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Review Article

The Importance of Body and Action in the Design of Technological Devices: For an Embodied Shift as an Alternative Conceptual and Methodological Framework in Gerontechnology

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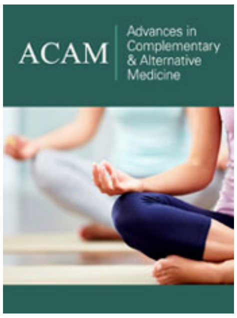

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Abstract

To what extent is the design of technological devices for older adults symptomatic of our way of thinking about human cognitive aging? So far, technology-based solutions for the older adults are employed as reactive rather than preventive interventions and are often focused on impairments and age/dementia-related declines. In more specific terms, technologies are designed as cognitive crutches, rather than extended-mind devices. The aim of the present paper is twofold. First, pointing out researchers' responsibility in the spreading of conceptual frameworks that drive the development (and failure) of technological tools for older adults. Second, proposing an alternative perspective about cognitive aging across the embodied shift. The embodied cognition paradigm provides both on descriptive and explicative view about how individuals engage their environment. Indeed, the methodological benefits of such a perspective stem from a better understanding about how the cognition emerges from the interaction between the bodily abilities and available resources in the current environment. It is argued here that the embodied cognition paradigm is a relevant theoretical framework for the gerontechnological domain.

Keywords: Aging and alzheimer's disease; Cognitive aging; Embodied cognition; Gerontechnology; Researchers' responsibility

Introduction

Aging is a complex and progressive process that affects parts of cognitive functions, and in which everyone will experiment some physical, psychological and social evolution. Beyond an important heterogeneity of the age-related effects, the advancing in age can be marked by spatio-temporal disorientation associated to severe perceptual, sensorimotor and cognitive impairments, which seriously compromise the older adults' autonomy. Typically, these troubles are symptomatic of dementia. One of the most represented types of dementia worldwide is the Alzheimer Disease (AD). According to the World Health Organisation (WHO), it is estimated that amongst the 50 million patients suffering from dementia, two thirds of them have the AD [1]. These figures are ineluctably doomed to grow [2]. For instance, in 2020, one in four French people more than 65 years old will be affected by the AD [3]. In the absence of curative or preventive treatments, the progression of symptoms related to patients leads to an increase of the older adults' dependence to their environment. In this context, a growing body of research in gerontechnology literature pointed out that Technology could potentially play an important role in maintaining a certain level of autonomy in older adults, while offering a safe environment and opportunities for social connectedness [4-6]. In particular, technological devices aim to provide tools that improve the cognitive efficiency and thus the quality of life of older adults across monitoring and managing of symptoms of the AD in daily activities [4,7,8]. Beyond these pious wishes and in spite of their potential benefits, it appears that technologies tend to be hardly or not at all, used [9-11].

The issue of the use and appropriation of technology during aging has received a considerable interest (for reviews, see e.g., [11-13]. A thorough focus has been made on the age-related changes, perceived cost to use, and cognitive factors as determinants patterns of technologies use and acceptance (for models of acceptance and use see e.g., [14-16]. Furthermore, the major identified barriers concerned the relationship to the perceived cost-effectiveness and age/dementia-related incidences on the sensorimotor and cognitive functions. Both factors were accounted as challenging the amplitude to which older adults' resources are allocated to learning new technology [17-22]. Beyond the important issue of technological use in older adults, such barriers raise a less explored critical question: To what extent is the design of technological devices, for older adults with AD, symptomatic of our way of thinking about human cognitive aging? Despite accumulating evidence about the effect of age on cognitive functions, a general understanding of how cognitive disturbances might arise in aging remains controversial. This controversy appears because scientific contributions to understanding aging has focused either on methodological issues, or on theoretical ones [19,23-27]. There is little consensus about questions that should be addressed in order to develop a psychological theory of aging. In this sense, the aim of the present paper is to question researchers' responsibility on the current technological trajectory and how it is shaped throughout the conceptualisation of aging and human cognition. Crucially, we point out researchers' responsibility in the spreading of theories and models that drive the development of technologies, and articulation of stakeholders in the designing.

