Exploring Gerontechnology for Aging-Related Diseases in Design Education: An Interdisciplinary Perspective

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Abstract –

Aging society is not only a crisis in the developed world but also a severe challenge in some emerging economies. However, the awareness of population aging and gerontechnology is far from sufficiently addressed in the architectural design education in universities. Therefore, an interdisciplinary approach in design education is urgently needed to raise the awareness of the aging crisis among the future architects, interior designers, and beyond. This article introduces a novel model of a design seminar offered by a German University, addressing population aging issues in the architecture department. The syllabus, formality, and the expected results of the seminar are revealed in detail. The participants are encouraged to apply interdisciplinary knowledge such as barrier-free architecture, mechanical engineering, electrical engineering, robotics, medicine, psychology, and business to achieve the goals of the seminar. Based on the originality and degree of completion, several students' works are selected and reported, targeting a variety of diseases or syndromes related to aging, such as dementia, immobility, and tremors. Overall, participants of this seminar are motivated and have positive feedback on this seminar, oftentimes claiming that they have seldom studied similar topics in previous architecture education. This enables students from architecture as well as other fields to be better prepared to tackle the upcoming challenges such as labor shortages and infectious diseases in a rapidly aging world. Furthermore, the seminar creates novel concepts that serve as a win-win "honeypot" for both students and their instructors, potentially sparking research topics and start-ups with concepts fostered in this seminar.

Keywords –

Aging-related diseases; Bauhaus 2.0; COVID-19; Dementia; Design education; Gerontechnology; Interdisciplinary

1 Introduction

The worldwide crisis of population aging has drawn the attention of more and more countries. According to the United Nations, the percentage of global older population 60 years or over is expected to rise to 21% by 2050 compared to 13% in 2017 [1]. Many studies pointed out that as the average life expectancy of the world's population increases, the number of people suffering from aging-related diseases increase as well. Therefore, the significance of gerontechnology became prominent in recent years. The terminology of gerontechnology was officially proposed at the 1st International Congress on Gerontechnology, Eindhoven, Netherlands in 1991 [2]. It is a broad interdisciplinary domain that includes subjects such as gerontology, assistive technology (e.g., medical devices, home automation, companion robots, etc.), and inclusive design. Ever since its establishment, researchers and developers around the world continuously made contribution in this field. In architectural design education, however, population aging and gerontechnology does not seem to draw sufficient attention. Furthermore, it is predictable that the ongoing coronavirus pandemic will fundamentally reshape architectural design, challenging doctrines formed since the Modernist Movement such as open plan and shared spaces in order to assist and protect habitants especially the vulnerable elderly [3]. As a result, gerontechnology naturally becomes a powerful tool in this transition. Therefore, future architects and interior designers need to be prepared to respond to the challenges that aging society brings. In conjunction, architecture educators need to provide them with opportunities to study in the related fields.

2 Research aim

This paper reveals an innovative method of teaching interior design seminars in the context of aging society, mimicking the environment of a business incubator, which distinguishes itself from traditional interior design studios. It involves cross-disciplinary knowledge in inclusive design, mechanical engineering, electrical engineering, robotics, medicine, psychology, and business, based on the key concepts and methods of a large European research project. The results of selected student projects addressing several commonly seen aging-related diseases or syndromes will be presented. Last but not least, the effectiveness and key learnings of this teaching process will be discussed.

3 Methods

Oftentimes, in an interior design or architecture studio, after reviewing exemplary designs, a certain design task is given to the students. Next, students and instructors work together, pushing their sketches iteratively into final plans and renderings. In the end, the design is presented in the form of posters and architecture models.

The seminar presented in this paper entitled "Incubator" is offered to the master level students primarily from an architecture background, also among other fields. Incubators are used in the innovation science and industry to specifically generate innovations or to systemize the innovation process. The aim of the seminar is to let the student study and develop their projects using interdisciplinary knowledge in a simulated environment of an incubator. The key concepts and methods of this seminar are based on the REACH project, a large European interdisciplinary research project aiming at developing customized healthcare systems to promote the elderly's activity level and independence [4]. In REACH, a special type of smart furniture named Personalized Intelligent Interior Unit (PI^{2}U) was developed, which seamlessly integrates the required functions (e.g., unobtrusive sensing and monitoring, training/gaming, nutrition, AI assistant, etc.) into the different living environments. The development process of the PI^{2}Us (including but not limited to PI^{2}U-SilverArc, PI^{2}U-MiniArc, PI^{2}U-SilverBed, PI^{2}U-ActivLife) follows iterative design principles on both hardware and software levels, which allows the project team to optimize the products through prototyping, testing, analyzing, and refining (see Figure 1).

