Presence and human development: age-specific variations in presence and their implications for the design of life-enhancing interactive applications

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Abstract

This paper examines the relatively unexplored topic of changes in the sense of presence corresponding to individual development from early childhood to old age. How does presence change over the lifespan and how can presence-modulating interactive environments be designed to accommodate the needs of different age groups in the light of these changes? To address these questions, we adopt an existing framework for theorising about relevant aspects of the sense of presence, emphasising the distinction between presence and absence based on attentional focus, and the role of presence as a link between intentions and actions. We explore changes in presence and absence over the course of the human lifespan, and in relation to various psychological and cognitive problems. This includes a consideration of the significance of age-specific changes in levels of consciousness, as revealed through patterns of waking, sleeping and dreaming. Finally, we explore the implications of our position for the design of interactive environments, especially as applied to psychotherapy, and to cognitive training and development.

Keywords: Human development, life-enhancing technology, sleep, presence and ageing, cognitive games, calming technology

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How does presence change over the lifespan and how should presence-modulating interactive environments be designed to accommodate the needs of different age groups? There is little in past research findings to inform an answer to these questions. We see this paper as a first step in developing a potentially valuable new area of age-calibrated, presence-related research and development. Since little is currently known about age-specific changes in presence, this paper is necessarily speculative. In spite of this current uncertainty, we postulate that managing presence better in targeted populations may lead to major improvements in the status and wellbeing of those populations. We argue that the future design of age-appropriate presence-modulating interactions could enhance cognitive status and mental wellness, particularly in vulnerable populations with developmental, neurodegenerative, and mental health challenges. In this paper we suggest that, other things being equal, presence declines as an individual develops from babyhood to old age. Young children experience high levels of presence; a baby may feel present whenever he or she is conscious. At the other end of life, the very old person experiences relatively little presence; they are mostly psychologically absent from the world, absorbed in an inner world of thoughts and imaginings. In the next few sections, we present a framework for understanding presence, and then apply it to age-related changes in perception and cognition that occur during an individual's lifetime, including during both waking and sleeping. From this perspective, we outline ways in which developmental changes in presence and absence can help us understand various cognitive and psychological problems as mal-adaptions of the sense of presence. We go on to indicate how these problems can be addressed through the design and development of interactive environments.

Feeling present in a world

We view mediated presence as the perceptual "illusion of non-mediation" (Lombard & Ditton 1997) and presence in general as the feeling of being located in a perceptible external world around the self. Adopting the theoretical position of Waterworth et al. (2015), we see presence as a universal animal faculty enabling any sentient organism to distinguish what is part of the organism from what is not – separating the self from the other – and knowing (on some level) which is which. Over the course of evolution, humans and some other animals have acquired the ability, and need, to form mental representations of situations and things that are not currently present in their physical surroundings. The calibrated sense of presence possessed by humans is needed so that we can identify when and to what extent we are dealing with internal representations of past, possible future, or imaginary events as compared to when we are dealing with current events actually happening in our present environment. When we focus more on the former, we experience a low level of presence in our environment, whereas focusing more on the latter – on concrete rather than abstract information – is accompanied by a stronger feeling of presence. Concrete information is realized *as the world* or, through digital technology, as *a (virtual) world* that we experience as existing outside our minds and bodies. As far as our sense of presence is concerned, there is no difference between a fully convincing immersive virtual reality (VR) and the physical world. Thus, mediated presence is no different, from the point of view of the organism, from physical presence, precisely because it is the illusion of non-mediation (Lombard and Ditton, 1997).

Following Riva et al (2004), we distinguish three distinct layers of presence that have emerged over our evolutionary history, each associated with one of the three levels of self as identified by Damasio (1999). The most primitive, proto presence, arises basically from movement of the

body and operates primarily through proprioception. The next level, core presence, is perceptual in nature and is the principle determinant of the feeling of presence of which we are aware. Finally, extended presence relates to how the significance of events – essentially the reflective meaning of what is currently happening – influences presence. Presence is experienced most strongly when all three layers are integrated and conscious attention is focused on the same external situation, whether this is physical reality, virtual reality, or a mixture of the two. In contrast, we experience maximum absence when conscious attention is focused but the layers are not integrated (see **Figure 1**).