Based on the embodied shift that is relatively recent in the cognitive and social sciences, we will highlight the conceptual and methodological consequences of the use of embodiment in gerontechnology (in the same vein, see [28]. For nearly twenty years, Varela and colleagues (1991) published a major work about the embodied and situated cognition. The innovative central proposals were that the cognition is embodied because it is deeply dependent of the body that supports it and situated insofar as it emerges from the body's interactions with the current environment. Moreover, the crucial contribution of this major work resides in the highlighting about the fundamental role of the action in the emergence of knowledge. Similarly, to the [29], which suggested that actions and sensorimotor abilities support the cognition, the embodied cognition argues that knowledge are the enacted experiential outcome of our actions in the world. In specific terms, it is our actions and action intentions that, in a given situation, make that a stimulus (or one of these physical components) will be meaning for us. Thus, the cognition is closely linked to our body, which acts and interacts with the objects composing the environment. It is in this sense that the cognition is expressed as embodied and situated [30,31]. Such a paradigmatic change has profoundly challenged our understanding of the human cognitive functioning and, by extension, our way to think cognitive aging. In respect to this perspective, we argue that it implies to review our expectations about the design and end-purpose of technologies for older adults with an AD diagnosis.

Technology as a Cognitive Crutch or Extended-Mind Device?

Consider the development of a technological device whose end-purpose is to allow aging adults with AD conserve a certain level of autonomy in taking their medical treatment, such as a smart pill dispenser. If the end-purpose has been unanimously voted in the pre-designing briefing with stakeholders, a heated debate would arise over how this technological device should promote the older adults' autonomy. The outcome of this debate would then rely on the question addressed by the researchers on aging. Especially, if it is constrained by the scientific paradigm in which are embedded theoretical, methodological, and societal way of understanding and apprehending the phenomenon of aging.

The questions about the "what" and the "where" of aging

How should a technological device promote the aging adult's autonomy? On the one hand, some stakeholders consider that technology must be automatized, focused on deficiences and pathologies. Ideally, it should be designed like a substitute to aging adults' memory. The advancing of dementia-related effects induces progressive and severe declines on perceptual and memory functions [28,32]. Although these declines progress concomitantly [33], it was classically assumed that perception and memory processes are independent, both functionally and structurally [34]. In this respect, it is reasonable to think that designing a technological device as a cognitive crutch of the memory function should allow replacing the impaired function, and thus, restoring the autonomy of aging adults with an AD diagnosis. Their argumentation is based on a traditional structuralist paradigm of the cognitive aging. In this context, scientists attempt to provide answers to the questions of *what* and *where* of the phenomenon of aging decline. Answering the question of *what* is relevant to define the phenomenon to be studied. However, to date, age differences concerned by research literature are usually narrow in scope, and only provide a descriptive taxonomy of age declines without any broad understanding of aging. Answering the question of the *where* intends to localize age-related impact to particular components of a proposed stage model (i.e. encoding, storage, retrieval, episodic or working memory), or particular brain areas that are activated during a particular task (or a small set of tasks). There again, defining different loci affected by age only provide a narrow theory of aging and not a compelling explanation. Most of this field of research relies on computational conceptions of the mind considering cognition as a set of serial components that can be studied in isolation. The questions of *what* and *where* are helpful with regards to the evaluation of cognitive declines by providing a description of the phenomenon of aging. Nonetheless, structuralism raises the idea that aging is inherently a sum of deficits, and thus focuses mainly on the differences in cognitive abilities between the youth and elders. Crucially, structuralism has pointed out the "normative" declines in aging and has participated in the elaboration of palliative rather than preventive devices for the elderly.

