciplinary network of researchers from all sectors, to foster awareness and to support the creation and implementation of smart, healthy indoor and outdoor environments for present and future generations [32].

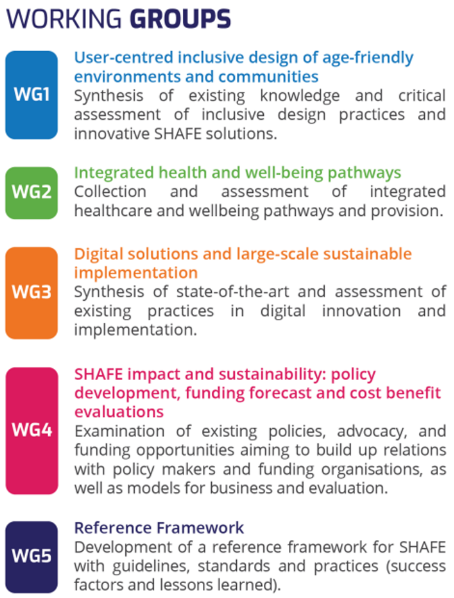

Fig. 2. NET4-Age-Friendly Working Groups

This paper is focused on the one of the four NET4Age-Friendly's thematic working groups: user-centred inclusive design in age-friendly environments and communities, because the universal design, also known as *design for all* or *inclusive design*, has been regarded as one of the few guidelines for designing a home environment without architectural barriers [33, 34, 35]. Even if, for example, the risk of falling in daily activities cannot be eliminated, there are several strategies provided by literature studies for enhancing indoor safety. Universal design can reduce indoor barriers, and improve the versatility of structures and spaces to facilitate functional expansion and installation; can suggest optional fittings to add architectural components such as handrails, ramps, and stairlifts that protect for the daily activities; can implement the co-creation design to build a senior-friendly home environment according to the specific circumstances of occupants; and can also employ smart technology for detecting dangerous situations and calling rescue by installing fall detection sensors and automatic alarm [36, 37, 38]. Hence, universal design is an approach to the design, construction and adaptation of housing to meet the needs of all occupants regardless of their age, functioning or social situation [19]. Designers must produce homes that meet the needs of older people, support their everyday activities and enhance their independence and active engagement in all facets of society [39].

As the population ages, inclusive design is an essential need, and no longer a choice. The design of buildings and spaces should reflect inclusive design principles established by the Commission for Architecture and the Built Environment in the UK. The principles demand inclusive, responsive, flexible, convenient, accommodating, welcoming, and realistic design [24, 40]. Thus, there is a need for an inclusive design approach to meet the needs of people of all ages, and to help them remain independent in their homes. For example, some focus solely on architectural features, others focus only on energy efficiency, and others concentrate on environmental design [24].

3 Research method

3.1 Aims of the literature review

The purpose of this study is to provide an overview of the scientific literature on existing studies, approaches and applications for the design of living spaces that are truly responsive to the changing needs of people in the long term and, in particular, to the specific needs of the elderly. The literature research and its critical analysis is based on the contribution that environmental design can make to the innovative SHAFE approach, which supports the health, independence and autonomy of older people. The study is based on three phases: (i) literature research, (ii) inclusion and exclusion criteria and (iii) study selection, according to the PRISMA guidelines [41].

3.2 Literature research

The literature research strategy was guided by topics that concern new architectural methods and solutions for the design of living spaces that are suitable for ageing in place, improving the quality of living environments. The strategy was based on researching the following keywords: Active and Healthy Ageing, Age-Friendly Housing, Inclusive Interior Design, Built Environment, Smart Technologies for Ageing in place, SHAFE, using the following databases: Google Scholar, PubMed, ScienceDirect and Scopus.

3.3 Inclusion and exclusion criteria

The inclusion and exclusion criteria were established according to the aim of the paper. The studies included and analysed were those concerning the latest and most innovative design solutions to ensure living environments for active and healthy ageing. Firstly, the solutions have been preferred which promote the design of age-friendly environments both for the layout of the domestic environments and for the modifications that can be applied. In addition, the selection also covered user-centred inclusive design, functional-spatial aspects for resilient environments and assistive technologies. Studies from other disciplines whose results are not related to environmental design, such as studies in medicine or biology, were excluded from the literature review.

3.4 Studies selection

The selection of studies was defined by preferring literature review articles in order to have a broader overview of the issues analysed in the existing scientific literature. The studies included concern 2 reports, 29 scientific articles, 6 systematic reviews, 1 thematic review and 2 critical reviews. The systematic reviews contain links to a further 50 studies, making a total of 90 studies consulted.

4 Results

The first results, to be considered as a starting point, state that the existing scientific literature seems to report mainly on the adoption of smart technologies related to the process of home modification, in terms of the built environment for ageing in place. Studies affirm also that the construction sector is investigating the role of ICT (Information and communication Technologies) in the management of space to support innovative housing models. The measures adopted for the home modification process include the reconstruction of the building structure for a functional improvement, the rearrangement of the housing layout to increase usability and safety of indoor features, and now also contains the installation of smart technology devices to support activities. Among these measures, two levels of invasiveness were found. The first one is lower and consists in devices placed on the surface of architectural components or installed inside the infrastructure and furniture, such as indoor climate sensors on walls or ceilings, pressure sensors under mattresses, water meters on taps, and contact sensors on doors. The second one is more invasive and concerns structural technologies that require retrofitting the existing housing structure for some specific purposes, such as using fall detection floor to replace slippery floor tiles in risky areas. Furthermore, it is estimated that a user-centred approach is essential to ensure that customised adaptations meet specific needs.
Another important aspect is the usability of smart devices in the homes for older people, in which the user interface should be reliable, user-friendly and suitable for everyday use.

In particular, the Table 1 shows the technologies that seem to be most used and related to the built environment, divided into Assistive Technology, Ambient Intelligence, Information and Communication Technology.

Tab. 1. Classification of smart technologies, Modified by [4]

CLASSIFICATION OF TECHNOLOGIES	
ASSISTIVE TECHNOLOGY (GERONTECHNOLOGY)	• Emergency alarm • Walker • Stairlift • Handrail • Electric radiator • Air ventilation
AMBIENT INTELLIGENCE (AMBIENT ASSISTED LIVING)	• Contact sensor • Smart meter • Fall detection floor • Pressure sensor • Indoor climate sensor • Smart wall • Assistive robot
INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)	• Bedside call unit • Bio-data health collection device • Smartphone • Laptop

5 Discussion

5.1 Conclusions

The literature review revealed studies that are perfectly aligned with the goals of Working Group 1 of the NET4-Age-Friendly, the first recent application of SHAFE. The main common goal is the user-centred inclusive design to build innovative environments by introducing smart technologies into living spaces.

5.2 Final remarks

The paper shows that the home modification process, aimed at ensuring age-friendly environments, is joined by smart home design and renovation that still needs to be explored in future research and verified in real-life projects. The literature also highlights that there are only a few proposals regarding the usability of smart technologies by the elderly population. Although studies present many experiments, there is still not a set of criteria that can be followed as design guidelines for the use of smart technologies applied to living spaces. Finally, the study presented here emphasises that the role of environmental design with regard to accessible, adaptive, flexible living spaces, focused on people's needs in the long term, is still to be investigated.

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