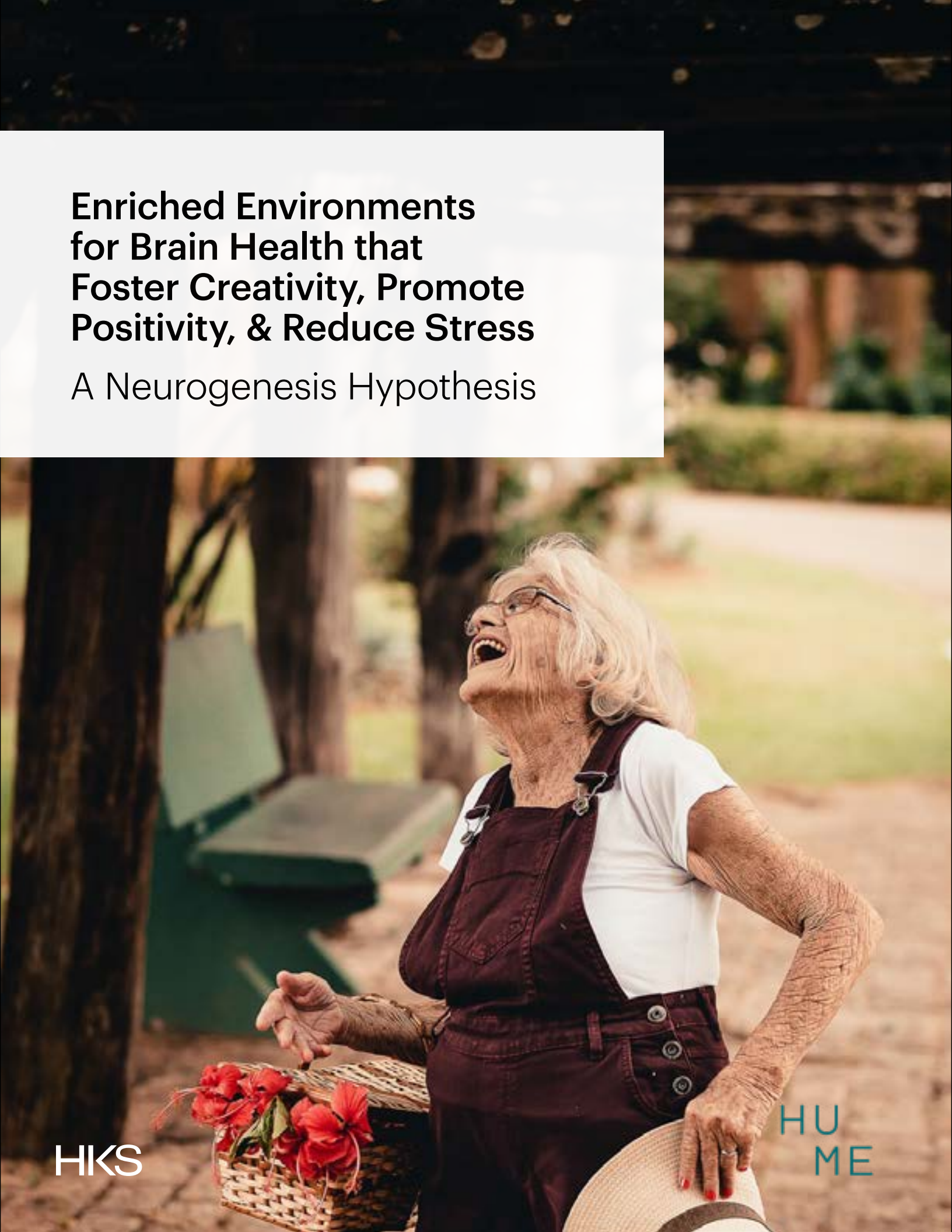
Enriched Environments for Brain Health that Foster Creativity, Promote Positivity, & Reduce Stress

A Neurogenesis Hypothesis



HKS

HU
ME

Enriched Environments for Brain Health that Foster Creativity, Promote Positivity, and Reduce Stress: A Neurogenesis Hypothesis