The questions about the "why" and the "how" of aging

A second way to address theoretical issues of aging answers is to the questions of the *why* and *how* of the phenomenon of aging. As such, scientists attempt to give a plausible account for a shared age influence on a variety of tasks. They proceed by gathering and integrating prior findings about memory, comprehension or cognitive resources for instance, into a global framework [19,23,25-27]. In this view, research is concerned by the determinants and moderators of aging (and not only by a description of the various and isolated impacts of aging on the cognitive functioning). This second approach addresses the extent to which changes in cognitive processes would not reflect an age-related decline, but rather a necessary cognitive adjustment to new environmental constraints. Such an adaptive hypothesis lies on a dynamic approach of the cognition in which cognitive abilities, environmental features and the way participants cope with their environment are taken into account.

In that context, stakeholders would argue that delegating the medical treatment to an automatized technological device could increase the aging adults' dependence to their environment. Hence, they would propose that the smart pill dispenser should create situations in which the aging adults' actions will be afforded. These stakeholders claim that it exists a close functional link between perception and memory processes, which is the core idea of the embodied approach to cognitive aging [35]. Furthermore, such a close link is likely to explain why the reported perceptual impairments are typically associated with the cognitive ones, in particular those of the episodic memory [33]. The embodied approach does not deny the effects related to the progression of the AD on perceptual and cognitive systems, respectively. Nonetheless, it argues that the cognitive system conserves the traces of its sensorimotor experiments [36-38]. Conceptualizing cognitive functioning this way implies that new knowledge could continue to emerge across the dynamic interplay between aging adults and their environment. Accordingly, the stakeholders suggest that a technological tool should be conceived as an extended-mind device [39], affording action opportunities to aging adults and promoting their anticipatory ability through environmental cues. Such theoretical debate does not concern only the cognitive and social sciences, it may have important consequences in the emergent field of the gerontechnology [40]. Indeed, the development of technologies for aging adults requires the integration of technical and fundamental knowledge from the technological and psychological domains [9,20,41]. For instance, when it comes to gaining a better understanding of the aging adults' barriers to technology use and adoption, psychologists can propose theoretical approaches of cognitive aging that could help technologists in removing these barriers [42]. Theorists are crucial drivers of conceptual models and empirical research, and theories are reflected in the way technologies support aging adults. To date, technology-based solutions are employed as palliative rather than preventive and integrative interventions, and often focused on impairments and age/dementia-related declines rather than resources [43]. There is a danger that such technological devices increase the disempowerment and dependence of aging adults with an AD diagnosis, insofar as their designing is framed on the theoretical basis that the cognitive system is too severely impaired to be solicited.

We argue that the key issue is not so much about what the aging adults are no longer able to perform, but rather what kinds of interactions with their environment could allow the technological tools. Specifically, it would be interesting to focus about *why* and *how* such devices should afford aging adults' actions, while supporting a new form of cognition (such as distributed cognition), rather than focus about were replacing the cognition. It is quite possible to develop technological devices outside the idea that the structure constraints the cognitive functioning (i.e., the issues about what and were raised by the structuralism). For example, focusing on the *how* [12] report on a study of the use of neurofeedback for well-being in older adults. Participants performed ten minutes of mindfulness exercises each day for six weeks, using a headband to measure brain activity, EEG monitoring and an iPod. Results showed an improvement in attentional reaction time and a reduction in somatic symptoms for the neurofeedback group compared to the control group. This study shows the value of neurofeedback techniques to improve the quality of life of older adults by engaging their cognitive abilities. In this context, the embodied paradigm can provide an alternative conceptual and methodological framework in gerontechnology.