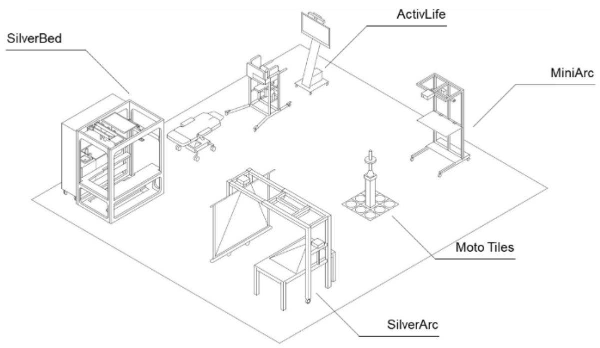

Figure 1. Various PI^{2}Us developed in the REACH project

Based on a variety of PI^{2}Us, the project team proposed a modularized smart home solution, namely the Total Room Assistive Care Kit (TRACK) concept (see Figure 2), which integrates PI^{2}Us and key technologies in REACH to create a complete interior living and care environment for elderly users in different living environments such as home, hospital, and community [5].

Figure 2. TRACK concept including real-life testing of the PI^{2}Us

At the beginning of the seminar, the instructors provide an overview of the key concepts and methods in the REACH project and give various lectures on topics such as the phenomenon of population aging, aging-related diseases, gerontechnology with a special focus on the field of Ambient Assisted Living (AAL), and previous examples from both selected student projects and other relevant research projects such as USA² [6] and LISA "Habitec" [7]. After, specific tasks are defined for all groups with expectations to develop their own approaches and strategies of the solutions based on the abovementioned concepts and methods. The proposed solutions must be interdisciplinary approaches, combining knowledge in barrier-free architecture, mechanical engineering, electrical engineering, robotics, medicine, psychology, and business. Seminar and demonstration sessions are held in the chair's laboratory. By supervising the students' work and evaluating their intermediate presentations, the progress is ensured, and relevant questions are discussed. This process fosters students' awareness of subject-specific problems, and furthermore, uncovers their personal weaknesses and strengths. Through this problem-oriented approach, the course participants are motivated and thus maximize their knowledge gain. The teaching process is highly student-oriented. Work groups are intentionally formed, comprising students from various backgrounds. The instructors actively assist them with both problem solving as well as developing and improving the student's concepts within the project task.

The expected results from the group work are supposed to include 1) an overall study of a specific target disease (or in some cases a series of diseases with certain similarities) related to aging, 2) a systematic and interdisciplinary design solution to assist the target elderly patients to independently perform their activities of daily living (ADLs) in the form of design drawings, mock-ups or prototypes, and/or experiment setups, and 3) business aspects of the proposed solution (e.g., business model generation, a simplified cost-benefit analysis, etc.). At the end of the seminar, students are to present their project solutions in front of the whole class and the course instructors in order to finalize the whole semester's progress and outcomes.

4 Results

As mentioned above, at the end of the semester, student groups are to present their projects in front of the seminar participants and instructors, targeting various diseases or syndromes associated with aging, such as dementia, mobility impairments, and tremors. Several selected works representing a variety of perspectives of diseases are reported as follows.

4.1 Dementia

The word "dementia" comes from Latin, literally meaning "without mind". According to the World Health Organization, dementia is "a syndrome in which there is deterioration in memory, thinking, behaviour and the ability to perform everyday activities" [8]. A large number of the world population is suffering from dementia, and Alzheimer disease is estimated to contribute to 60-70% of the cases. By 2015, roughly 47 million people suffer from dementia and the number is expected to reach 132 million in 2050 [9]. In Germany, for example, more than 1.6 million people were affected by dementia [10]. With no effective treatment currently available to cure it or reverse its progression, the dementia epidemic has a significant negative impact in terms of physical, psychological, economic, and social aspects, not only on the patients themselves, but also on their caregivers, families, and society. Therefore, innovative solutions are needed to mitigate the impact of this disease. In the following sections, three assistive systems, MAK, METIS, and Dooropener are proposed by the course participants to address the severe challenges brought by dementia.

