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At-home fitness system
for healthy ageing

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At-home fitness system for healthy ageing

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0. Abstract

To maintain a healthy aging process, participating regularly in physical activity is necessary. However, many older adults do not exercise due to physical, sensorial or cognitive impairments, limited access to fitness facilities or programs, or lack of motivation. In this context, home based physical activity programs and innovation in technology have the potential to assist older adults in keeping healthy and independent for longer. Thus, this thesis aimed at the design of a product-service system that motivates the participation of older adults in physical activity at home. In particular, this thesis project examines the use of ICT and tracking technologies as potential facilitators for the adaptation of training programs to those people who, due to obstacles arising from their intrinsic capacities, environments and / or motivations, can't or are not willing to participate in physical activity. As a by-product of the thesis, guidelines were developed to provide some recommendations for the design of other future products and services in the context of at-home fitness for older adults.

Key words: healthy ageing, older adults, physical activity, home, inclusive technology

Per mantenere un processo di invecchiamento sano, è fondamentale praticare regolarmente attività fisica. Tuttavia, molti anziani non si allenano a causa di disabilità fisiche, sensoriali o cognitive, accesso limitato a strutture o programmi di fitness, o per una semplice mancanza di motivazione. In questo contesto, i programmi di attività fisica attuabili in casa e l'innovazione tecnologica hanno il potenziale per aiutare gli anziani a mantenersi sani e indipendenti più a lungo. Pertanto, questa tesi mira alla progettazione di un sistema di prodotto-servizio che motivi gli anziani a praticare l'attività fisica in casa. In particolare, questo progetto di tesi esamina l'uso delle tecnologie informatiche e di tracciamento come potenziali supporti per l'adattamento dei programmi di fitness a quelle persone che, a causa di ostacoli derivanti dalle loro capacità intrinseche, l'ambiente circostante e/o la propria motivazione, non possono o non vogliono praticare attività fisica. Come sottoprodotto della tesi, sono state sviluppate delle linee guida utili a fornire alcune raccomandazioni per la progettazione di altri prodotti e servizi futuri nel contesto del fitness a casa per gli anziani.

Keywords: healthy ageing, anziani, attività fisica, casa, tecnologia inclusiva

1. Introduction

The world ageing population is growing and life expectancy is increasing, to the point where by 2050, a large portion of society as we know it will be over 60 years old (World Health Organization, 2020). Most older adults face impairments at the motor, sensory-perceptual and cognitive levels that range from small loss of skills to major impairments, as a result of the great variety of molecular and cellular changes that occur in the body over the years (World Health Organization, 2020). Beyond these physiological limitations, older age also involves other significant changes in the way they relate to their physical and social environments (World Health Organization, 2015). The environments that people live in combined with their personal characteristics, have long-term effects on how they age (World Health Organization, 2019).

Physical inactivity and sedentary behavior in older adults is one of the main factors in their functional capacity decline. Long periods of physical inactivity predispose older adults to frailty, the development of comorbidities, and falls, which generates a loss of independence and a poor quality of life (Valenzuela, et al., 2011). Physical inactivity is also of particular concern to countries as care dependency, morbidity and poor quality of life represent a direct and indirect economic burden. However, investments aimed at creating age-friendly physical and social environments can enable older people to keep contributing to society while retaining their autonomy and health.

Physical activity, especially in the form of guided and structured exercises, has been linked to the improvement of functional capacity in older adults, that is, the improvement and maintenance of physical and mental capacities, the prevention of diseases and reduction of risks and the improvement of social outcomes (World Health Organization, 2020).

There are, however, a number and variety of barriers at the intrapersonal, environmental and motivational levels that make it difficult for older adults to participate in physical activity, such as the reduction of intrinsic capacity, lack of easy access to facilities and infrastructures, and the lack of a source of personal and social support (Baert, et al., 2011; Moschny, et al., 2011; Kruger, et al., 2007). All these factors added make that even in cases in which older adults participate in a conventional physical activity program, mid- and long-term adherence to it drastically decreases (Picorelli, 2014; Yardley, 2006).

To guarantee higher participation in training programs, home-based physical activity is seen as a good alternative over facility-based physical activity, as it is reported to have better adherence rates that ultimately translate into more long lasting positive benefits in older adults (Valenzuela, et al., 2011). However, in order to improve the components of health, increase adherence rates, and decrease the

prevalence of adverse events, a combination of equipment that facilitates the performance of physical activity and monitoring and supervision strategies are recommended when devising a home-based program (Geraedts, et al., 2013).

Technology innovations of the last decade have revolutionized the ways in which physical activity can be performed. New technologies, like wearables, internet-connected devices and gamified systems, have the potential to assist older adults in keeping healthy and independent for longer (Geraedts, et al., 2013), by providing timely interventions achievable from the home context. Although there are many other theoretical advantages to using technology-based exercise programs, more work is required toward tailoring products and services more suitable for older people (Gschwind, 2015; Sherrington, et al., 2008). The elderly tend to have a wide range of variation in their intrinsic capacities so trying to group this population by standardizing programs and environments is ineffective. Moreover, motivating older adults at home to exercise is challenging due their heterogeneous tastes and interests (Ijsselsteijn, et al., 2007).

1.1. Research Objectives

Given the context, the barriers and challenges mentioned above, the goal of this master's thesis is to *design a product-service system that motivates the participation of older adults in physical activity at home*. The main target are the older adults that, due to obstacles arising from their intrinsic capacities, environments and / or motivations, can't or are not willing to participate in physical activity. In addition, as a complement to the design, the use of ICT and tracking technologies is proposed as potential facilitators for the adaptation of training programs to the heterogeneity of this population. Thus, the specific objectives are:

- Allow the participation of older adults in exercise programs remotely from home.
- Enable motivational persuasion strategies as tools of adherence to exercise programs.
- Facilitate remote monitoring and tailoring of exercise programs for personal trainers.

1.2. Structure of the thesis

This master's thesis emphasizes the research and analysis of the context of healthy aging and physical activity, and the subsequent application in a design solution. The literature collected and analysis findings are organized in chapters explaining the various phases followed. Thus, the main topics discussed in each

chapter are summarized below:

- Chapter 2 describes the elderly population and briefly summarizes what is known about the aging process, what has been defined by the World Health Organization on the concept of healthy aging, the relationship between physical activity and well-being, and the access barriers that older adults commonly present to participate in physical activity.
- Chapter 3 presents an alternative scenario to overcome these barriers. In the first part, the conditions for implementing training programs at home that comply with the physical activity guidelines for older adults are studied. Then, a sweep is made of the possible technologies that can facilitate the implementation of these programs.

- Chapter 4 provides an overview of the fitness market in two moments. In the first moment, the market dynamics that has historically been presented in brick-and-mortar gym models are described. Subsequently, it is described how the COVID-19 pandemic has impacted this market and the adaptations and solutions that have been developed as a result of the restrictions and regulations imposed to control the spread of the virus. Additionally, the study of some of these solutions is presented, which are used as a reference for the development of the project.

- Chapter 5 analyzes three trending scenarios related to the concept of healthy aging to obtain a more detailed perspective of the limitations, needs and desires that older adults manifest in topics such as home, objects, technology, and the market. of fitness. The summaries at the end of each subsection reflect the main findings of the literature review and the conduction of short interviews of potential users of the design that is presented at the end of the project.

- Chapter 6 makes a final definition of the user and their needs, and some personas are presented as an example of what is described. As a by-product of the thesis project, a guide developed from all the information collected and the analysis carried out in previous chapters is presented, which aims to provide some recommendations for the design of products and services in the context of at-home fitness for older adults. Lastly, a brief is created to give direction to the final design concept.

- Chapter 7 describes the final design concept, the result of the preceding research and the guidelines presented in the previous chapter. The chapter is organized in 6 sections, starting from the description of the design of each of the ecosystem components, moving on to the user experience, and ending with the presentation of the product-service system map.

- Chapter 8 ends the document by summarizing the main objectives of the project and discussing the conclusions of the research work.

2. Background

2.1 Ageing and Older Adults

2.1.1 Defining older people

Longer lives are one of our most remarkable achievements as a society. They reflect the advances in social and economic development as well as in health and technology. A longer life is a potential valuable resource. It provides the opportunity for rethinking not just the meaning of what older age is but also how our whole lives might unfold (World Health Organization, 2020). There are different ways of defining older people, given that perception as to what constitutes being old can widely differ. The United Nations defined older people as those aged 60 or 65 years or more, while the World Health Organization states that older people are commonly defined as those aged 60 years or more. Although setting a threshold is important to statistics characterizations, the WHO points out that older age is actually characterized by great diversity. For example, some 80-year-olds have levels of physical and mental capacity that compare favorably with 20-year-olds, whereas others of the same age may require extensive care and support for basic activities like dressing and eating (Eurostat, 2020).

The number and proportion of older people in the population is increasing. In 2019, the number of people aged 60 years and older was 1 billion. This number, according to the World Health Organization (2015) will increase to 1.4 billion by 2030 and 2.1 billion by 2050. To this day, there are more elders than children under 5 years. By 2050, there will be more than twice as many people above 60 as children under 5, and they'll also will outnumber adolescents and young people aged 15–24 years. This increase is occurring at a very fast pace and will accelerate in coming decades, particularly in developing countries, from 652 million in 2017 to 1,7 billion in 2050, whereas more developed countries will have an increase from 310 million to 427 million (World Health Organization, 2019; World Health Organization, 2020).

This shift in distribution of a country's population towards older ages, where the proportion of people of working age shrinks while the number of older people expands, is known as population ageing (Eurostat, 2020). While low rates in fertility and increasing longevity thanks to economic, social, medicine and public health developments are key drivers in the process demographic ageing, international migration contributes to some extent to changing population age structures in some countries (United Nations, 2019).

The ageing of the population is of particular concern to countries as they represent both challenges and opportunities. Because care dependency increases with age, societies will need adaptations in the near future across all sectors that structure them like in health care and long-term care, transportation, housing and urban planning, among others (World Health Organization, 2015). It will also require a large,

dedicated trained workforce and intensify the need for physical and social environments to be made more age-friendly (World Health Organization, 2020). Yet, these investments can enable older people to keep contributing to society – whether it be as part of the labor force, within their family and social circle, or to their local community (World Health Organization, 2019) – while retaining their autonomy and health.

The extent of the human and social resources invested in this transformation of society, and the opportunities available to older people, are heavily dependent on health (World Health Organization, 2015). If the added years are lived in good health, population ageing will be associated with a similarly growing human resource that will contribute to society (World Health Organization, 2015). On the contrary, if people are living longer but experience limitations in capacity, this means greater demands for health and social care, and older people will be more limited in the social contributions they can make (World Health Organization, 2015). Therefore, it is important that as the population ages, people are able to have a healthy aging.

2.1.2 Ageing

At the physiological level, ageing results from the impact of the accumulation of a wide variety of molecular and cellular changes that come over time, that results in a progressive, generalized impairment in body functions, an increased vulnerability to environmental challenges and major risk of disease and death (World Health Organization, 2015). By 60, the major burdens of disability arise from age related sensory losses and non-communicable diseases, including heart disease, cancer, chronic respiratory disorders, and dementia (World Health Organization, 2015). However, these changes are neither linear nor consistent, and they are only loosely associated with a person's age in years (Steves, et al., 2021). While some 70-year-olds enjoy extremely good physical and mental health, other 70-year-olds are frail and require significant help from others to meet their basic needs (World Health Organization, 2015).

Beyond these biological limitations, older age also involves other significant changes. These include shifts in roles and social positions, and dealing with the loss of friends and partners. In response, older adults tend to set fewer and more meaningful goals and activities, optimizing their existing abilities through practice and the use of new technologies, and compensate for the losses of some abilities by finding other ways to accomplish tasks (Baltes, et al., 2005). It's thus important not just consider approaches that ameliorate the losses associated with older age but also those that may reinforce adaptation and recovery.

Developing and maintaining the functional ability that enables well-being in older age is a multi-dimensional process (World Health Organization, 2019). Although some of the variations in older people's health are due to genetic inheritance, much is due to people's physical and social environments, including their homes, neighborhoods, and communities, as well as their personal characteristics, such as their sex, ethnicity, or socioeconomic status (World Health Organization, 2015). These factors start

to influence the ageing process at early stages. The environments that people live in combined with their personal characteristics, have long-term effects on how they age (World Health Organization, 2019).

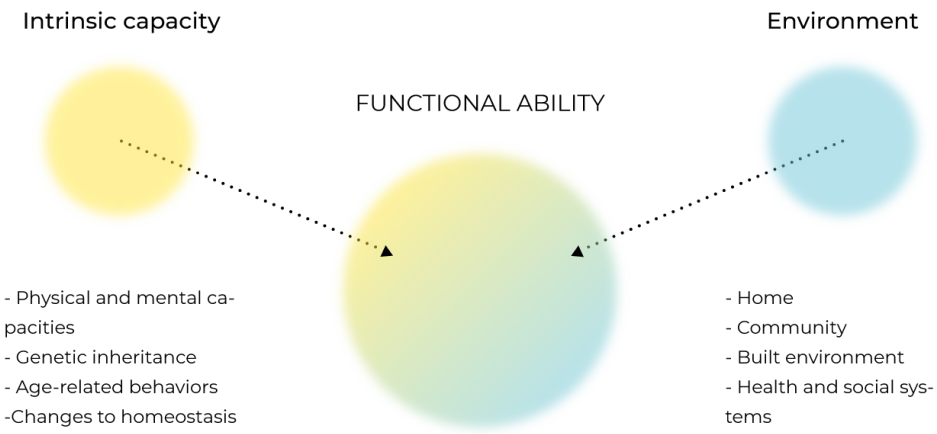
Most of the disease burden in older age is due to non-communicable diseases, therefore, risk factors for these conditions are important targets for health promotion. Strategies to reduce the disability and mortality in older age by enabling healthy behaviors, like engaging in regular physical activity, and controlling metabolic risk factors should start early in life and continue across the life course (Michel, et al., 2008). Even when not starting early, these strategies continue to be effective in older age.

2.1.3. Healthy Ageing

Every person should have the opportunity to live long and healthy. However, the environments in which people live can impact health, since they're highly influential on behavior, they can be the source of health risk factors (like air pollution or violence), and allow or restrict access to quality health and social care. Healthy ageing is about creating the opportunities and environments that enable people to be and do what they value in their lives while enjoying wellbeing (World Health Organization, 2020).

The WHO defines healthy ageing as "the process of developing and maintaining the functional ability that enables wellbeing in older age" (World Health Organization, 2015). This includes a person's ability to meet their basic needs, move and be active, learn, grow, make decisions, build and maintain relationships and contribute to society (World Health Organization, 2020).

Functional ability comprises the intrinsic capacity of the individual, relevant environmental characteristics and the interaction between the individual and these characteristics. Intrinsic capacity



includes all of the physical and mental capacities that a person can draw on, and is influenced by factors such as diseases and age-related changes (World Health Organization, 2015). Environments include the home, community and society in general, and all the elements within them such as the built environment, people and relationships, health and social systems, among others. Being able to live in environments that support and maintain an individual's intrinsic capacity and functional ability is key to achieve healthy ageing (World Health Organization, 2020).

Two major considerations arise from the analysis of the elements necessary for healthy aging. On the one hand, there is the high diversity in the generational group of people over 60. In this sense, products and services should be framed to improve the functional ability of all older people, whether they are robust, care dependent or in between (World Health Organization, 2015). On the other hand, around 75% of the diversity in capacity and circumstances in older age is the result of the cumulative impact of barriers and facilitators present across people's lives (World Health Organization, 2015). The relationships people develop with their environments are shaped by several factors that can be demographic, cultural, ethnical or economical, among others (World Health Organization, 2015).

2.2. Physical Activity

According to The World Health Organization physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure – including activities undertaken while working, playing, carrying out household chores, travelling, and engaging in recreational pursuit." (World Health Organization, 2020).

While some activities can be done by choice and provide fund, other work or domestic-related physical activities may be mandatory, and may not provide the same mental or social health benefits compared with the former (World Health Organization, 2018). However, all forms of physical activity can improve health if performed regularly and with sufficient intensity and duration (World Health Organization, 2018).

Engaging in physical activity has multiple benefits in older age. These include improving physical (by maintaining muscle strength, balance, motor coordination, among others) and mental capacities (by keeping cognitive function, reducing anxiety and depression, and improving self-esteem); preventing disease and reducing risk (e.g. coronary heart disease, stroke and diabetes); and improving social outcomes (for example, by increasing community involvement, and maintaining social networks and

links with other generations) (World Health Organization, 2020). For example, studies suggest a 50% reduction in the relative risk of developing functional limitations among those reporting regular and at least moderate-intensity physical activity (Tak, et al., 2013; Paterson & Warburton, 2010). Physical activity also preserves and improve the cognitive function of people without dementia (Paterson & Warburton, 2010; Jak, 2012), reducing cognitive decline by nearly one third (Blondell, et al., 2014).

In addition, physical activity protects against some of the most relevant health conditions in older adults. Physical inactivity and sedentary behaviors like prolonged sitting account for nearly 20% of the population-attributable risk of dementia, and around 10 million new cases globally can be avoided each year if older adults met the recommendations for physical activity (Norton, et al., 2014). Similarly, moderate physical activity may reduce the risk of stroke by 11-15%, and vigorous physical activity has even greater benefits, reducing this risk by 19-22% (Diep, et al., 2019). However, despite the numerous reported benefits of physical activity, the proportion of the population that meet recommended levels falls with age, and analyses of data from the WHO World Health Survey and SAGE suggest that around one third of 70–79-year-olds and one half of people aged 80 years or older fail to meet the WHO guidelines for physical activity in older age (Bauman, et al., 2016).

Essentially all domains of fitness – aerobic, strength and neuromotor (balance) – are important for older populations (World Health Organization, 2015). However, the relevance of strength and balance training should precede aerobic training, with new evidence showing that progressive resistance and multi-modal training has favorable effects not only on muscular strength, physical capacity and the risk of falls (Liu & Latham, 2009), but also improves cardiovascular function, regulates metabolism and grants protection against coronary risk factors (Pollock, et al., 2000) for those with or without cardiovascular disease. Aerobic physical activities, on the other hand, such as walking, which is the main mode of aerobic exercise among older adults, has no correlation with the improvement of balance (Howe, et al., 2011), have no effect on preventing falls (Sherrington, et al., 2008; Voukelatos, et al., 2015), and no clear benefit in relation to strength. Therefore, the WHO suggests that older adults whose mobility is compromised start by increasing their strength and improving their balance before engaging in aerobic training (World Health Organization, 2015).

2.2.1. Physical activity recommendations

Being physically active makes it easier to perform activities of daily living, such as climbing stairs, personal care, grocery shopping, and moving around the house or neighborhood. Physically active older adults are less likely to experience falls, and if they do fall, they are less likely to get injured. Physical activity can also preserve physical function and mobility, which may help maintain autonomy longer and delay major disability (U.S. Department of Health and Human Services, 2018). In addition to the benefits mentioned in the previous section, evidence also shows that physical activity can improve physical function in adults of any age, adults with overweight or obesity, and those who are frail (U.S. Department of Health and Human Services, 2018). Promoting physical activity and reducing sedentary behavior for

older adults is especially important because this population is the least physically active of any age group, and most older adults spend a significant proportion of their day being sedentary (U.S. Department of Health and Human Services, 2018).

Many factors influence the decision of older adults to be active, such as current physical activity habits, health and safety considerations, and personal goals (World Health Organization, 2018). Healthy older adults generally don't need supervision to increase their weekly amounts of physical activity (U.S. Department of Health and Human Services, 2018). However, health care professionals and physical activity specialists can help people reach and maintain a healthy level of physical activity at a safe and steady pace. Older adults with chronic conditions, instead, should talk with their professionals to deterwmine the appropriate types and amounts of exercise (U.S. Department of Health and Human Services, 2018).

Given that older adults are a varied group, as most, but not all, have one or more chronic conditions, guidelines such as the Physical Activity Guidelines for Americans or the WHO Guidelines on Physical Activity and Sedentary Behavior (2018), seek to set the types and amounts of physical activity appropriate for the abilities of each individual. Physical activity recommendations for older adults focus mainly on two types of activity: aerobic and muscle-strengthening. Additionally, evidence supports the importance of multicomponent physical activity that emphasizes balance and muscle-strengthening training to enhance functional capacity and prevent falls (U.S. Department of Health and Human Services, 2018).

Aerobic activity (U.S. Department of Health and Human Services, 2018)*:* Also called endurance or cardio activities, are activities in which the body's large muscles move in a rhythmic manner for a sustained period of time. Walking, running, jogging, biking, dancing and swimming are some examples of aerobic activities. With aerobic activity a person's heart beats faster and breathing rate increases to meet the demands of the body's movement. Over time, regular activity makes the cardiorespiratory system stronger and more fit. For health benefits, the total amount of moderate-to-vigorous physical activity is more important than the length of each physical activity session.

Older adults should do at least 150-300 minutes of moderate-intensity aerobic activity a week, or at least 75-150 minutes of vigorous-intensity activity (World Health Organization, 2018). They can also do an equivalent amount of activity by doing both moderate- and vigorous-intensity activity. Older adults who perform more aerobic physical activity have a reduced risk of loss of physical function and physical function limitations compared to the general aging population (U.S. Department of Health and Human Services, 2018). Aerobic physical activity should be performed at least 3 days a week and should be spread throughout the whole week to reduce the risk of injury and prevent excessive fatigue (World Health Organization, 2018).

The intensity of the activity can be measured in two ways: absolute intensity and relative intensity. Most studies on older adult's performance use relative intensity to track aerobic physical activity (U.S. Department of Health and Human Services, 2018).

- Absolute intensity: measured in metabolic equivalent of task (METs) which represent the amount of energy expended during the activity without considering a person's cardiorespiratory fitness. The energy expenditure of light-intensity activity, is 1,6 to 2,9 times the amount of energy expended when a person is at rest. Moderate-intensity activities expend 3 to 5,9 and vigorous-intensity activities expend 6 or more times the energy expended at rest (Kramer, 2016)

- Relative intensity: the level of effort required to do an activity. Less fit people usually require a higher level of effort than more fit people to perform the same task. Relative intensity can be estimated using a scale of 0 to 10, where sitting is 0 and the highest level of effort possible is 10 (U.S. Department of Health and Human Services, 2018), however, other methods can be used in daily life to individually calculate relative intensity, such as heart rate, energy cost and step-count (Kramer, 2016).

Muscle-Strengthening Activities: Older adults should do muscle-strengthening activities that involve all the major muscle groups (legs, hips, chest, back, abdomen, shoulders and arms) at least 2 days a week. The improvements in, or the maintenance of muscular strength are specific to the muscles that are being used in the activity, so to achieve a balanced muscle strength, a variety of activities is necessary (U.S. Department of Health and Human Services, 2018).

Muscle-strengthening activities (also known as resistance training) make muscles do more work than they are used to during daily life activities, increasing their strength, power, endurance and mass (World Health Organization, 2018). Some examples include lifting weights, resistance bands training, calisthenics that use body weight for resistance, climbing stairs, and carrying heavy loads (such as groceries and moving furniture). To meet the key guidelines, these activities need to be performed with a moderate or greater level of intensity (World Health Organization, 2018). No specific amount of time is recommended, but muscle-strengthening exercises should be performed to the point at which it would be difficult to do another repetition. Also, the development of strength and endurance is progressive over time, so the gradual increases in the amount of weight, number of sets or repetitions, or the number of days a week of exercise performance will create stronger muscles (U.S. Department of Health and Human Services, 2018).

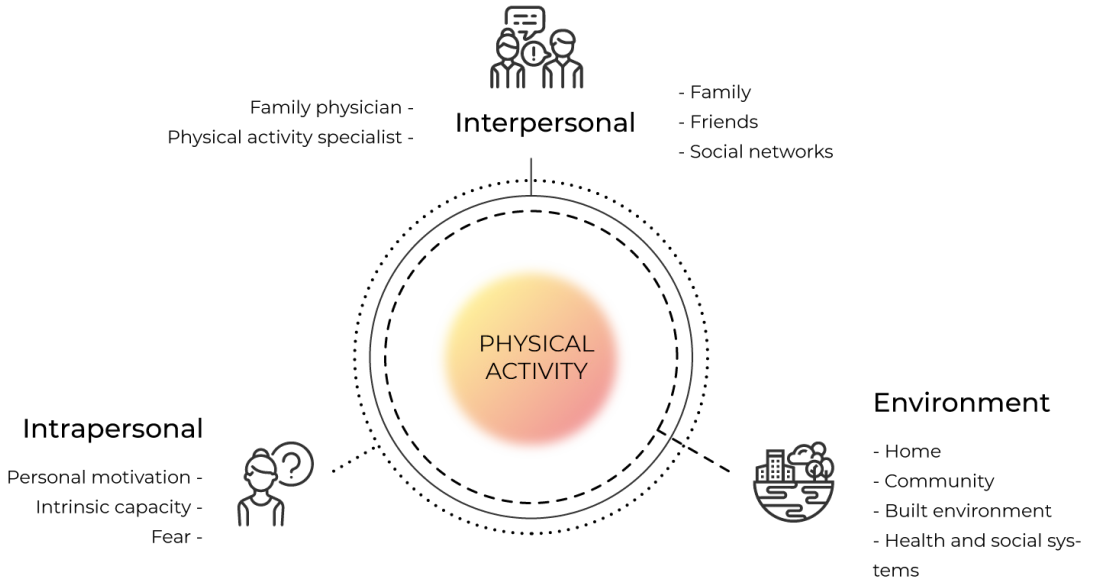
Balance activities: Balance activities are static and dynamic exercises that are designed to improve an individual's ability to resist challenges from postural sway or destabilizing stimuli caused by self-motion, the environment, or other objects, that cause the body to fall. The inclusion of this kind of activities are proved to reduce significantly the risk of injury, such as bone fractures, if a fall occur (U.S. Department of Health and Human Services, 2018).

Multicomponent physical activity: For older adults, multicomponent physical activities are important because they reduce the risk of injury from falls and improve physical function (World Health Organization, 2018). Multicomponent refers to physical activity that includes more than one type of physical activity, such as muscle strengthening, aerobic, and balance training. Multicomponent physical activity can be done at home or in a community setting as part of a structured program (World Health

Organization, 2018). An example of multicomponent physical activity program could include walking (aerobic), lifting weights (muscle strengthening) and walking backwards or standing on one foot (balance) (World Health Organization, 2018). Recreational activities such as tai chi, yoga, dancing, or sports can also be considered multicomponent as they often include multiple types of physical activity (U.S. Department of Health and Human Services, 2018).

2.2.2. Barriers to perform physical activity

Participation in physical activity is a dynamic and complex process influenced by various factors. Motivators for and barriers to physical activity in older people have been intensively researched during the last decade (Baert, et al., 2011). Several internal factors, as well as social support and environmental factors have been reported to influence the physical behavior of older people and their willingness to exercise (Dishman, et al., 1985).



At the intrapersonal level, lack of time is considered a rather infrequent barrier compared to young people (Baert, et al., 2011), while the lack of motivation in literature is considerably higher, ranging from 10% to 45% (Bethancourt, et al., 2014; Moschny, et al., 2011). Among the factors that affect motivation, self-efficacy (i.e., perceived capability and confidence), is less exhibited in the elderly population compared to other age groups (Phillips, et al., 2004). Health status, or intrinsic capacity, on the other hand, is considered relevant both as a motivator and as a barrier for participation in physical activity (Baert, et al., 2011). While a poor level of intrinsic capacity is reported as a barrier, the beneficial effects of physical activity on physical and mental health, as well on physical function and autonomy, are main motivators for participation of older people in physical activity (Lim & Taylor, 2005).

Fear from different origins is also mentioned as a barrier for physical activity in a plethora of studies. Fear can occur in different situations, like when going outside during the evening or for exercising outside, and can also be related to the individual's health condition, like fear of getting injured or feeling pain (Baert, et al., 2011). Fear of falling is a recurring factor among the existing literature, with several studies promoting the tailoring of falls prevention exercise programs, with a focus on balance and strength (Cavil & Foster, 2018).

Interpersonal factors, such as the lack of company are found to be a barrier. Several studies confirm the relevance of company for physical activity behavior in older adults as it represents a source of support and motivation (Moschny, et al., 2011). Elders are more often single or widowed, making them socially isolated, and exercise programs involving social interaction may be especially effective for increasing their participation in physical activity (Unger & Johnson, 1995). Health care and physical activity specialists seem to play an important role as their advice has an important influence on the behavior and adherence of older people to this programs (Baert, et al., 2011).