Cognitive Aging and the Embodied Shift

Individuals are embedded in a permanent dynamic interaction with a physical and social environment in perpetual evolution. To navigate in such environment, it is crucial to acquire and develop anticipation and adaptation abilities. Classically, this thesis has been introduced by the bio-cultural lifespan co-constructivism perspective [44], which assumes that aging is dynamic, non-linear, multifunctional, and multi-determined by cultural, ontogenetic and person-related factors [45]. In this view, successful aging relies on a dynamic developmental compromise that maximises resources gains (e.g., knowledge, expertise) and minimises resources losses (e.g., sensory and motor efficiency) throughout aging [46]. Such gain-loss compromise is the core of the Selective Optimization with Compensation model [47] Within the SOC model, it is postulated that aging adults can manage age-related losses by the means of three mechanisms of developmental regulation. First, investing their resources on a set of available behavioral alternatives (i.e., Selection mechanism). Then, optimizing the application and coordination of the invested resources in selected domains to achieve a better functional level (i.e., Optimisation mechanism). Finally, in order to compensate the incidences of the resources losses while maintaining an efficient functioning i.e., Compensation mechanism; for an exhaustive view, see [13].

The emergence of knowledge or resolution of a problem with the advancing in age remains possible only if aging adults conserve the ability to optimize their cognitive functioning to compensate for the losses [16]. Yet, it appears that, with the advancing in age, the losses tend to become more important than gains due to age-related changes on perceptual, sensory, sensorimotor, and cognitive systems increase the cognitive resources demand [48]. Following this, the resources allocated to SOC mechanisms and functional brain efficiency are doomed to decrease [13]. It is precisely at this level that technologies act as a help to enhance the allocation of currently available resources by reducing the resource-demand on the cognitive system [45]. Although the principles conveyed by the SOC model can be applied to other developmental step than aging, this model remains a descriptive view of individuals adaptive mechanisms. Few explanations about the underlying processes were provided. Furthermore, some of the contributions appear to be contradictory. Indeed, it is argued through this latter model that the sensory, sensorimotor and cognitive functions maintain a close connection [49-52] whereas they continue to be considered as qualitatively distinct both functionally and structurally [53]. The bio-cultural lifespan co-constructivism perspective has mainly focused on the reciprocal influence between cerebral structures and cognitive functioning, suggesting therefore the idea that the cognition is constraints by the structural architecture of the brain.

In this respect, embodied approaches investigate the underlying processes rather than structures, and can provide an appropriate contribution in understanding cognitive aging outside of the representationalist and neurocentrist viewpoints. It is crucial to point out here that the embodied paradigm is not advanced to be "better" than the viewpoint supported by the bio-cultural lifespan co-constructivism perspective. Rather, an embodied perspective proposes another view angle by focusing on the core notion of embodiment, and not only on a developmental analysis of the interactive dynamic between the brain, culture, and environment. Furthermore, for two decades, a common definition of the embodiment has emerged in the embodied approaches [30,36,54-58]. Embodiment refers to the radical assumption that the brain is not the seat of the cognitive functioning, but rather a constitutive part of an enactive system [59]. In other words, the cognition is embodied, situated and distributed within a mind-body-environment complex system.

Cognition is embodied

To claim that the cognition is embodied implies to consider that this latter is no longer an instance residing in the brain, situated somewhere between the perception (i.e., input from the environment) and action (i.e., output from the cognitive system). In absolute terms, cognition is the emergent phenomenon of dynamic and adaptive sensorimotor interactions with the world [56]. As a consequence, its functioning is constrained by relatively fluctuating factors such as the ecology, material but also the body morphology, which determine the nature of interactions that individuals are able to engage in the world [36,60]. An embodied view of cognition argues that the action, body and its phenomenology hold a core place into the cognitive functioning [61,62]. Such postulate allows integrating a multitude of bodily factors into cognitive processes, and especially, to conceive those experiences and knowledge of the individuals about the world emerge from sensorimotor coupling of their organism with the world [57]. Hence, this latter theoretical approach rejects the idea that knowledge, and by extension the cognition, are the outcomes of a computational processing across an abstract set of internal representations. Rather, it is advanced that the cognitive system is able to conserve the traces of its sensorimotor interactions with the world. This set of sensorimotor-based traces is then re-enacted (or simulated, in terms of Barsalou) in order to apprehend the present situation in an adaptive way [36]. In other words, the individuals' feelings, emotional states, memories, and what they currently perceiving emerge from sensorimotor re-enactments of past experiences in the present situation. Such ability of the cognitive system highlights a crucial point assumed by the embodied approaches; perception, action, and memory maintain a close functional connection [63] [38,64-67].