4.1.1 Kitchen for dementia sufferers: Project MAK

The aim of the Modular Adaptive Kitchen (MAK) is to create an Ambient Assisted Living (AAL) concept for a kitchen that supports people who suffer from dementia. Although many ideas that have been implemented to support people with this condition, few holistic concepts fully meet the physical and mental demands of a dementia patient. This project explores an approach that addresses critical challenges by utilizing advanced technologies, such as assistive technology and automation. Eating and drinking are two of the most basic human needs. As a result, daily nourishment is one of the strongest driving fields of human behavior. Due to increased life expectancy, the number of those who suffer from dementia worldwide is also increasing. Among other aspects, this disease is associated with the inability to accomplish everyday tasks. People who suffer from dementia also lose the normal urge to take in nourishment over time. The patients can no longer assess the importance of adequate nutrition and fluids, nor understand the dangers related to malnutrition. In addition to the physical meaning of eating and drinking, food can also influence feelings, evoke memories, stimulate contacts and relationships, and ultimately influence the well-being and quality of the patients' life in a positive way.

Figure 3 depicts the kitchen system, composed of functional modules, a sliding system, and a guidance system. The functional modules ensure high customizability and flexibility for the individual users.

The sliding system not only offers height adjustment and accessibility for both standing patients and users of wheelchairs, but also prevents patients from reaching possibly hazardous products as the disease advances. The guidance system includes symbol stickers to remind the users of the right locations of items meanwhile keeping the integrity and elegance of the kitchen, and a combination of a projector and a motion sensing device (e.g., Microsoft Kinect) which projects a gesture-operable user interface to guide patients' cooking step by step. The advantages of this kitchen system benefit all members of society, especially people with dementia [11].

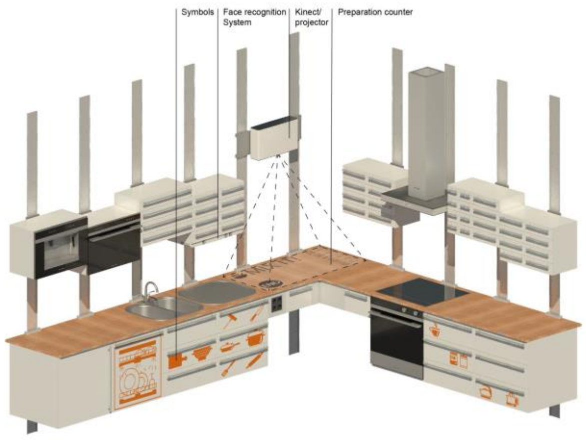

Figure 3. Modular Adaptive Kitchen for dementia patients (Image: A. T. Braun and M. Zanchetta)

4.1.2 Assistive home system for dementia sufferers: Project METIS

The Multifaceted Equipment to Independence System (METIS) for dementia sufferers (METIS) comprises an assistive home system for people suffering from dementia. After a comprehensive analysis on dementia, including its general specifics, forms, courses, and treatments, a research on caregivers was conducted. The research revealed an increasing number of elderly people affected by the disease within care of informal caregivers and living alone because of a highly important correlation between home and identity. Therefore, a special emphasis was placed on prolonging the independence of seniors and their preferred stay at home on the backdrop of architectural guidelines for physical and cognitive support. The various needs of a person with dementia have to be met in order to ensure their individual comfort. This requires a flexible and modular system, which can adapt to said needs. This system is specifically designed for seniors who live independently or are in home care. Different concepts for health, database, orientation, safety, and process guide yield METIS. One of the key components of the project is the multifunctional floor tiling system. The system features embedded microchips that ensure the interconnectivity, integrated pressure-powered energy generators and storage units that provide electricity for the whole floor titling system, and an embedded RGB LED lighting system that creates an illuminated path to remind the user of his or her daily routes. In addition, the embedded pressure sensors can be integrated with a gaming system to perform various productive games (see Figure 4).