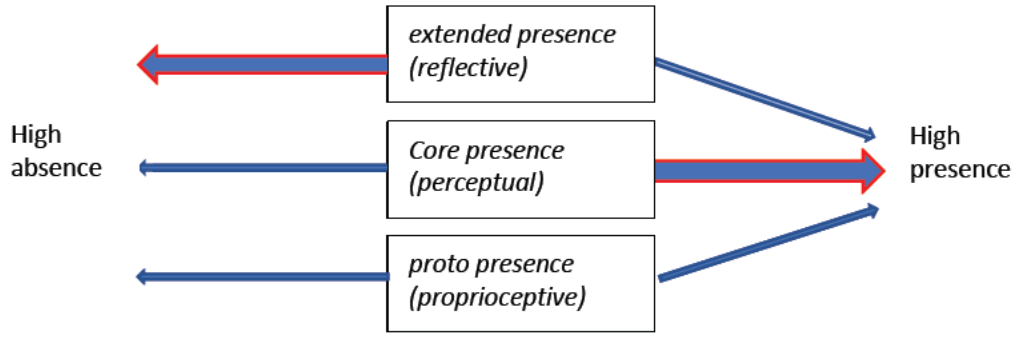

Figure 1 – Strength and focus of attention in high presence and high absence states

Developmental changes in presence

As mentioned earlier, we suggest that presence can be expected to decline as an individual develops from babyhood to old age. The development of the individual is correlated with the development of absence, not presence. Young children most likely experience high levels of presence; a baby may feel present whenever he or she is conscious. At the other end of life, the very old person experiences relatively little presence; they are mostly psychologically absent from the world, absorbed in an inner world of thoughts, imaginings, and especially memories. Contrary to some views of presence, we do not equate presence with the ability to act. Rather, we believe that an optimal level of presence is needed to maximise the efficiency with which intentions can be translated into actions (Riva et al., 2015). As well as shortcomings in their motor competences, we hypothesise that babies may experience too much presence to effectively translate intention into action. Old people, in contrast, may experience too little presence at key times, diminishing their capacity to act effectively on their intentions.

Figure 2 shows our hypothetical view of how presence varies across the human life span and this pattern of variation will be referred to in the following discussion. In infancy, presence will be high and absence will be low. As a person develops into adulthood and beyond, presence will decrease and absence will grow as the person tends to be more internally and memory focused. While only one decreasing straight line is shown in this figure, there are likely to be many different trajectories (some curved) varying between different types of people, but all tending to move downwards over time (to the right).

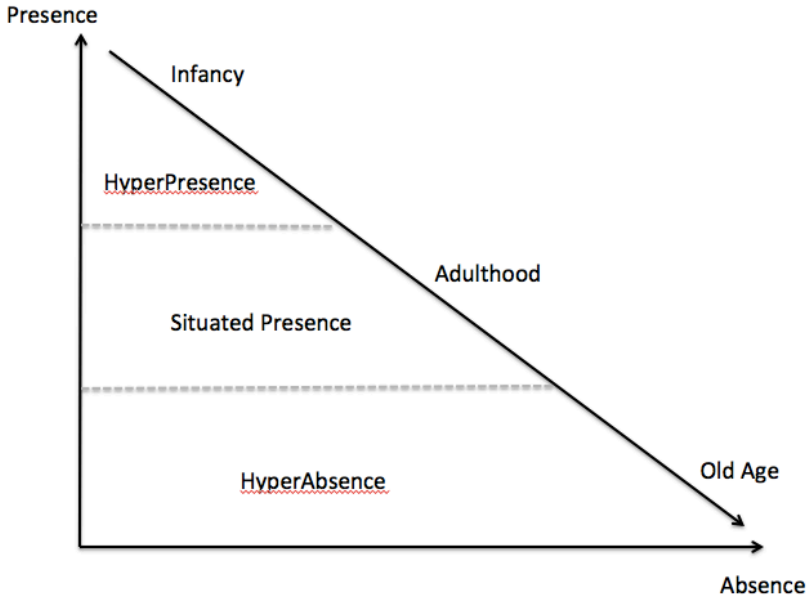

Figure 2 - Hypothesized changes in presence and absence across the lifespan.

In the very young there will be a state of high presence (hyperpresence) where the focus is on observing the surrounding world and learning about it. As the person learns and grows into adulthood, executive functioning develops and cognitive control can be exerted (see e.g., Luna et al., 2015). In this zone of situated presence, the degree of presence varies appropriately from situation to situation (e.g., watching television versus working on a project). Thus, the person is able to choose the right mix of presence and absence for each given situation. As a person ages there is an increasing risk of transitioning into a zone of predominant absence (hyperabsence), first temporarily, but eventually perhaps permanently.