Along these lines, we argue that the development and maintaining of cognitive abilities stem from sensorimotor abilities [28] for an early developmental theory that supports this idea [29]. Given the sensory and motor anchoring of the knowledge, alterations of these latter properties, caused for instance by a less good perceptual (e.g., visual and auditory) or motor acuity, should have a direct impact on cognitive performances. Aging and AD present such sensorial alterations concomitant with cognitive functioning changes [33] Vallet et al. 2010, [68]. However, contrary to healthy aging adults, the advancing of impairments related to the AD implies that the disability to discriminate the knowledge, as being previous, tends to be more and more important [32]. Indeed, they present a certain difficulty to simulate an episodic memory, which require the re-enactment of several sensorial modalities with a precise spatial context, and by extension temporal ones [69]. Such impairments highlight the core role of the body in cognitive functioning and maintaining of the adaptive ability. At the same time, recent study showed that compatibility effects, and in particular the action compatibility effect (a phenomenon generated when a sentence describing a movement direction matches with the direction of the movement required to answer the sentence, see Glenberg & Kaschak (2002), may promote faster decision-making and memory performances of the elderly with an AD [70]. This compatibility effect is particularly interesting for devices such as command robots that assist people with reduced mobility. One of the use of these robots is to act as a stretched arm that can hand a glass of water, for example. If the robot hands the glass an elderly person, the reaction of the latter will not be the same depending on whether the robot is stretching his left arm or his right arm. In this context, it is mandatory to investigate the dynamics between the body and technological interfaces during aging. Consider that the body is an intrinsic constituent of the cognitive functioning implies to develop devices respecting the users' sensorimotor preferences. However, these preferences change across lifespan, and cannot be induced from nonspecific population [71].

Cognition is situated

Cognition is "deeply rooted in the body's interactions with the world" [58]; it cannot be apprehended outside from a complex system involving the mind, the body, and the environment in which individuals interact. The sense in which cognition is called situated refers to the idea that actions in the world are constitutive of the perception, and by extension, ground the cognition [62,72,73]. The daily goal-directed individuals' activities are intrinsically situated in the world, co-determined both by the physical and social structures of the current environment, and the bodily limits of the individuals. [74] proposed a concept that captures the dynamic interactive nature of the relationship between the changes within environment, and the emergence and performance of actions, which concept is typically called affordances. An affordance corresponds to action possibilities offered to individuals by the environment with reference to the individuals' action abilities [75]. For instance, a chair may to afford sitting as well as climbing on it, like a stepladder in order to change a bulb. The tool in itself does not hold the function. Rather, the function of a tool affords from the emerging outcome between the individuals' needs/expectations and the action possibilities offered by the environment.