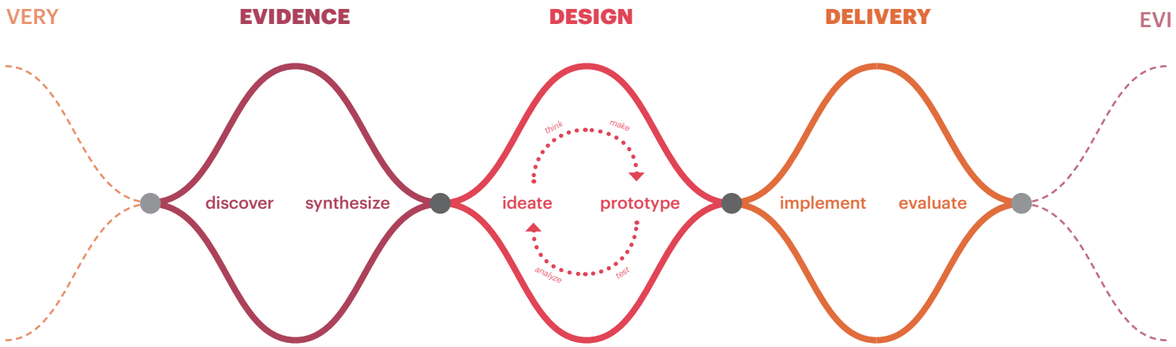
hume.space

Itai Palti, MArch
Aishwarya Narayana, M.Sc. Neuroaesthetics
Natalia Olszewska, M.D.
Maighdlyn Hadley, MArch

HKS, Inc.

Upali Nanda, PhD, Assoc. AIA, EDAC, ACHE
Rebecca Soja, Assoc. AIA, WELL AP, EDAC, Fitwel Amb., LFA
Divyal Nautiyal, Assoc. AIA
Melissa Hoetling, Assoc. AIA, WELL AP
Grant Warner
Emily Disque
Laura Pike-Seeley

Introduction



DESIGN IS A HYPOTHESIS.

Research for the sake of research is meaningless without application. At HKS, we deeply understand the value of literature reviews, data (quantitative and qualitative), metrics, problem-seeking and lessons learned, but it was challenging to package all of this intellectual capital in a way that was actionable. How many reports must we read, or occupancy evaluations must we conduct, to discover one nugget of knowledge we can apply to a current project now? This resource explores new ways to disseminate research to designers and their extended teams of co-creators to directly engage with scientific evidence during design, rather than only use it to justify strategies later. Our motivation in sharing this approach is two-fold. First, it is one step towards bridging the gap between research and practice. Second, it dismantles our unconstructive assumptions about aging towards more positive outlooks and advocacy for our elders.

We must start with science and empathy and this means building partnerships towards a common purpose. This is what we have put in place with HUME to create this resource for science-informed design.

Contents

Abstract

Science-Informed Design proposes that to provide solutions that best improve the outcomes of any design project, we must draw from a continuously evolving pool of scientific knowledge.

A science-informed approach to design - focused on the cognitive sciences - has the potential to shift the way we evaluate spaces away from traditional efficiency metrics focused on form and mechanical performance, to effectiveness metrics focused on experience quantified as cognitive and emotional effects.

In this document we investigate what capacity design holds to positively affect brain structures via improved neurogenesis; and environmentally supported neuroplasticity and propose design mediated solutions for a number of typologies which could potentially reduce stress, boost creativity and positive feelings, hence prevent aging-related cognitive decline.

This effort is intended to inspire designers to create enriched environments which will prevent age-related cognitive decline, foster positive stereotypes around aging, and strengthen inter-generational communities that promote healthy aging as a goal across all age-groups.

Neurogenesis and environmentally mediated neuroplasticity remain the main candidates for a biological foundation explaining how built environments could support healthy physiological aging. Animal models demonstrate that so-called 'enriched environments' are capable of stimulating positive behavioral changes, i.e. animal's curiosity and exploration linked to creativity in humans, and are beneficial in a number of psychiatric and neurodegenerative disorders.

The body of research suggests that the process of age-related cognitive decline is linked with a decrease in dopamine receptors, next to slower neurogenesis in various brain regions. Hence, the importance of creating stimulating enriched environments which can positively affect higher order functions, i.e. creativity and this same support healthy aging preventing cognitive decline. Furthermore, according to lifespan theory of human development[1] two components, 'neurobiological mechanics' and 'socio-cultural pragmatics', interact in a reciprocal fashion across the lifespan. This theory implies also that there is no 'end state' an individual aims for and that growth and change are possible at all stages of life.

Architectural design plays an important role in fostering social and environmental input which is required to maintain cognitive stability[2] throughout a lifetime.