Also, environmental factors such as lack of transport and lack of opportunities are relevant barriers in international research. Several studies found transport difficulties, such as inadequate availability frequency and reliability of affordable transport, distance to sport facilities, high cost (Kruger, et al., 2007) and lack of appropriate programs and facilities for elders, to be a barrier to physical activity performance (Moschny, et al., 2011). Additionally, the weather seems to be a potential barrier for the elderly to be physically active in some regions. According to Chan and Ryan (2009), there is evidence that rainfall has the largest negative correlation with physical activity. Additional research on this topic is suggested to be helpful in the development of promotion campaigns and in and outdoor interventions to exercise (Baert, et al., 2011).

3. Home-based physical activity:

An alternative to overcome barriers

3.1. Definition of Home-based physical activity

Long periods of physical inactivity predispose older adults to frailty, the development of comorbidities, and falls, which generates a loss of independency and a poor quality of life (Valenzuela, et al., 2011; Bell, et al., 2016). These risk factors can be improved through the increasing of physical activity and properly designed exercise programs (Sherrington, et al., 2010; Smith, et al., 2011). Particularly, resistance and multimodal training are the most effective strategies to prevent the deterioration of muscle strength, mass and function (Johnston, et al., 2008; Bonato, et al., 2020), by stimulating the increase in muscle protein synthesis and fibers hypertrophy (Burton & Sumukadas, 2010; Vitale, et al., 2019). Despite this evidence and the availability of best-practice guidelines to support the design of interventions for improving physical function in older adults, exercise participation and adherence in older people is often low (Valenzuela, et al., 2011).

Developing resistance and multimodal interventions in suitable settings and guarantying the compliance of older people remains a challenge. In addition to the barriers already presented in the previous section (Lack of motivation, fear of falling, accessibility, safety, and cost) (Nyman & Victor, 2012; de Groot & Fagerstrom, 2011), older adults who are new to exercising sometimes feel intimidated by fitness facilities and group exercise settings (Costello, et al., 2011), referring concerns about the speed at which an exercise class progress, the differences in the performance between each individual, and the complexity of the exercises (Costello, et al., 2011).

To guarantee higher participation in training programs, home-based physical activity is seen as a good alternative over facility-based physical activity, as it is reported to have better adherence rates, that ultimately translate into more long lasting positive benefits in older adults (Valenzuela, et al., 2011). When comparing the two exercise programs, studies show that in the long term, the positive effects are more likely to remain when exercising at home rather than in a center (Ashworth, et al., 2005). Home-based physical activity also offers additional benefits, since it implies low implementation costs, reduces the need for transportation and facilities, and eliminates common barriers to participation in a routine (Lopez, et al., 2018; Schutzer & Graves, 2004).

Home-based physical activity refers to all the physical activity that it's carried out indoors in an informal, flexible setting typically in an individual's home (Ashworth, et al., 2005).

Throughout the literature, it is seen as a type of activity distinct from exercise done outdoors or in a fitness center or gym (Lopez, et al., 2018). Moreover, home-based exercise is typically prescribed by a qualified exercise professional to be performed either with minimal supervision or as a part of a full supported guided program, that it is not necessarily funded by the district health boards or the 'traditional health care system' and that instead, any costs associated with the program can be covered by the individual (Ashworth, et al., 2005; Lopez, et al., 2018).

Participation in home-based exercise programs is influenced by a variety of indoor characteristics. For example, Lopez et al. (2021), describe the importance of having dynamic environments rather than big amounts of space, where the individuals are able to make changes to the environments to facilitate the performance of physical activity. Similarly, in-home features like chairs, handrails, doors, and bannisters, help improving aspects of the performance such as support and maintenance of balance (Lopez, et al., 2021). Additionally, utilizing a space with access to screens (e.g., tablets, television) to follow exercise videos and receive real-time guidance, as well as the presence of mirrors, facilitate the engagement in exercises (Lopez, et al., 2021). Lastly, the presence of exercise equipment compatible with the level of function or impairments of the users, improves the range of activities that can be performed as long as it can be accommodated inside the house without affecting the dynamics of the spaces (Lopez, et al., 2021).

Home-based exercise programs seem effective improving components of health (i.e., muscle strength and muscular endurance), and skill-related (i.e., muscle power, balance) physical fitness in older adults aged 65-83 years (Chaabene, et al., 2021), by increasing mainly the lower body strength. However, in order to obtain moderate effects on muscle strength and balance, favorable adherence rates, and low prevalence of adverse events, a combination of equipment that facilitates the performance of physical activity and supervision strategies such as phone calls or internet-based interventions are recommended when devising a home-based program (Geraedts, et al., 2013).

3.2. Resistance Training

There are a variety of resistance-training modalities that can be used to develop strength in training facilities. However, when it comes to home-based exercise programs, not all of them are appropriate, and some even need to be re-interpreted and adapted due to logistical and practical reasons (Gentil, 2020).

Home-based resistance training, then, refers to any exercise routine performed in a home setting using body mass or equipment as part of an exercise program that has the objective of increase muscle mass and strength (Thiebaud, et al., 2014).

Most conventional approaches suggest that resist training should be performed with moderate to high loads, therefore, the use of specific equipment like strength training machines has been historically recommended to achieve fitness goals, which is why in fitness facilities this specific product typology is very popular (Kraemer, et al., 2002; ACSM, 2009). Training machines in fitness facilities are fairly self-explanatory, are often less intimidating than dumbbells or barbells, they're quick to set, and may be a good option for those who lack stability or have other functional limitations, such as the elderly (Clark, et al., 2014). However, strength training machines offer little improvement in balance, they fail to accommodate to multi-joint movements, and not all of them are designed to fit all body types, limiting the effectiveness of the exercise and creating more stress to joints in older people (Clark, et al., 2014).

The conception that equipment that provides high-external loads is the most ideal for increasing muscle mass imposes a barrier for the implementation of resistance training in exercise programs for older adults, who often do not have access to brick-and-mortar fitness facilities, and when they do, require constant supervision when performing the routine (Gentil, 2020). Yet, it's important to note that resistance training does not necessarily involve the need of conventional equipment and facilities which allows it to be performed in a range of alternative situations (Gentil, 2020).

Studies in untrained (Mitchell, et al., 2012; Assunção, et al., 2016) and trained people (Morton, et al., 2016) have demonstrated that training with low-external loads promote similar gains in muscle mass and strength compared to high-external loads, given that muscles are stimulated more with effort and the type of exercise performed than with the application of load. Moreover, some studies (Counts, et al., 2016; Barbalho, et al., 2019) have verified that even when working out without external-load, gains in mass and strength can be observed after some weeks of continuous performance of the routine.

With this in mind, training with small implements without the need of specialized resources or facilities is a feasible option for resistance-training at home (Gentil, 2020). Several effective, safe, low-cost, time-efficient modalities based on low-external or body-weight load that are applicable for their implementation in programs for older adults are listed below (Clark, et al., 2014).

Free weights:

Free weights such as barbells and dumbbells allow individuals to perform exercises with various degrees of amplitude and ranges of motion similar with those experienced in daily life and sport. Many free-weight exercises can be easily progressed to provide greater demands on balance and strength and performing complex exercises requires more energy, enabling individuals to expend more calories in a shorter period. Although free weights offer many benefits, they can be potentially dangerous for novice exercisers until proper technique is mastered, they may require supervision and require multiple dumbbells or barbells to change the load.

Cable machines:

cable machines offer a variety of fitness performance benefits because they allow similar freedom of movement as free weights, they can be adapted to offer resistance for all body parts and are effective for developing balance and improving functional capacity. Cable machines are also a good choice since they can be used for both standing and seated position exercises. Once the individual learns to position the machine with respect to the lines of motion of the joints, the exercise can be performed without the need for constant monitoring by the trainer. However, like strength training machines, many of these machines are bulky and heavy, making them unsuitable for the home context.

Elastic Resistance:

Rubber tubing and bands are inexpensive alternatives to training with resistance. They allow to move in multiple planes of motion, can be set in different angles, and come in different shapes and thicknesses which allow for different levels of resistance and a vast range of exercises that can be combined seamlessly. In addition to its versatility, one of the greatest advantages of elastic resistance over free weights is its low cost and portability. Elastic resistance bands are lightweight, they're easy to use in different spaces, they can be used for the most varied audiences, they are safe, and have a high potential for application in domestic environments (Campos, 2020).

Kettlebell training:

A kettlebell differs from a dumbbell, barbell, or medicine ball in that the center of the mass is away from the handle, which requires more strength, coordination inward focus and conscious attention when performing the exercises. Therefore, proper form and technique must be mastered to avoid injury, and the skill required to perform many kettlebell movements, makes this modality not appropriate for all populations.

Body weight training:

Body weight exercises are exercises that do not require additional load such as barbells, dumbbells, or strength-training machines. Instead, an individual's own body weight along with gravity provides the resistance for the movement. By performing body-weight training exercises, individuals can learn how to train in all planes of motion and may acquire greater kinesthetic awareness, making it an optimal alternative for multimodal training. In addition, body-weight training can be virtually performed anywhere, which is an added benefit for those who don't enjoy or don't have access to training facilities.

3.3. Technology based exercise

Just as with traditional center-based exercise programs, one of the main problems when developing home-based exercise interventions in older adults is the adherence rate. To maintain the health benefits of home-based exercise programs, older people are recommended to follow their routines consistently and progressively (Mittaz Hager, et al., 2019). However, older adult's adherence to exercise interventions declines over time (Picorelli, 2014; Yardley, 2006), due to a variety of psychological, cognitive behavioral, physical, or simply organizational factors that act as barriers to participation in physical activity (Forkan, 2006).

To promote physical activity and improve adherence in older people at home, technology-based systems are promising tools. New technologies, like wearables, internet-connected devices and gamified systems, have the potential to provide timely interventions to assist older adults in keeping healthy and independent for longer (Geraedts, 2014), increasing the exercise uptake and long-term adherence as they may result engaging, provide immediate feedback and allow for customization and progression of the exercise programs (Valenzuela, et al., 2011).

Technology-based exercise programs offer several advantages over traditional exercise programs that can contribute to a more stimulating and enjoyable exercise experience. Among these are the improvement of physical functioning components like balance and postural control and cognitive functions like attention and memory (Bleakley, 2013). Other benefits include the opportunity to tailor the program to include different exercise modalities (balance, strength, functional exercises, etc), offer a wide variety of exercises, routines that can be performed with little to none supervision, and the ability to provide exercises that are both physically and cognitively challenging, further increasing the motivation to continue exercising (Valenzuela, et al., 2011).

Although there are many other theoretical advantages to using technology-based exercise programs, more work is required toward tailoring products and services more suitable for older people with limited technical experience and skills (Gschwind, 2015; Schoene, 2015). Studies made with commercially available products report the difficulty of participants in using the technology, as the systems often lack clear instructions, are fast-paced, and present too much graphical information (Gschwind, 2015; Schoene, 2015). Similarly, studies where the programs were specifically designed for older people, to provide balance and strength exercises, and cognitive-motor activities, found their specific desire for explicit on-screen instructions, tailored exercise prescription and progression, a variety of activities to perform, and the ability to exercise at home in their own time (Valenzuela, et al., 2011). Therefore, to facilitate the implementation of these technologies, the development of products and services should take into account the specific needs of older people along with the recommendations of physical activity for this age group (Sherrington, 2008).

3.3.1. Internet of Things

The Internet of Things (IoT) is a system of inter-related computing devices or objects with embedded technology for sensing, interacting with the environment and offering autonomous communication by transferring data over a network with intelligent device-to-device interactions (Kang, 2020; Stavropoulos, 2020). IoT has been gaining popularity quite rapidly in recent years and their new developments and applications are shaping daily life. According to Blanter & Holman (2020), there were about 30 billion devices and over 7,7 people connected to IoT networks during the first months of 2020.

Among the IoT different application domains, fitness is a very relevant sector that has gained interest in the last couple of years. By giving users the ability to monitor and track their exercise, IoT-based applications and devices can be one solution for improving people's exercise compliance, as they have significant potential for providing automated, tailored services for people who perform physical activity (Kang, 2020). In older adults, these devices have the advantage of boosting physical activity through the integration of behavioral change techniques such as goal setting, self-monitoring, feedback, social support, social comparison and rewards (Mercer, 2016; Lyons, 2014).

These IoT devices can be of various types and include smart watches, smart exercise machines, fitness trackers, clothing/footwear, implantable sensors, and other interconnection devices (Golovnya, 2020) with several technologies like sensing technology, wired and wireless communications, cloud computing, middleware, service interface technology and security technology (Lee, 2015). Analytics and artificial intelligence techniques are also often coupled with these technologies to extract intelligence, patterns, trends, user profiles, outliers for deeper assessment and care (Stavropoulos, 2017).

3.3.1.1. Activity trackers

Development of activity tracking systems regarding physical activities in older adults has been done mainly in the context of rehabilitation (Gerling, 2017). However, the knowledge obtained from this researches have allowed the creation of commercial grade trackers with the potential to enhance exercise programs at home by rising awareness of personal limitations, giving social motivation, establishing and adapting to routines and finding enjoyable activities (Faber, 2006). For gathering data of physical performance, there are two different methods: wearable and non-wearable devices.

Non-wearable devices: measure the activity of the user through sensors (e.g., accelerometers and gyroscopes) embedded in objects. For example, sensors in specialized fitness machines like barbells, dumbbells, leg press devices, among others,

that are capable of accurately monitoring the activities of the user. Information like speed, location and weight can be measured according to the type of exercise or segment of the user's body (Farrokhi, et al., 2021).

Fig 3. JaxJox smart dumbbells

Regarding the architecture, proposed non-wearable system solutions in the literature are composed of a device with an embedded IMU (Inertial Measurement Unit) that sense and send data, a server that manages the data collection process, a date warehouse that archives history of the processed data and a connection to an expert, who can provide advice on the performance of the exercise (Farrokhi, et al., 2021). An example of this type of architecture is the Wii Remote controller. In this case, accelerometers and gyroscopes sense the initial and final position, as well as the movement of the device, to determine what type of workout the user is engaged in (Farrokhi, et al., 2021).

This type of solution requires an application where the administrator, the expert and the user can access information related to the exercise program. In this case, the expert can monitor the information collected by the device of the users' performance, and modify their training schedule according to their needs (Farrokhi, et al., 2021). Moreover, the same device can be used by different individuals, and the information generated will be recorded according to the application account of each user. Related to this topic, researchers like Schmidt et al. (Schmidt, 2015) have proposed the use of digital personal coaches, based on mathematical models to study the user's activities and gather more in-depth data to improve the tailoring of home-based programs. Some market solutions like Tonal and Freeletics already rely on non-wearable trackers and AI based coaching to provide a complete feedback, monitor and advisor system that improves with use.

Some issues related to the accuracy sometimes make difficult the development of non-wearable tracker systems. Given that non-wearable sensors need to be more accurate in the processing of data, more attention to age, gender, workout history, and more monitoring parameters like action duration, angle, distance from the device, time, etc., should be paid off when monitoring the correctness of the movements. Moreover, the cost of smart fitness devices, particularly smart gym equipment, still needs to decrease (Ring, 2021). Implementing a small fitness system has important costs comprising

costs for appropriated sensors to include in the products, and for the development of a system to process the gathered data (Farrokhi, et al., 2021).

Wearable devices: measure the activity of the user through sensors directly attached to the user's body. Wearable devices automatically track and monitor various indicators of physical activity, such as pulse, heart rate, calories expended, steps taken and even duration and quality of sleep (Asimakopoulos, 2017). Wearables synchronize these data with the user's account, ensuring access from any device (Kononova, 2019) and provide immediate feedback to the user, which may be beneficial in providing motivation to older adults for improving physical activity (Rao, 2019).

Fig 4. Fitbit Smartwatch

The miniaturization of sensors and electronic circuits based on the use of microelectronics has played an important role in the development of wearable devices (Patel, 2012). Particularly relevant to applications in the field of fitness and rehabilitation are advances in microelectromechanical systems (MEMS), as they have allowed the development of very small inertial sensors that capture data of motor activity and other physiological markers. By using batch fabrication techniques, great reduction in size and cost of these devices has been achieved (Patel, 2012).

Regarding the hardware of wearable devices, one of the most commonly used sensor in wearable devices is the accelerometer, as it can track step detection and walk intensity, however, other sensors like gyrosensors, heart rate, and magnetometers, used to quantify the amount of effort the user exerts can also be found in these systems (Vargemidis, 2020). Tracking systems often rely on sensors included in devices such as smartphones, which can be carried in the pockets or the hands. Other systems can be attached to the wristbands, the legs, (in the thighs, knees or shin), or at the waist (Vargemidis, 2020). The processed results about the physical activity are most often reported on a computer screen or a smartphone, but other systems reported in literature use also VR headset, and other types of screens, like televisions and tablets (Vargemidis, 2020).

The most frequently tracked activity with these devices is walking, along with all related ones, such as running and jogging (Vargemidis, 2020). General exercising is also commonly tracked, especially when in combination with exergames or gamified exercise programs. Some systems track activities of daily living, which include physical activity done during common tasks or daily habits, such as routines at home, house work or leisure (Vargemidis, 2020).

Wearables provide older adults with relatively unbiased data about their performance, and eliminate the hassles of self-reporting. Additionally, fitness trackers work as helpful motivators for elders in achieving walking goals and competing with other people (Agency for Healthcare Research and Quality (AHRQ), 2004). However, sometimes older adults can find wearables very difficult to use, and it is therefore important to consider factors like the usability, comfort and feasibility of the trackers for the oldest of this age group (Alharbi, 2019).

3.3.1.2. Movement analysis

One of the major motivations for the development of IoT products is the ability to determine a person's movements given their potential of application in healthcare innovation, such as motor rehabilitation and autonomous monitoring of patients (Farrokhi, et al., 2021). Although over the years, the use of these technologies has been relegated to research due to the high costs and complexity of operation, nowadays there are low-cost options that are more suitable for wide adoption in everyday life applications such as entertainment and fitness (Milosevic, 2020).

Video based-motion capture

The use of cameras and computer vision algorithms for movement analysis is a well-established application field, and has contributions from both research and industry (Poppe, 2007). Video-based motion capture and Marker-based Stereophotogrammetry systems (MBS) are the standards for high-precision applications, especially in biomechanics and clinical gait analysis (Cappozzo A., 2005). In MBS systems, multiple cameras use infra-red illuminators and triangulation algorithms to track the position of reflective markers moving within a stablished field of view (Milosevic, 2020). When used for motion capture, the user is dressed with a set of reflective markers to identify and track relevant parts of the body, and the system uses their positions to reconstruct and track the user's body segments and joints (Della Croce, 2005).). There are a number of commercially available systems with high-performance hardware and software that offer accurate and reliable motion tracking, like Vicon Nexus, Elite, and Optitrack Motive (Milosevic, 2020). The main

downside of the MBS though, is the high cost and the complexity of its setup and use, which makes it an option more adequate for research rather than everyday context (Milosevic, 2020).

Case Study: The Kinect

As an alternative to MBS, marker-less motion capture systems integrated with depth sensors have been developed to improve usability (Milosevic, 2020). Microsoft first introduced the Kinect sensor to be used as an add-on for the Xbox game console. It featured a standard digital video camera, a depth sensor based on infra-red illumination, and a directional microphone (Milosevic, 2020). The integration of the Kinect with dedicated algorithms allowed marker-less tracking of the body's segments and movements, creating a user interface based on gestures (Shotton, 2013). Although initially developed and sold as a game controller, the Kinect has been applied to a great range of both academic and industrial projects, including robotics, interaction, and biomechanics (Mousavi Hondori H, 2014), due to its offer in sensing capacity at a very low price.

The second-generation device and its updated algorithm have been validated further within the context of clinical motion analysis, in applications such as fall detection, posture and balance evaluation, gait assessment and rehabilitation exercises (Milosevic, 2020). With respect to inertial sensors, such as wearable tracking devices, the Kinect system is less invasive, as the body of the tracked subject is free of any instrument (Milosevic, 2020). Moreover, the performance of Kinect-based home exercise programs has been researched, providing insights on the user adoption with good results and indications for future improvements (Valdés, 2014; Brokaw, 2015).

Fig 5. Azure Kinect Developer Kit

The Azure Kinect developer kit has a stronger performance by mixing an RGB camera with depth sensors and the already known IMU. Although the new generation of Kinect achieves good overall performance in the tracking of human pose and basic movements, it shows some limitations when dealing with more complex exercises or when the movements are not performed with the user standing facing the sensor

(Milosevic, 2020). These results reduce the use of the Kinect as an accurate tool for applications in the clinical context (Milosevic, 2020), but it still retains the potential for use in more qualitative assessments of posture and exercise, such as at-home monitoring of exercise programs.

Inertial-based motion capture

Wearable sensing devices are another way of sensing human motion. To obtain information regarding specific movements, one or more sensing devices are worn directly on specific body parts and connected to a central processing hub for data collection and processing, forming a Body Sensor Network (Yang, 2006) which recreates a model of the body and all of its joint motion. There are several examples in the market, ranging from high-end solutions for body motion capture used for animation and clinical movement analysis (Roetenberg, 2009) , to ubiquitous motion trackers and sensors embedded in smartphones (Lane, 2010). Notable examples include MVN Biomech from Xsens Technologies and Opal from APDM Technologies (Milosevic, 2020). However, this multi-sensor setup presents several technological requirements in terms of its sensing capabilities, signal bandwidth, and throughput, as well as general challenges like the wearability of the device, system usability, and data reliability (Hanson, 2009).

Other systems, more compact like wearable IMUs, allow the collection of motion data relative to the body segment where its worn, through the integration of multiple sensors within the same device (accelerometer, gyroscope and magnetometer) (Milosevic, 2020). Research and clinical studies have validated the use of wearable IMUs in postural evaluation, fall monitoring and prediction, rehabilitation and gait analysis. Usability aspects of the implementation of such systems for home contexts have also been investigated providing evidence of their accuracy and reliability when compared with high-precision MBS systems, and their benefits when used in home-based exercise programs (Milosevic, 2020).

Considering at-home uses, wearable IMUs have an additional requirement when compared to the Kinect, since the user has to wear the sensors. Although wearing the device can be as simple as using an elastic band, it can be a source of uncertainty, like for example the misplacement of the sensor, or it can be problematic for elderly or impaired users (Milosevic, 2020).

Case study: Wii Remote

The Wii Remote is a wireless low-cost controller for the Nintendo Wii console that allows the user to interact with games and applications via gestures, thanks to a combination of accelerometers and gyroscopes that measure velocity,

orientation, and gravitational forces. Sensing acceleration along three axes and measuring angular velocity, the technology provides simple visual bio-feedback training for upper or lower limbs (Tsekleves, 2014).

Fig 6. Wii Remote Controller

Due to the motivational advantages, the relatively safe setup conditions, and its affordability, over the years it has caught the attention of researchers, who have used it for numerous application studies in rehabilitation settings (Tsekleves, 2014). Additionally, there has been extensive discussion in the literature regarding benefits of the use of Wii remotes in the implementation of home-based exercise programs (Tsekleves, 2014). In general, it is reported that this type of IMU's in combination with exergames (e.g. Wii Sports) usage, has positive effects such as improved physical functioning, decrease in depression, improved cognition, improved socialization, and increased motivation to exercise (Chao, 2014).

Although originally the Nintendo Wii is intended to provide entertainment and not to be used in exercise or rehabilitation programs, thanks to the compatibility of the system with open source software applications and integration with infra-red cameras, the Wii Remote can be customized to develop solutions that capture the user's limbs motion in a more accurate way compared to the conventional remote, and that allow for the gathering and extraction of data for analysis (Tsekleves, 2014). While its customization allows the user to perform specific exercises and receive immediate feedback of his/her physical actions and movements on a screen, the calibration of both the device and the applications to each user's morphology to accurately measure speed, reaction time and range of movement remains a challenge (Yong Joo, 2010).

3.3.2. Applications

Applications play a key role in technology supported fitness, and they have evolved over the years to the point where they can now constitute a category by themselves. They can provide several functionalities to the users, connect to activity sensors and devices, provide examples of training sequences, connect people and can even serve as alternatives to wearable devices (Farrokhi, et al., 2021).

According to Khagani Far et al. (2016), in the design of training applications three different aspects of the interaction with the app can be identified: direction, input type, and training output. Regarding the interaction direction, some apps provide the users with prerecorded exercises that don't require the user's feedback (unidirectional approach), while others employ user feedback before and during the training to monitor and tailor the training program (bidirectional approach). In terms of how the user interacts with the medium, the inputs can be indirect, when the actions require a translation (e.g., using a mouse pointing device), direct, when the action doesn't need translation (e.g., using a touch-enabled device), and natural, when the input components are invisible and the interaction happens using natural gestures (e.g., posture recognition with cameras). Lastly, the training output refers to how the training is represented, and it can be either as text, illustrations, audio, video, or even an immersive environment.

Different types of instruments can be used to capture data relevant for the training. Many applications rely on self-reported questionnaires, as they allow to gather training-related data, like level of performance and adherence to the training, as well as the overall wellbeing, without requiring specialized sensors (Khaghani-Far, 2016). However, self-reporting is time-consuming and can be a complex cognitive task, especially for age groups with memory limitations such as older adults (Sallis, 2000),), which could lead to misreporting (Fitness Apps for HB training, ref 2). In addition, from the user's perspective, entering data manually can lead to a decline in app usage (Ahtinen, et al., 2009). As a way to improve the usability, other apps employ sensing technologies to measure activity levels in a more objective and fast way, through the integration with activity trackers, mobile phones, or environmental sensors and motion-sensing devices, such as MS Kinect and Nintendo Wii Remote (Khaghani-Far, 2016).

In terms of the coaching process that some of the fitness apps offer, technology provides different levels of support, from entirely human to fully automatic (virtual) coaching (Khaghani-Far, 2016). In the support provided by a human coach, the coach provides not only information and feedback, but also knowledge about the exercises, encouragement and emotional support while the user goes through exercising sessions (Chi-Wai, et al., 2011). The technology can act just as a communication tool between the coach and the user, or it can also help the coach monitor and tailor the training program. Virtual coaches instead, rely on pre-programmed or smart machines that monitor, prescribe and tailor the exercise program for the user (Ruttkay, 2006). However, coaching in this form doesn't provide the social support that is needed when dealing with sensitive users such as older adults (Hanneton S, 2009).

4. Evolutionary aspects of Fitness Industry

4.1. Fitness Pre-COVID-19

Over the last fifty years, participation in fitness has developed as one of the fastest growing modalities of physical activity, especially in economically advanced countries. Nowadays, fitness is an integral part of daily life, making fitness and health services expand given the high demand for participation (Scheerder, 2020). The global growth of the fitness industry plays and important role in expanding the access to physical activity, by offering alternatives more affordable, convenient, personalized and fun (Scheerder, 2020).

Health clubs and gyms have experienced a massive expansion during the last decade, with near 50% growth in revenues reported between 2007-2018 (Global Wellness Institue, 2018). According to the Global Wellness Institute (2019), in 2017, the fitness industry was worth %595 billion; an important component of the $4.2 trillion global wellness economy. Additionally, it was estimated that in 20019, 3,7% of the world's population were members of gyms, health clubs and fitness studios and/or participated in independent or structured fitness activities or classes on a regular basis.

The fitness was most developed in North America, with $40,5 billion in expenditures and a 29,1% participation rate in 2018. Europe ranks slightly below for its expenditures of $33,8 billion but its participation is significantly lower, at 9,2%. Average annual spending per participant is higher in Asia-Pacific ($494) and Middle East-North Africa ($495), despite having lower overall expenditures compared to North America and Europe. This is likely because the fitness market at that time, was less advanced across those regions, with a lower prevalence of budget gym concepts and subsidized/free exercise programs (with the exception of key countries such as Australia, New Zealand, Singapore and Japan) (Global Wellness Institute, 2019).

In the case of Latin America-Caribbean, the average spending per participant was relatively low ($180). This is mainly because a great number of countries across Latin America have institutional public programs to fight overweight and physical inactivity, including free outdoor gyms in parks, as well as government-sponsored programs of free fitness classes in outdoors. Approximately 20% of the fitness participants in Latin America are served by these programs, which raises the overall participation rate

while keeping a low spending rate average across the region (Global Wellness Institute, 2019).

More recent data from the International Health, Racquet & Sportsclub Association (IHRSA), showed that prior to 2020, the global club fitness industry, which is the section of the fitness industry that encompasses the brick-and-mortar facilities, was enjoying a steady boom with generated revenues of $96,7 billion in 2019, compared to $67,19 billion in 2009 (Ring, 2021).