Presence and wellbeing: exercising the brain and other fun activities

Since presence varies over time, with young children having very high levels of presence and elderly people having low levels of presence, how can wellbeing be improved by modifying presence appropriately with exercises and activities? Let's look at the mental health implications of the transitions shown in **Figure 2**. If one considers various psychiatric syndromes, many of them seem to involve a loss of presence and an unhealthy increase in absence. In depression, for instance, the person may ruminate excessively on intrusive negative thoughts. In psychoses such as schizophrenia, the person forms an alternate reality accepting mentally constructed percepts and experiences as if they are real. In delirium (a form of acute brain failure that can occur in the elderly), the person becomes confused, and is no longer attending effectively to the outside world (Inouye et al., 1990).

While loss of presence may be maladaptive, there are many times when it is necessary to perform a task. For instance, a mathematician attempting to solve a problem, or a novelist working on her latest book, may get into productive flow states where the outside world is completely forgotten for periods of time. Thus, loss of presence is adaptive when it is voluntary and useful and enjoyable, but maladaptive when it is involuntary and damaging to the person or to nearby people. A person is suffering from excessive hyperabsence when they have frequent and involuntary excursions into absence, with the problem increasing as these excursions become more frequent and prolonged.

How can presence be re-established when absence becomes maladaptive? One method is to use techniques such as mindfulness training. Parents and educators also use camping, sports, and outdoor activities to increase presence in children and young people. Activities like dancing, as

well as exercises and games, may be used throughout the lifespan to moderate or promote presence.

Since children play, it is tempting to think that play is inherently associated with presence, but the relationship between play and presence is unlikely to be that simple. A popular view of children's play is that it builds the skills that will be needed when the child becomes an adult (e.g., Piaget, 1962, Vygotsky, 1978). The play of very young children is in some senses purposeless (Rubin et al., 1983), with the means being more salient than the ends. However, while self-driven play may seem purposeless in young children, in the internet age the technologically-mediated games that older children and teenagers play can be highly purposive, involving goals such as building, conquering, winning, or completing various tasks.

As play becomes more purposive and task oriented, attention switches from presence in an experienced world to a focus on the task salient aspects of the game. Thus, in a game like Breath of the Wild, play takes place in a virtual world that is rendered in detail, but the presence is no longer that of a neutral and detached observer, but of an actor who has tasks to perform. Task oriented play, and visual attention in general, typically requires acquisition of perceptual data using two distinct attentional (focusing) systems (Chica et al., 2013). Endogenous attention is "top-down" and driven by internal goals. Exogenous attention tracks new, and potentially relevant information in the environment.

One of the challenges that people face is how to balance the need to pay attention to novel information in the environment (exogenous attention) with the need to focus on attentional information that is relevant to the current task (endogenous attention). One view of high presence states is that they involve pure exogenous attention, a focus on the surroundings without intruding thoughts and goals, the task of "concentration" as practiced in certain religious and

philosophical traditions (e.g., Buddhism and yoga). Absence, however cannot be simply equated with over-riding endogenous attention since it is possible to be relatively absent but unfocused or mentally drifting, in which case there is no clear focus of attention, rather than endogenous attention. This relates to the idea of voluntary (often task-driven) absence vs. involuntary (maladaptive) lack of presence.

If as children we are naturally playful and immersed in the world around us, what is lost when we lose that presence with age and become more ensconced in our own thoughts and memories? In our view, sustained hyperabsence in the elderly is a threat to physical, mental, and cognitive health. In the extreme, an elderly person may enter a state of delirium or permanently enter a state of dementia driven by organic changes to the brain.

How can games, exercises and activities increase presence in the elderly, thereby improving physical, mental, and cognitive health? In order to address this question, it may be useful to reconsider the construct of mindfulness. Mindfulness is a deceptively simple word, but it can be deconstructed into a number of inter-related concepts. For instance, the eight-factor model of mindfulness presented by Bergomi et al. (2014) includes the following individual factors of mindfulness:

- awareness towards inner experiences;
- awareness towards outer experiences;
- acting with awareness (being in the present moment);
- acceptance (accepting, non-judging, and self-compassionate orientation);
- de-centering (non-identification and non-reactivity);
- openness to experience (non-avoidance);
- relativity of thoughts and beliefs;

- insightful understanding.

Of these factors our notion of presence is most closely related to the second and third, i.e., awareness towards outer experiences and acting with awareness (being in the present moment). When awareness towards outer experiences and acting with awareness are combined this becomes interactive presence. When tasks or goals are added to the experience this becomes motivated presence; the three layers of presence referred to earlier are integrated (to some extent).

To illustrate the difference between these types of presence we will use a recent activity developed in the Centivizer project (see Tong et al., 2017 for an introduction to the Centivizer project). The activity in this example involves viewing a 360-degree travel video and we consider below three versions of the activity, each representing a different type of presence.