The concept of affordances allows to illustrate that the current perceptive and motor experience relies on sensorimotor contingencies that initiate adapted actions in the world [62,72]. The emergent action guided by affordance is co-determined both by the bodily and environmental constraints, which lead to a more or less important perceived energetic costs [76]. Hence, insofar as the individuals' perception is depending on the biomechanical constraints of their legs functioning [77]. It is likely that the affordance associated to the chair in our precedent example will not be the same for a younger adult than an aging adult. Indeed, aging is marked by a natural muscular atrophy that leads to a reducing of muscular tonus, a global behavioral stiffness and loss in flexibility, as well as an enhancing of difficulties to keep balance [78]. Again, we point out the core importance of the bodily phenomenology across its interactions with objects of the world. Illustrated here by the concept of affordances, there is reason to think that the situated aspect of the cognition implies a certain dependency of the cognitive functioning on the opportunities offered by the environment. It is true that the environment is an integral part of the cognitive system, and strongly affects the emergence of an adequate motor response face to permanent changes in the current situation. However, despite situational constraints that the environment may generate, it may also operates as an abundant source of cognitive resources. Affordances do not limit the nature of the actions that may be performed in such a environment. On the contrary, affordances extend/distribute the individuals' action possibilities. In the present paper, if affordances were described as relative to objects, in such a phenomenon it is not tool-dedicated but may entirely emerge from interactions with other individuals [79,80]. For example, our working team is developing a connected bandage that informs the caregiver about the condition of the wound without having to remove it. Currently, the function of this bandage has been diverted into an indicator of the level of staining of diapers that are used for elderly persons. Similarly, one of our elderly patients used a compact disc tray as a cup holder and that did not seem to bother her. In regard to these examples, we observe that the function of an object emerges from its functioning which is itself a product of a situational affordance. Concretely, whether with a tool or other individuals, the cognitive system builds (and rebuilds) the memories of its interactions based on the sensorimotor contingencies of a body embedded in the environment. Considering cognition as situated is in agreement with the IOS 9241-11 definition of usability of a device as: "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments" (International Organization for Standardization, Geneva, Switzerland). According to this definition, the usability of a product is not a property of the product as such, but only in relation to a specific context of use. Like cognition, product usability is therefore also situated.

Cognition is Distributed

Cognition is not implemented in the brain, but rather "as spreading out of the head and into the changing techno-social world" [81] Such property of the cognitive system typically qualified as distributed [82], extended [83] or projected [31]. The taxonomy is different, but the core idea is the same; that is cognitive resources distributed over the mind, body, and environment are substantial participants in the cognition functioning. Cognitive processes often draw on outsourced resources of the environment, which includes other individuals as well as technological tools. Cognitive system is able to integrate certain constancy or regularity present in the environmental structures, and to exploit them across a continued coupling between perception and action in order to perform adapted and appropriated behaviours. Such embodied ability of the cognitive system can be employed in complementarity with technological tools as well as other individuals [84]. Accordingly, the cognitive activity is distributed across a set of available bodily responses, dynamically re-enacted and afforded by complex interactions between technological, social, and physical factors [81]. For these reasons, one of the crucial issues investigated by the embodied cognition account is the close relationship between the current efficiency of the individuals' cognitive abilities, the kinaesthetic aspect of their behaviours and their episodic memory performance [63].

In this view, individuals' behaviours emerge from interactions with external supports that serve as cognitive resources, and these activities are situated, guided, constrained, and to some extent, determined by some bodily and situational factors. Despite our beliefs that we control most of our behaviors, a distributed conception of cognition proposes that most of our cognitive resources are in the environment. We act unconsciously more often than we think. This is especially true for the prospective memory, which is defined as the ability to remember intended actions in the future. For example, when the sun is setting down, working colleagues are leaving and the strain of the day is being felt, these are indicators that it is almost 5pm and time to pick up the kids from schools. In this case, prospective memory is a process (and not a function) that takes place in the person and his/her situation even though we have the illusion of thinking about it voluntarily. If so, the concept of affordances that was discussed in the precedent section may be considered as an illustration of a distributed functioning across the individuals' bodily and cognitive resources, and those provided by the current environment. The key question is to apprehend and anticipate how the different components of such distributed system (i.e., individual mind and body, other individuals, technologies, tools) coordinate between them, and enabling the cognitive system to make the emergence of an adaptive behaviour [84]. In this respect, to consider that the cognition functioning is distributed across the mind-body-environment system also implies investigating the interactive nature of their relationship, rather than the components separately. Therefore, technology must not offer representational content but rather be a support to daily routines. A possible area to develop could be externalising individuals' resources rather than their cognition. In that case, new technology must be able to integrate daily lives of people and be adjusted to these changes. For example, our laboratory incubates the Resilient Innovative Society that develops an auditory stimulation device synchronising the steps of elderly people with motor troubles. The rhythm of the emitted sound is a distributed recursive signal informing the individual about the quality of his/her path and promoting a better self-adjustment and coordination of steps.