People engage in fitness activities in a wide range of places. In 2019, about 190 million people were members of brick-and-mortar fitness facilities, 33,8 million used public facilities and 16 million used university centers and hotel gyms with public access (Global Wellness Institute, 2019). Additionally, it was reported that about 103,2 million people worked out independently or at home, using treadmills, stationary bikes, weights, and other home-based fitness equipment, as well as videos, books, and other technologies. It's noteworthy that a significant portion of the people who work out at home also used at least one of the former categories. Also, among those doing exercise at home, an estimated 28,8 million had subscriptions to on-demand and streaming fitness services (Global Wellness Institute, 2019).

4.2. The COVID-19

The fitness industry has been among the hardest hit by COVID-19. In a year unlike any other, 2020 tested the resiliency and strength of the fitness industry. For months, clubs were forced to close due to lockdowns and social distancing measures, sometimes more than once with without a clear guarantee of support from governments. The image of fitness facilities was challenged as they were marked as sources of spread of the virus along with other indoor business like bars and restaurants. When allowed to operate, heavy restrictions regarding capacity, distancing measures and use of masks, prevented brick-and-mortar facilities re-opening properly, often causing many memberships to be cancelled or go on "freeze" (Club Industry , 2021).

To this day, business still have large percentages of members from the closures of 2020 still on freeze with no committed return date. Revenue declined 58%, and about 6.800 facilities, which represents the 17% of all U.S clubs (IHRSA, 2021), among them major chains, like Town Sports, Gold's Gym and 24-Hour Fitness, have declared bankruptcy and closed permanently (LEK, 2021), while others have remained open but have reduced their footprint down to 50%-60% compared to last year (Club Industry , 2021). As a way to fight back the restrictions and maintain the flow of people in their facilities, traditional brick-and-mortar clubs, especially those with outdoor components, implemented outdoor usage under tents or temporary pavilions (Club Industry , 2021) and changed their subscription models to be flexible and allow for suspensions and payments month-to-month. But while the industry expects to rebound to pre-

COVID-19 levels with this new measures, consumer hesitance around using in-person will likely push a full recovery out to 2024 (LEK, 2021).

As soon as the lockdowns took effect, many people made significant changes to their exercise regimens. Those who used to exercise regularly at brick-and-mortar facilities turned their full attention to home-fitness, investing in at-home gym equipment or make use of the equipment they already had (Rizzo, 2021). Health and fitness equipment revenue more than doubled, to $2,3 billion, from march to October, according to data provided by NPD group (Shaban, 2021), with U.S citizens investing an average of $96 in equipment during first three months (Freeletics, 2021). Yoga mats, resistance bands and dumbbells became the top fitness equipment that people invested in, depleting the inventories (Freeletics, 2021).

With no guarantees to continue training regularly in fitness facilities, people were forced to discover new ways to keep fit at home. While traditional brick-and-mortar gyms and boutiques were struggling to adapt their services, solutions that were digital in nature, like online fitness content, courses, classes, and subscriptions experienced growth during 2020, as many people started considering them as the best options to achieve fitness goals during the closures of gyms (Shaban, 2021).

This digital shift didn't appear overnight though. Even before the pandemic, fitness trends were focusing on home workouts, with wearables, at-home training equipment, and social communities rising to the front (Rider, 2021). The pandemic, as Stephen Owusu, CEO and Inventor of connected fitness company JAXJOX says, simply propelled the at-home fitness scenario, with online tools like Zoom, YouTube, and Instagram, serving as virtual fitness communities online, and lockdowns making people adapt their living spaces to support home fitness routines (Rider, 2021).

The at-home fitness boom and a growing desire for professional, on-demand workout programs, sparked a massive increase in health and fitness app downloads (Shaban, 2021). According to Sensor Tower, from January through November of 2020, approximately 2,5 billion health and fitness apps were downloaded around the world, a jump of 47% from the same period in 2019 (Shaban, 2021). Sensor Tower also showed that users downloaded Home Workout – No equipment, the top fitness app of the year, 43,5 million times, which represented more than double of its downloads from the previous year (Shaban, 2021).

The 2020 showed that home fitness companies with digital approaches were the best to adapt to the pandemic scenario (Rizzo, 2021). While they originally generated most of their revenue through hardware sales, digital subscriptions and membership started making up a significant portion of their business. One notable case, Peloton, recorded 382% growth for digital subscriptions which did not require any of their hardware products (Rizzo, 2021). Similar to the dynamic of mobile devices,

wearables and gaming consoles, this companies discovered a way to extract consistent fees from customers by offering services and software focused in overall wellbeing, a trend that has continued in 2021 (Shaban, 2021).

Now as the second half of 2021 approaches, the $94 billion fitness industry has demonstrated an undergoing digital transformation in all its sectors, with the digital fitness sector alone forecast to reach $27,4 billion in 2022 (Club Industry , 2021). Consumer preferences are changing, with exploding interest in integrated ecosystems of hardware, software and livestreamed or on-demand content (Club Industry , 2021; LEK, 2021). For the most part, consumers say they are willing to return to in-person fitness once the pandemic is under control (IHRSA, 2020), however, the frequency is expected to decline from pre-COVID-19 levels, as 46% of participants intend to make virtual classes part of their weekly routine even after fitness facilities reopen completely (Club Industry , 2021).

The full impact of the pandemic may not be quantified for some time, but early feedback from IHRSA shows an encouraging future (IHRSA, 2020). Despite, the challenges of COVID-19 still lingering in 2021, the fitness industry remains positive in the growth of some of their sectors. More digital solutions, as well as hardware for fitness at home will keep appearing in the market, while traditional brick-and-mortar gyms will have to adopt a hybrid or omni-channel approach, offering a combination of in-facility, outdoor, and online via on-demand or live programming to meet the demands of fitness club members (IHRSA, 2021). Luckily, future fitness industry growth can be further stimulated, as the pandemic has revealed numerous development opportunities throughout sectors of the population that were previously ignored or underserved, that can benefit from innovation in fitness products and services (IHRSA, 2021).

4.3. Benchmarking

To understand how innovation in the fitness industry can keep its regular consumers engaged, as well as to reach those segments of the population that are still considered physically inactive, it is important to have a look at the situation in one of its key enabling sectors.

Technology has been one of the biggest trends driving change in the fitness economy, bringing new business models and methods of participation, new devices and equipment and new ways to reach people. Its landscape encompasses a diverse range of equipment, devices, software and services that support people's participation in physical activity, in several ways. The Global Wellness Institute (2019) estimates that technologies related to physical activity represented a $26,3 billion market in 2018. During that year, Asia-Pacific was the largest regional market, at $10,8 billion, being the world's largest consumer market for fitness trackers and wearables, while North America ranked second in size for technology, at $8,6 billion, being the largest region for fitness technology services (i.e., apps, streaming

services, software, among others) (Global Wellness Institute, 2019). Although for the pandemic scenario there are still no official figures, what is certain is that since the COVID-19 outbreak the growth of the technology sector has exploded, to the point where by 2021, only in the wearable device market share $63 billion are expected in end-user spending (Glofox, 2021).

As the 2021 advances, the fitness industry has had to adapt to the new normal, launching new concepts to the market leveraging on the swift progress of wearable technologies, AI, applications and home-equipment, to fill the gaps in the lifestyles of the pandemic scenario (Glofox, 2021). With promises of making exercise more convenient, affordable, personalized, portable, trackable, personalized and fun, these technologies have seen a rapid uptake by consumers all over the world, even in countries that have not previously had developed fitness offerings (Global Wellness Institute, 2019)

4.3.1. Connected equipment

Fitness gym equipment and sporting goods with embedded sensors and online connection are a small but rapidly growing section of the fitness equipment market. The connected gym equipment category includes equipment with smart functions that track metrics, analyze performance, provide virtual coaching, among other functions, thanks to the combination of hardware and software (Global Wellness Institute, 2019). Valued at US$ 510.5 million in 2020 and projected to reach US$ 3,472.7 million by 2028, this market is segmented mainly into cardiovascular and strength training (Research and Markets, 2021). While the cardiovascular training segment is projected to be the larger market shareholder, the strength training equipment segment will also possess a robust market presence as more people are paying more attention to increasing muscle mass, and strengthening bones (Fortune Business Insights, 2021)

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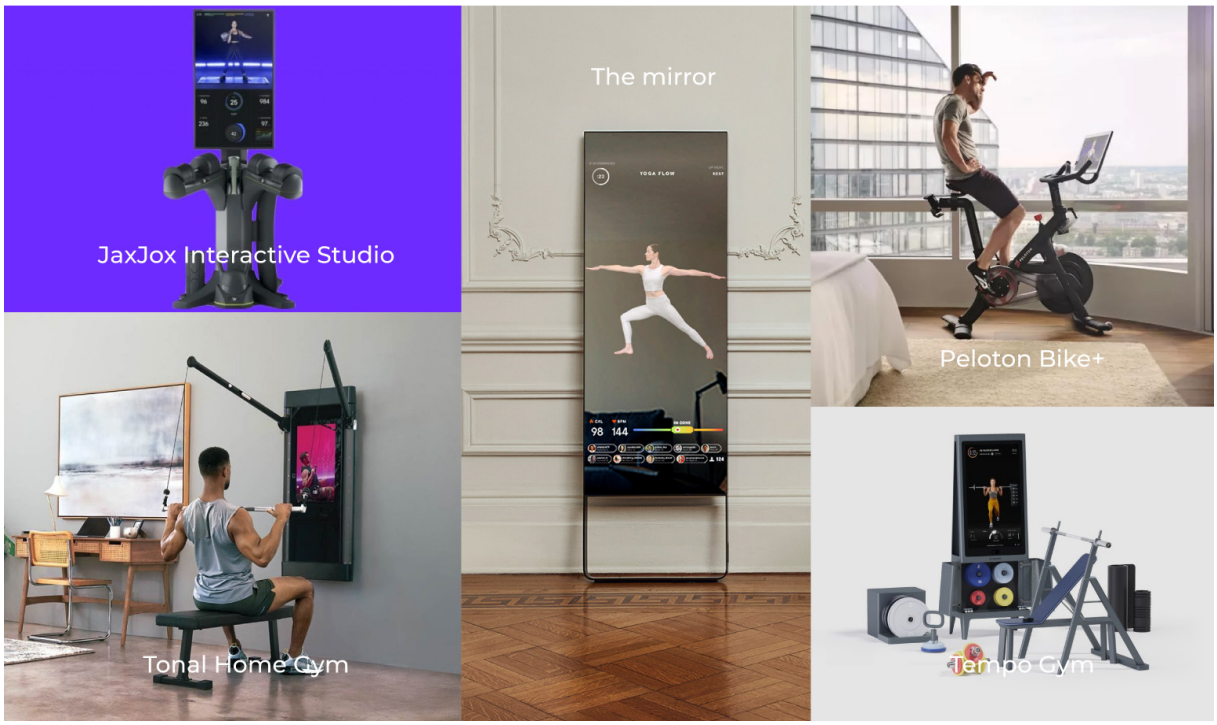

Fig 7. Connected equipment

Comparison between equipment

		JaxJox	Tonal	Tempo	Peloton	Mirror
Hardware	Training modality	Kettlebell, Dumbbell, foam roller, push up stand	Magnetic Cable machine	- Barbell, 2 Dumbbells, and 16 plates – Optional: folding squat rack and bench, kettlebell, extra storage	Magnetic Pedals	Body-weight
	Equipment size	2 m x 0,8 m	0,54 x1,29 x 0,13 m	1,8 m x 0,7 m	1,49 x 0,58 x 1,49 m	1,32 x 0,56 x 0,03 m
	Exercise space	1,5 m	2,13 m	1,8 m	0,60 m	1,5 m
	Sensing and monitoring	Heart rate, Repetition count, weight and power output	-3D motion sensing, heart rate, weight. -Can be paired up with smart-watches	3D motion sensing, heart rate	-Resistance, cadence, output -Can be paired up with smart-watches	-Can be paired up with smart-watches
	Screen	43" Rotating	24" Rotating	42"	23,8" Rotating	53"
Interaction	Medium	Touchscreen, mobile app, equipment	Touchscreen, mobile app, equipment	Touchscreen, mobile app	Touchscreen, mobile app	Mobile app
	User's feedback	Sensor's data	Sensor's data	Sensor's data	Sensor's data, self-repot	Self-report
AI-Support		Performance tracking, Fitness IQ	Spotter mode (resistance auto-adjust), Form correction, Performance tracking	Performance tracking, Form correction	Non-supported	Non-supported
Membership	Training features	Live and on-demand classes				
	Social-motivational features	Leaderboards, in-person Partner workouts	Leaderboards, in- person Partner workouts, virtual groups workout, Achievements badges	Leaderboards, personalized form correction during live classes	Leaderboards, coach correction during live classes, virtual group riding	Personal training, in-person Partner workouts, Group programs
Type of PA supported		Resistance, Cardio, Recovery training	Resistance, Cardio, Multi-modal	Resistance, Cardio, Multi-modal	Cardio	Cardio
Price		$2399	$3490	$2495	$2495	$1345

Table 1. Connected equipment comparison

Connected equipment focuses on simulating the experience that a user can have in a regular gym by implementing hardware modalities that people are already familiar with (kettlebells, dumbbells, cable machines, bikes). However, unlike the equipment that can be found in regular gyms, in this case customizability and economy of space prevail so that the equipment can be placed and used inside the home without major inconveniences. Regarding the types of physical activity supported, in the market the equipment that focuses more on cardio training prevails, such as bicycles, treadmills, stair climbers, and mirrors, while only a few equipment (JaxJox, Tonal, Tempo) they focus on resistance training and multimodal activities.

The implementation of sensors for monitoring physical activity is a game changer when it comes to training at home. In particular, the tracking of movements and the number of repetitions or cycles are more effective than other sensed variables to improve the quality of the exercise. In cases where the equipment does not have the appropriate technology to sense physiological markers such as heart rate or oxygen saturation, these include synchronization with wearables to offer a more complete analysis of user performance.

As for the interaction, while the sensors are responsible for providing the system with most of the information about the workout performance, the feedback that the latter offers to the users in all cases is done almost entirely through screens (cellphone). Only in the cases of Peloton's Bike + and the Tonal Home Gym, the output of the system is also seen through the automatic adjustment of resistance in equipment components such as pedals and cables.AI support is convenient in most cases to keep track of the performance, tailor the training programs for the users and help them reach their fitness goals easier. However, the constant data tracking and AI support is sometimes overwhelming for those who are only interested in the physical part of the training (Clark, 2021)) or for those who require more support and time to adapt to the system, such as older adults (the potential role of tech). Moreover, in most cases the use of AI support is directly linked to membership, so the most useful functions will always be accessible only to users who are willing to pay more.

Along with membership, all systems grant access to live and on-demand classes. At this point, all brands agree that it is the most effective way to complement exercise programs and bring the experience of guided training from the gym directly to the home, in a massive and completely virtual way. These classes are additionally designed to increase user motivation, and filtered between libraries and categories to suit their needs, either through AI data processing (JaxJox, Tonal, Tempo) or through self-report (Peloton, Mirror). Although most systems come with cameras, only Mirror uses it to connect with trainers and physical rehabilitation experts for completely personalized workouts.

Additional motivation features to increase adherence can be divided into two major categories: individual, referring to strategies that leverage the individual will and natural drive of the user, and social, referring to strategies that require the presence of a community (Khaghani-Far, 2016)). Some individual persuasion strategies used are, reminders and suggestions, rewards (e.g., achievement badges, additional content), form correction, and self-monitoring. Social persuasion strategies instead, include social learning (eg, comparison through videos), cooperation (eg, in-person partner workouts, virtual group

riding), competition (eg, leaderboards), social support (eg, high fives, live chats), and recognition (eg, group recognition of awards, progress and contributions) (Khaghani-Far, 2016).

Finally, a characteristic shared by all connected equipment is its high price. The implementation of state-of-the-art technology such as touch screens, environmental sensors, embedded trackers, and self-adjusting weights makes the cost of all this equipment much higher than that of traditional training equipment and represents a limitation in access for less wealthy populations (Global Wellness Institute, 2019). Additionally, memberships generate recurring expenses, which, although they are cheaper than many of the memberships of fitness facilities, can influence the purchase decision of older adults who are already reluctant to acquire and adopt new technologies (Czaja, 2017).

4.3.2. Wearables and trackers

The wearables and trackers segment is defined as “devices that are explicitly intended for fitness”. This category includes fitness bands equipped with sensors and other type of activity trackers that range from simple pedometers to dedicated high-tech health sensors, and analyze the physical activity and body functions of the wearer (Ring, 2021). According to MarketsandMarkets, the market size wearables and trackers is projected to grow from $116,2 billion in 2021 to $265,4 billion by 2026. The key factors contributing to the growth of the wearable and trackers market include consumer preference for sophisticated gadgets, the increasing growth prospects of next-generation displays in the devices, and the growing popularity of IoT and connected equipment (MarketsandMarkets, 2021).

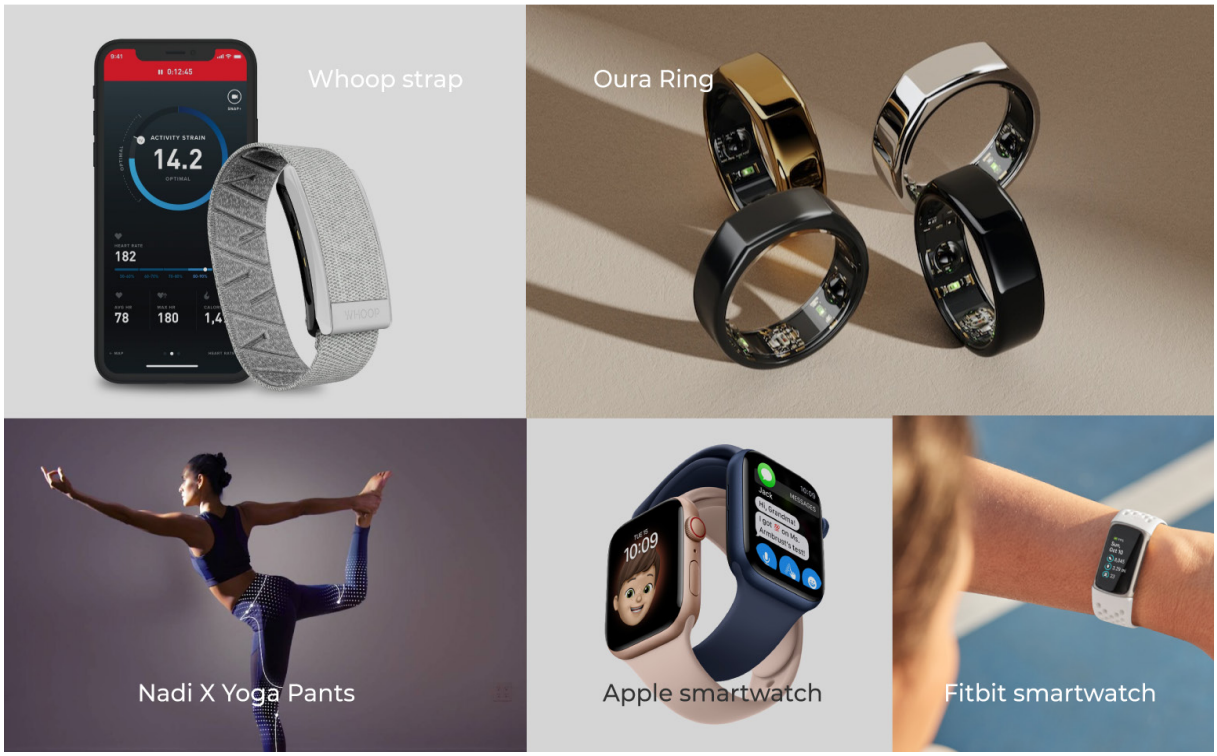

Fig 8. Wearables and trackers

Comparison between equipment

		Apple	Whoop	Aura	Fitbit	Nadi X
Hardware	**Tipology**	**Watch**	**Strap**	**Ring**	**Watch/Strap**	**Yoga Pants**
	Size	44 x 38 x 10.4 mm	25 mm wide. Adjustable length	7,9 mm wide, 2,5 mm thick	35,8 x 22,7 x 12,5 mm	XS, S, M
	Sensing and monitoring	Blood oxygen level, heart rate, sleep monitoring, calories, step count, height detection, falls detection, GPS	Heart rate, heart rate variability, electro-dermal activity, ambient temperature, 3D acceleration	Calories, step count, inactive times, heart rate variability, respiratory rate, body temperature, and quality of sleep	Blood oxygen level, heart rate variability, calories, steps, height, sleep quality, GPS	Motion sensing, performance time
Interaction	**Input**	Tactile, voice	Tactile	Tactile	Tactile	Tactile
	Medium	Watch, Touchscreen, Mobile app, Sensors	App, Sensors	App, Sensors	Watch, Touchscreen, Mobile app, Sensors	App, pulse, Sensors
	Training output	Text, Video, Animation, Vibration	Text, Animation	Text, Animation	Text, Video, Animation	Vibration, Video, Audio
Coaching and support	**Tailoring/AI**	Progress tracking, Personalized suggestions (older adults' programs)	AI supported health coach, Performance tracking, Personalized suggestions	AI supported health coach, Performance tracking, Personalized suggestions	Performance tracking, Personalized suggestions	Form correction, Progress tracking
Membership	**Training features**	On-demand classes	Weekly reports	Reports	On-demand classes, reports	On-demand classes
	Social-Motivational features	Burn Bar, Leaderboards, Friends' challenges, Notifications, Podcasts, Activity goals	Suggested communities based on interests	Community blog	Activity goals, Communities	Share stats and progress with community
Price		$399	Free with membership purchase ($288)	$314	$150	$249

Table 2. Wearables and trackers comparison

The wearable market is extremely broad and varied, with smartwatches being the largest portion of this category. For this review, only the top rated brands of smartwatches with training features included in their memberships were screened, since these already include all the hardware specifications and functions that can be found in this typology. Other typologies that are prominent in the market were also screened, but were eventually discarded because their purpose as a wearable focused more on tracking health markers rather than their use as a fitness equipment.

In the hardware section, as with connected equipment, the leading wearable brands have focused on offering the greatest number of functions in the smallest possible space to facilitate portability and constant tracking, making it possible to find devices as small like a ring, as is the case with Oura and so specialized that they can identify the different phases of sleep during the night (eg, Fitbit, Oura, Whoop).

With the exception of the Nadi X Yoga Pants, which focus on motion sensing and are specifically designed to correct the form of exercises when the user is following a Yoga course, all other devices aim to sense as many physiological markers as possible, which ranges from the step count to the breaks that the person has taken during the day. Although brands such as Whoop and Oura include AI support to process, interpret and synthesize all the tracked activity in simplified score systems that users can more easily follow, sometimes people who have acquired these devices question whether the large amount of information collected about your daily activity is really necessary or useful in monitoring your training programs (Oney, 2021).

Regarding the interaction, with the exception of the Apple Watch, which also includes voice input, the operation of the systems always requires a tactile input, either through buttons or touchscreens. In exchange, the feedback of the devices is given through videos, text or audios presented either on the screen of the wearable or the synchronized phone. Only in the cases of the Apple Watch and the Nagi X Yoga Pants, feedback is also given through vibrations that inform the user of pending activities or postures that must be corrected during the exercise. Although the wearables reviewed report good levels of precision in the inputs, it is in the output where some users consider that there are aspects that can be improved, such as the size of the screens, or the lack of these in the devices, as in the cases of Whoop and Oura (Oney, 2021).

The coaching and tailoring in the case of wearables depends much more on AI and self-reporting compared to the connected equipment. In addition to performance tracking, the AI is in charge of giving all the necessary suggestions for the user to reach a “healthy state” by changing not only elements of the training such as intensity or frequency, but also others more established in daily life such as drinking water or going to bed before midnight, which for some can generate strain as they feel that the tracking activity begins to take control of their life.

With the exception of Oura, which is conceptually designed as a health tracker, and Whoop, which is aimed especially at professional athletes who already follow a training program, wearables include training features similar to those of connected equipment such as on- demand classes and social communities. It should also be noted, in the motivational features section, the gamification of the

interfaces (e.g., Apple Watch's activity rings) to promote the completion of tasks, which according to Koivisto and Malik (2020) it is an effective strategy to increase adherence and self-efficacy in programs for older adults. Access to these features is given in all cases through an app on the cell phone that is synchronized with the device. In cases where the devices have integrated screens, interaction with the app is also possible through this medium.

Finally, in terms of prices, there is a big difference compared to connected equipment. Although the equipment is designed primarily to monitor physical activity and does not include hardware that facilitates resistance training (thus, relegating the responsibility of this type of training to other additional home equipment or body weight training modality), the simplicity in the functions of the device and the technology applied allow to keep costs relatively low while granting users access to membership features similar to those of connected equipment.

4.3.3. Fitness Apps

Following the the first lockdowns due to COVID-19 in march 2020, many users transitioned from going to the gym, to working out at home with the help of fitness apps. Although brick and mortar facilities are re-opening, the fitness app market is expected to grow by $3,5 billion during 2021-2025, which represents an annual growth of almost 15% (Technavio, 2021). Most fitness apps focus on tracking, measuring, and analyzing various health and fitness metrics, like tracking workouts, monitoring fitness goals, counting calories, counting steps, etc (Global Wellness Institute, 2019).

Some popular apps in this category are free for users, although many are paid or offer a premium/paid upgrade option. Apps are increasingly adding a social and community dimension (e.g., Runtastic, Joyrun), or an element of gamification, rewards and competition (e.g., Fitocracy, Yodo Run, Nexercise). Some include informational/educational tutorials, while some provide personal 1:1 training or even live and on-demand classes. Some popular apps are connected with wearable devices (e.g., Fitbit, Codoon), and other type of connected equipment, and some are connected with major fitness brands (e.g., Nike Run Club, UA Record) (Global Wellness Institute, 2019).

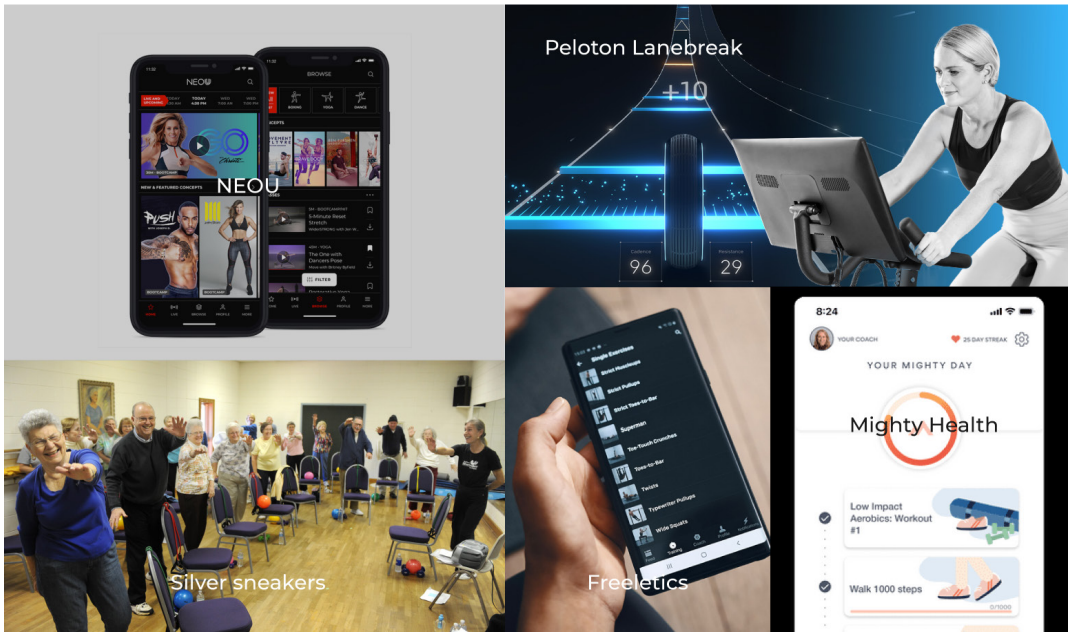

Fig 9. Smartphone Applications

Comparison between equipment

		NEOU	Peloton Lane-break	Freeletics	Silver Sneakers	Mighty Healthy
Interaction	**Input**	Tactile	Tactile	Tactile	Tactile, Voice	Tactile
	Medium	Mobile, any other smart device	Mobile, Bike, Touchscreen	Mobile	Mobile App, Phone calls	Mobile, Smart TV
	Output	Text, Video	Audio, Video, Text	Text, Video	Video, Text, Audio	Text, Video
Sensing and monitoring		Self-reporting	-Resistance, cadence, output -Pairable with smartwatches	Self-reporting	Self-reporting, Regular in-person checkups	Self-reporting
Coaching and tailoring		Customized suggestions	AI supported exergame	AI supported coach, customized suggestions	Performance tracking	Personal coach, food and exercise tracking
Membership	**Training features**	Live and On-demand classes	Cycling, running, swimming simulations	Training journeys	Live and On-demand Classes, Access to gym facilities	Daily to-do list, on-demand classes
	Motivation feautres	Live group-classes, community	Game cooperation, music	Leaderboards, Community, Activity goals	In-person group classes	Personal coach, app community, facebook
Price		$4,99/month	N/A	$1,36/week	Included in medicare plan	$79/month

Table 3. Smartphone applications comparison

As previously mentioned, the market for fitness apps has grown so much in recent years that they constitute a category by themselves, in which it's possible to find: apps that only require a cell phone to be used (eg, NEOU, Freeletics), apps that pair with wearable devices to obtain more accurate metrics (eg, Apple's Fitness +), and apps that function as part of an integrated hardware and software ecosystem for home training (eg, Peloton, Mirror).