Version 1 - Perceptual Presence: The person watches a 360-degree travel video (e.g., a gondola ride through Venice) where the viewpoint changes as the video plays, but the person has no control over the viewpoint.

Version 2 - Interactive Presence: The person watches the 360-degree travel video while holding a joystick. As they move the joystick the viewpoint changes accordingly so that they create their own personal version of the tour and explore the scenery from different perspectives.

Version 3 - Motivated Presence: In this version the experience is more explicitly game-like. The person is given a bingo card and told that she will get a prize if she finds all the numbers on the card and clicks on them. Numbers are placed on various viewpoints and different time points in the video. If the person clicks on a number, and it matches a number on the bingo card then that number is collected. If all the numbers on the card are collected then the person wins the game and gets the prize. Note that since numbers may only be visible from some viewpoints and

only one viewpoint can be seen at a particular point in time, the person may have to go through the video several times in order to collect all the numbers on the bingo card.

In the motivated presence version of this activity the person has to do the following:

- Use selective attention to scan the 360-degree video for targets
- Either use working memory to keep one or more targets in mind, or match each viewed number with the number on the bingo card
- Use memory and motor control to select promising paths through the video

In this example there seems to be a trade-off, with perceptual presence providing the most immersive experience, but with motivated presence provided the strongest cognitive exercise. One could imagine providing type of presence as a setting or choice.

For example, the activity could be enjoyed with, or without, the joystick, and with or without the associated Bingo game. One could also create a version of this activity that involved physical exercise. For instance, instead of the joystick in the interactive presence version there could be a large and somewhat heavy wheel for selecting the viewpoint, which would require physical effort to move. There could also be accelerator and brake pedals to control the speed of playback of the video and even a gear lever which would allow the person to move forward, or back up, through the video. Note that there is also a potentially huge design space of tasks that could be superimposed on 360-degree video. For instance, instead of a bingo task people could do a pathfinding task, where they have to find numbers, or letters in a certain order, for example from 1 to 10. There could also be a mystery task where the person has to find clues in the video and then solve the mystery.

Many games and tasks have been proposed for preventing, or slowing, physical and cognitive decline in ageing, from existing games such as Guitar Hero, Wii Fit, Sudoko, and Crossword puzzles, to purpose-built activities such as Lumosity (www.lumosity.com). However, we see games that include a strong component of presence or mindfulness as being particular beneficial. Since our grip on the external world and the immediate moment tends to weaken with age, games should deliberately implement and exercise a sense of presence.

Presence increases the sense of engagement and is also associated with optical flow, something that the ageing brain tends to experience less of, particularly if a person is not driving every day or is sitting down watching television most of the time. The flow in television is no substitute for perceived bodily motion because it tends to be discontinuous, disembodied and non-immersive. In contrast, interactive presence applications draw the person in, and can then be linked to physical and cognitive exercises so that the experience of engagement and presence amplifies the level of motivation, and, we would hypothesize, the benefits of those exercises.

Designing for age-specific changes in presence (and its modulation) appears to be a promising route for the development of therapeutic interactive applications. In the following section, we stress the importance of a nuanced and informed understanding of age-related changes in cognition, by considering attendant variations in waking and sleeping patterns – an understanding that opens up further avenues for treatment.

Presence and absence in waking and dreaming

Neuroscience has established the existence of a fluctuating state of consciousness mediated by oscillations in absence/presence, correlated with oscillations in brain "hardware" functionality, e.g. electroencephalographically (EEG, functional MRI- or magnetoencephalography), which may be modifiable through external/environmental inputs (Moller & Barbera, Nofzinger, 2005, Moller, 2008a,b). The existence of fluctuating states of consciousness (implying also fluctuating levels of presence) has also been well established within the neuroscience of sleeping/waking consciousness research (e.g.Tononi, 2004). In fact, it is within unconscious (or low-presence) states that off-line consolidation of crucial learning and memory cognition is thought to occur, alongside more physiological or non-mental phenomena such as tissue and cellular repair and immunological and endocrine regulation, amongst others (Moller et al., 2004).

A low-presence individual, such as an old person losing faculties due to, for example, dementia or a mood disorder process, may be seen as residing in a parallel consciousness or metaverse state of being, while absenting him or herself to escape from the conventional one that demands performance- and goal-oriented behaviour (Moller, 2008a,b). Employing this explanatory model, it is not difficult to see why some attempts to engage an individual affected by neuropsychiatric compromise (no matter the cause) in performance-task oriented rehabilitative activities runs the risk of setting the individual up for failure, due to severe limitations of presence in the world-at-large. In this sense, procedure and/or protocol-based therapies that disregard the inner life may be limited in their efficacy and therapeutic value. Furthermore, excessive early reliance on task-based rehabilitation may also contravene inclusive design principles, which demand employment of aesthetically pleasing interfaces with naturalistic,

minimally encumbering affordances and inherent ease-of-use for optimal impact on individuals with handicaps and disabilities (Marti, 2012).