1. Baltes, Paul B. (2006). Lifespan development and the brain. Cambridge, UK: Cambridge University Press

2. Coen and Rugg. (2019). Neural Dedifferentiation in the Aging Brain. Trends in Cognitive Sciences

Aging: A Global Challenge

The global population aged 60 years or over numbered 962 million in 2017, more than twice as large as in 1980 when there were 382 million older persons worldwide. The number of older persons is expected to double again by 2050 when it is projected to reach nearly 2.1 billion[3].

The European population, for example, is undergoing an unprecedented aging process, which is taking place as a joint effect of the baby boom that followed the Second World War, the low birth rates of the 1980s[4], increased life expectancy and reduced fertility. The percentage of persons aged 60+ increased from 9.2% in 1990 to 11.7% in 2013[5]. The total population in the EU is projected to increase from 511 million in 2016 to 520 million in 2070[6].

It is estimated that between 2000 and 2040, the number of Americans 65 and older will more than double to 80 million. For Americans 85 and older, the number will nearly quadruple[7].

It was predicted that in Asian and Pacific Region, the number of people 60 years or older will have increased to 1.3 billion by 2050[8].

The growth of the **aging population** is also striking in the developing world, moreover, it is important to highlight the fact that about 64% of persons aged 60 years and over in the world reside in developing countries[9].

Aging of the workforce is a growing problem. As workers age, their physical, physiological and psychosocial capabilities change. Various initiatives are undertaken worldwide to promote wellbeing of older workers. Keeping these workers healthy and productive is the main goal of European labor policy and health promotion is a key to achieve this result[10]. In the U.S. the National Center for Productive Aging and Work (NCPAW) was launched in 2015 by the National Institute for Occupational Safety and Health (NIOSH) to promote both the lifelong well-being of older workers and the concept of productive aging[11].

Cognitive impairment is a major health and social issue due to an increasingly aged population which creates a strain on economies. At the same time it is among the most feared aspects of aging[12], although normal aging does not imply unavoidable cognitive decline, and dementia is not an inevitable consequence of old age[13]. Even in the absence of detectable pathology, a number of cognitive abilities, including episodic memory, executive function, and processing speed, decline with age. Understanding the causes and protective factors of **age-related cognitive decline** becomes urgent given how quickly human populations worldwide are aging[14].

THERE WILL BE **2.1 BILLION PEOPLE** WORLDWIDE **AGED 60+ BY 2050** AND GROWING...

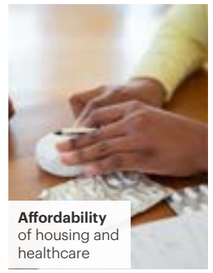
CAUSES

+ Widening gap of future caregivers for elderly
+ High rate of growth of population aged 60+
+ Increased life expectancy
+ Low birth rate
+ Reduced fertility
+ Age-related physiological and cognitive decline

Understanding the causes and protective factors of cognitive impairment is paramount.

CHALLENGES

Disparities between developed and undeveloped countries



Affordability of housing and healthcare

Resources for **care/ support of elderly** burden on families

Productivity and wellbeing of an aging **workforce**

Maintaining **quality of life** at all life stages

KEY TAKEAWAY

A rapidly aging population will have compounding and co-dependent effects at a global scale.

DESIGN PROMPTS

HOW CAN DESIGN RAISE AWARENESS THAT THE PROCESS OF **AGING AFFECTS EVERYONE, EVERYWHERE**?

3. World Population Ageing. Highlights. (2017). United Nations.
4. Poscia et al. (2016). Workplace health promotion for older workers: a systematic literature review. BMC Health Services Research.
5. Raggi et al. (2016) Determinants of Quality of Life in Ageing Populations: Results from a Cross-Sectional Study in Finland, Poland & Spain. PLoS ONE.
6. Overview - Population - Eurostat.
7. Johnson, R.W., (2003). Changing The Age Of Medicare Eligibility. [online] Urban Institute.
8. United Nations ESCAP, Social Development Division. 2016 Population Data Sheet. 9 September 2016 revision.
9. Gureje et al. (2015). 'Profile and determinants of successful ageing in The Ibadan Study of Ageing'. J Am Geriatr. Soc.
10. Poscia et al. (2016). Workplace health promotion for older workers: a systematic literature review. BMC Health Services Research.
11. Burdick, G. (2019). The Workforce Is Aging—We Need to Keep It Healthy and Safe - EHS Daily Advisor. EHS Daily Advisor.
12. Corley et al. (2009). Age-associated cognitive decline. British Medical Bulletin.
13. Kravitz et al. (2012). Cognitive Decline and Dementia in the Oldest-Old. Rambam Maimonides Med J
14. Coen and Rugg. (2019). Neural Dedifferentiation in the Aging Brain. Trends in Cognitive SciencesBaltes, Paul B. (2006). Lifespan development and the brain. Cambridge, UK: Cambridge University Press