Training applications in mobile and equipment platforms rely more prominently on direct input provided by touch-enabled screens, which according to Czaja et al. (Czaja, 2019) is more accessible for older adults. Only one app also considered voice as an input through phone calls. In terms of the training output, multimodal interfaces that combine audio, text and video are the most common, and are preferred by older adults' dedicated apps. In the case of Mighty Health, they even go beyond the app interphase and do part of the coaching through text message as a redundant option in case the users get lost in the navigation of the app (Mascarenhas, 2020).

For apps that don't pair with sensors, self-reported questionnaires are the instrument of choice to gather data about the user's performance and adherence to the training. In only one of the cases, monitoring is complemented with regular in-person checkups, but this service is not considered as part of the app, but as part of a medicare plan, and also involves the user's movement outside the home to a clinic. As for apps that depend on sensing technologies, the times in which the user must operate manually are considerably reduced, but some report discomfort when using wearables.

Regarding coaching and tailoring, the application of technology in the configuration of apps, provides different levels of support in this process, from entirely human to fully AI supported coaching. Dedicated apps for older adults like Silver sneakers and Mighty Health make use of human coaching not only to provide an exercise program and give feedback related to its performance, but also to provide encouragement and emotional support. On the other side, while virtual coaches don't provide the same quality of social support that a human coach can provide, their use allows to keep the prices of the memberships low and maintain the progression of the exercise programs.

Similar to the connected equipment and wearables, the memberships of mobile dedicated apps feature live and on-demand classes as the core of exercise programs, as well as communities and leaderboards as the main motivational features. However, additional to the training features, some of the apps take a more holistic approach and include nutrition and spiritual coaching in the membership through to-do lists, personalized suggestions and podcasts.

The prices, compared to the other two categories, are much lower, since the only cost that the user assumes in this case is the weekly, monthly or annual payment of a membership since no other type of hardware apart from the cell phone is required for the subscription and use of these apps. However, it should be noted that for the progression of several of the exercise programs, the use of traditional equipment is required, such as dumbbells, pull up bars, or elastic bands, so the purchase of these objects should be considered as part of the total spend to get the most out of the app content. 4.3.4 Summary

4.3.4. Summary

This benchmarking has shown that home-fitness landscape is growing with more tech-based ideas, offering a variety of models that are starting to compete with traditional brick and mortar business models, as the world transitions to more virtual and connected settings. Current solutions seem to provide good support for the general population, however, only few solutions, especially in the applications section, are designed with older adults in mind, or at least their level of interaction skills and physical limitations (Khaghani-Far, 2016). Table 4 summarize the results of screening current design solutions against the various design considerations motivated in this section.

Design features	Current solutions	Trends and Gaps
Hardware	- Connected equipment represents the most comprehensive category in terms of what the combination of hardware, software, and content can do to improve physical activity performance at home. The hardware enables resistance training to be performed without the need for additional equipment. - Wearables are small enough to be worn most of the day without major problems and their shapes are reminiscent of everyday objects such as watches, rings or bracelets, which is friendly for older adults.	- The types of equipment that allow resistance training are more aimed at young audiences than at older adults. - Bodyweight, cable machines and rubber bands are friendlier modalities for older adults who are new to resistance training (Clark, et al., 2014). - Most solutions use screens to provide most of the output to the user. In cases where there is no integrated screen, the systems allow pairing with a cell phone or some other smart device through a dedicated app.
Interaction	- All solutions offer a combination of output formats, being text and video the most common. - Input is mainly done through tactile commands.	- Direct input like when using a touch-enabled screen is preferred in this solutions. - Other forms of output are not widely available for the visually or hearing-impaired.
Sensing and Monitoring	- Connected equipment focuses on the automatic detection of indicators strictly related to the performance of the training routine. Wearables, on the other hand, sense a broader spectrum of indicators that provide information about other aspects relevant to general health, such as sleep and diet.	- Wearable sensors are the core technology in trackers, while non-wearable and environmental sensors are mostly used in connected equipment. - Sensors are preferable when it comes to objective measure. Still, self-reporting is a valid tool for data collection when sensing technologies are not available.
Coaching and Tailoring	- Most solutions employ some form of coaching and monitoring, either through human, AI-supported coaches, or a combination of both. - Environmental sensors allow real time form correction. - The most common form of coaching is the prescription of exercise based on progress tracking.	- Training programs supervised by a human coach are more suitable for older adults (Hanneton S, 2009). However, most of the solutions rely on virtual coaches. - Connected equipment provide more complete support during the training phase than wearables or single apps.
Training features	- Streaming of live and on-demand classes, and personalized suggestions or to-do lists are the main outputs for the realization of physical activity.	- Videos are recorded in collaboration with expert trainers, but are made to reach wide audiences. Small groups or 1:1 training sessions are not common.
Motivation features	- Self-monitoring is the most popular individual persuasion strategy, followed by reminders and suggestions and rewards. - Comparison and competition are the most popular social strategies, followed by social support. - Social support comes mainly from a virtual community, but personal trainers can also be a source of support.	- Persuasion strategies are used to boost adherence, especially in older adults (Khaghani-Far, 2016) - Compared to individual strategies, social strategies represent only a small part of the motivational strategies used in home training solutions.
Price	- In most cases, the payment of a membership is required to be able to use the equipment/ wearables/apps	- Non-wearable and environmental sensors are much more expensive technology applications compared to wearable sensors.

Table 4. Benchmarking Summary

5. Creating opportunities for healthy ageing

5.1. AGEING IN PLACE – Product Design & Homes of the elderly

Ageing in place refers to a common preference among older people for remaining in their local community throughout the ageing process. It's a concept that has been proposed to address older adult's desire to remain and live in their own homes without having to relocate to support facilities such as hospitals or nursing homes (Wiles, 2012), as they view their existing home as having the advantages of maintaining a sense of connection, security and familiarity, as well as being related to their sense of identity and autonomy (Wiles, 2012).

However, while older adults show a desire to stay independent as they age without having to give up their own lifestyle, ageing in place can introduce some challenges. These include performing various activities of daily living, keeping social connections and managing one's own health (UK Active, 2017; Choi, 2020). Additionally, previous research has also shown that in cases where older adults live alone, they can face issues related to isolation, mobility, health and home management, safety and nutrition among others (Mynatt, 2001; Heinz, 2012).

Ageing in place is a process that involves both the person and the environment. Many of the challenges arise from changes in people's needs and capabilities as they age. Commonly experienced physiological features include changes in dexterity and strength, memory and cognition, sensory ability and mobility (Office for Product Safety & Standards, 2021). While difficulty often appear as a result of changes in ability that makes the person unable to meet the demands of the environment, issues can be exacerbated by the quality of the environment itself and features of daily life objects that render the performance of higher functioning activities such as cooking, managing medications, housework, exercising, etc., more difficult (Fausset, 2011).

Managing these challenges require older people to make transitions in their living environments, by adapting their current residences with objects and systems that are not heavy to operate, that are comfortable to use, that are not complex in their set-up or operation, and above all, that facilitate the continuity of their daily life (Office for Product Safety & Standards, 2021). To identify the design features that have an impact on the usability of products in the home context and the possible changes that would improve them, a review of results from previews researches was carried out, as well as a qualitative exploration with older adults, making use of a modified version of the questionnaires designed by The Office for Product and Safety Standards (OPSS) in its Ageing Society research report (2021). A total of 5 participants were recruited from a mix of rural and urban areas. All participants were aged 60 or over, and all experienced some level of difficulty using products of the home context.

Key findings

Common elements emerged from the products described during the interviews, regarding the features that older people found most difficult to use, regardless of the typology of the product. These features are summarized in tables 5, 6, and 7 along with some of the participants' suggestions on what would improve the usability of products with these features and findings from previews researches.

Product shape and size

Feature	Difficulties	Possible improvement
Parts that require grip or twisting	Products that require a certain amount of grip strength to open/close and use can be difficult for those with reduced strength in their hands (Office for Product Safety & Standards, 2021).	- A material/texture that encourages better grip. - A different shape easier to grab
Cords/cables	- Cords along the floor create trip hazards (Office for Product Safety & Standards, 2021). - Charge connectors that are concealed can be more difficult to access.	- Cordless, rechargeable products - Visible charge connection points (Office for Product Safety & Standards, 2021)
Number of parts	Products with several parts that require handling to make use of the product are too complex	- Simpler shapes / Less parts
Height	Products that are low to the ground require bending and coordination to stand back up without getting hurt (Office for Product Safety & Standards, 2021)	- Installing products at waist or shoulder level (Office for Product Safety & Standards, 2021). - Additional handle to move the object
Width	Grabbing narrow/wide products can be difficult or painful (Office for Product Safety & Standards, 2021)	- Include handles
Weight	- Heavy products require strength to lift, especially during grip gestures. - Heavy products are difficult to move and/or store in the house.	- Lightweight products, smaller, easy to lift and grip. - Wheels
Stability	Unstable products can cause falls if the person support their weight on them	- Sturdy bases to provide support - Wall/floor anchors
Surfaces	When the product's surface becomes wet or oily, they can become more difficult to grip or lift (Office for Product Safety & Standards, 2021).	- Texture or rubbery material that is easy to grab (Office for Product Safety & Standards, 2021)

Table 5. Product Shape and Size

Product interphase

Feature	Difficulties	Possible improvement
Options and menus	Products with too many options and features are too complex	-Simplified options and menus
Displays	- Small and/or low contrast text can be difficult to see for those with reduced eyesight. - Digital displays that are not backlit are hard to read in illuminated environments (Office for Product Safety & Standards, 2021).	- Large, bold, high contrast text (Eldertech, 2021). - Sans Serif instead of serif fonts (Eldertech, 2021). - Digital backlit displays (Office for Product Safety & Standards, 2021) - Bigger screens
Buttons	- Small buttons are difficult to press and determine what it does - Buttons close together are difficult to press individually -Buttons in odd locations are harder to find/touch	- Larger buttons that contrast with the background and clear icons depicting what they do. - A reduced amount of buttons/only the key features needed - Touch-enabled screens instead of actual buttons. - Buttons with lights

Table 6. Product Interphase

Product functions

Feature	Difficulties	Possible improvement
Set up	-Too many and/or complex steps make the product set up too difficult	-Simple instructions with large text and icons - Pictures or videos of how the step should look like - Automated set up by voice command (Kim & Abhishek, 2021)
Automation	- Products that do not turn off on their own can be a safety concern for people with memory impairments - Products that require configuration from scratch each time they are used discourages their use	- Automatic switch off if the product is not in use. - Products with big on/off buttons on the body of the product - Product that "remembers" the most used configurations
Foldability/Disassembly	Big products that can't be folded or disassembled are hard to store	- Modular or stackable components - Easy to fold components

Table 7. Product Functions

5.2. INCLUSIVE TECHNOLOGY – Interaction Design & Technology for seniors

At the same time that the population of older people is increasing, the world is witnessing an explosion in the development of technologies (Czaja, 2017). Technology has become ubiquitous in all aspects of life and is becoming more important in society (Czaja, 2017), creating opportunities to assist older people in everyday activities. According to the Pew Research Center, American ages 60 and older are spending more than half of their daily leisure time on their TVs, computers, tablets or other electronic devices (Livingston, 2019). This rise in screen time coincides with a significant growth in the adoption of digital technology and Internet by older adults, who went from 14% in the 2000's, to 85% in 2021 (Perrin, 2021).

Technologies such as Internet of Things (IoT), Ambient/Active Assisted Living (AAL), sensing devices and artificial intelligence have been shown to have great potential in fostering independent living and improving mental and physical health (Mihailidis A., 2004). Main fields of application where technology can play a supportive role in older adults' homes include caregiving, social connectivity and engagement (Czaja, 2017) and at home physical activity (Vaportzis, 2017).

Adoption of new technologies among older adults is slower compared to other user groups. Yet older adults will be eager to adopt technologies if they appear to have value in improving or maintaining their quality of life (Heinz, 2012). In order for this age group to receive the benefits of technology, applications and systems must be available, useable, useful, reliable and responsive to the needs of its users (Czaja, 2017).

However, despite a plethora of reported cases of successful interventions where technology provides support for older adults, the adoption of these technologies has been limited (Hoque & Sorwar, 2017; National Institute on Aging, 2018). According to Wang et al. (2019), one key barrier to wider adoption has been the "top-down" design process that is often used in designing technology for seniors, given that it's a process mostly based on technologists', geriatricians', or caregivers' preconceptions of what older adults need that don't take into account real-world constraints or the user preferences and perspectives.

While studies have shown that older adults could use technologies designed to be inclusive in their daily lives, few have addressed user-related issues in their design process (Khosravi & Ghapanchi, 2016). To make technology more age-friendly, it's important to understand the difficulties and advantages that older adults perceive when they use it. To identify the design features that have an impact on the usability of support technology for daily tasks and the possible changes that would improve them, a

review of results from previews researches was carried out, as well as a qualitative exploration with older adults, making use of a modified version of the questionnaires designed by The Office for Product and Safety Standards (OPSS) in its Ageing Society research report. A total of 5 participants were recruited from a mix of rural and urban areas. All participants were aged 60 or over, and all experienced some barriers using technology products.

Key findings

Common elements emerged from the products described during the interviews (which included smartphones, tablets, and activity trackers) regarding the features that older people found most difficult to use and their perspectives on technology, regardless of the typology of the product. All participants reported their willingness to contribute in the design process of technologies that would allow ageing independently. These features are summarized in tables 8,9,10 and 11, along with recommendations from previews researchers and some of the participants' suggestions on what would improve the adoption of new technologies. Given that the problems reported by older adults regarding the shape and size of the products are the same as those mentioned in the Aging in place section, these were omitted from the summary of this section.

Interface usability

Features	Barriers	Recommendations for improving
Vision	- Small and/or low contrast text can be difficult to see for those with reduced eyesight. - Scrollable content impairs its visualization (Blendinger, 2015) - Visual clutter, non-relevant information and distracting visual stimuli (Blendinger, 2015)	- Large, bold, high contrast, sans serif text. (Blendinger, 2015) - Use colors for relevant information. (Blendinger, 2015). - Static text. (Eldertech, 2021) - Simple layout design (Blendinger, 2015)
Hearing	- Verbal instructions go too fast or are too complex - Notifications and reminders are not audible	- Combine hearing and visual instructions (Eldertech, 2021) - Use sounds with multiple frequencies (Eldertech, 2021) - Combine sound alarms with haptic or visual stimuli (Blendinger, 2015)
Gestures	- Small buttons are difficult to press and determine what it does - Buttons close together are difficult to press individually (Office for Product Safety & Standards, 2021) - Single buttons to perform multiple tasks are hard to manipulate for those with motor limitations (Office for Product Safety & Standards, 2021)	- Larger buttons that contrast with the background and clear icons depicting what they do. (Blendinger, 2015) - A reduced amount of buttons/only the key features needed - Voice commands (Wang, et al., 2019) - Avoid multiple or sustained touches (Fisk, et al., 2009)
Navigation and menu structure	- When the location of elements and functions changes across views makes it more difficult for users with memory impairments. - Too many steps make the fulfilment of a task more complex - Menu items too similar in name or category - Some icons or animations are not understandable	- Consistency in the content structure (Blendinger, 2015). - Minimize the number of steps as well as the number of controls - Clearly labeled information or functions (Blendinger, 2015). - When possible, provide text for icons or graphic instructions.

Table 8. Findings in interface usability

Functions

Features	Barriers	Recommendations for improving
Number of functions	Products with too many options and features (Fisk, et al., 2009)	- Simplified menus according to user's most used features - Simplified manual interaction with the device (Eldertech, 2021)
Pairing with other devices	Pairing commands are too complex or hidden	- Specific button with multimodal feedback - Devices that are already connected
Adjustments	Not being able to adjust parameters like the size font or the volume.	- Enhancement features for personal needs

Table 9. Findings in functions

User training and support

Features	Barriers	Recommendations for improving
Tutorials and manuals	- Lack of understanding of or familiarity with the technology that results on dependence on others or underutilization of the product (Office for Product Safety & Standards, 2021) - Lack of instructions or guidance - Instruction manuals with unclear steps (Fisk, et al., 2009).	- Provide a source of learning material available at any time and location (Blendinger, 2015). - Introduce features gradually over time to prevent cognitive overload (Campbell, 2015) - Combination of text and images (animations if possible) in step-by-step instructions
Language	- The instructions are too technical and full of unknown terminology (Blendinger, 2015).	- Option for extended initial training regarding information content (Blendinger, 2015) -Provide a glossary - Simple and short instructions

Table 10. Findings in User training and support

Data management

Features	Barriers	Recommendations for improving
Data entry	- Complete major data entry tasks within an adequate time require mental and physical effort (Blendinger, 2015).	- Keep data entry tasks to a minimum (Blendinger, 2015) - Provide predefined values, or buttons or slider bars (Caprani, et al., 2012) - Include sensing technologies for physiological data (Khaghani-Far, 2016)
Feedback	- Not knowing when a gesture or a command is being done correctly. - Lack of feedback of data collected, especially when participating in health research (Tech to support aging in place) (Wang, et al., 2019)	- Use vibrotactile, visual or auditory feedback (Blendinger, 2015). - Error messages with expanded information of consequences and how to recover (Blendinger, 2015) - Provide simplified, understandable metrics of the processed data (Wang, et al., 2019).
Privacy	- Lack of knowledge about the uses of the data provided.	- Brief summaries of meaningful returned data (Farrokhi, et al., 2021).

Table 11. Findings in Data management

5.3. SENIOR FITNESS – Tailoring fitness programs for Older Adults

It has been mentioned previously that maintaining an active lifestyle is key to have a healthy ageing. While taking part in any amount of physical activity, at any moment in life, can have a positive impact on a person's health, amongst older people it's crucial to maintain independent life for longer and preventing the appearance of several non-communicable diseases and functional decline. However, despite a growing trend towards the aging of populations and the need for people in later stages of life to be physically active, currently people over 60 years of age are the least represented age group in the fitness industry (Schmaltz, 2020).

According to IHRSA research (IHRSA, 2019), the fitness industry over the years has been consistently representative of the wider American population up to the age of 44. People between 45-56 who own a fitness club membership were still representative during the 2019 report, after which there are noticeable levels of under-representation for the 55-64 age group and people over the age of 65. The recurring comment made each year by the IHRSA is that "health clubs are the playgrounds of the young, as the industry appeals most to those between the ages of 25 to 44" (Algar, 2017).

Some parts of the health and fitness industry are strategically configured to support people that are already athletic. Servicing the already active and experienced trainees seems to have been the major industry behavior over the past decade (Algar, 2017). For older adults, traditional brick-and-mortar facilities are considered as being too expensive and not convenient, while the low-cost gyms are generally affordable but are not typically designed to provide support in cases of disabilities and reduced physical function (Algar, 2017).

Fortunately, in recent years, the mindset towards older adults has been changing. The primary noticeable shift has been toward an encouragement for the inclusion of vigorous trainings instead of the basic recommendations of walking slowly and avoiding fatigue, as mounting evidence shows that high-intensity interval training (HIIT) in different forms, as well as combinations of aerobic and resistance, are more effective in improving functional capacity (Byra, 2020). In this sense, the range of activities available for older adults to exercise is much broader than what was thought a decade ago.

Many brands and startups realize that this is an active, lively, and connected generational group that deserves the same attention given to younger consumers (Global Wellness Institute, 2020), as it has continued to reject the stereotypes of ageism, frailty and inactivity (Adams & Sevene, 2017). Moreover, with the emergence of COVID-19 and the widespread shake-up it caused across all sectors of society, the landscape of the fitness industry has been shifting towards one that is more inclusive. Along with the rise of fitness programs addressed specifically for older adults, the appearance of other trends such as

online training, technology-supported physical activity, personal training, and free weights equipment, has opened the possibility of exploration in the design of products and services that allow people to stay healthy, active and independent for longer (Algar, 2017; Thompson, 2021).

Older adults are willing to try new things and embrace physical activity in their daily lives, but at the same time they face barriers that limit their access or adherence to fitness facilities or healthcare programs (UK Active, 2017). To understand how new business models in the fitness industry can address these barriers and appeal to seniors by offering products and services tailored to their abilities and needs, a semi-structured interview was conducted with Julián Urrego, professor at the Santiago de Cali University physiotherapy school, and an expert in physical conditioning and rehabilitation programs for older adults. This interview was structured in three sections, that gather questions of the current issues of exercise programs regarding areas of training, the home, and the use of technologies. The responses were audio-recorded and transcribed for later analysis.

Key findings

Tables 12, 13 and 14 summarize the barriers identified during the conduction of the interview, as well as recommendations for improving the current solutions in the prescription, monitoring and progression of home-based exercise programs for older adults. Many of the findings in the home and technology sections reaffirm aspects of usability already described earlier in the research. The space of the house is established as an important variable for the implementation of an exercise routine, with all the barriers mentioned in this variable being linked to the lack physical space or their inadequacy for the location or storage of equipment, or the performance of the exercise itself. Guided training by a human trainer is the most frequent solution referred to by the interviewee, and it has the greatest potential to positively impact the performance of exercise programs at home. Some of the other recommendations were supplemented with findings from previous research. Additionally, an unexpected finding in conducting the interview is the potential of technology to help not only the elderly, but also the coach, who plays a crucial role in the implementation of exercise programs from the time of initial evaluation to the compliance of goals and program adjustment.

Exercise programs

Features	Barriers	Recommendations for improving
Set-up/Prescription	- Age-related changes and chronic conditions unique to each person	- Initial evaluation by a fitness expert or a healthcare professional
Types of physical activity	- Exercises that require constant supervision - Routines that take a long time - Programs that are not engaging or challenging (Khaghani-Far, 2016)	- On-demand classes to guide the movements - Remote monitoring tools with visual support
Access	- Fear of different origins - Lack of motivation - Intimidation/embarrassment - Difficult transportation - Bad weather - Customized programs for older adults are very expensive	- Guided training programs - Taking fitness closer to older adults' homes - Flexible program schedule (Bethancourt, et al., 2014) - Programs with progression of difficulty - Low-cost programs (Bethancourt, et al., 2014)
Adherence	- Lack of social support - Slow achievement of goals	- Personal training - Small groups sessions - Reminders and suggestions through phone calls or mobile notifications (Khaghani-Far, 2016)
Business models	- Ageism within the fitness industry: the perspective that older adults are not worth investing in - "One size fits all" programs	- Communication to change age-related stereotypes - Programs focused on categorized, smaller groups

Table 12. Findings in Exercise programs

Home exercise programs

Table 13. Findings in Home exercise programs

Features	Barriers	Recommendations for improving
Equipment	- Machines have a learning curve. Can cause injury if not operated properly (Clark, et al., 2014) - Most home equipment is focused on cardio - Body weight and low-resistance intensity equipment have a progression limit	- Systems that allow for both cardio and resistance training. - Opting for more senior-friendly equipment like resistance bands - Free weights can be used to keep gaining muscle mass if accompanied by constant guidance.
House space	- Some older adults are not sure of how much free space they have to leave clear for training - Lack of support points for performing some exercises (Lopez, et al., 2021) - Lack of a dedicated room or area for training (Lopez, et al., 2018)	- Visual guide for clearance of space - Weight-resistant seating and/or leaning structures (Lopez, et al., 2018) - Small equipment
Coaching and tailoring	- No correction of postures or contraction and relaxation times when exercising independently - Uncertainty about when to progress a routine - Loss of interest when working out independently	- Live / on-demand classes AND personal training - Regular visual monitoring of exercise performance - Progression checks/goal setting every 15 or 20 days - Daily motivation boosts, even when the trainer is not present. - Additional form of social support other than that provided by the coach.

Supporting technology for home exercise programs

Table 14. Findings in Supporting technology

Features	Barriers	Recommendations for improving
Hardware	- Screens or other equipment are too complicated to be operated independently by the older people (Vaportzis, 2017). - Wearable trackers may be uncomfortable to wear (Khaghani-Far, 2016). - Interconnectivity between devices of different brands sometimes is challenging. (Farrokhi, et al., 2021)	- Touch-enabled screens are friendlier and more intuitive for older adults (Vaportzis, 2017) - Non-wearable trackers that gather physiological data at certain points of the exercise routine (Farrokhi, et al., 2021) - The wrists are places older adults are already familiar with in cases where they have to wear objects. (Farrokhi, et al., 2021) - Devices that share the same operative system.
Support for trainer	- Difficulty of the coach in accessing sensor tracked or self-reported data from patients (Farrokhi, et al., 2021) - AI and algorithms still have problems adjusting routines for people with specific limitations (Khaghani-Far, 2016) - When the coach has many trainees in charge, it becomes difficult to keep track of the needs that each one of them has	- Mixed systems of AI for user profiling, and trainers to tailor the exercise programs. - Platforms for entering and processing quickly and easily data regarding the exercise. - Trackers that send data directly to the trainer
Sensing and monitoring	- Low accuracy of self-reported data. (Khaghani-Far, 2016) - Too much and not so important sensed data. - Loss of interest of the elder user to track their activity.	- Automatic sensing of activities and physiological measures. - Simple and meaningful feedback on training progress for the trainees (Wang, et al., 2019). - Limit sensor activity to tracking specific training markers.

5.4. Summary

To design meaningful solutions, it is important to first analyze the user involved. Section 6 focused on the qualitative search for patterns or changes in consumer behavior, as well as failures or gaps in the market through the lens of 3 scenarios corresponding to major trends related to healthy ageing: aging in place, technology for older adults, and senior fitness. While each scenario gave rise to different insights, one thing is for sure, and that is that most of the desires and needs of older adults revolve around health. This generation of older adults is more engaged in maintaining good health, because they are increasingly aware that this is one of the most important factors for enjoying a good quality of life in old age. Likewise, issues such as the preservation of independence and the desire for greater general inclusion in society are of particular interest to older adults, given their recurrent mention throughout the interviews. Table 15 summarizes the main findings of the trend analysis presented in section 6.

Scenario	Main findings
Ageing in place	- Older adults desire to remain and live in their own homes as they view them as a way to maintain their identity and autonomy. However, changes in people's abilities as they age make interaction with their environment increasingly difficult. - Objects found in houses can potentially increase the difficulty in the performance of higher functioning activities - Changes and the needs derived from these are very wide-ranging, and as a result there are several features that older adults find difficult when using products. -The most prevalent features that hinder the usability of products in the home context are: products requiring grip (Office for Product Safety & Standards, 2021), heavy objects, small displays, small buttons, and devices that require too many steps for the set-up.
Inclusive technology	- Older adults can use technology and they are eager to adopt technologies if they have value in improving or maintaining their quality of life. They just need more time compared to other user groups to adopt a new technology. - Particularly in the case of health support technologies, one key barrier to wider adoption is the lack of the user perspective in the design process used for this technology. - Several of the referred usability problems of the interfaces can be handled if users are given the possibility to customize the parameters according to their own limitations (Wang, et al., 2019). - All of the interviewed expressed a desire for larger screens.
Senior Fitness	- Contrary to popular belief, older adults are not so fragile or inactive that they can't exercise. They can do much more than "slow walks". This ageist stereotype has for many years prevented the expansion of options in the fitness market for older adults. - High intensity training is recommended over low intensity training in older adults. - Brick-and-mortar fitness facilities are not designed to provide support in cases of reduced functional ability. - A personal trainer is highly recommended for coaching and monitoring in home exercise programs. - Technology can be of help, not only for the older adult who is going to start training at home, but for the coach, who would be an essential part of the process from the initial evaluation, to the fulfillment of the goals and the constant progression of the program.