By convention, and in light of more than ample scientific evidence, most neuroscientists currently view human consciousness as consisting of essentially the trinity of wakefulness, non-dreaming (unconscious) sleep and rapid-eye-movement (REM) sleep, patterns in the cycles of which are known to vary with age (**see Figure 3**).

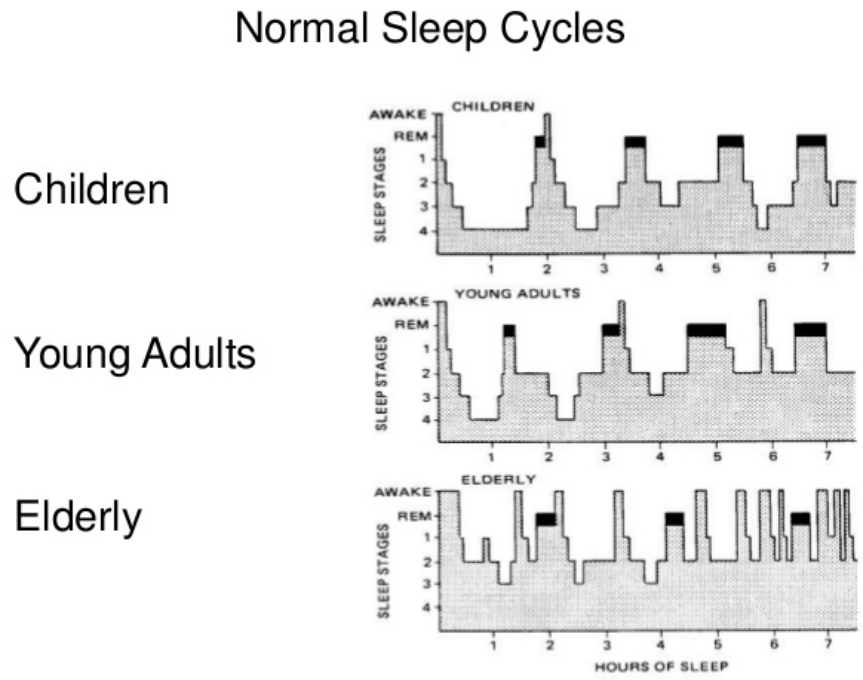

Figure 3 – Sleep architecture changes and ageing. Reprinted with permission from Kales and Kales, N Eng J Med. 290 (9): 488.

Returning to the notion of a relatively high level of presence during infancy and early childhood, and the opposite of that during late life, it is worth looking at these patterns of sleep, dreaming and wakefulness as embodied at the two extremes of age. Infancy and childhood, like old age and senility, exhibit a variation from adult patterns of consciousness (**Figure 3**). In both, there is

a general trend towards a circadian pattern that involves a propensity for polyphasic sleep patterns, which may involve afternoon as well as morning sleep cycles. These cycles include REM, slow-wave sleep (SWS) and "light" sleep. On the surface the circadian oscillations of consciousness embodied in infancy and senility could thus be seen as mirror images of one another with respect to quantitative analysis of sleep need and drive. However, within the gerontologic spectrum there is a relative paucity of SWS and REM at the expense of light sleep, and light sleep is thought to be, relatively speaking, neither physically nor cognitively regenerative compared to REM. and SWS (Moller et al., 2004).

There is now an extensive evidence-based literature to support the role of cognitive exercise in delaying dementia and other states of neurocognitive compromise (e.g. mood disorders), and the idea of "use-it-or-lose-it" has become a staple amongst clinicians and researchers in the field. However, as a supplement to performance-based views of amelioration we propose that access to unconscious processes such as sleep and dreaming may be an undervalued and therefore underemployed modality of therapy (Moller & Barbera, 2006) in relation to changes in presence with ageing.

Moller & Barbera (2006) proposed the construct of "dream simulation therapy", where oneiric multisensory stimuli are presented while a person is in REM sleep, with the goal of creating alterations in consciousness (and presence). Another approach is to use entrainment of brainwaves, using either sound (e.g. rhythmic oscillations such as binaural frequencies) or visual input (e.g. through stroboscopic presentation of lights or other analogous stimuli), to modify affective or motivational states (Moller et al., 2016).