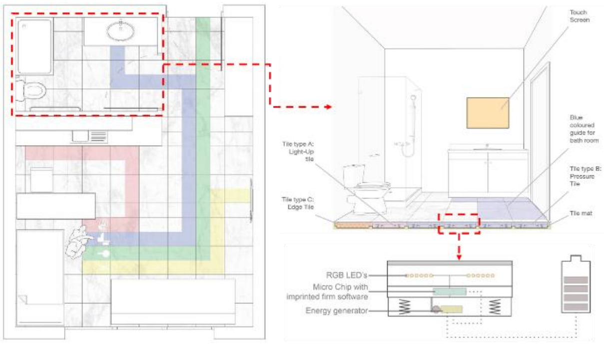

Figure 4. The assistive smart floor tile system (Image: J. Bielski and L. Alsammak)

4.1.3 Smart door handle for people living with dementia

Demographic change is one of the most impactful challenges for our aging population facing new socio-economic, technical and health challenges. We therefore need to find new design solutions to assist older people to stay independently, safe and keep them in a good mood to prevent social isolation. The design of the smart door handle can provide a solution to help older adults to improve their quality of life.

The design responds to the progressive condition of dementia with a modular, as well as adaptive system for three different dementia stages. The three focus aspects of the design configuration variants are mood (for early stage of dementia), independence (for mid stage of dementia) and safety (for late stage of dementia). The system consists of the door, door handle, speaker, passive infrared (PIR) sensor for silent alarm, light module, intelligent switch, security switch and interface (see Figure 5).

Based on the term anticipation, the intent of the project was to design a door system which prevents people suffering from dementia at home and in nursing home from leaving a designated area or building when doing so could otherwise endanger themselves or others. People living with dementia exhibit behavioral disturbances such as mood disorders or wandering, which can lead to serious safety issues. That is why the system has a few security features such as the security switch, intelligent switch, and speaker to prevent wandering. Additionally, the system keeps them in a good mood through mood nudging with a light module, as well as guarantee their independence through the progressive condition of dementia. The project seeks to combine intuitive technology with a minimalistic form to create a design that can be universally implemented.

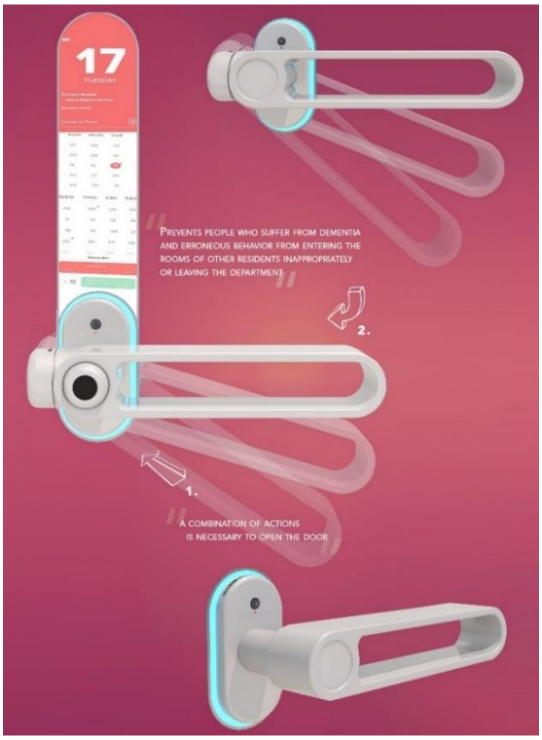

Figure 5. Three configurations for three stages of dementia (Image: M. Schmailzl)

4.2 Mobility impairment

Mobility impairment generally refers to the lack of ability of a person to use one or more limbs in order to move. In general, there are two types of mobility impairments: orthopedic and neurological, both of which have a negative impact on patients' quality of life as well as the healthcare system. Research suggests that among the elderly people aged between 60 to 69 years old, the epidemic of disability in mobility as well as basic and instrumental ADLs is growing at a significant rate [12]. Rosenberg et al. summarized that increasing physical activity has strong benefits on physical, cognitive, and mental health for all age groups, let alone the older adults [13]. Therefore, developing systems that assist patients with limited mobility to move independently meanwhile promoting their activity level is substantially beneficial. In the following sections, such kind of a proposal developed by the course participants will be reviewed.