Table 15. Scenario analysis summary

5.5. SWOT Matrix

Based on the information collected in the interviews, as well as the findings of the benchmarking and the general review of the literature, a SWOT analysis is used to identify the possible strengths, weaknesses, opportunities, and threats related to a possible solution that responds to the needs referred to by the users studied, and determine a planning route for its elaboration.

STRENGTHS	WEAKNESSES
- Tailored exercise programs - Flexible training times - Focus on an underrepresented population of users - Product-system that can operate from home - Social connection for the most isolated - Compatibility with hybrid training models (mix of indoor facilities, outdoors and home fitness)	- No support for other remote health related services (nutrition, telemedicine, etc) - Positioning of a product on non-traditional distribution channels - Older adults might feel intimidated by the technology - Concerns regarding data management and privacy
OPPORTUNITIES	**THREATS**
- With the COVID-19 outbreak, people are not rushing back to the gyms - Ageing of the population - Rise in awareness of health issues related to physical inactivity and sedentary behaviors - Digitalization of services - Personal trainers looking for new channels to provide their services	- Stagnation of the population growth - Low adoption of new technologies by the target market segment - Users preferring traditional cardio-based physical activity

Table 16. SWOT Matrix

6. Research synthesis

6.1. Definition of the user group and their needs

A series of interviews were analyzed to define the target user group and their needs. In addition to the interviews conducted to the potential target user, an interview with an expert in physical conditioning and rehabilitation programs for older adults was also used for defining the user needs. As a result of the analysis of all the interviews, a second user was defined. The results of target user groups are as follows:

The primary users are adults over 60 years who require or are willing to embrace physical activity in their daily lives. The solution presented in this project may help those seniors who face barriers that limit their access or adherence to fitness facilities or healthcare programs. These barriers can be categorized in three levels:

- Intrapersonal: such as the level of functional capacity and physical conditions unique to each person, fear of injuries (particularly fear of falling), and lack of motivation.
- Interpersonal: such as the lack of company or social support in general, isolation and the absence of monitoring by health care and physical activity specialists.
- Environmental factors: such as the distance between the house of the user and the training facility and the means of transport available, difficult weather conditions, the ageism in the fitness industry that results in the lack of appropriate programs and facilities, and high price of customized programs.

Other challenges also appear for those who wish to follow training programs remotely from home as a way to maintain their identity and autonomy, or simply for convenience. In this scenario, challenges can be found in:

- Homes: such as the lack of space, inflexible environments for carrying out different activities, and objects in houses that are difficult to use or that hinder the performance of higher functioning activities.
- Technology: such as not user-friendly devices, presence of complicated and unnecessary features, and absence of parameter customization features to match the unique limitations of each user.

The secondary users are the personal trainers that use digital platforms in their work to keep track of their clients' performance, set hybrid half-at home, half-training facility programs, or to reach a wider audience. Another secondary group are the physical activity specialists who work with rehabilitation. The solution in this project can facilitate their work to give better results and achieve goals, and/or to improve the connection with their clients before, during, and after training and achieve adherence to the programs. Some of their current challenges regard the monitoring of training programs, especially when these programs are offered on a remote modality, such as difficulty in following up a large number of patients/clients or the difficult access of sensor tracked data (in the cases in which there's access to fitness trackers) or self-reported data from patients.

6.2. Personas

Persona 1

Name: Hector *Age:* 61

Facts:

- Classical guitarist. University appointed professor
- He uses the computer to do most of his work-related activities, and his cell phone to check social media, take photos and make payments.

Fitness level: high

Fitness interests: weightlifting

For 20 years he has exercised as a way to relieve stress and keep his blood pressure and triglyceride levels in check. He lives in the countryside and only travels to the city to teach at the university or for some social commitment, since the rest of the time he spends at his house composing new pieces. However, since he no longer lives in the city, and in the absence of a gym close to home, reaching his goals with exercise has proven much more difficult. He has tried going for runs and riding his bike, and although he has noticed that he has lost some weight, his blood pressure and triglyceride levels remain the same, so now he feels that there's something that he's not doing right.

Persona 2

Name: Oliva *Age:* 77

Facts:

- Retired. Likes to knit to keep herself busy.
- She uses a smartphone mostly to stay in touch with her daughters and grandchildren

Fitness level: low

Fitness interests: swimming (formerly)

She has two daughters but does not live with either. She prefers to live alone because she thus feels freer and avoids "putting an additional burden" on her daughters. For several years, her family doctor has been telling her that she should exercise to lose weight and reduce the effort that is being generated in her

arthritic joints. On her recommendation, she took swimming lessons but had to stop after a year after being injured in a fall while she was making her own way out of the pool. After this event, she decided to stop exercising and control her weight with diet alone. She now she goes for a walk from time to time, and she does it very cautiously for fear of hurting herself again, but she feels that despite this her joints hurt more and more as time goes by, and activities such as cooking, cleaning or taking care of her plants now are more difficult to do.

Persona 3

Name: Martha *Age:* 68

Facts:

- Economist. She works with the government in the implementation of development policies for cities.
- She has never considered herself a tech savvy person. Occasionally asks her husband for help when she needs to set up her computer or find a specific function on her cell phone

Fitness level: medium

Fitness interests: yoga, pilates

She has a very busy lifestyle. In addition to having a demanding job, she occasionally helps her daughter by taking care of her grandchildren, and is thinking of starting a startup to have an additional income after her retirement. During the start of the pandemic, her mental health was highly affected by the confinement at home, and the numerous emails and meetings at Zoom as a consequence of the switch to smartworking. As a measure to control her crippling anxiety, she decided to pay for a subscription to a fitness app. Although she did not find the application intuitive enough and it was difficult for her to follow the exercises through the cell phone screen, she decided to keep it because she found the routines and classes very entertaining. A year later she has created a habit and has found other benefits of exercise, such as a more stability and better physical state, and wants to continue training at home and increase the difficulty, but she feels that the application is no longer enough for her.

6.3. Guidelines for the design of technology-assisted systems for home training

To design products and services that can be used by older adults, several aspects must be considered. In particular, common age-related changes, as well as the adaptation of the environment, play an important role in defining the design requirements. Therefore, within this chapter a guideline is developed and briefly discussed to provide a better understanding of these changes and how they can be compensated by design. To determine a meaningful structure for the guideline, three categories were created from the analysis of the concept of healthy aging in relation to the context of fitness. As mentioned in previous chapters, functional capacity is comprised of the intrinsic capacity of each person and the environmental conditions (physical, social, cultural, among others) that surround them. A good product-service would be one that adapts to the functional capacity of each individual, that is, on the one hand, it can be used by a person regardless of the limitations that they may have in their physical and mental capacities, and on the other, can be accessed regardless of the environment that these people inhabit. However, throughout the research, several authors emphasize that even when the solutions are accessible and offer good usability, adherence to the use of the solution, and therefore to a training program, is not guaranteed, and that in in this case, appealing to the motivation of users is a key factor in the design of products and services for the elderly. For each category, the literature collected, specially the works of the Office for Product Safety & Standards (2021), Fisk et al. (2009), Khagani-Far et al. (2016), Lopez et al. (2021), Clark et al. (2014), and the interviews conducted in chapter 6 served as the base to identify findings, recommendations and principles that should be considered by future developers to make fitness oriented products and services more suitable for the elderly.

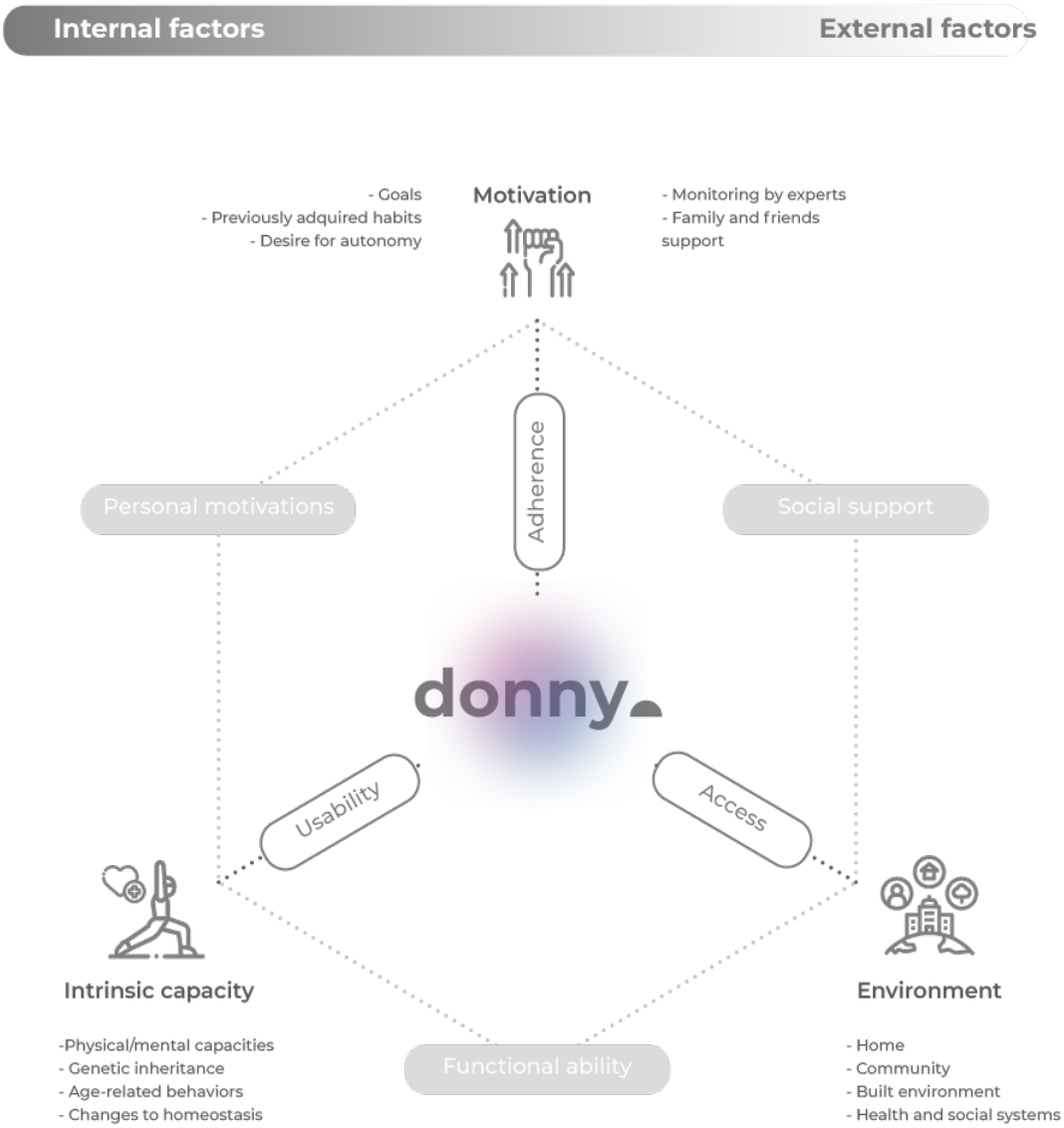

Figure 10. Correlation between factors that influence the design of products and services aimed at older adults

6.3.1. Intrinsic Capacity

Mobility: with ageing, physical and psychological changes influence the way people move and control their movements. Body movements become more error-prone due to changes in the transfer of signals from the brain to the muscle, and the decline in muscle strength and body flexibility restrict older people's range of movement (Fisk, et al., 2009). As the movement of the body is one of the main ways of interaction with a product, compensation in the design of the latter is fundamental to have good usability.

- Product physical aspects: hardware design decisions can influence the way users touch, grasp, reach, and move the product.
    - Dimensions: Product dimensions become important when older adults show decreased strength and/or mobility. For people who find it difficult to bend and stand back up, especially when holding something, products that are low to the ground represent a hard task. Similarly, large and/or heavy products that require force to be lifted must be adapted when the user has a loss of strength or worsening grip. Also the general size of a product should be considered when it has screens or displays with relevant information for the user (Office for Product Safety & Standards, 2021). According to the above, the following recommendations are given:
        - IC 1: Install products close to hip or shoulder level, or eliminate the need to bend over.
        - IC 2: Lightweight, small products, easy to lift and grip, or mobility aids that can be used at any moment.
        - IC 3: Keep the screens big enough to allow the correct display of interface elements.
    - Textures: Smooth surfaces can become difficult to grip, especially when they get wet or oily (Office for Product Safety & Standards, 2021). In those cases, people require increased use of force or awkward hand positions that can result in injury. Therefore, the following guideline is:
        - IC 4: Materials or surface textures that facilitate grip.
    - Components: Products that have many parts or that require the handling of several of them to fulfill a function, become difficult to use in cases of loss of dexterity. In particular, products that include cables that are located in strange places with respect to the product, or that are not very visible, create trip hazards (Office for Product Safety & Standards, 2021). Thus:

        - IC 5: Simpler shapes and/or less components.
        - IC 6: Cordless products or visible charge connections.

    - Grips and twisting: Changes in overall bodily strength or chronic conditions such as arthritis lead to a decline in dexterity, particularly strength and grip in the hands, that result in frustration among the users when they try to open lids or grab or turn small parts (World Health Organization, 2020). According to this, the following guideline can be derived:

        - IC 7: Hand-held features or shapes that encourage better grip

- Special movements: There are some types of movements that, even in users with good functional capacity, can be difficult to perform because the conditions to perform the action are too specific, such as unnatural types of grip, very complicated gestures or those that are too fine, or movements that displace the body's axis of balance, among others. In these cases, in the design it is important to take into account the ergonomics and the prior knowledge that people have about the use of the product.

    - Gestures: This is an area in which older adults can have difficulty, especially when gestures must be performed on a touch screen (Blendinger, 2015). People with arthritis or Parkinson's may find gestures that require more than one finger, rapid movements, or multiple movements particularly difficult. For this reason, the following guidelines imply:

        - IC 8: Keep the gestures as natural and simple as possible.
        - IC 9: Favor familiarity of a gesture pattern over its execution efficiency.

    - Pulling: Movements that require pulling put an additional load on some joints. Especially in people with reduced elasticity or osteoporosis, very small grips and strange angles in which the action is performed, can lead to injuries (Clark, et al., 2014). Therefore:

        - IC 10: Include handles where there is contact with the palm of the hand.
        - IC 11: Provide support or allow a safe body position in cases where the pulling action is above or below shoulder level.

    - Buttons: The buttons, whether analog or digital, become more difficult to reach with aging, especially if the target to hit is quite small; is in a reduced area or screen; is accompanied by other buttons or elements of the interface (Fisk, et al., 2009). To compensate for the user's level of precision, the following guidelines are established:

        - IC 12: Keep the button size according to screen size and large enough to work even with small deviations of the finger
        - IC 13: Keep spacing between adjacent buttons

        - IC 14: Keep spacing between buttons and other prominent features of the product interface.

Sensation and Perception: Recognizing an element or an object requires the body's ability to sense physical stimuli (e.g., hearing a noise), as well as the ability to interpret those stimuli (e.g., recognizing that noise as the song of a bird) (Fisk, et al., 2009). With ageing changes in sensory capability concerning all senses may occur. For these guidelines, only vision, hearing and touch are considered, since these are the most commonly involved when interacting with a product.

- Vision: Age is associated with a series of changes in the eyes like presbyopia, cataracts, and macular degeneration that lead to reduced vision, poor discerning of colors, lower adaptation to light changes, diminished capability to detect contrast and narrowing of the visual field (World Health Organization, 2020).

    - Color and contrast: reduced discerning of colors especially of those in the short wavelength end of the spectrum can make the recognition of color coded elements in interfaces difficult (Fisk, et al., 2009). Moreover, when combined with a decreased contrast sensitivity, the distinction between adjacent colors or text displayed on screens may be affected (Fisk, et al., 2009). To compensate these changes, the following guidelines are presented:

        - IC 15: Use color conservatively and, if necessary to carry information, use colors of the long wavelength end of the spectrum (Blendinger, 2015).
        - IC 16: Keep color contrast high, especially for buttons and text.

    - Text: With age the ability to focus objects at low distance decreases which leads to older people to spend more time reading text and instructions on screens (World Health Organization, 2020). In this case, some requirements for displaying text have to be considered:

        - IC 17: Use sans serif font types and avoid decorative, italic, underlined and condensed font styles (Fisk, et al., 2009).
        - IC 18: Font size should be preferably large and depend on screen size and the visual capability of the user.
        - IC 19: Increase line spacing to allow readability.
        - IC 20: Keep text static (Fisk, et al., 2009).

- Hearing: High frequency auditory signals (2000 Hz and above) are less likely to be perceived by older people. Moreover, higher sound intensity is needed in cases of hearing impairments (Blendinger, 2015).

    - Voice: Because the capability of distinguishing different sounds from each other and

high-pitched consonants become harder to understand, speech recognition and distinguishing speech from background noise is commonly challenging for older adults (Fisk, et al., 2009). In this case, both the intensity and the pitch of the voice must be considered:

- IC 21: Lower pitched voices like those of men are preferred over women voices.
- IC 22: Volume control should be available.
- IC 23: Limit sounds to one at a time or avoid similar intensities between speech and background noise.

- Signals and alerts: Like the voice, non-verbal auditory information is more difficult to grasp with decreased hearing (World Health Organization, 2020). For signals and alerts additional recommendations are presented:

  - IC 24: Auditory feedback should be provided with an adequate intensity and frequency. In the cases where high frequencies have to be used, the duration should be increased.

- Touch: Concerning haptics, the elderly more commonly have issues in sensing and perceiving touches or pressure, as well as vibration (Fisk, et al., 2009).
  - Pressure: With changes in skin sensitivity and proprioceptive receptors, contact with surfaces or changes in the position of movable objects, such as buttons, can go unnoticed. For pressure feedback this means:

    - IC 25: Favor hardware buttons over buttons on touchscreens
    - IC 26: Provide additional feedback to communicate that the button is pressed using light, color, vibration or sound.

  - Vibration: similar to hearing, vibration receptors within the skin and muscles to detect high frequency vibration (60 Hz and above) become less sensitive while sensing the low frequency vibrations (25 Hz and below) remain less impaired (Blendinger, 2015). For vibrotactile feedback this means:

    - IC 27: Use low frequency vibration for vibrotactile feedback

Cognition: Cognitive functions are affected differently by age-related changes. While long-term memory and knowledge concerning well-known and practiced behaviors or activities remain more or less intact, short-term memory and time-based future actions are generally harder to acquire and access with increasing age (Blendinger, 2015). Besides memory, attention becomes affected as the action of focusing on a certain stimulus or event and processing its information declines over the years. Spatial cognition as well changes, as locating objects and developing mental images based on external cues becomes more difficult (Blendinger, 2015).

- Product functions: On some occasions, due to the fact that the communication capacity of the product fails to meet people's cognitive abilities, difficulties appear in understanding how to operate a product.

    - Number of functions: Having a large number of functions in a single product is sometimes overwhelming for older adults, especially those with a short learning curve (Office for Product Safety & Standards, 2021). To avoid the product being under-used, it is recommended:

        - IC 28: Limit the number of functions that the product can fulfill.
        - IC 29: Divide the functions into different components or products.

    - Complex tasks: Similar to the number of functions, having complex tasks or settings increases the difficulty of using the product and the probability that the user will lose track of the task, especially when the task is part of an exercise routine.

        - IC 30: Simplify the task, reduce the number of steps required for a setup, or create analogies with tasks already known to the user (Fisk, et al., 2009).

- Navigation and Structure: The design and structure of a menu affects the users understanding of their interactions and the possibilities of the product. Thus, it influences the way they navigate through the interface and interact with it.

    - Consistency: every interface requires a certain amount of training to memorize how it's structured and actions are performed. Older people tend to rely on external cues to gain information from memory, and therefore, must make additional effort if elements and functions don't remain similar and consistent throughout the interface of the product (Fisk, et al., 2009). To make interactions more predictable, the recommendations are:

        - IC 31: Location of elements and functions should remain the same across screen views, and similar functions should act the same way throughout the product (Blendinger, 2015).

    - Hierarchies: Menus with many subcategories represent more decisions that need to be made to reach the desired function or information. In this case, it can be difficult for the user to find a route through such a deep hierarchy. This causes a high demand on working memory (Fisk, et al., 2009). This means:

        - IC 32: Avoid deep hierarchies in menu structures
        - IC 33: Provide navigation cues and make obvious the current location of the user in the navigation at all times.

- Assistance: Even if the functionality is provided as intuitively as possible, problems like misunderstandings, or misalignments with the user's skills may arise when learning and understanding how to use a new product or service (Office for Product Safety & Standards, 2021).

    - User support and training: Older people may have doubts about their ability to learn or tend to avoid getting into situations where they have to learn new things. A product, in this case, should provide supportive material that is accessible at any time (Fisk, et al., 2009).

        - IC 34: Provide a source of learning material at any time and location within the interface.
        - IC 35: When possible, provide a combination of text and images in step-by-step instructions.
        - IC 36: When the user fails to perform an action, provide feedback on the possible causes of the error and possible actions to solve it.

    - Personalization: With age, while some abilities may be impaired, others may remain intact depending on the person. Due to this variance introducing a number of adjustable factors may increase the usability (Fisk, et al., 2009).

        - IC 37: Allow customization of certain factors of the interface according to personal needs.

6.3.2. Environment

Coaching and Tailoring: is the process of identifying the needs, abilities, desires and goals of the users, prescribing a tailored workout program, monitoring the progress of the users, and modifying the training plan accordingly (Khaghani-Far, 2016). Traditionally, this is a process that is carried out in person by human trainers in fitness facilities. However, technology can provide different levels of support in this process, from entirely human to fully automatic coaching. For the users at home, the coaching (either by a human or an AI) makes the training more effective, safe and engaging (Offli, et al., 2015).

- Programs: Some parts of the health and fitness industry are strategically configured to support and create fitness programs for people that are already athletic. In these cases, the adaptation of older adults is not only challenged by their functional capacity, but by the environment in which they try to perform physical activity (Algar, 2017).

- Assessment: The great variation in the abilities of older adults often implies an exhaustive assessment to know all their limitations, as well as their needs and goals (Khaghani-Far, 2016). This requires the knowledge and opinion of experts at some point in the creation of a program.

    - EN 1: If possible, include initial and/or periodical assessments lead by a fitness expert or healthcare professional.
    - EN 2: Include tools or protocols that allow the assessment of the user's fitness

- Plans and Progressions: Unlike younger people, older adults often fail to adapt to standardized training programs, not only because they ignore the variations in the functional capacities of each person, but also because they do not provide the necessary guidance to achieve the goals set (Algar, 2017). To overcome the reductionism of training programs, it is proposed:

    - EN 3: Create customized programs to meet the needs and goals of each person.
    - EN 4: Provide a progression or difficulty selection system for training programs.
    - EN 5: Created programs focused on categorized, smaller groups.
    - EN 6: Include a guide of some kind for the performance of fitness programs and their progression.

- Support: Nowadays there are models of programs that are supported both by humans and by algorithms and artificial intelligences programmed to learn from the needs of the user. In both cases, however, some issues may arise.

    - Human support: Human coaches are the safest and effective way to design programs for older adults (Khaghani-Far, 2016), but when users cannot be monitored or the coach has too many in charge, errors are likely to start to appear in the prescription, guidance and progress of the programs. Because of this:

        - EN 7: If possible, include a human expert in the system (Khaghani-Far, 2016).
        - EN 8: A channel of communication and monitoring should be available at all times (Fisk, et al., 2009).
        - EN 9: Include tools that facilitate the data management by the human coach for tailoring of the programs.

    - AI support: Some older adults find it difficult to connect with an AI because of the personality or language they use. Additionally, AIs have a learning curve that requires information that older adults do not want or cannot provide (Farrokhi, et al., 2021).

- EN 10: Provide an AI with emotional support, and speech and language as natural as possible (Khaghani-Far, 2016).
- EN 11: In cases of lack of human-like conversational components, provide question-answer format dialog of conversation (Kim & Abhishek, 2021)
- EN 12: Include tools that facilitate the data collection of the AI for user profiling.
- EN 13: A mixed support system of AI and human coach is preferred over the use of just one of the two, and preferred over a solution without coaching (Khaghani-Far, 2016).

Sensing and monitoring: capturing training data is important for the tailoring of workout programs. In recent years, technological advances have allowed the transition in the way in which data is collected, from analog measurements to constant automated data flows thanks to specialized sensors. The choice in the way in which this data is collected depends on the type of activity carried out (e.g., indoor, outdoor), the desired markers, and the level of precision required (Khaghani-Far, 2016).

- Data collection: sharing data is an essential form of interaction for systems which acquire, process or communicate data as part of their functions. In older adults, a combination of self-reported data and automatic detection is preferred, given that for them it becomes difficult to complete major data entry tasks within an adequate time and a minimum of mental and physical effort (Blendinger, 2015).

    - Self-reported data: Can be used for more subjective measures, but particularly motor impairments lead to a slow input speed while less capacity of the working memory requires more concentration to fulfill tasks. Therefore, it's important to provide options that facilitate and speed up data collection.

        - EN 14: Keep data entry tasks to a minimum (Fisk, et al., 2009)
        - EN 15: Provide predefined values or buttons or slider bars (Blendinger, 2015)

    - Tracked data: Sensors are preferable when it comes to objective measure (Khaghani-Far, 2016). Still, some older adults have trouble adjusting, especially to sensors that need to be placed somewhere on the body, held constantly, or with very small screens.

        - EN 16: Include sensors when precise data is required from older adults
        - EN 17: Environmental sensors are preferred over wearable sensors. When wearable sensors are unavoidable, use body areas that older adults are already familiar with wearing things.

- Nature of data: The data collected by a system can be subjective or objective in nature. In the fitness context both types are collected to get an idea about general activity, physiological indicators, or movement patterns. However, in older adults the interaction can be affected, on the one hand, with the decrease in the accuracy of the subjective data provided, and on the other, with the excess of aspects that can be measured with sensors, which translates into useless and confusing information from the user's point of view (Khaghani-Far, 2016). To find balance in the data collected, it is suggested:

    - EN 18: Limit sensor activity to tracking specific training markers.
    - EN 19: Provide simplified, understandable metrics of processed and returned data.

Built environment: Physical activity and patterns of mobility among older people are influenced by environments' physical features, aesthetics, accessibility and connectivity of urban design, and safety among others (World Health Organization, 2019). One key approach to enabling autonomy is maximizing the intrinsic capacity of older adults, but autonomy can also be enhanced regardless of an older person's level of capacity. This may be achieved by implementing changes in the environments they inhabit or providing assistive products and services that help them manage their limitations (World Health Organization, 2019).

- Environment adaptability: While difficulty often appears as a result of changes in ability that makes the person unable to meet the demands of the environment, issues can be exacerbated by the quality of the environment itself and features of daily life objects that render the performance of activities more difficult (Lopez, et al., 2021).

    - Flexible spaces: having dynamic environments allow people to make changes to where they exercise or changes within the environment to facilitate exercise. For older adults, having spaces that are too busy, with too many divisions, or with machines or furniture that are too heavy to move, becomes a barrier to exercising (Lopez, et al., 2021).

        - EN 20: Space should be dynamic enough so that it can be quickly accommodated to perform different activities.

    - Enabling features: Some spaces are more appropriate for physical activity than others. The availability of secure and supportive features provides older adults with a sense of greater security and comfort (Lopez, et al., 2021). Things that can be done to make a space adaptable are:

        - EN 21: Provide support or anchor, or leaning structures.
        - EN 22: Have equipment modular, easy to fold or disassemble.
        - EN 23: Have connection points for electronics.

- Location: The location of the space designated for exercise is of special importance for older adults due mostly to the ability to move. Facilities that are very far from the place of residence or spaces that require the constant use of stairs to be reached are main barriers to accessing a training program (Kruger, et al., 2007).

    - EN 24: Allow the exercise program to be carried out in different spaces according to the user's needs

6.3.3. Motivation

Individual persuasion: Older populations can benefit from individual persuasion strategies, as they can be tailored according to older adults' abilities, interests and preferences. However, these strategies require individual will and natural drive, which are elements commonly not present in those who are not used to doing physical activity or who do not see an obvious benefit in it (Khaghani-Far, 2016).

- Reminders and suggestions: Changes in memory functions due to aging can make it difficult to follow or accept training routines and to memorize exercises, actions, or system functions (Khaghani-Far, 2016). In those cases, it is important to offer additional support to ease the burden of mental effort and encourage action.

    - MOT 1: Provide reminders and alerts for pending tasks. If possible, use more than one mode of dissemination of the message.
    - MOT 2: Provide instructions and training opportunities to improve habits.

- Positive and negative reinforcement: Clearly informing the user about the cause and consequences of an error is essential for successfully recovering from it. For older users, though, the way the message is conveyed is especially important, as they are more likely to give up on a task they find difficult to perform. In the opposite case, positive reinforcement helps the user to stay motivated and remember when and how an action is being performed correctly (Khaghani-Far, 2016).