From the perspective of presence versus absence, dreams are typified by a kind of presence within a self-generated virtual reality. Sleep patterns change with ageing, and disturbances to sleep are associated with cognitive impairment and risk of dementia (e.g., Cochen et al., 2009). Loss of sleep-related dream presence may be a forerunner of age-related neuro-degeneration. Relevant research questions in this regard are:

1) Can presence-promoting activities have a beneficial effect on sleep in older people? and

2) Can techniques such as brain entrainment during REM sleep improve sleep and thereby have a beneficial impact on cognition either through improving status or slowing decline?

Factors affecting the commercial viability of presence-modulating technologies

Without successful commercial exploitation, the kinds of technologies we have discussed will have a negligible impact. In this section we explore the potential opportunities for the commercial application of technology-mediated experiences, especially for the older population. We consider how designing such systems could be approached in order to achieve high, ongoing adoption while being technologically feasible and financially viable to build and operate.

Older adults still face unique challenges and barriers to adoption of new technologies. These challenges range from physical, where users might have difficulties manipulating devices, to a lack of comfort and familiarity with technology (Anderson & Perrin, 2017). Only 26% of internet users aged 65 and over in the US describe themselves as very confident when using computers, smartphones or other electronics to do necessary things online while 23% have little confidence and 11% are not confident at all using electronic devices for activities they need to do online (Anderson & Perrin, 2017). In addition, 48% of adults 65+ in the US feel that the phrase *"When I get a new electronic device, I usually need someone else to set it up or show me how to use it"* describes them very well (Anderson & Perrin, 2017). These findings suggest that 3rd parties, like caregivers, have a significant role in helping to break down these barriers and in mitigating these challenges. Despite these challenges, 58% of seniors in the US feel that technology had a positive impact on society versus only 4% feeling that the impact was mostly negative and, once these users are online, a majority of them, roughly 75% in the US, access the internet at least once a day (Anderson & Perrin, 2017).

Given these trends it can be assumed that there is a significant audience for products that address the wants and needs of seniors and that this audience will only increase in the foreseeable future. It also indicates that seniors in the developed world, especially more affluent ones, would be an

ideal market segment for an initial product rollout, given their mostly positive attitude towards technology and their ability to afford it. It should also be noted that caregivers are important stakeholders since they most likely will be involved in purchase decisions considering the low confidence level that many seniors have when it comes to engaging with new technologies and that they will most likely be expected to help seniors operate these devices or applications on an ongoing basis (Executive Office of the President - President's Council of Advisors on Science and Technology, 2016).

In 2016, the President's Council of Advisors on Science and Technology in the United States released a report on Independence, Technology, and Connection in Older Age (Executive Office of the President - President's Council of Advisors on Science and Technology, 2016). In the report three main areas of importance in regards to seniors interacting with technology were identified: social connectivity and emotional health, cognitive ability and physical ability (Executive Office of the President - President's Council of Advisors on Science and Technology, 2016), which the World Economic Forum (WEF) mirrored in their 2016 report on "Technological Innovations for Health and Wealth for an Ageing Global Population" (World Economic Forum, 2016). See **Figure 4**.

Technology Focus Area	Impact on Healthy Ageing
Social connectivity and emotional health	Sense of purpose, meaning in life, emotional contact and overall mental well-being
Cognitive ability	Mental well-being (anxiety, depression), alcohol intake, nutrition and medication adherence
Physical ability	Mobility, musculoskeletal disorders and mental well-being (dementia, cognitive decline)

Figure 4 - Healthy Ageing Targeted through Technology

In the same report the WEF published their "Landscape of Healthy Ageing Technologies for Older Adult" infographic capturing these three areas in more detail (Figure 5: World Economic Forum, 2016).