Older Adults as a Vulnerable Group

Coronavirus disease 2019 (COVID-19) and other pandemics have demonstrated that the elderly population is particularly **vulnerable** as accumulating evidence indicates a strong age-related gradient for risk of severe disease, hospitalization, and death[15].

Coronavirus disease 2019 (COVID-19) encompasses a broad clinical spectrum caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The risk of getting seriously ill increases continuously from 60-years of age, and becomes even higher among individuals over 70-years and those with underlying medical comorbidities. One model-based analysis demonstrated that hospitalization estimates for COVID-19 were 1.04% for those aged 20-29 years, and 18.4% for those aged 80 years and older[16].

Age turned out also to be a predictor for COVID-19 mortality. Case fatality rates for patients with confirmed COVID-19 in China were 8.0% amongst patients aged 70-79 years and 14.8% for patients aged ≥80 years in comparison to 2.3% for the entire cohort of confirmed cases. Case fatality rates in Italy were also positively associated with age, with 12.8% and 20.2% amongst patients aged 70-79 years and ≥80 years, respectively[17]. In Europe, which remains the region with the world's largest proportion of older persons and almost 1 in 4 Europeans (that is 24% of the continent's total population of 850 million) is 60 years or older, almost 95% of deaths occurred in this age group[18]

The WHO has estimated up to half of COVID-19 related deaths in Europe are residents of aged care facilities. In the U.S., nursing homes account for over 40% of coronavirus deaths[19].

Long-term care facilities turned out to be perfect virus incubators. Their residents, who often have many **comorbidities** are more susceptible to severe Covid-19 infections, and many of them need assistance with basic activities making it more likely they could get an infection from the aides working often in several facilities[20]. The layout of these facilities further increased the risk of viral transmission as most residents of nursing homes share bedrooms, bathrooms, activity rooms, and dining rooms. In many cases, the shared spaces of the facilities have helped spread the virus[21].

The COVID-19 pandemic has demonstrated that there is a need for greater investment in improving how societies age. Focusing on health measures and research which have potential to slow down the rate of biological aging becomes an urgent matter as there has been an enormous increase in life expectancy achieved worldwide. We need also to find means to minimize the costs of future pandemics which might again put the elderly, the most vulnerable, at high risk[22].

Ageism

One major challenge faced by aging populations is the multifaceted **positive and negative stereotypes constructed around aging and elderly**. Some of them are culture dependent.

The most common negative stereotypes about older populations include: decreased views of physical attractiveness, decreased capability to perform tasks, and decreased ability to learn.

The most common positive stereotypes about the elderly populations include: perceived growth in wisdom and worthiness of respect, increased perceived authority in family, and life satisfaction[23]

Age stratification and discrimination are widespread in Western cultures where older people are marginalized and socially excluded. This negative cultural view on aging remains a major barrier to greater social inclusion of the elderly.[24]

Social stereotypes actively reinforce **institutionalized ageism**[25, 26] which is defined by the WHO as the stereotyping, prejudice, and discrimination against people on the basis of their age[27]. Research suggests that activation of both explicit and implicit negative age stereotypes can detrimentally impact older populations performance on physical or mental tasks such as memory, handwriting skills, walking, and overall cognitive performance[28]. In extreme cases, negative stereotypes can produce life threatening effects; one study found that older men exposed to negative health related stereotypes were less likely to seek medical attention out of fear of appearing sick or weak[29]. The majority of people perceive aging solely as a time of cognitive and physical decline and this negative stereotype has been widely accepted as a norm not only by the general public but also by scientists. However, this outlook on aging is being challenged[30].

Reinforcement of positive stereotypes could counteract the effect of negative stereotypes. Realistic positive stereotypes can have a positive impact on performance. Some studies found positive stereotypes were correlated with an increase in older adults memory, swing time, walking speed and balance[31].

Research on stereotypes on aging and their link with their health suggested that older adults exposed to more positive stereotypes are more **resilient** to the effects of negative stereotypes and are more likely to accept life-prolonging medical treatment[32].