    - MOT 3: Provide error messages that are informative about the error, the consequences and how to recover from it.
    - MOT 4: Give clues or notifications when relevant actions are being carried out appropriately.
    - MOT 5: A combination of text and other visual, auditory, or tactile cues should be available.

- Rewards: Earning a reward helps older adults maintain adherence to an exercise program. However, finding rewards that are meaningful depends on the personal motivations of each user (Khaghani-Far, 2016).

    - MOT 6: Implement a reward system in which the user has the possibility to choose their reward.

Social persuasion: Although it is true that social persuasion strategies that involve a community are especially effective in achieving greater adherence to training programs, in older adults most of the time the only support comes from their own motivation or that of their doctor or professional in physical activity (Baert, et al., 2011).

- Social learning, cooperation and competition: Older adults in general are interested in having social interaction in dynamic ways. When it's about competition and collaboration, users should be able to collaborate or compete with equal peers. However, diversity in impairments means that the abilities of each user could be significantly different from their peers, even if they are in the same age range (Khaghani-Far, 2016). Thus, strategies are required that level the users who belong to the same level of activity.

    - MOT 7: Create activity groups of people with similar abilities through user profiling.
    - MOT 8: Include advantages that proportionally level impairments in dexterity or cognition.
    - MOT 9: Include features that allow users to create their own challenges.

- Social support: Although support given by family, friends, and caregivers can improve the motivation of older adults to perform physical activity, finding ways to keep them connected during the training program, when the user requires them, remains a challenge (Khaghani-Far, 2016).

    - MOT 10: Provide features like messaging or forums that enable the creation of communities.
    - MOT 11: Include quick interaction features like taps or likes.

- Recognition: Similar to rewards, older adults feel more motivated when socially recognized for their achievements, progress, and contributions (Khaghani-Far, 2016). Thus:

    - MOT 12: Allow recognition actions from other users, as well as the sharing of information about training when the user wishes.

6.4. Design brief

After having completed the introduction and research about ageing and physical activity, done an overview of the current market, set the benchmarks, identified some pain points through the analysis of trending scenarios and collection of data through questionnaires, and created guidelines that can be used when designing for this particular user, the next step is to create a brief to give direction to the final design. As stated in earlier chapters, physical activity is key to maintain the functional ability that enables wellbeing in older age. While being physically active makes it easier to perform activities of daily living with autonomy, some older adults face barriers that make it difficult for them to access fitness facilities (chapter 3) and/or exercise programs that are appropriate for their unique abilities (chapter 6).

As an alternative to explore solutions that fit the target audience, the home has been stated as a promising scenario, based on the extensive existing literature on physical rehabilitation programs in older adults (chapter 4) and the current transition of the fitness market towards digital solutions (chapter 5).

Thus, the objective of the project will be to devise a system for the performance of home-based workout programs that stimulates the participation of older adults in physical activity. Taking into account the data gathered in chapter 6, it is possible to establish some key points to continue with the development of the product service system:

- Setting of the system in the home context. The system must be flexible enough to adapt to different types of residential spaces.
- Devising of the products to best suit the unique capabilities and limitations of each user, both in the hardware and in the interaction with the digital interface.
- Provision of support for resistance training.
- Use of both a touchscreen and pairing with/connection to other screen devices as main output providers of the system.
- Implementation of motivational strategies through a combination of individual and social persuasion strategies.
- Tracking of fitness related markers restricted to non-wearable sensors to keep the interaction as less invasive as possible.
- Inclusion of a human trainer for the coaching and tailoring of the workout programs.
- Provision of a sense of human connection even when human coaching or group workout aren't available.

7. Final design concept

7.1. The Device

Donny is a product-service system that aims to bring to users' homes the experience of a personalized and monitored workout training, through a smart product that blends into the home smoothly and that adapts to the functional ability of each user.

The Donny concept is built upon the idea of combining all the positive aspects of resistance and functional training with live remote coaching as an alternative to weight machines and the traditional brick-and-mortar gyms model. The product works paired with a TV or any other device with a screen, either through a Bluetooth connection or an HDMI cable, providing access to a number of live and on-demand classes, 1:1 classes with a physical activity specialist, and group workouts.

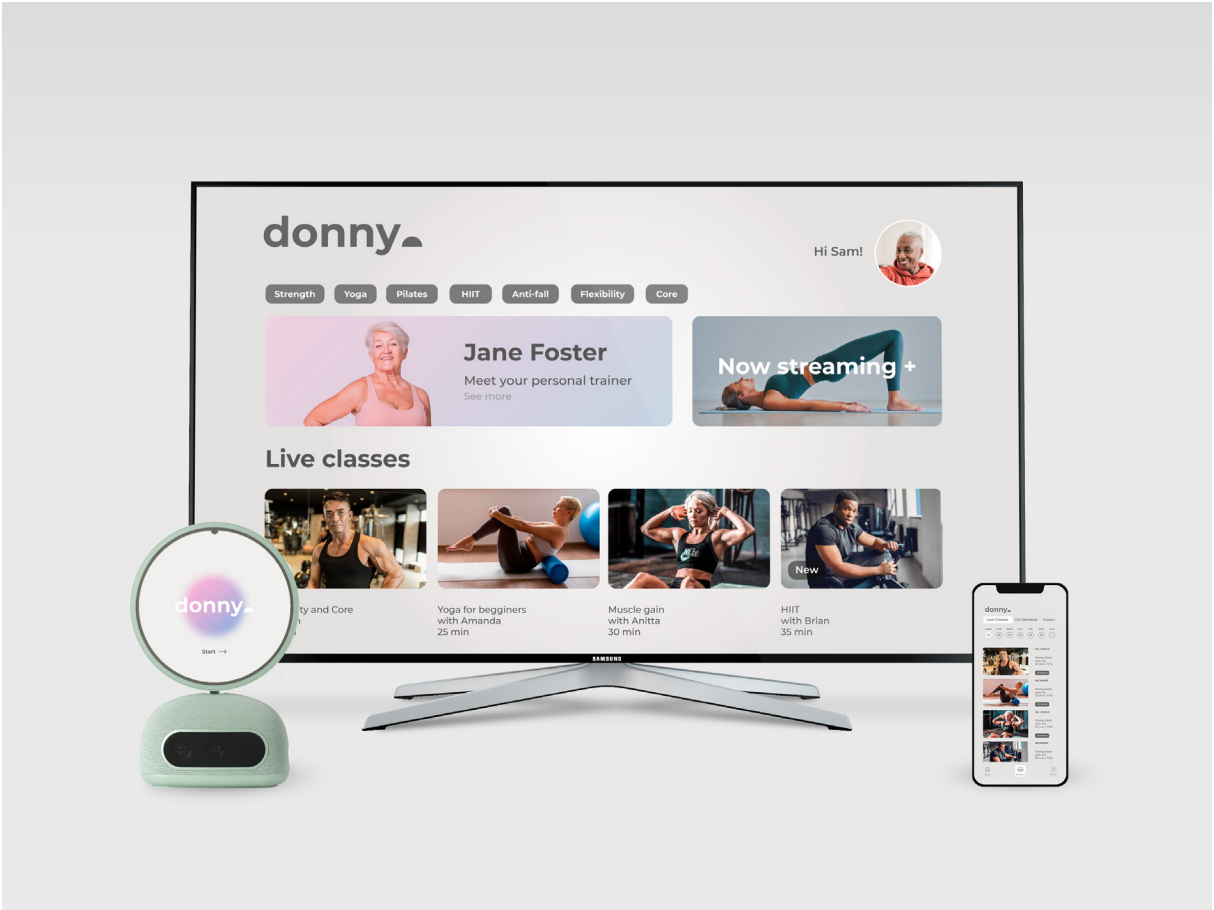

Figure 11. Donny interconnectivity

The design was inspired by home assistant devices, the morning sun, and the gesture of approval that the coaches make when trainees are performing the exercise correctly. Compared to other smart home training systems with larger and more complex hardware, this device seeks to simplify the interaction with the system and occupy the least amount of space in the home by taking advantage of other products and equipment already available there. Moreover, this system takes advantage of technology to implement persuasion strategies, paying particular attention to the more motivational and social aspects of training, in order to achieve greater adherence of older adults to exercise programs.

Figure 12. Donny device in home context. The shape and dimensions of the device allow it to blend in smoothly with other home items

7.1.1. Components and technology

The main device is made up of eight components: body, hinge, screen, on/off button, Bluetooth button, volume button, camera module and base. The largest components, that is, the body, the hinge, and the screen are distinguished from each other by both their shape and their finishes. On the one hand, the body has a rounded and robust shape that conveys friendliness, and a surface that is mostly made of fabric that gives the product a cozy and familiar feeling with which it fits seamlessly into the home environments. The hinge and the screen, on the other hand, have much more delicate shapes, which give a sense of lightness that compensates for the general height of the object, and plastic and glass finishes typical of devices with a screen to subtly remind the user of the purpose of this part of the product.

Figure 13. Device Details. Changes in surface textures and the inclusion of lights provide additional sensory input that makes it easier for the user to navigate the device's hardware

The body is divided into two parts. In its upper portion, it presents the on / off, Bluetooth and volume control buttons, which are located on the side faces, while in front the surface is briefly interrupted with a glass that hides the camera module. In its lower portion, on the other hand, are the input ports for the power and HDMI cables.

The hinge rests on the upper portion of the body, and connects the latter with the screen. While the portion that is in contact with the body rotates horizontally, the portion that connects with the screen allows the screen to move vertically.

The last section of the product comprises a circular touch screen with a small 1-megapixel camera that barely interrupts its continuity and an LED light frame around it. The circular shape of the screen is a conscious decision both to differentiate itself from other smart devices and to unify the display of the different features of the interface (such as live and on-demand lessons or the options menu) that would otherwise require a change of the aspect ratio between one and the other.

Figure 14. Donny dimensions. The device has been designed as compact as possible without sacrificing the usability of the interface.

As for the technology implemented, much of the hardware with which the device works is located inside the body. It includes a 12-megapixel camera in combination with a 1-megapixel depth sensor for capturing movement during training, a 7-microphone array for far-field speech and sound capture, and a 75mm woofer and 19mm tweeter speaker system.

7.1.2. Features

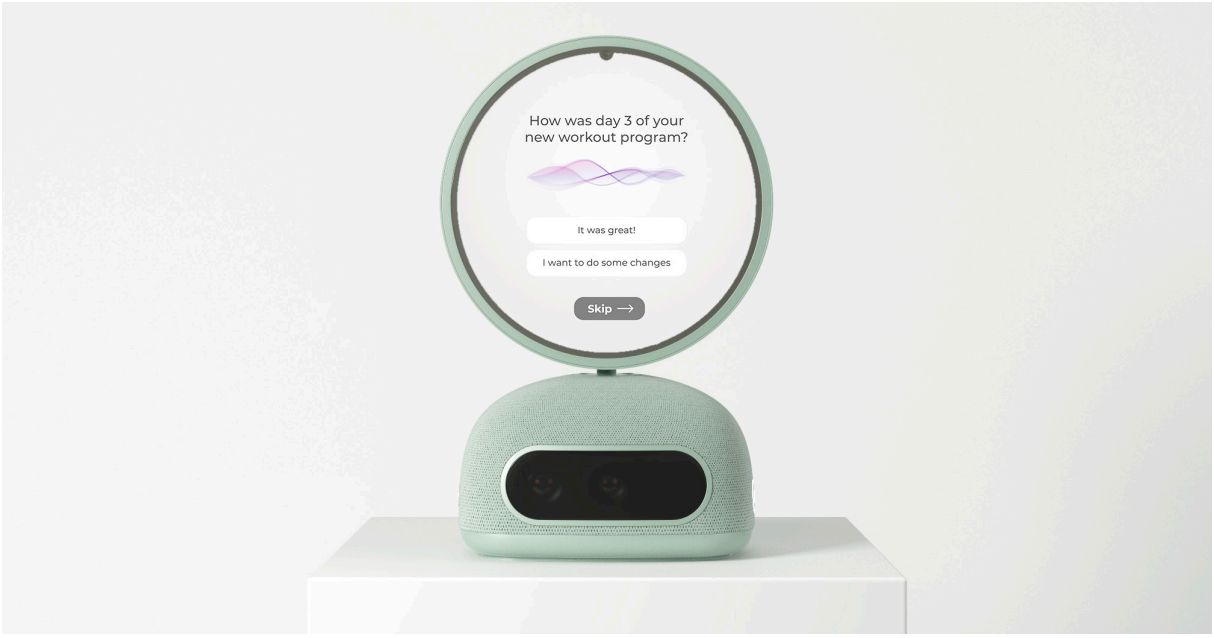

Figure 15. Donny constantly learns from user preferences and activity to provide an increasingly personalized experience.

Built-in Assistant: Donny comes with a built-in assistant that actively learns from the user's interests and personality, as well as the physical activity performed. Evaluating the training progression from the feedback given by both the trainee and the trainer, it sets the difficulty of the training session by adjusting the weights, repetitions and types of exercises.

The assistant is capable of voice interaction. As mentioned in chapter 6, voice commands are a friendly option that improves the interaction of older adults with digital devices. Not only because they are an optimal solution for people with sensory or motor limitations of some kind, but also because the verbal responsiveness makes it easier for users to perceive the assistant as a personified entity that provides emotional support and companionship (Kim & Abhishek, 2021) For this, the smart assistant makes use of a technology similar to that of home assistants such as Alexa or Google, including speech recognition, natural language understanding and other skills commonly integrated in conversation interfaces.

In addition to voice commands, the assistant provides button-to-action support, which is a bit closer to technologies previously known to users, and its interface, as well as the general device shape, are designed to provide affordance to some of the functionalities of the assistant.

Figure 16. The device monitors the user's performance and provides real-time feedback to help the user improve their technique and avoid injuries.

Form correction/Real time coaching: Good physical exercise does not depend solely on the amount of exercise performed during the week, but on the quality with which it is performed. Part of the personal trainer's job is to correct the trainees' posture during exercises to improve exercise effectiveness and prevent injury. In cases where the personal trainer is not available, the AI coach can take over this task, making use of the RGB camera in conjunction with the depth sensor to actively learn about the physical activity performed by the user, and create guidance in real time that improves form and technique by showing on the screen the reflection of the user performing the exercise and specifically pointing out the gestures or postures to be corrected. Thus, thanks to this combination of current coaching experience and A.I coaching, the user can always benefit from real-time form feedback.

Figure 17. The automatic tracking of the user's activity and physical condition helps to avoid self-reported questionnaires, thus reducing the user's mental load.

Progress tracking: Donny is the ultimate remote coaching and training tool. It keeps track of all information related to training and makes it available to both the user and the personal trainer. While the trainer can view the data collected throughout the days to monitor and tailor the training programs, the user can access their progress stats, track their workout, like number of series and repetitions, calories and range of motion, and access program summaries that will also be available in the dedicated mobile app.

Additionally, the smart device can be paired with other tracking devices such as Fitbit or Whoop to collect physiological metrics such as heart rate, respiratory rate and calories burned and thus generate extended program summaries that will help the personal trainer to tailor the programs with greater precision.

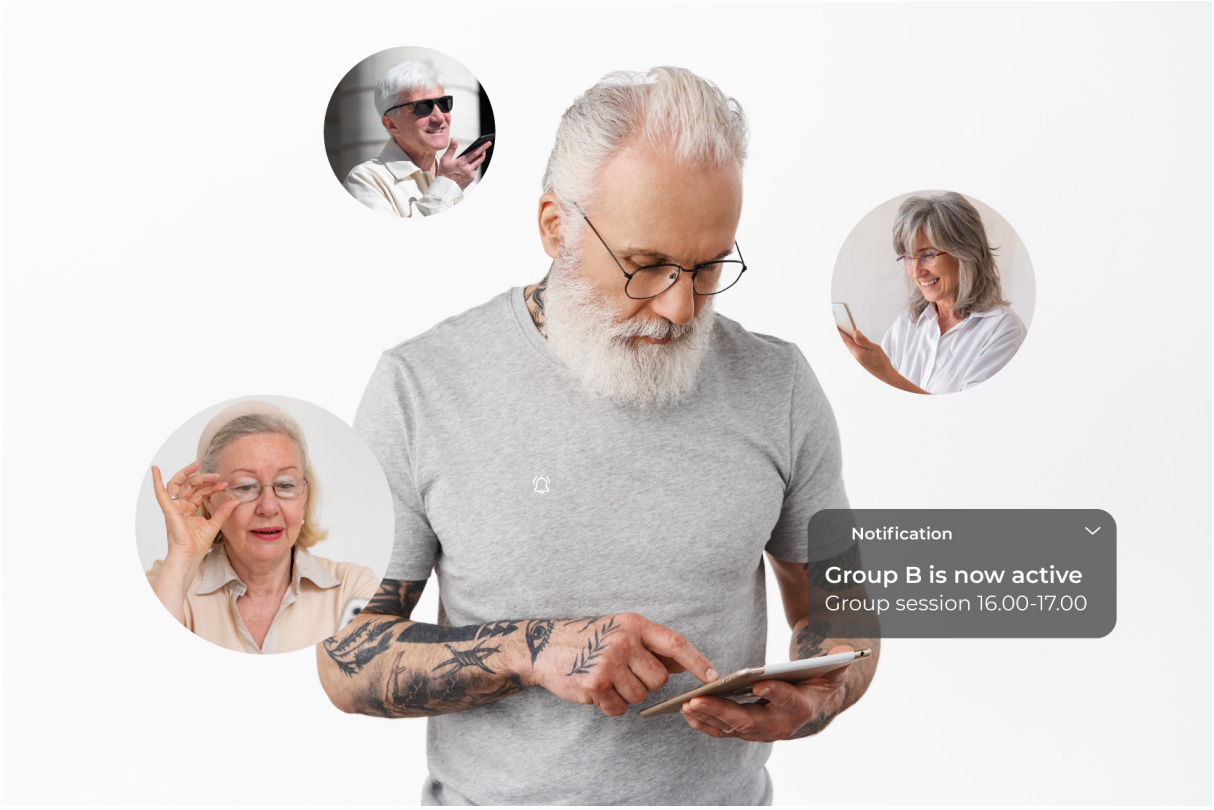

Figure 18. By keeping users in small groups, coaches have greater control over the variables they must take into account to organize group class sessions.

Groups: Donny assesses the user's functional capacity and workout performance and creates a profile with which it is possible to know in which part of the functional spectrum the user is. Unlike other smart home training systems, this profile is not used to evaluate the user's position in a leaderboard's ranking, but to find profiles similar to each other that can perform the same exercises and go at the same pace in group classes.

The use of AI for the assessment of the profiles on the one hand facilitates the task of the physical activity specialist to tailor training plans for profiles of people instead of always creating a training plan from scratch for each new trainee. On the other hand, it promotes the creation of a sense of community by bringing users with the same abilities together in small groups, and gives them the possibility of supporting each other even when they are not training in group classes.

7.2. The resistance bands

Donny is designed to perform resistance training with the least amount of equipment possible and keeping in mind that the user may already possess additional equipment at home. In cases where the user is completely new to the home fitness experience, along with the device they can purchase a set of bands with different thicknesses which allow for different degrees of resistance that can be exchanged or stacked as the progression of the training program is made. As mentioned in previous chapters, resistance bands are a very versatile solution, since they allow movement in multiple planes of motion, can be set in different angles, and allow for a vast range of exercises that can be combined seamlessly. Furthermore, they are safe and easy to use by older adults, and allow for challenging workout while only taking up little space.

To enhance stability and comfort, the set of resistance bands come with a pair of removable handles. The handles work by being snapped on to one or more resistance bands and allow to keep a stronger grip on them when stretching the band, optimize control and avoid injuries normally caused due to the stretching and contraction of the bands against the palm of the hands. Moreover, by having only one pair of handles for the entire set of bands, a minimum number of items are kept for training, and this facilitates the storage of the equipment at home.

The resistance bands are made of natural rubber latex, are color coded, and come in levels of resistance of 15-35 lb, 25-60 lb, 35-80 lb, 50-115 lb, 65-150 lb. The handles come with an anti-slip foam grip cover and can be used with the first three levels of the resistance bands.

Figure 19. The resistance bands come color coded to facilitate the process of picking the right resistance level during the routine.

Figure 20. Keeping simple assembly mechanics allow users with mobility impairments to change between resistances without much effort.

7.3. Weights system

For more experienced trainees or those who are more advanced in the progression of their training programs, Donny's product-service system provides an optional set of weights that can be incorporated into the home with the same ease as the rest of the system, and that allows to achieve and even bigger variety of exercises and a greater difficulty when performing the routine.

Figure 21. The material and texture of each part of the weight system is designed to offer safety and comfort.

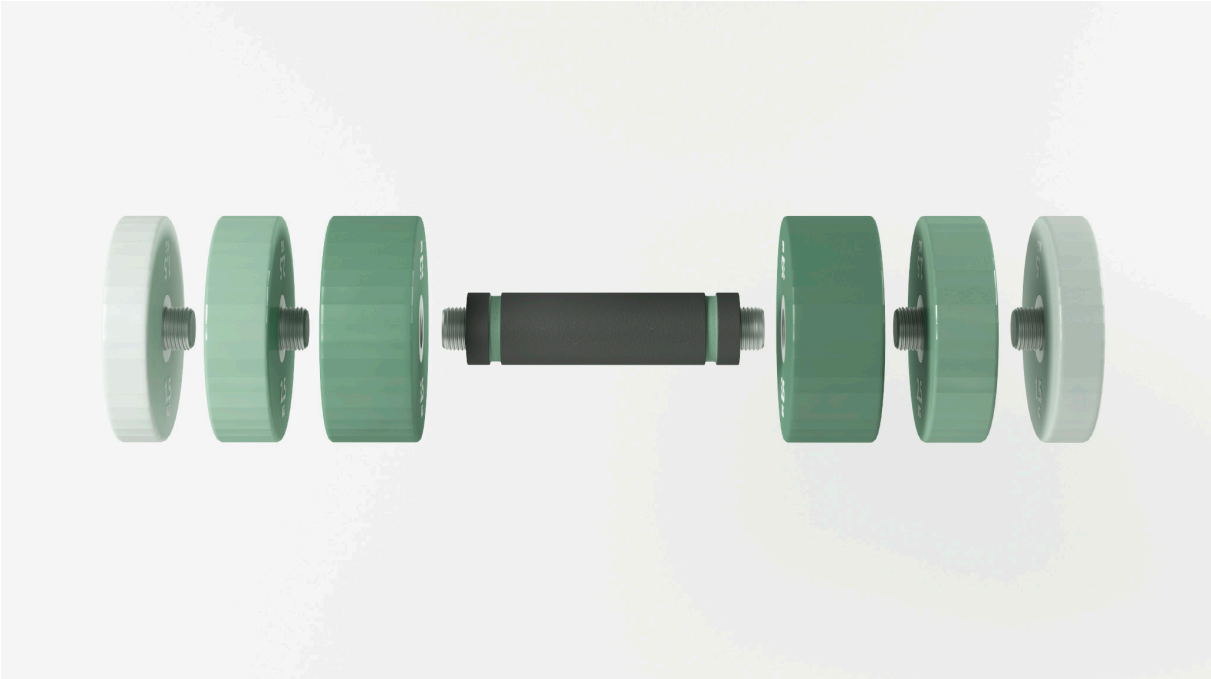

Figure 22. Donny's weight system reduces the number of items required for proper weight progression during training, while offering versatility in the type of equipment without taking up a lot of space in the house.

To meet older adults' needs an alternative design of traditional free weights' system is proposed. Traditional dumbbells and barbells are bulky and sometimes limit the range of the movements as they bump into the body during the routine performance.

Additionally, adjusting the weight can be particularly difficult for people with limited grip strength and/or precision, either because of the size or shape of the weights, or because of the systems used to secure them to the bars. Donny's weights are made of steel, are compact in size and easy to grasp thanks to their slightly polygonal shape.

To assemble them, each weight is secured to the next thanks to a threaded fixing design in each of the weights that is firmer than the nut traditionally used at the ends of the bars to secure the discs, which avoids the problem in which weights shake due to a loose nut. By adjusting the number of weights put together, the trainee can choose a suitable weight for each exercise of their routine.

Figure 23. The user can continue to acquire discs as they progress and acquire greater strength in their training.

To complete the assembly of the weights, different types of handles can be attached. Depending on the type of exercise, the weights can be configured as a pair of dumbbells, a barbell, or a kettlebell, all of them made of a comfortable, anti-slip, thick foam material, which reduces the hand pain caused by heavy objects being carried for a sustained period of time.

The weights can be adjusted to 5 kg, 7 kg, 12 kg, and 15 kg, which saves the need to get multiple dumbbells, and therefore the need for more storage, as one handle can easily be adjusted thanks to its modular design. If more weight is needed, the user can simply buy more weight plates.

7.4. Donny's app

7.4.1. User Experience

By connecting the device to a smart TV, registering and creating a user, it is possible to access all remote coaching and training functions online. The connection system between the device and the TV is done through Bluetooth pairing, however, it is the screen of the device the one used as a medium for the inputs, which means that even if the TV is not a smart device, it is possible to make the connection through an HDMI cable and in that case, use the Donny base device to connect online and navigate between all the system services, either through the use of the touchscreen or voice commands.

Each screen fulfills different functions. The TV screen makes use of its larger size to project elements that contain greater loads of visual information, such as training program exercises, tracked metrics, and posture correction. Meanwhile, the Donny device screen displays the menu as well as features most related to persuasion strategies. Additionally, a version of the application is downloadable on cell phones to use as an additional remote control in case the device is not to hand.

Figure 24. To fit in any home, instead of having a large screen, Donny makes use of the screens that the user already has.

Figure 25. The device screen is large enough to allow customization of the interface for people with motor and sensory limitations.

Navigation

The main control of the system is done through the touch screen of the smart device, which is active from the moment the device is turned on and which shows all the functions of the system. Like any other device with a touch screen, the input is generated directly, which means that it is only necessary the touch of a finger on the element of the screen with which the user wants to interact, without the need for other additional elements such as a mouse or a pointer. As mentioned above, touch devices require less hand-eye coordination, are easier to learn, and easier to use for people of all ages. Especially in older adults, these lower cognitive demands improve interaction with the device and consequently increase its acceptance (Czaja, 2019).

Voice commands

The use of voice commands is an alternative feature when the use of the touchscreen is not preferable or possible, either due to limitations in the user's abilities (visual impairments, reduction in precision movements, etc.) or because it is not within reach. Very similar to other smart assistants, the voice recognition unit is always active, so it is possible to go directly to voice control at any time by saying the activation command, "Donny". The vocal commands correspond to simple instructions that follow the logic of the common language, such as "Donny, call my specialist", thus making the interaction with technology much more natural. In cases where the assistant fails to understand the user's commands, it will provide possible causes of the error in its responses. For example, you can provide common causes of the error and suggest actions by saying "sorry, I don't understand your request. It may be because you are speaking at a very low volume" to help users correct and prompt them to engage more with the voice assistant.

Figure 26. The natural speech of the voice assistant makes it easier for the user to engage with the device and consider it as a personified entity

Figure 27. The personal trainer creates training programs in a list format, where each exercise can be viewed with a pre-recorded example, so that the user can follow the routine on days when no appointments have been scheduled.

Workout

Donny offers three exercise modes as part of the training program, each designed to meet the specific needs and desires of the user.

Personal training: The core feature of the training program is 1:1 lessons with a physical activity specialist, of user preference. By scheduling each lesson in advance on the calendar, the user will have a physical activity session monitored by the coach through the device's camera set. In cases where the trainer is not available, or when desired, the user can perform individual training and follow the routine with explanatory tutorials for each exercise and monitored by the AI.