4.2.1 Interior mobility assistance: Project 3D Movement

Individuals without mobility are exposed to a list of physical and mental problems that affect many of their organs. The 3D Movement system slows the progressive decline of a patient's functions, allowing the users to take care of themselves. Considering the patient's age and physical condition, consistent and intelligent physical activity could reduce or even prevent the degeneration of the patient's state. Researchers have proved that muscular stem cells will decrease with time, but with training, these cells continually regenerate, counteracting the process of aging. The proposed system is designed to support the patient by making movement possible and preventing falls. Assuming the system will be used by people who can stand up on their own, but have difficulties moving independently, the machine allows the patient to regain autonomy in basic daily tasks (e.g., going to the bathroom, cooking, or walking around the living space). Through the integration of a mechatronic system with an appropriate guide-and-support "vest", the system will keep the user in a steady position while preventing the user from falling. When the user intends to move, the force sensor will detect the direction and strength of the movement and move in a safe velocity accordingly. Therefore, the user will be able to move independently while being safe and feeling secure (see Figure 6). As a result, the physical and mental conditions of the patient will improve. The objective of the 3D Movement system is to help people with reduced mobility of all ages, by creating a system that eliminates the use of a wheelchair within confined space. The system can be fitted in hospital rooms and particular types of homes, further benefiting a variety of members of society [14].

Figure 6. Visualization of 3D Movement interior mobility assistance (Image: F. Martini and C. Guernier)

4.3 Parkinson's disease

Being the second most common neurodegenerative disorder, Parkinson’s disease (PD) is a progressive nervous system disorder specially affecting the elderly community. It affects about 6 million people around the world, and the number of patients is expected to double over the next generation [15,16]. Without a known cure as of today, PD oftentimes leads to tremors, rigidity, disability, long-term care (LTC), deteriorated quality of life, and eventually premature death, which put increasing burdens on the caregivers and affect the patients and their families both financially and emotionally [17].

Therefore, it is important to create environments that can assist PD patients’ activities of daily living (ADL) while minimizing the need for constant care. Therefore, one course participant proposed Project PATRICK (“Parkinson’s and Tremor Rehabilitation Interior Care Kit”) to empower the PD patients to enhance their ADL through architecture, industrial design, and mechatronics techniques.

4.3.1 Parkinson’s and tremor rehabilitation interior care kit: Project PATRICK

This project begins with research into the diseases prevailing in the elderly community. The primary focus is on PD; hence the project is named PATRICK. The research revealed issues with mobility for a large majority of patients, drawing focus on independent movement through the project. The project aims to integrate multiple systems within the architecture of the home, concealing “assistance” and encouraging independence.

Developed through the project focusing on the primary tasks of daily living, there are four systems: the walking assistance, sleeping assistance, fall assistance, and dining assistance. The project creates a secured circulation handrail system for patients within the wall that can extend out when the embedded touch sensors are triggered. The handrail system (walking assistance) is ubiquitous for the entire circulation of the apartment, connected to the sleeping station and eating station. The bed structure (sleeping assistance), maneuvered by a pulley system hidden in the ceiling, can assist the patients to change positions (e.g., lying, sitting, etc.). Meanwhile, the floor and ceiling work together to detect falls and assist the patients with a descending handle. In addition, the dining assistance integrated within the walking assistance features an integrated exoskeleton arm to offset tremors of the user’s arm while eating (see Figure 7). In this sense, the entire interior space of the home becomes an assistive robot for the PD patients. The minimalist design ensures that PATRICK can be easily installed and operated within any space, creating a plug-and-play system. Through the research of the disease, understanding its symptoms, investigating current assistive systems on the market, PATRICK make independence possible for PD patients.

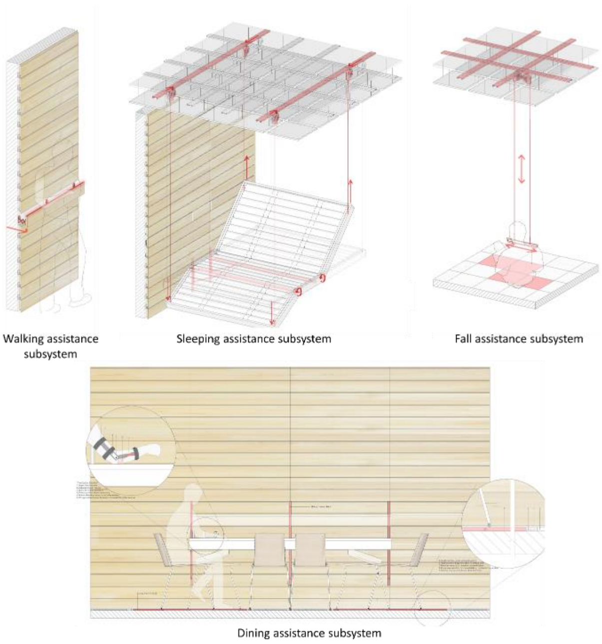

Figure 7. Four subsystems proposed in project PATRICK (Image: H. Bavishi)