15. Holt, N.R.; Neumann, J.T.; McNeil, J.J.; Cheng, A.C. (2020). Implications of COVID-19 in an ageing population. Published online: 6 May
16. Ibid.
17. Ibid.
18. UNFPA EECARO. (April, 2020). Ageing populations & COVID-19 risk.
19. McEvoy, J., 2021. Nursing Homes Account For Over 40% Of U.S. Coronavirus Deaths. [online] Forbes.
20. Harrison, S., 2020. Some Nursing Homes Escaped Covid-19—Here's What They Did Right. [online] Wired.
21. Ibid.
22. Scott, A. & David, J. (April 2020). The interaction between Covid-19 and an ageing society. https://voxeu.org/
23. Löckenhoff et al. (2009). Perceptions of aging across 26 cultures and their culture-level associates.Psychology and Aging
24. Corner et al. (2006). Social aspects of ageing. Women's Health Medicine.
25. Dionigi, R. A. (2015). Stereotypes of Aging: Their Effects on the Health of Older Adults. Journal of Geriatrics
26. Corner et al. (2004). Social aspects of ageing. Psychiatry
27. https://www.who.int/ageing/ageism/en/
28. Abrams et al. (2006). "An age apart: the effects of intergenerational contact and stereotype threat on performance and intergroup bias," Psychology and Aging
29. Dionigi, R. A. (2015).
30. Lupien, S. J., & Wan, N. (2004). Successful ageing: from cell to self. Philosophical transactions of the Royal Society of London. Series B, Biological Sciences, 359(1449), 1413–1426.
31. J. M. Hausdorff, B. R. Levy, and J. Y. Wei, (1999). "The power of ageism on physical function of older persons: reversibility of age-related gait changes," Journal of the American Geriatrics Society, vol. 47, no. 11, pp. 1346–1349.
32. Dionigi, R. A. (2015).

KEY TAKEAWAYS

The pandemic has illuminated age-related disparities and an urgent need to invest in design for an aging society, the resulting priorities must address not only physical health, but also social and cognitive health.

Ageism causes people of all ages to succumb to stereotypes.

DESIGN PROMPTS

HOW CAN DESIGN **PROACTIVELY REDUCE THE VULNERABILITY** OF ELDERLY GROUPS AT RISK?

WHAT ENVIRONMENTS HAVE YOU EXPERIENCED OR OBSERVED THAT ARE **EXPLICITLY OR IMPLICITLY AGEIST**?

HOW CAN DESIGN **CHALLENGE TRADITIONAL STEREOTYPES** OF AGING AND **PROMOTE POSITIVE** ONES?

WHAT IMPACT MIGHT **INTERGENERATIONAL** STRATEGIES HAVE?

Healthy Aging

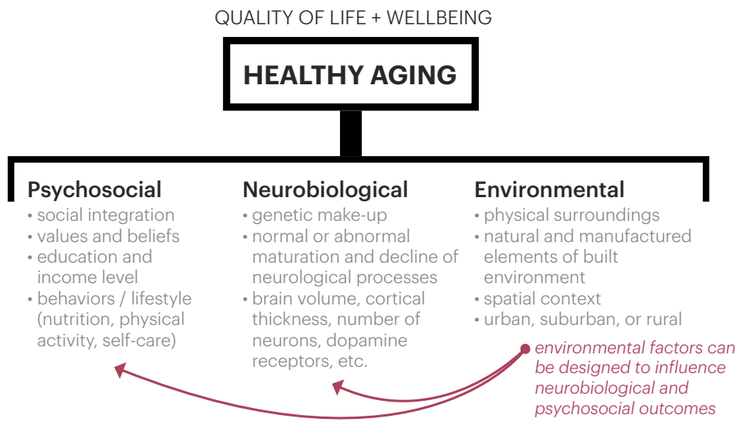
Aging is a complex **physiological** process, a series of events which trigger alterations in normally a functioning organism[33]. It is characterized by waning physical and often cognitive capacities and increased risk for illness and death[34]. As a matter of fact it is common among older individuals to have multiple chronic conditions[35].

Everyone experiences aging differently since it involves the interplay between an individual's biological and molecular mechanisms, hence underlying genetics, and the environment in which one resides, including its social aspects.

'Healthy aging' is defined as 'the process of developing and maintaining the functional ability that enables well-being in older age [36, 37].