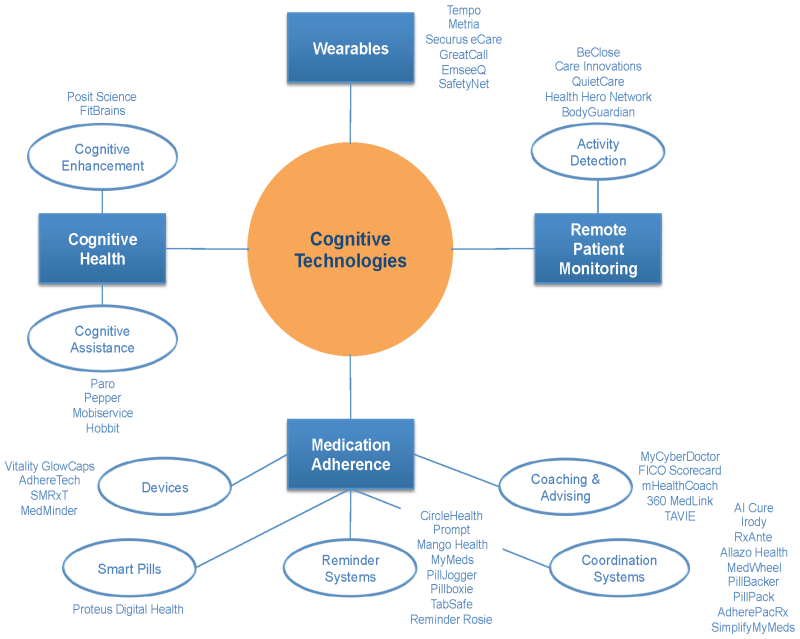

Figure 5: Landscape of Healthy Ageing Technologies for Older Adults - Cognitive Technologies

Governments across the globe are working on strategies to address the challenges of a rapidly aging population and see technology as one of the main pillars in supporting these efforts. They also acknowledge that these efforts have to be supported by, and in conjunction with, private industry in order to be successful (European Commission, 2015).

Who are the customers?

While the customer segment identified in the previous section are adults aged 65 or over, other stakeholders and/or potential users should also be considered. The Centivizer (Tong et al., 2017) for example, a device developed for slowing down the effects of dementia, could be designed to allow for children to interact with it. This would not only increase the user base, helping to justify the expense of purchasing such a device, it could also help facilitate multigenerational

interaction and communication which, in turn, could have an overall positive effect on everyone involved. Content that appeals to different age groups and users could also be developed potentially creating a type of game console with a tangible interface.

With the recent renewed hype around VR, presence has become integral to a number of applications for audiences of almost all ages (although VR is generally not recommended for use under the age of 13). The most obvious ones are gaming and entertainment, which is where all major HMD (Head Mounted Display) manufacturers see the biggest potential for growth in the near term, especially for youth and young adult audiences. Another area of rapid growth is education and training where simulations of real world scenarios help students and trainees prepare for the challenges of their professions. There are countless use cases for applications that allow users to learn or practice a specific task or workflow and where feeling present is imperative for them to have an impact and be useful. These range from putting firefighters and police officers in potentially dangerous situations, to enabling medical students to practice surgeries in a virtual Operating Room. However, the lack of stimulation of multiple senses still limits this type of application. In the medical sector VR is used to help children with Autism Spectrum Disorder (ASD) (Cai et al., 2017) and teenagers with body image issues (Keizer et al., 2016) among many other examples.

Regardless of the use case, the best system has little value without engaging content. While it might seem feasible to come up with a few interesting things to start with it is much more difficult and potentially expensive to keep creating new content without becoming repetitive and, as a result, alienating users. One of the main reasons for the quick demise of the Nintendo Wii, the fastest selling console in history at the time, was a lack of fresh content. A long-term content strategy is key for ongoing success for systems like the Centivizer or VR experiences.

Hardware vs Software

While it has never been easier to prototype hardware due to inexpensive sensors and microcontrollers, like the popular Arduino boards, as well as the wide availability of consumer 3D printers among other things, it is still very difficult to successfully bring hardware products to market and to sustain a hardware business in the long run. There are a number of reasons for this. For example, one could make a product that is too reliable and does not break for a long time. This might sound like a great product and it is, for the consumer, but it is a serious problem for a company like GoPro which is struggling to justify why customers should upgrade to a new camera when the old one is still perfectly fine. GoPro is still trying to figure out a sustainable business model after an attempted transformation into a media platform failed and the release of a new hardware product, a drone, did not work out either. Pebble, one of the first modern smartwatch makers, had a different problem. It wasn't that there was no reason to upgrade to a newer device, rather the issue was that the wearable technology sector as a whole lost its lustre and only a few players survived, highlighting the risk of rapidly evolving and changing consumer sentiment. Pebble was ultimately acquired by Fitbit, another wearable tech company, for far less than it was valued at just a short time before the sale. Another, far more common issue with hardware products is support. Managing customer support, repairs, returns and replacements as well as physical storage facilities is both, complex and time consuming and therefore expensive. In addition, in most cases production at scale is needed in order to achieve a viable price point for consumers, which usually means dealing with a global supply chain. This requires large upfront investment and carries a substantial amount of risk in regards to actual cost, quality and time to market. Tech giants like Apple and Samsung routinely have to deal with

hardware related quality issues or delays, which shows just how difficult the hardware business really is when even conglomerates and billion-dollar companies struggle to get it right.