5 Discussion

In this paper, the authors presented an interdisciplinary approach in design education to raise awareness of the aging crisis among the future architects and interior designers. Several exemplary results from the participants of this course are revealed in detail.

Experts in related fields already predicted that emerging technologies will have a substantial impact on society, such as replacing a large amount of human jobs [18,19]. Moreover, there is no doubt that emerging technologies will also significantly influence higher education in many aspects in terms of admission, curricula, and organization. Ma and Siau suggested that advanced technologies should be introduced in the curricula of all faculties, not just in STEM majors (i.e., science, technology, engineering, and mathematics), in order to enhance students’ ability to adapt to the rapid development in technology [20].

It is widely known that Germany’s Bauhaus Movement revolutionarily transformed our world as well as the design education system since its establishment in 1919 [21]. As its founder, Gropius, famously said in the Bauhaus Manifesto [22], the goal of the movement is to “create a new guild of craftsmen, free of the divisive class pretensions that endeavored to raise a prideful barrier between craftsmen and artists". 100 years have passed since the initiation of the Bauhaus, and facing the severe challenges caused by population aging and emerging technologies today, a "Bauhaus 2.0" Movement, which refers to applying cutting-edge emerging technologies to the education approach of the Bauhaus, is needed to tackle these challenges. To summarize, the key features of both movements can be seen in the following formulas (Figure 8).

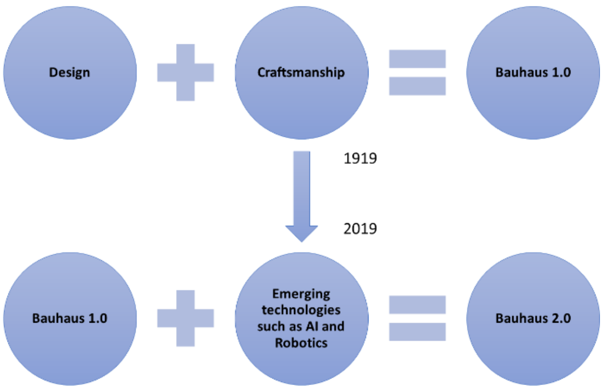

Figure 8. Equations of the Bauhaus 1.0 and the Bauhaus 2.0

As a result, the seminar reported in this paper created a win-win "honeypot" for both students and academic researchers. On the one hand, most students were motivated in the beginning and satisfied in the end of the course because as many claimed they have never experienced such kind of course in architectural education before. The benefits they gain is manifold: the participants obtained a deeper understanding of the impact of population aging through studying various aging-related diseases; they reinforced their design skills in the context of ongoing aging society; they also cultivated an interdisciplinary and flexible mentality in order to better embrace the upcoming age of AI and robotics; more importantly, they learned to collaborate with peers in a simulated business incubator environment. On the other hand, researchers can potentially foster the students to further co-develop their project results into scientific research projects, innovative products, and business startups.

In addition, this approach will inspire educators in the design field to experiment with novel curricula in their teaching practices. Furthermore, the COVID-19 pandemic started in late 2019 has fundamentally changed our society in many aspects. It forces us to rethink the status quo in elderly care today. A trend of applying advanced technologies such as robotics and AI in disease prevention, screening, diagnosis, and operation has already been observed, which especially protects and benefits the elderly individuals who are among the most vulnerable population to the novel coronavirus [23]. Apparently, gerontechnology introduced in the above-mentioned course goes in line with this trend and beyond, making the students better prepared to develop intelligent living environments that promote independent living and well-being of the elderly in the future. The methods and proposals from the past design seminars presented in this paper are by no means an exhaustive range of possibilities. The opportunities for new architectural and technological innovations for aging society are endless, especially with the ever-increasing demand for the young yet promising research field of gerontechnology integrated in the built environment.

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