Conclusion

Aging is a progressive process that presents a mosaic of phenomena, and an important heterogeneity of the age-related effects. Specifically, it may be marked by symptoms related to dementia such AD, which is illustrated by severe perceptual, sensorimotor and cognitive impairments responsible for a decreased of aging adults' autonomy in their daily activities. Some technological tools have been produced and marketed with the objective to preserve a certain level of autonomy and promoting the cognitive functioning of the aging adults. However, it appears that such technological devices are few, or not used. Vaportiz, Clausen & Gow [42] highlighted various barriers to the use and appropriation of such technologies, including the inadequacy of the comparison with younger generations. In that context, the aim of the present paper was twofold. First, pointing out the researchers' responsibility in the spreading of conceptual frameworks that drive the development (and failure) of technological devices. In particular, the scientific paradigms supported by the researchers have a major impact on technologies insofar as they guide their conception and determine how technologies should operate. Second, we proposed an alternative framework about the cognitive aging across the embodied shift. Any paradigm is always internally valid and intrinsically valuable. They define a version of the reality and a way to see the nature. Paradigms represent highly selective gestalten embodying more or less powerful heuristics. In this context, we suggested that important factors about the nature of the cognition have not been incorporated in technological innovations [85-89]. Along these lines, we argued that the embodied paradigm could be a relevant theoretical framework for the gerontechnological domain. Indeed, the methodological benefits of such a perspective stem from a better understanding about how the cognition emerges from the interaction between the bodily abilities and available resources in the current environment. Although it is not easy to predict whether and how aging adults will use and appropriate the technological tools [6]. However, embodied approaches provide both on explicative and descriptive view about how individuals engage their environment, despite the advancing in age.

Due to age/dementia-related impairments on sensorimotor and perceptual abilities [68], it has often been described that the maintaining of an efficient cognitive functioning is compromised. Yet, such impairments do not illustrate a programmed cognitive death. Rather, they come to highlight a poorly adapted response of the cognitive system faced by environmental demands in perpetual changing, pointing out the modification of the interaction of aging adults with their environment. It has already been raised in the gerontechnology literature that technology must improve the link between environment and aging adults [4,5,11,13,41]. However, question is not only to improve the social connectedness and autonomy through technological devices. Rather, the end-purpose should be to improve the adaptive strategy consisting the use of outsourced resources provided by a given tool, in order to continue to mobilize aging adults' anticipation ability. Such an ability is a crucial proactive response of the cognitive system informing on its capacity to take behavioral opportunities in the environment. In this respect, it is necessary to keep in mind that individuals are embedded in an environment that is perpetually evolving, and these changes are faced to the embodied impairments of the aging adults. A technological tool must be able to promote aging adults' autonomy by providing a continuous adjustment between the perceived environmental demands, and the preserved abilities of the aging adults. Only then can design technologies serve as an extended-mind device, affording aging adults' actions and promoting the re-enactment of knowledge, rather than serve as a cognitive crutch substituting their cognitive abilities without improving their autonomy.

In this respect, if technological devices were designed in view to promote the involvement and maintain of the aging adults' interactions with their current environment, they will achieve a competitive advantage by optimizing the availability of cognitive resources. An embodied shift as an alternative conceptual and methodological framework in gerontechnology will help to understand older people's perceptions and use of technologies. To go further than [42] it is not about finding a way to introduce new technologies to the ageing population, but about integrating the ageing world as part of new technologies.

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