Software, on the other hand, has very few of these issues. Updates can be done in inexpensive increments without having to create a whole new product forcing users to purchase it again for full price. Many companies sold packaged software bundles with yearly updates that cost a fraction of the original price. However, more and more software products are switching to subscription models, similar to what Adobe did with its Creative Suite, making it even easier to push updates or fixes to their products as soon as they become available. Changing features or whole products based on market demand is also easier and cheaper since no physical pieces have to be assembled and shipped around the globe. Support is still time consuming and expensive but without a physical item, returns, repairs, replacements and storage facilities are not required, reducing the overall product support effort.

Systems like the Centivizer, which are combinations of both hardware and software, could be turned into a platform. This would enable 3rd parties to contribute custom hardware devices as well as software in addition to offering its own solutions, reducing the pressure of creating everything in house. However, a strict certification process should be in place in order to avoid sub-par hardware or software being offered for the Centivizer, which could potentially harm its reputation.

VR experiences for well-being would not require any custom hardware since a number of different VR headsets are already available, instead the focus should be on supporting the widest range of headsets. Even with the challenges described in this section, it has never been easier for small companies or individuals to create products and bring them to market, potentially reaching a global audience.

Conclusions: towards adaptive presence throughout the course of life

We have adopted the view that to feel highly present is to be sensually, perceptually and cognitively engaged with a world in which the observer feels embodied, even if this feeling is illusory (the illusion of non-mediation). Maximal presence can be seen as one extreme on a continuum with its opposite state at the other extreme, maximal absence, being characterized by a lack of engagement in the currently surrounding world. We have proposed that, other things being equal, very young children tend to feel highly present in their environment while conscious, whereas the very old do not. We could say that it is not the sense of presence that develops through the course of an individual's life, but that of absence – the capacity to be absorbed in thoughts, plans and other imaginings – and that at the extreme this results in an effective and damaging loss of presence.

New-born babies may always feel present when conscious, since they have not developed the mental capacity for absence, nor do they experience themselves to be separate entitles. A young child is mostly present when conscious, whereas a very old person tends to be mostly absent and pays relatively little or infrequent attention to the world or worlds, physical or virtual, around her or him. Successful functioning in any world centrally involves the smooth execution of intentions as goal-directed and effective actions. This is why some authors have equated mediated presence with the ability – or the feeling of having the ability – to act in a virtual world. But successfully acting out intentions is not only about presence, which implies paying attention to relevant cues in the environment in a timely fashion. It is also about absence, about forming and holding plans for actions and their completion. Very young children tend to have too much presence to do this, whereas very old people lack the needed level of presence to execute their plans in practice.

We can identify “disorders of presence”, sub-optimal levels of presence for successful functioning in the world, in relation to the stage of development of the individual. For example, young children may suffer from what are seen as attentional problems, typified by a tendency towards distraction by events in the immediate environment. This can be seen as an over-active or too easily engaged presence mechanism. Teenagers and young adults may tend to focus too much on their developing sense of personal identity, at the expense of a realistic perception of their bodies and place in the world, perhaps encouraged by excessive use of social media. This can result in emotional problems, such as body image distortions and eating disorders, panic in public places, depression and anxiety. These young people have the capacity for presence and action, and yet have become trapped in self-absorbed states of absence. And a body of existing evidence suggests that this can be alleviated by experiencing presence in appropriately-designed VRs (e.g. Gutiérrez-Maldonado et al., 2018). As people gradually become older and eventually old, more of their waking time is naturally spent in a state of absence – in reminiscence, stories and daydreaming. At some stage, the ability to be present at the right time – giving timely attention to the environment as needed to carry out their plans – may become lost. Old people in this state exhibit what can be called intentional problems – difficulties in enacting their plans in the world around them.

We suggest that interactive technology can, in principle, be designed to help with all these problems, and we have presented some suggestions to address this need and niche. The presentation forms used will partially determine the level of presence that will be generated by an application. For presence, concrete perceivable objects are needed, whereas for greater absence the emphasis will be on more abstract elements and activities. But we should remember that “content is king” when it comes to take up and continued use of interactive systems. A

boring VR will not elicit presence for long, and a less than intriguing cognitive game will not produce deep absence for more than a short time. Even the best system, in terms of therapeutic efficacy or even initial entertainment levels, will have little long-term value without the availability of engaging content. Long-term content strategies will be key for the ongoing success of systems like the Centivizer, Calming technologies, or indeed any interactive experience designed for well-being. And this will apply equally to all kinds of problem addressed, and across all age groups.

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