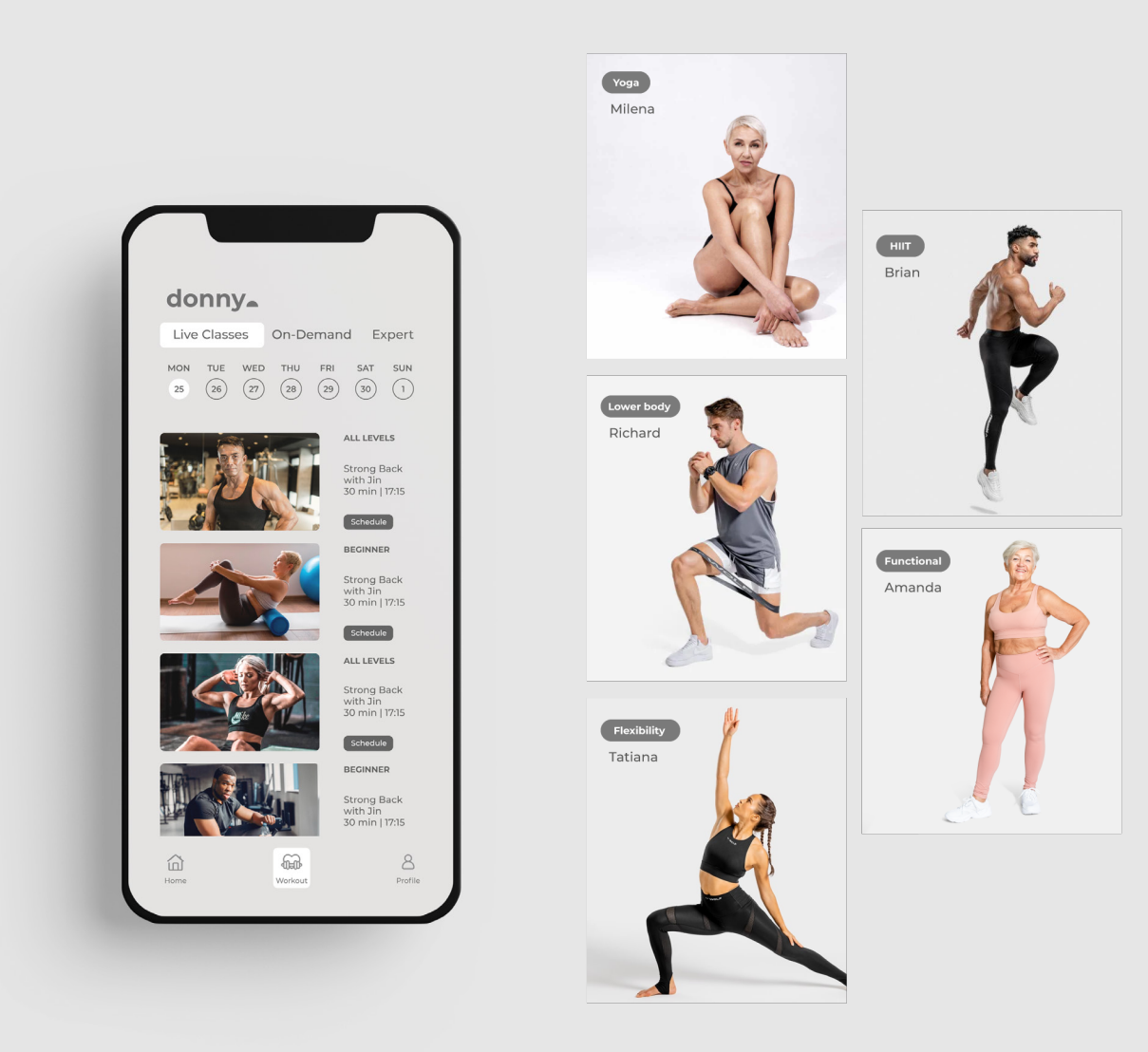

Figure 28. The calendar allows the user to view both scheduled live classes and personal training sessions. On-demmand classes can be filtered by tags.

Live classes: Scheduled in a constantly updated calendar, the user can access different lessons recorded in real time together with other users of the platform and receive instructions, motivation and real-time feedback from the instructors, who will always adjust the classes to the level of performance of the trainees. With new live classes daily, the workouts always stay fresh, which prevents trainees from getting bored easily.

On-demand classes: Donny has a library of pre-recorded classes with experts in different types of fitness fields (such as yoga, boxing, HIIT, among others) and divided by levels of difficulty and available training equipment, which the user can access any time they want and watch through the TV screen. Donny's AI is in charge of displaying and suggesting classes according to the user's profile and preferences. The more information the user provides when interacting with the library, the more accurate the recommendations that the system will display.

Motivation

One of the most important aspects to ensure adherence to a training program is motivation, which, as has been said in previous chapters, can be encouraged through individual and social persuasion strategies. In this section Donny focuses on three features to keep the user motivated before, during, and after training.

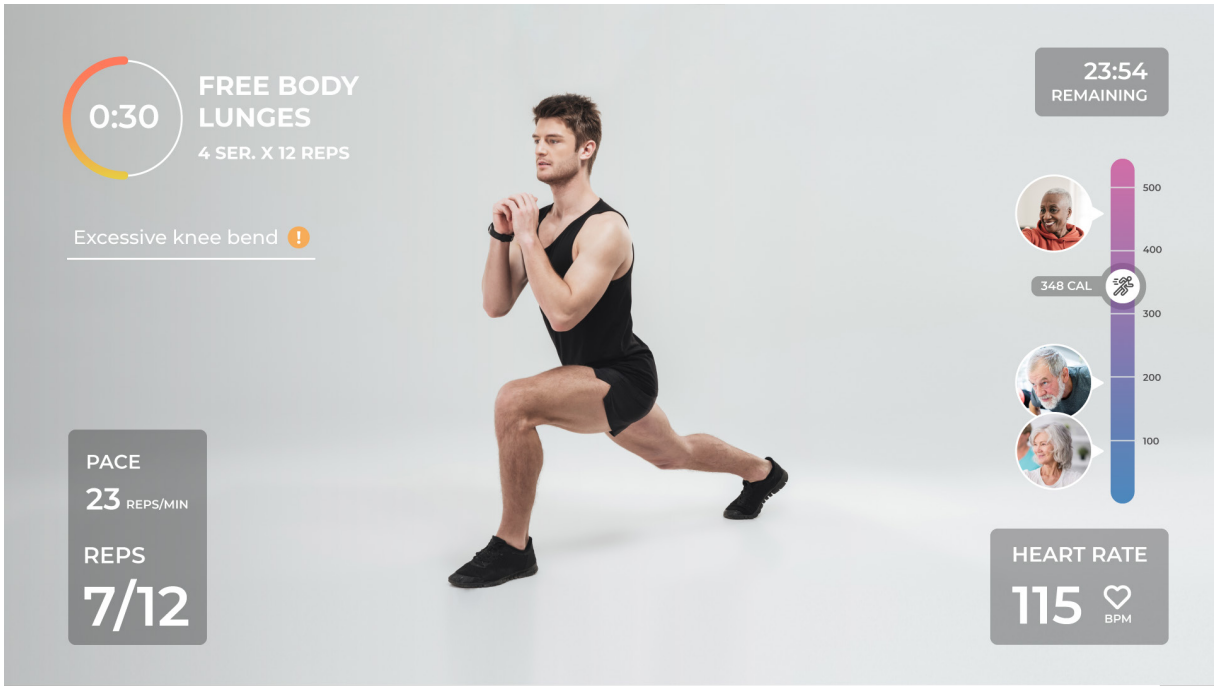

Figure 29. Competition dynamics can be implemented in group classes to give a higher level of motivation.

Community

By organizing user profiles into groups that share similarities in terms of interests and skills, users will always have the assurance that both the coach and their training partners will understand their needs and will have greater opportunities to connect with each other both in training and on a personal level. Through dynamics of cooperation or competition, the coach can contribute to a greater sense of community and provide more motivation.

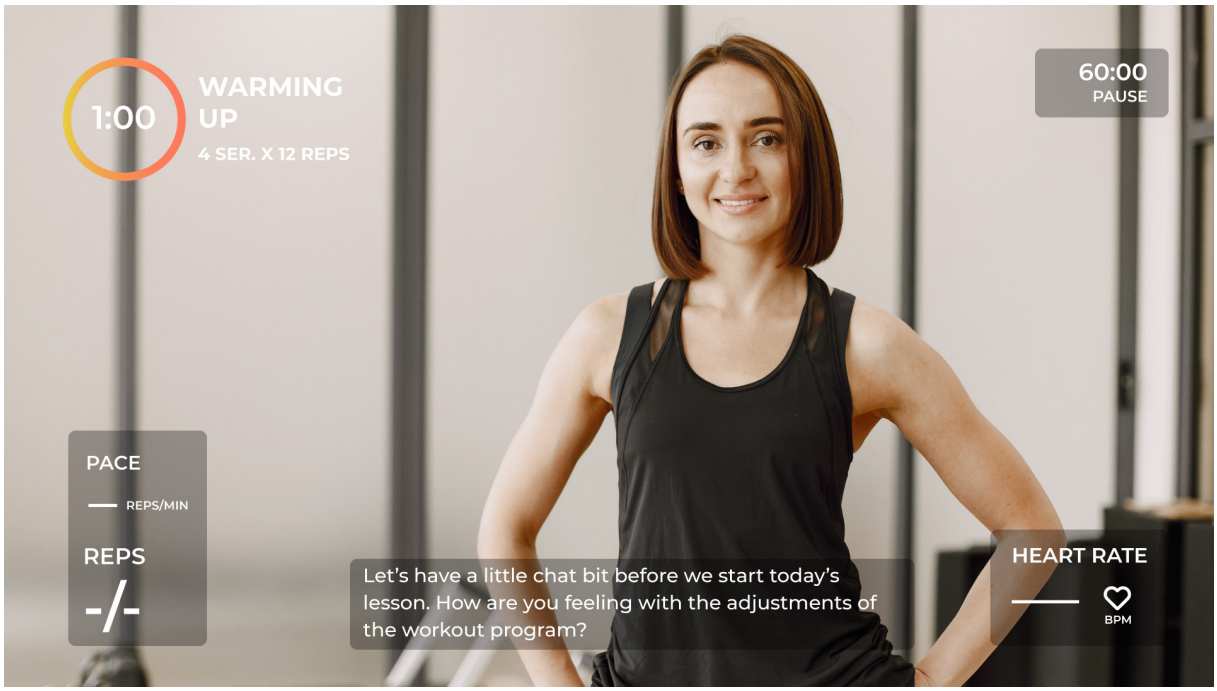

Figure 30. Personal trainers are assigned according to the goals and interests of the users. Through a questionnaire that the user answers during the early phases of the training program, Donny's AI will look for a trainer with the personality and training techniques that best suits the user.

Remote personal trainer

Donny's technology can provide different levels of support, but while automated processes can save time and money, human contact is still important for older adults. A human trainer not only provides information and feedback regarding the workout, but also exercises knowledge, encouragement and emotional support while the user goes through the workout sessions (Khaghani-Far, 2016), which translates into a better experience.

Coach Donny

While there will be some moments when group dynamics or personalized training will not be available, that does not mean that the user will be unsupervised or without motivational support. In those cases, Donny's AI takes over through reminders of the trainee's exercise sessions and suggestions about better exercise habits and metrics of the user's current progress. While Donny's conversational component is not on par with the natural speech of a human trainer, simple question-answer format dialog about the experience with the workouts and the goals achieved is effective enough to keep users engaged. Additionally, Donny includes a system of physical and vocal gestures that simulate the positive and negative reinforcement that human trainers perform towards the exercising behavior of the trainee, this in order to give users the feeling that they are always accompanied and supervised.

Figure 31. Reminders. Thanks to the dedicated application that can be installed on smartphones, Donny can show reminders and notifications to the user even they're not at home.

Figure 32. At the beginning and end of each training session Donny asks a series of questions to collect information for the tailoring of the training program, as well as to make the user feel that the system cares about them in the same way that a human coach would.

Figure 33. Donny performs physical and vocal gestures that mimic the positive and negative reinforcement that personal trainers perform when conducting a routine to make the user feel that there's an actual trainer in the room with them.

Customization

Changes in perceptual, cognitive and psychomotor skills occur with increasing age, and while some of these skills may be impaired at a certain age, others may remain sharp, which is the reason why individual capabilities vary much more among older people (Blendinger, 2015). To compensate for these impairments, Donny allows a number of factors including font size, combination of audio, tactile and visual feedback, background contrast, among others, to be customized to individual needs and preferences to keep the interaction smooth. When configuring the device for the first time, Donny asks the user a series of questions to understand the degree of their abilities and propose a customized interface according to what they answer. Then, once the device is configured, the customization options will always be accessible from the main menu.

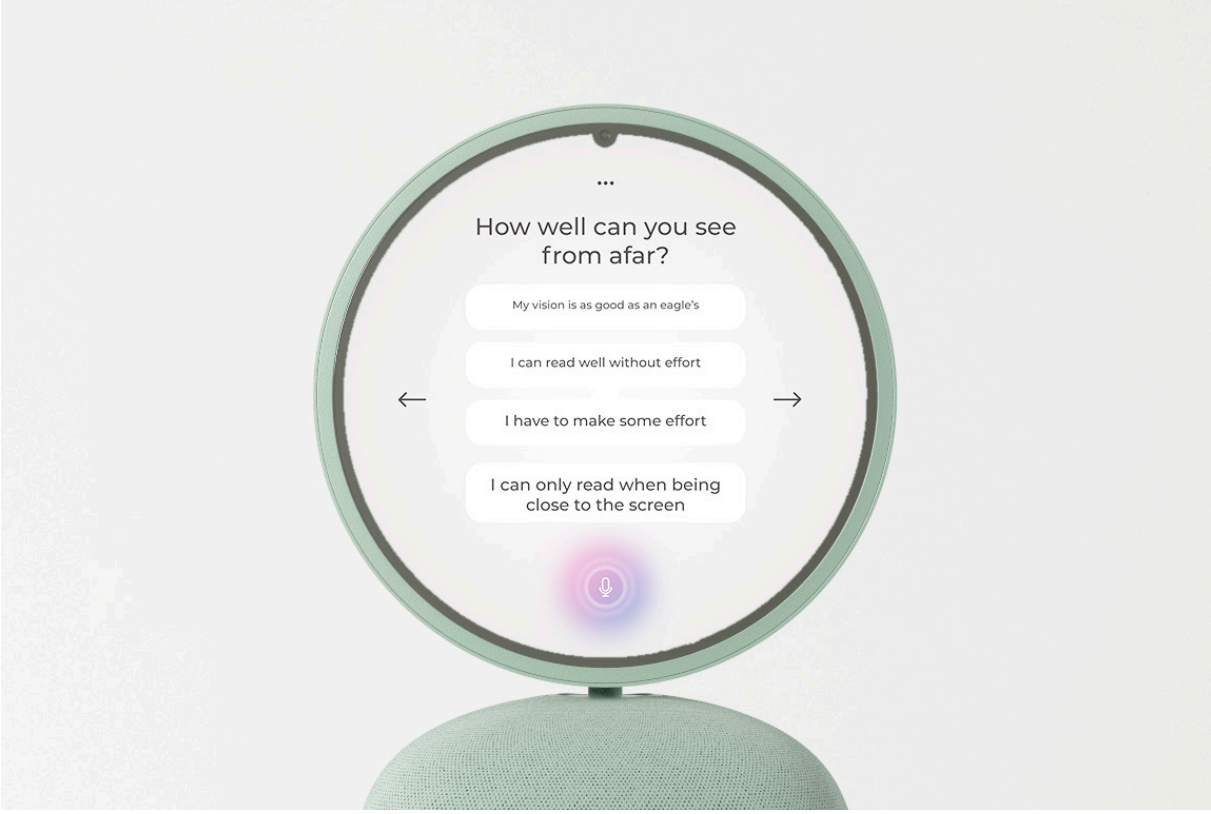

Figure 34. The initial customization questionnaire can be answered with both the touch screen and voice commands.

7.4.2. User Interface

As mentioned in chapters 5 and 6, older adults have a greater probability of presenting impairments at the perceptual and motor level, which is why it is necessary to design an interface that is simple to use, safe, easy to navigate, with support for the user and with clarity of all its functions and instructions, in combination with an appropriate screen size that facilitates interaction with all elements of the interface.

Generally speaking, for the design of the interface, it has been chosen to have the maximum possible simplicity, with backgrounds in very subtle color gradients and with space that allows the correct distance and differentiation between the elements, titles and static texts with sans serif fonts and high contrast, large buttons and clear, simple icons. In order not to sacrifice screen space of the smart device, extended descriptions of the functions of some elements (whether in the form of text, video or a combination of both) are projected on the TV screen.

Figure 35. Donny's TV and smart device UI design is kept minimalist to not overwhelm the user. During lessons only essential exercise stats are displayed.

Figure 36. Donny's UI design is responsive in order to provide a good experience in the navigation regardless of the aspect ratio of the screen to which the device is connected.

The functions, buttons and number of actions have been kept to a minimum so as not to overwhelm the user, so the menu and other sections of the app show only the essential elements. Similarly, the progress stats and other relevant information in the user's profile have been summarized in graphics, labels, and icons to keep the information display understandable and simple. In cases where there are multiple options as in the libraries of live and on-demand classes, categories and filters are used to facilitate the user's search.

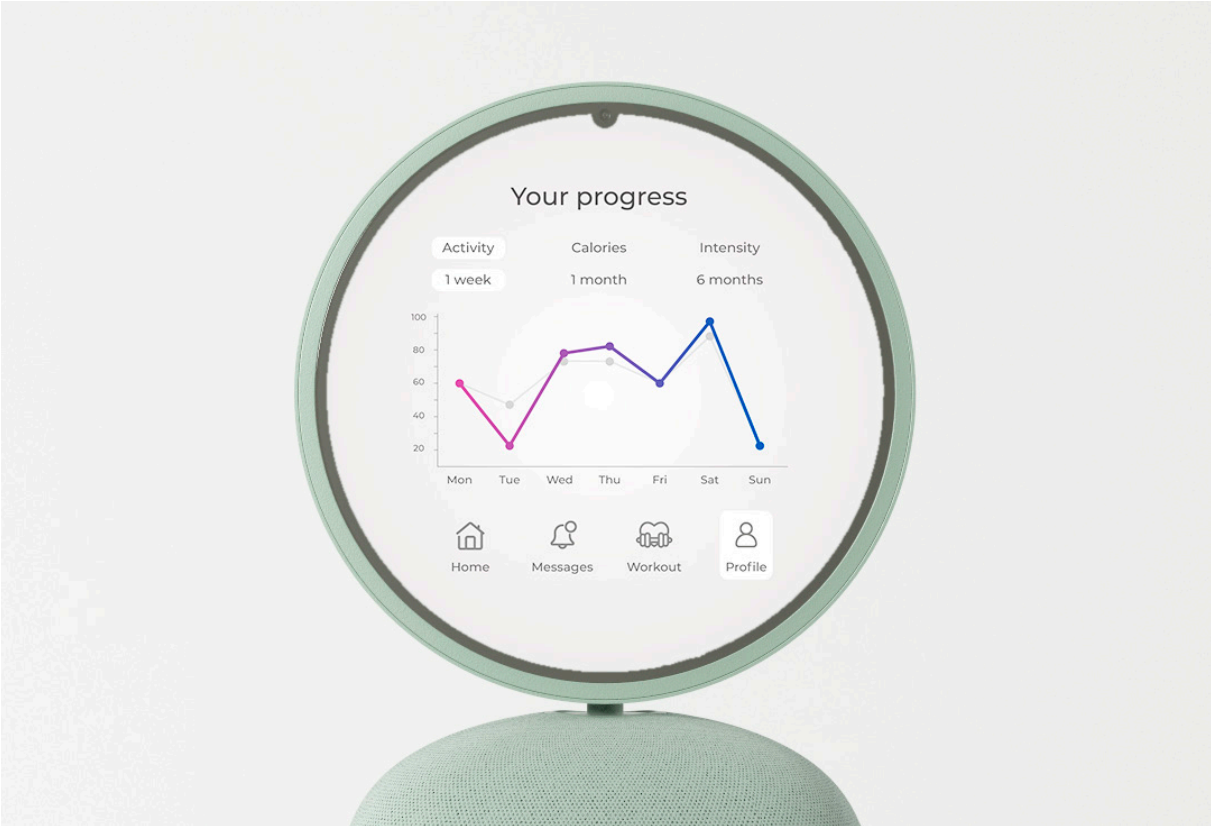

Figure 37. Metrics are kept as simple as possible. Expanded metrics can be accessed by the trainers to help them in the tailoring process of workout programs. The user stats can also be seen through the smartphone app.

During training, recordings of classes or videos of exercises from the user's current training session are projected on the TV screen. Only essential exercise stats are displayed in the corners and occasional messages on the screen appear in cases where form correction is active. The screen of the device, meanwhile, remains active in case the user wishes to pause the training or return to the other options of the app. After training is complete, simplified, understandable metrics of the workout performance data is provided.

Lastly, vocal support is always available to allow the user to control the app's options as well as to provide additional feedback on short instructions, alarms, error or motivational messages.

7.5. System Definition

Donny is an ecosystem in which users, internal stakeholders and external stakeholders are involved in the operation, delivery, innovation and expansion of the product-service. To clarify how the different components and roles are connected to each other, a system map was created. Figure 39 shows the basic structure of the product-service model.

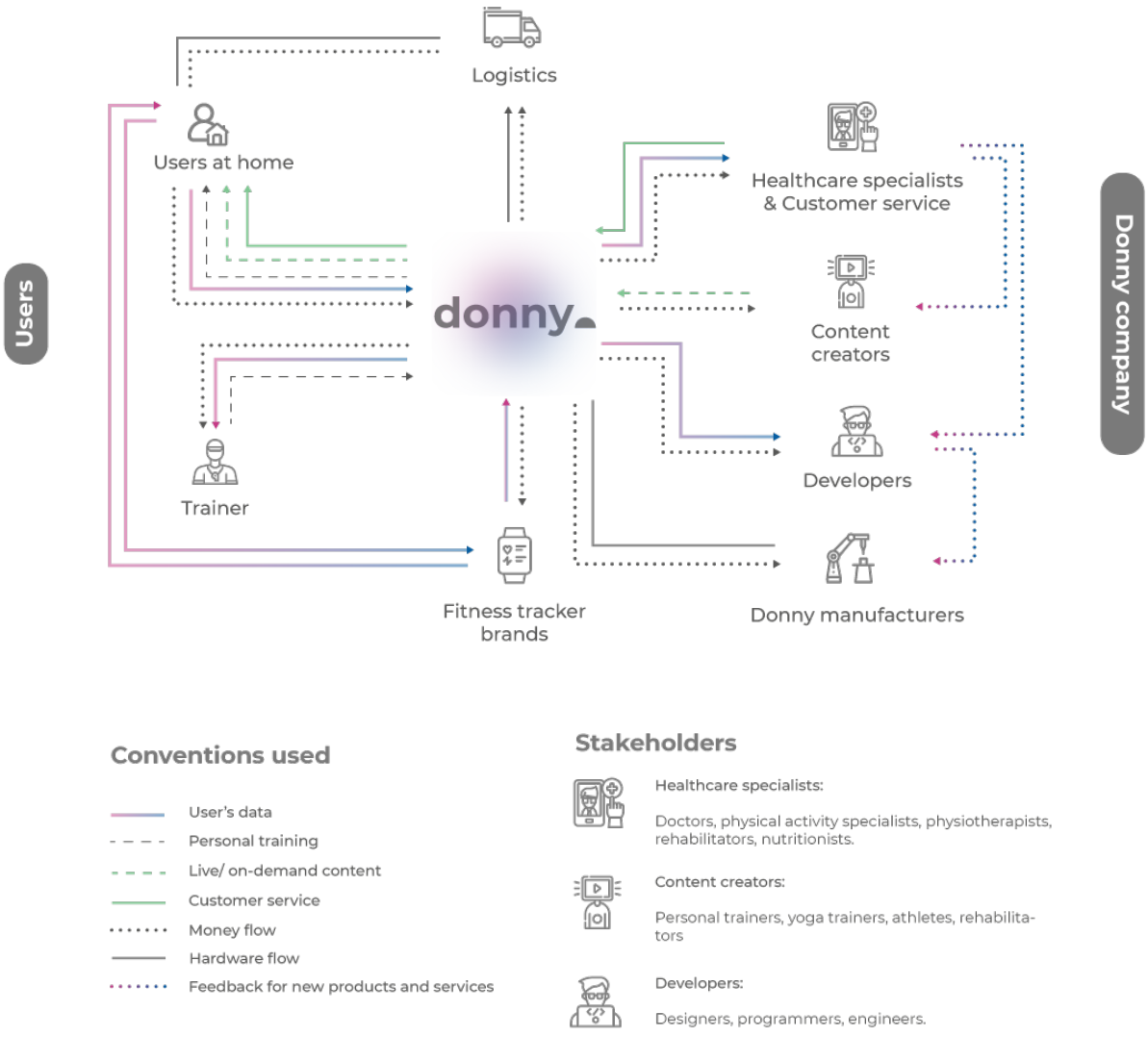

Figure 38. Donny System Map

On the left are the interactions between users and the Donny ecosystem, which begin with the acquisition of the smart device and other complementary products directly from the company, and delivered to the user through logistics companies. The hardware flow, not only represents the acquisition of the products for the first time, but also the ordering and supply of additional components like spare sets of resistance bands, weight plates, or spare parts of the workout station. As mentioned above, Dawn is not intended as a one-time, contained product, but as a base solution that expands according to the preferences or physical progress of the user. To compensate for the products provided, the user can pay the full price when ordering, or alternatively, as part of the monthly or annual subscription plan to the platform.

The system is very flexible in the sense that apart from the smart device, it is not necessary to own all the other components of the system to have a good training experience. The programs, as well as the interaction itself, are designed thinking about the possible scenarios in which users already have other equipment such as weights, yoga mats, or trackers, for training at home. In these cases, these teams do not compete with Donny's functions, but on the contrary, they can be integrated to complement the training sessions.

Although part of the company's profits is due to the sale of hardware, the real impact comes from the provision of digital services that is given through the smart device, such as live and on-demand classes and customized training sessions, which the company constantly develops and renews taking into account the data collected when users engage with the platform. The development of these digital services comes largely thanks to the collaboration of the company with content generators such as professional trainers and athletes, and health specialists. Similarly, the company makes use of the occasional feedback provided by users about their experience training at home to continue developing products that expand the catalog of the ecosystem. In this process, the contribution of developers such as designers, engineers and programmers, among others, is key.

Other stakeholders involved in providing services for primary users are the secondary users, that is, physical activity specialists in charge of personal training sessions, who use the platform to monitor and guide primary users, as well as to tailor the training programs making use of the information collected by the smart device and other fitness tracker devices from external brands that are connected to the system.

Additionally, Donny allows the creation of an online community through the use of the smart device and the mobile app, which connects different users of the system with each other and with the company to provide and exchange information about exercise and other user interests. Thanks to the presence of the community, the company obtains enough information to continue improving its services and users remain motivated with the social mechanics.

8. Conclusions

Healthy ageing is about creating opportunities and environments where people can develop and maintain the functional ability that enables wellbeing in older age. Although physical activity is one of the best ways to achieve healthy aging, many older adults face barriers that make it difficult to access facilities or programs that allow them to meet their needs and goals. Thus, this master's thesis focused on the comprehension of these barriers, the creation of guidelines for the implementation of solutions that potentially facilitate the access of older adults to physical activity, and the design of an exemplary product-service concept that encourages the participation of older adults in physical activity in a home-context.

To arrive to the final concept, this thesis briefly summarized fundamental issues like the characteristics of aging, general access and usability aspects, and benefits of integrating technology and decentralized solutions with focus on older people. Within this document a set of guidelines were created as a by-product derived from literature review, benchmarking of current solutions in the market, and the analysis of trending scenarios connected to the concept healthy ageing. These guidelines cover three aspects that serve as the basis for the main research findings: older adults' functional capacity, the external factors that impact the access to physical activity programs, and the motivational strategies that can maintain adherence to this programs.

Regarding older adults' functional capacity, it was evidenced that older adults are a heterogeneous population that has a wide range of variation in their motor, sensory-perceptual, and cognitive abilities. This means that solutions aimed at this group must be flexible enough and offer as much support as possible to facilitate their usability regardless of the impairments that each user may have. In these cases, the integration of technology in products, especially the use of AIs and sensors, can reduce the physical and mental burden of the user and facilitate interaction.

Other external factors can also affect the access and integration of older adults to fitness products and services. On the one hand, similar to what happens at the intrapersonal level, designing workout programs is often challenging as trying to group this disparate population to follow a similar program or use standardized products is not effective and can actually represent a risk to health. Personal training and tailoring of programs facilitate meeting the needs, preferences, and goals of the users, especially when the implemented system offers support for the fulfillment of the coach's tasks. On the other hand, the space itself can represent a barrier to access, since many of the facilities traditionally designated for physical activity fail to adapt to the needs of older populations, either due to the equipment used, the service provided or even its geographical location. Implementing solutions in alternative contexts such as the home, not only increases access and participation in physical activity, but also the adaptability for a wide body of older adults.

It should be noted that even when the solutions offer good usability, and are accessible to older adults, adherence to the training program can still be a challenge. To achieve long-term engagement and adherence, the implementation of persuasion strategies to boost user motivation is key. Although the

learning from the literature highlights that social persuasion strategies are more appealing for the elderly, individual persuasion strategies are still effective, can be implemented in conjunction with social strategies, and are easy to execute when supported by sensor technology and artificial intelligence.

As can be seen in the three aspects mentioned above, the technology has great application potential in supporting physical activity at home. Whether thanks to the ease it offers to monitor activity, to access personalized programs, or to connect with other people, technology should always be considered when developing solutions for the elderly. In particular, the implementation of persuasive technologies can facilitate the stimulation of behavior change towards the creation of physical activity habits. At the same time, technology also represents new opportunities in the creation of products-services in the context of fitness. Especially in a population that has historically been relegated to the background by the industry, such as the elderly, technology is a tool that can be used to create solutions tailored to the specific needs of each of the people who make up this age group.

Lastly, due to limitations of time and resources, some aspects of this project were not properly expanded, so the final product remains as a concept. For future applications, further studies are needed in the analysis of data from a larger sample of interviewed potential users, as well as prototyping and testing the solution proposed to validate the guidelines.

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Annexes

ANNEX A: Descriptions of benchmarking products

Connected equipment

JaxJox Interactive Studio

JaxJox is a company that creates compact, smart workout products that are powered by AI. The brand is dedicated to making it easy for its consumers to reach their fitness goals without leaving their homes. The InteractiveStudio combines smart adjustable equipment with an AI-powered performance tracking to deliver an experience of a complete home gym system that allows cardio, weight training and recovery exercises, with the equivalent of a personal trainer.

The studio comes equipped with a 43" touchscreen monitor, that works as the control module for the entire system. The screen doubles as a stand for an adjustable kettlebell (12 lbs.- 42 lbs.), adjustable dumbbells (8 lbs.- 50 lbs.), a vibrating foam roller with 5 levels of intensity, a digital push up board, and a water bottle. The whole system size is about 7' tall, 3' wide, and 2' deep, and it doesn't require additional actions like drilling for its installation. Additionally, the system includes a soundbar that connects with Spotify and Apple Music.

The use of an AI for performance tracking in pair with a mobile app, allows for the automatic tracking of repetitions, sets, weight, and average power output. This AI also assigns the users a Fitness IQ to help them see how much they improve using the InteractiveStudio, and as long as the user keeps using the mobile app, they can keep track of the exercises performed even when not in front of the station, or when taking one of its components (the Kettlebell for example) and heading outdoors.

JaxJox has a subscription-based model that helps get the most out of its hardware. At $39/month, up to 6 members of the same household can access to daily live and on-demand classes that combine strength, cardio and recovery, workout programs, interactive personal training with JaxJox coaches, friendly competition with live class leaderboards.

Tonal Home Gym

Similar to smart home fitness competitors like Mirror, Tonal is a large, rectangular, wall-mounted device with two adjustable arms with cable handles on either side that allow for more than 170 movements. The grips can be swapped out for either two handles, a bar, or a rope. The starter set also comes with a floor mat and a bench. The design is more compact than most traditional cable machines. The center

features a 24” touchscreen that works as the control module and show feedback of the performance of the routines, and 17 different sensors that keep track of the workouts in real-time and uses AI to watch and correct the postures.

Tonal’s digital weight system uses electromagnetic energy to deliver up to 100 lbs. on each arm. Since this system doesn’t require physical weights or dumbbells, it allows for changes of resistance throughout the range of motion of each exercise. When the user first set up Tonal, it will measure the weight the person can handle and based on the speed and force, the system will auto-adjust the resistance, recommend weights for each program, give adjustments as the routine progresses and deliver automatic workout tracking and reporting.

This system focus mainly on resistance and balance training, rather than cardiovascular workouts, and improves the experience with an “spotter mode” that adjusts weight resistance in a way that mimics when someone spots the user in real life. Tonal connects with personal trainers for live and on-demand classes, provides virtual group workouts with other Tonal users at the same time, and includes a “partner classes” mode that allow for two people to take on a class together, alternating sets.

Tempo

Tempo is a smart home gym built around resistance training that goes back to basics in terms of weight lifting, but keeps it smart with interactivity and intelligence. The center features a 42” screen with 3D motion sensors to track the form. The Tempo comes included with barbell, dumbbells, and plates, to adjust manually the resistance and difficulty. The Plus and Pro versions also include a folding squat rack and bench, a kettlebell system and heavier weight storage, that allow for more versatility and difficulty with the exercises.

Like JaxJox, Tempo doesn’t need to be mounted on the wall. It’s more like a piece of furniture, whose basic version is about 6’ high, 2’2” wide and 1’4” deep. To use the system, at least a 6” perimeter is required. Below and on the back of the screen there are storage compartments for the weights and the other equipment. During 2020, the company has kept designing several other accessories that can be purchased individually to complete the gym at home.

Regarding the AI support, the 3D motion sensors help count the reps and let the user know if they need to improve their form. Also, this technology lets live instructors watch the form of the users through a skeleton-like avatar and allows them to give tips in real time. The system also comes with a heart rate monitor that gives another piece of data to track the progress, hit milestones and achieve fitness goals.

Tempo has a monthly $39 subscription that allows access to a library of live and on-demand workout classes. It has HIIT, cardio, bootcamp style workouts, yoga, and strength training among others. Up to six members of the same household can have their own membership. In addition, Tempo adds friendly competition through the community of members and a live leaderboard to give extra motivations to the user.

Peloton

Peloton is the most famous example of connected equipment for at-home training. The company reported revenue of $758 million in 2020, a 232% increase compared to 2019. The bikes, their main products, are built around cardiovascular performance, and use magnetic resistance to power the flywheel. The original bike features mechanical resistance adjustment while the Bike+ uses a digital adjustment system that includes “Auto Follow” technology where the instructor can adjust the bike as the user rides. It also features a 21,5” or 23,8” touchscreen right in front of the bike. Although it doesn’t fold up or disassemble, it’s on wheels so it can be moved around the house easily.

The bikes track resistance, cadence and output and show real-time data on the screen. The Bike+ can also be paired with an Apple Watch to keep track of the heart rate. Unlike other connected equipment, Peloton doesn’t include AI support. Instead, instructors can access the metrics to give live-feedback of the workout session.

Peloton’s approach to workouts is the reason why they’ve become a cultural phenomenon. The main concept of the product is give the most realistic in-studio cycling experience and bring it to the homes. With the Peloton App, the user can access to a full lineup of live and on-demand classes. When riding in a live workout, the user rides with many other Peloton users at the same time. There’s also an interactive leaderboard to incite competition, but it also allows to build a community and cheer others on with “high-fives” and live chats.

Peloton not only includes cycling workouts in their app. Although they don’t include other equipment like free weights or elastic bands, they encourage the user to expand the routines with different body weight trainings to get a well-rounded experience.

Mirror

The mirror home gym is the most discrete of home gym equipment on the market. Instead of looking like a piece of exercise equipment, it looks like a sleek, full-size mirror when not in use. Unlike other connected equipment, Mirror features nothing other than the mirror itself. Since it doesn’t come with any physical weights or cable mechanism, it is a far more cardio-based device.

The entire Mirror is a touchless screen, and to control it, a dedicated mobile app is required. With the screen, the user can follow workout routines and get real-time feedback and personal shout-outs to stay motivated. Although it doesn’t have any AI tech in it, nor sensors that track the performance of the physical activity, it supports synchronization via Bluetooth to Apple Watch or other trackers to measure heart rate. The app algorithm track the results and builds personalized programs.

Mirror's monthly subscription grants access to the largest collection of both on-demand and live classes, as well as personal training sessions with an expert. The subscription allows up to 6 user profiles, and its size allows for several people of the same household to follow the workouts. In addition, an extensive music selection that synchronizes with the pace of the training, gives an additional boost to the experience to keep the user engaged.

Wearables and trackers

Apple (smartwatch)

The first Apple Watch was released in 2015 and quickly became the best-selling wearable device. As of December 2020, more than 100 million people were estimated to use an Apple Watch. The original goal of the device was to complement the iPhone and add new functions to assist people when not using their phones. Since then, it's seen a course correction from a focus of apps for the device, to focusing primarily on health.

All of last Apple's smartwatches have built-in GPS, optical heart rate sensor, speaker, microphone, gyroscope, accelerometer, and ambient light sensor. The Series 6 also adds a blood oxygen sensor and an electrical heart rate sensor for ECG. These versions can monitor heart rate, steps, calories burned, workouts and sleep.

For personal activity tracking, the Apple Watch has the Fitness app which encourage their users to complete move, stand and exercise goals by gamifying activities every day in the shape of rings. At key moments, the activity rings will pop-up in the screen, and once the rings are closed, the smartwatch will show animations to celebrate the effort. Paying the membership to Fitness+, members have access to a growing library of workout classes like strength, core, yoga, HIIT, among others that can be watched from other apple devices. In addition, for certain cardio workouts, a Burn Bar is displayed for an added push, showing how the users stack up against everyone in that particular workout.

Whoop

Whoop 3.0 is a sleek and compact strap that is typically worn on the wrist, but can also work on other parts of the body. It doesn't have a display or buttons, and the only way to interact with the device is to double-tap to see the remaining battery life via three tiny LEDs on the side. While the device itself looks really simple, it packs several sensors that measure heart rate, heart rate variability, electro-dermal activity, ambient temperature and 3D acceleration at a speed of 100 times per second. By collecting a great amount of data, Whoop detects how the body responds to exercise, rest and other stimuli throughout the day.

Whoop comes with a companion mobile app with an algorithm that detects the strain caused by different activities and gives feedback in the shapes of tips and indicators to relax or switch up the routine when

stress is adding strain. It also tracks the sleep quality, and learns the sleep patterns, giving heads ups about when the user should go to bed. Finally, it makes a comparison between the strain and sleep gathered data to analyze the body's recovery rate and help the users adjust their habits and daily patterns.

While the strap itself is free, a membership is required to see the benefits. In addition to the analytics, that work as an AI health coach, the membership grants access to different communities based on similar interests, goals, and lifestyles. Like many smart devices supported by apps, this system also includes a daily leaderboard, where Whoop members can do friendly competition.

Oura

Oura is a smart ring that uses sensor technology and a minimal design with a mobile app to deliver precise, personalized health insights. It's one of the smallest wearables in the market with a 7,9 mm width and 2,5 mm thickness, and a weight of 4 to 6 grams which makes it lighter than a conventional ring. The device technology includes NTC (negative thermal coefficient) body temperature sensors, infrared LED sensors and an accelerometer, that allows to measure calories, steps, inactive times, naps, heart rate variability, respiratory rate, body temperature, and quality of sleep.

With this technology, the device gathers data throughout day and night, and then compiles it into three scores, similar to how Whoop does. The Readiness score provides an overall measure of the body's recovery by analyzing daily habits and body's signals. The sleep category evaluates the sleep quality and tracks insights about REM, deep and light sleep. Lastly, the Activity score looks at daily activity and movements to determine levels of physical activity. All of this information is not directly accessible from the ring, but requires a AI supported mobile app instead. Oura's monitoring functions require some time to be actually accurate, given that its AI needs to learn first the daily habits and general activity levels of its user.

Fitbit

Fitbit's approach in the wearables market is more diverse. They offer a large variety of devices that seem to appeal to the broader market. While every device includes an interface, some are larger and more equipped, like their smart watches, Versa and Sense, while others are simpler trackers. Charge 4 and Inspire 2, are the most similar to Whoop and Apple Watch, and in addition to the expected sensors, they also feature a built-in GPS, Tap-to-pay, and Spotify connectivity.

Fitbit devices track heart rate variability, all day activity tracking like calories burn, steps, floors climbed,

sleep quality, and real-time pace and distance. It also features Next, an AI standard on all Fitbit devices that offers over 20 modes of workouts (e.g. running, swimming, biking), and shows all the data gathered on the screen without the need of a phone.

Fitbit's membership grants access to guided programs, like special classes and community challenges, all with the assistance of the dedicated app. Similar to Whoop, it gives personalized health recommendations. Fitbit also offers premium health coaching memberships, with personal action plans and a fitness to-do list for the week.

Nadi X Yoga Pants

Nadi X are a pair of biometric, flat seamed, four-way stretch fabric, washable leggings that vibrate to correct user's yoga positions. This technical apparel with embedded sensors brings home the corrective touch of an instructor without the physical contact of the ongoing class fee. Nadi X also includes a "Pulse" rechargeable module and an USB charging cable.

It uses haptic multi-node sensors sewn into the nylon layers in the hip, knee, and ankle to track the position of the body. To get started the leggings need to be connected to the dedicated app on the phone through Bluetooth, and by attaching the Pulse into the pants, the user is able to set the vibrations strength. The wearer can select multiple poses and the app provides visual and audio cues that break down the poses setp-by-step with corresponding vibrations coming from the leggings.

The membership includes a progress tracking function, that tracks how much time the user spends practicing yoga and how many classes has completed, personalized recommendations, classes from personal trainers with real-time haptic feedback, and a feature to share your stats and or progress with friends and teachers.

Fitness apps

NEOU fitness (app)

NEOU (Neo You) is a fitness platform that features live and on-demand classes that can be streamed from any device. The company market their platform as a way for other brands and trainers to be able to scale their reach to a wider audience. They host renowned fitness experts and workout concepts from all around the world and make it available online, like HIIT, Yoga and meditation, dance, strength, stretching and recovery, endurance, pilates, among others.

To start using the app, the user fills a questionnaire to help the app personalize the experience and recommend classes based on age, training style and goals. After that the user gets access to a giant

library of options that don't need to be taken in any kind of sequential order or as a part of a specific program, although they have those options too. Some of the features of the app include workouts and guided programming for all fitness levels, a progress tracking and achievement recognition, reminders to help the user stay on track, and filters to find the most adequate routines

Peloton Lanebreak

Lanebreak is a rhythm-based exergame on Bike and Bike+ that incorporates music as part of the training. The users are challenged to match and sustain the cadence or resistance according to the cues on the screen to get the highest score possible, which they can later compare with other members.

Although the app is not yet available, Peloton has been testing several iterations with members in guided sessions. In the experiments they play with motivation mechanics that range from social cooperation to pure play. The core of the app is using the beat of music to connect all the experience like obstacles, difficulty levels, workout types and lengths, among others.

Freeletics

Freeletics is a fitness app that uses bodyweight as the foundation of their programs, but also offer complete training programs that require equipment. The system combines HIIT with HIT (high-intensity training) to create personalized programming to help the users reach their fitness goals. Over the years, the app and programming have evolved becoming a solution for anyone who is looking to achieve changes in their overall wellbeing. With the use of AI-powered coaching, the app also includes nutrition coaching, audio courses and additional educational and motivational content to create a well-rounded, holistic wellness plan.

To get started with the app the user is asked to fill a questionnaire and create a profile. With the free version of the app, the user has access to hundreds of workout variations that cover all areas of the body and has the option to customize the experience by choosing between standard, endurance or strength option, depending on the goal. They also offer mindset coaching, single exercises, warmups, cooldowns and running workouts. The paid version of the app features an AI-powered coach that is able to make adjustments and recommendations based on the feedback and progress of the user

Silver Sneakers

Silversneakers is a fitness program designed for the elderly that involves more than 17,000 facilities around the world, as well as live and on-demand classes through a dedicated app. All classes accessible in the app are specifically designed for seniors and are led by supportive instructors. This program was created as part of the Medicare insurance programs and is only accessible by those with any of the participating health plans.

Like many other fitness apps, it includes filter functions, difficulty selection, and type of exercises. But in addition to these functions, the application includes an option of assistance through phone calls, and a

calendar system to sign up for classes with other members of the program, and attend classes either at home, in a nearby community center, or in one of the gym facilities available.

Mighty Health

Mighty health is a fitness program focused on three things: live coaching, content focused on nutrition, regular checkups and preventative workouts, and a motivational system based on achievements. The app is designed taking inclusivity into consideration to guarantee optimum functionality. Regarding the workout program, every day the user logs in and gets three to five tasks to complete during the day, distributed among exercise and nutrition. The workouts are pre-recorded videos with specialized trainers. Most of the coaching is done through text message to facilitate the interaction with the general system.

ANNEX B: Interviews to potential users

Annex B1

Section 1: Introduction

Ask participants to introduce themselves: name/occupation (if working) / who they live with

Rola Schiaparelli / woman / 72 / Retired / lives with daughter and granddaughter

Section 2: Challenging products

- Please mention a product from your home that you use often (it can be any type of object)
    - **Coffee machine: moka, filter, nespresso**
- What is it about the product that you find difficult to use, and why?
    - **Not hard to use, the product is very intuitive**
- Are there types of products you find more difficult/frustrating to use than others? Why is it that you find them particularly difficult?
    - **Technologic products are very hard to use, sometimes I get lost on the mobile searching for something on the internet. Especially after the pandemic with all the QR things and scans.**
- How much of an impact does this have on you daily life? How does this affect your happiness/ health/independence?
    - **Sometimes I rather don't go out because I prefer not to use those QR codes.**
- Are there any other specific aspects or features of products that you find difficult? Why is it that you find them particularly difficult?
    - **Touchscreens are hard, products don't have buttons anymore, so navigation has become harder**
- Are there ways to get around these challenges?
    - Moderator to probe on self-implemented adaptations or changes to the product, replacements, etc., whether they need to rely on other people to help them, whether they have had to replace any products or stop using any products.
    - **Yes, I prefer to use old technology, some products are very nice though, they have nice screens that narrate the step by step.**
- What changes do you think could be made to improve the usability of products in the home?
    - **Consider the generation you are talking too, not everyone adapts to the digital ear. However, the AI Technology are great, because these devices help me understand what's going on.**

Section 3: Technologies

- Think about digital technologies that you use in your daily life. What are some of the technologies you are using?
    - **I use the Smart TV, Mobile, Tablet.**
- Do you a recall a particular moment when you felt that using technology has made your life easier? Can you talk about that moment?
    - **Yes, with Alexa… I don't have to think what to press, I just request things to be search for, the machine would know where to go.**
- Is the way you think about using technology different than how other people in your family/social circle might think about it?
    - **Yes, my granddaughter uses a lot of things in her phone, I use it only for basic needs… Sometimes I don't even find joy in them like she does.**
- Are there aspects or features of digital products that you find difficult? Why is it that you find them difficult?
    - **Yes, The touchscreens and lack of buttons… I don't like it Besides I don't feel like the products adapt to me, but rather I must adapt to them.**
- Are there features in these digital products that you think make interaction with them easier? Can you mention some of them?
    - **Yes… I told you about the AI and alexa knowing where to go with out me needing to click anything.**
- Are there features in these products that have allowed you to better adjust them to your preferences? Can you mention some of them? Have you found easy the use of these features?
    - **Voice commands**
- How do you feel about the way communication technologies (e.g. computers, cellphones, smart appliances) you use manage the data you provide?
    - **I don't really give away data… I don't feel comfortable, but Alexa is great**
- Are there any digital tools you use daily to track your health and to keep yourself healthy? If the answer is yes, can mention which ones do you use? Why do you use these tools?
    - **No, I go out for a walk in the park**
- What changes do you think could be made to improve the usability of digital technologies?
    - **AI guidance…**

Annex B2

Section 1: Introduction

Ask participants to introduce themselves: name/occupation (if working) / who they live with

Carlo Bottra /man / 65 / Chef / lives with wife

Section 2: Challenging products

- Please mention a product from your home that you use often (it can be any type of object)
    - **Oven and kitchen appliances**
- What is it about the product that you find difficult to use, and why?
    - **Kitchen appliances have to be handled with care or accients can happen**
- Are there types of products you find more difficult/frustrating to use than others? Why is it that you find them particularly difficult?
    - **Ai technologies are difficult… the devices rarely understand my accent.**
- How much of an impact does this have on you daily life? How does this affect your happiness/ health/independence?
    - **I end up doing most of the task manually, like setting the kitchen timers myself, because Chrome Cast doesn't really understand.**
- Are there any other specific aspects or features of products that you find difficult? Why is it that you find them particularly difficult?
    - **Touchscreens can be tricky when your hands are wet… But other than that technology is a friend in the kitchen**
- Are there ways to get around these challenges?
    - Moderator to probe on self-implemented adaptations or changes to the product, replacements, etc., whether they need to rely on other people to help them, whether they have had to replace any products or stop using any products.
    - **Yes, you can always go back to analog, Nothing like a good old pomodoro timer in the kitchen to count down the time of a turkey inside the oven.**
- What changes do you think could be made to improve the usability of products in the home?
    - **Can you make devices waterproof?.**

Section 3: Technologies

- Think about digital technologies that you use in your daily life. What are some of the technologies you are using?
    - **I use the Smart TV, Mobile, Tablet and Chrome cast (when it understand me).**
- Do you a recall a particular moment when you felt that using technology has made your life easier? Can you talk about that moment?

    - **Yes, ovens with digital thermometers included are amazing for making poultry and pies! You never over or under cook something.**
- Is the way you think about using technology different than how other people in your family/social circle might think about it?
    - **Not really, my wife and I we use everything mostly the same way, but chrome cast does recognize her voice better than mine.**
- Are there aspects or features of digital products that you find difficult? Why is it that you find them difficult?
    - **Yes, The touchscreens with wet hands are a pain...**
- Are there features in these digital products that you think make interaction with them easier? Can you mention some of them?
    - **It's nice not need to do something yourself, just saying it outloud**
- Are there features in these products that have allowed you to better adjust them to your preferences? Can you mention some of them? Have you found easy the use of these features?
    - **Voice commands, and presets for the timers I just have to say "turkey inside the oven" and a timer will start that's great!**
- How do you feel about the way communication technologies (e.g. computers, cellphones, smart appliances) you use manage the data you provide?
    - **I'm old, if they wanted my data they will already have it so… what ever**
- Are there any digital tools you use daily to track your health and to keep yourself healthy? If the answer is yes, can mention which ones do you use? Why do you use these tools?
    - **No, I Still work in my restaurant so I have to be on my feet for most of the day, no need to track that activity.**
- What changes do you think could be made to improve the usability of digital technologies?
    - **Water proof!**

ANNEX C: Interview with physical activity specialist

1. Please give a brief introduction about who you are and what you do.

Good morning, my name is Julián Andrés Urrego. I'm a physiotherapist specialized in elderly patients. I have been a professional for 15 years and I work in the area of physical conditioning and rehabilitation.

2. About exercise:

• *What are the requirements of a physical activity program for older adults? What are the differences with youth programs?*

The requirements to do physical training in older adults have to do with age and their medical history, so it is important to carry out an initial evaluation to know the current level of the person's intrinsic capacity and subsequently prescribe the exercise. While young people have more dexterity, agility or strength, older adults already have several underlying conditions that may or may not limit their motor, sensory or cognitive abilities.

• *What barriers and what facilitators do you perceive older adults to have in accessing physical activity?*

The main barriers in older adults are lack of motivation and their general health. Many times these barriers affect synergistically because older adults who have chronic diseases or movement limitations tend to be less motivated to enter a workout program.

Another limitation is the access this group has to fitness centers. Many times the main limitations are the distance they have to travel from their homes to the facilities, and the payment methods, which in many cases correspond to exorbitant annual payments that people have to pay in one or two installments.

Ah! And well, with the current context, COVID-19 is another very powerful barrier because many older adults are afraid of returning to gyms due to the risk of contagion to which they are exposed.

I would say that the main facilitator for an older adult to be able to train is the implementation of a training program tailored according to her abilities. Another facilitator is the pre-existence of an exercise habit. These lifelong exercisers generally have no problem exercising into old age.

• *What can improve adherence to a training program?*

Adherence to a training program depends on the motivation of the person and the support that is given throughout the process. Those people who are constantly monitored, who are motivated to meet a personal goal, and who have a strong social support network, have the highest levels of long-term adherence.

• *What activities, programs, or alternative training modalities (eg, sports, outdoor exercise) to gyms / fitness*

centers do you consider suitable for older adults?

Older adults can be physically active anywhere. It can be in the gym, at home or outdoors, as long as they have constant monitoring of general activity, body positions, rest times, etc.

• *What do you think is lacking in the senior fitness market?*

In the market there is definitely a need for more options for the elderly. One of the main flaws is that the fitness industry continues to think of older adults as completely disabled or disinterested people who do not deserve an investment of time or effort to think of solutions because they do not represent an exploitable market. I think quite the opposite, that these differences in the functional abilities of older adults are all opportunities for the development of new training programs, for example, programs for people with chronic heart conditions or adaptable equipment for people who use technical aids.

3. About training at home:

• *When is a home exercise program prescribed?*

These programs are prescribed when people do not have access to a gym or fitness center either because they do not have the time, it is difficult to get around, or because their homes are too far from these facilities.

• *What is required (equipment, people, processes) to make a home program viable?*

The main requirement for these home programs to be viable is that there are opportunities for progression. That is, that the person has equipment that allows them to increase the load and resistance as the body gets used to the effort, like resistance bands, dumbbells, barbells, kettlebells, etc. One common mistake is that most of the exercise equipment you find at home is focused on cardio.

Also, they need enough free space to perform all the exercises included in the routines. I've seen some cases during online lessons where the trainees hit themselves against furniture they have left to close to the training space.

• *What do you think about personalized training?*

That it is very effective in the context of home training. While unsupervised exercise is possible, monitored exercise offers better results and long-term adherence. An additional benefit of having a personal trainer is that it also represents a source of motivation for the trainee.

• *What measures can be taken so that the older adult is able to carry out physical activity independently?*

Having a constant source of motivation. I know that at this point it sounds a bit repetitive, but as long as the person is motivated they will have greater perseverance and discipline to carry out the training program.

• *How can you monitor the progress of a person exercising independently?*

Evaluating all the anthropometric components on a regular basis, every 20 or 30 days, to know the level of progression that the person has had with the training. Typically, the measurement of these components is done by the trainer, but with the proper instructions, the trainee can do it himself.

Additionally, nowadays there is a whole spectrum of products that allow this monitoring automatically and this also saves the trainer time.

• *What do you think can be improved from current home fitness solutions?*

A solution to improve fitness at home is to divide the populations with which the trainer is going to work, instead of leading a class for everyone, because that is where accidents and injuries occur due to not having an individual prescription. These classes would have to be divided into categories, according to the abilities and limitations of each person.

4. About the technology:

• *What technologies do you consider necessary and / or useful in a home training program?*

Well, definitely a technology that can definitely help is that of smartwatches or bands that can monitor vital signs, steps, calories burned, etc. All technologies that allow keeping track of the person's activity are welcome.

A bit obvious, but also a device that allows communication with the coach or following a class is also essential for carrying out a program at home.

• *Is there a process / activity in a regular exercise program that you think can be digitized or can be optimized with technology?*

Yes, I would say that the analysis of the anthropometric data of the trainees is a process that can be optimized. Regularly what is done with the collected data is to put them in Microsoft Excel tables and apply formulas to get relevant information for the tailoring of the programs, and it works well; the problem comes when the coach has a large number of people in charge, and in those cases the whole process of digitizing this data, especially if it is measured in an analog way, becomes very inefficient.

• *What do you think about live or pre-recorded online classes?*

They are good resources when targeting a large group of people. In the case of live classes, you can interact a little more with the users, also have them interact with each other, etc.

• *What do you think about apps that make use of artificial intelligence and algorithms to design training routines for people?*

I have a slightly divided opinion. I think that artificial intelligence and algorithms are very powerful tools to automate processes and improve communication channels between users and the personal trainer, but I would not say that an application that only uses these resources to prescribe training programs is a realistic replacement for a training program led by a human physical activity specialist. The best scenario would be one in which there is an application or a system that takes advantage of the benefits offered by both the personal trainer and technology. While the AI's can be used for user profiling, the trainers can

tailor the exercise programs with the refined gathered data.

• *What do you think about trackers like Fitbit, Apple Watch, etc?*

They are good for people who are dedicated to running or cycling because it gives them very detailed and fast information on distance, intensities, calories, etc. In the case of people who exercise at home, perhaps it is a bit overkill because in reality it is not necessary to measure so many physiological markers. Actually, the most relevant measurable variables of the exercise are the observable ones, such as the number of repetitions or the rhythm with which the person does a certain exercise. In the case of older adults, this action of counting repetitions or series is a challenge because many times they get lost in the count and do not know where they are in the progress of the routine.

• *How can technology help the coach in the prescription, monitoring and progression of a personalized training program?*

Well, there are several things that we have already mentioned. On the one hand, everything that has to do with anthropometric data analysis can be streamlined with technology. The trackers' sensors also provide expanded information that can be beneficial for tailoring programs, as well as to warn when something goes out of the parameters such as a rise in heart rate, or a decrease in general activity.


donny