'Successful aging' is about the capacity of elderly persons to enjoy good social, physical and psychological well-being[38].

The concept remains controversial due to its multidimensional and ambiguous nature. It can be interpreted differently by various scientists; for a biomedical scientist 'successful aging' means the absence of disease associated with a typical aging process, whereas for a psychosocial scientist 'successful aging' is about life satisfaction and well-being related to good socialization processes[39]. 'Healthy aging' remains a more inclusive concept and doesn't imply the avoidance of disease[40].



Some of the **social determinants of age-related health outcomes** that can impact the aging process include:

- Country—rich and poor countries (or the global north and the global south), underdeveloped, developing and developed economies are classifications based on HDI (human development index),
- Cultural context—values, lifestyle, etc.
- Area of residence—rural, semi-urban, urban[41]

For example, in Nigeria the life expectancy is about 50 for men and 52 for women, which is around two decades less than in Western Europe and North America[42].

Healthy aging impacts a person's quality of life, so understanding the determinants of healthy aging is becoming an important research area and a field of interest for policy makers[43]. For a proper evaluation of the **quality of life (QoL)** of the elderly, it is important to assess not only their health, but also their psychological, functional and existential wellbeing[44].

Most studies address determinants of 'quality of life' within a limited number of domains, such as:

- the presence of multi-morbidities,
- visual impairment,
- obesity,
- behavioral issues, such as higher levels of alcohol use, smoking or active lifestyle,
- social and family relationships,
- socioeconomic status[45].

According to WHO, the paradigm of 'healthy aging' calls for creation of age-friendly environments, as well as alignment of health systems to the needs of older people, development of systems for long-term care and a change in the way we think about aging and older people [46, 47].

KEY TAKEAWAY

Physiological aging is influenced by psychosocial, neurobiological, and environmental factors and healthy aging impacts quality of life.

DESIGN PROMPTS

WHAT ADDITIONAL **SOCIAL OR ENVIRONMENTAL DETERMINANTS OF AGE-RELATED HEALTH** CAN YOU THINK OF THAT ARE INFLUENCED BY THE BUILT ENVIRONMENT?

EVALUATE YOUR **QUALITY OF LIFE**; COULD IT BE BETTER?

33. Miquel et al. (2018). Poor cognitive ageing: Vulnerabilities, mechanisms and the impact of nutritional interventions. Ageing Research Reviews
34. Caballero et al. (2016). Advanced analytical methodologies for measuring healthy ageing and its determinants, using factor analysis and machine learning techniques: the ATHLOS project. Nature.
35. Ibid.
36. Raggi et al. (2016) Determinants of Quality of Life in Ageing Populations: Results from a Cross-Sectional Study in Finland, Poland and Spain. PLoS ONE
37. What Is Healthy Ageing? Available online: http://www.who.int/ageing/healthy-ageing/en/
38. Gureje et al. (2015). 'Profile and determinants of successful ageing in The Ibadan Study of Ageing'. J Am Geriatr Soc.
39. Wong, R. (2018). A New Strategic Approach to Successful Aging and Healthy Aging. Geriatrics
40. Ibid.
41. Gureje et al. (2015). 'Profile and determinants of successful ageing in The Ibadan Study of Ageing'. J Am Geriatr Soc.
42. Ibid.
43. Ibid.
44. Fassino, Secondo, Leombruni, Paolo, Daga, Giovanni Abbate, Brustolin, Annalisa, Rovera, Giovanni Giacomo & Fabris, Fabrizio. 2002. Quality of life in dependent older adults living at home. Archives of gerontology and geriatrics 35: 9-20.
45. Raggi et al. (2016) Determinants of Quality of Life in Ageing Populations: Results from a Cross-Sectional Study in Finland, Poland and Spain. PLoS ONE
46. Ibid.
47. Wong, R. (2018). A New Strategic Approach to Successful Aging and Healthy Aging. Geriatrics

Good brain health is a state in which every individual can realize their own abilities and optimize their cognitive, emotional, psychological and behavioural functioning to cope with life situations. Numerous interconnected social and biological determinants (incl. genetics) play a role in brain development and brain health from pre-conception through the end of life. These determinants influence the way our brains develop, adapt and respond to stress and adversity, giving way to strategies for both promotion and prevention across the life course.

- World Health Organization

Brain Health

A better understanding of brain health, similar to the heart, shows that it is affected by both our lifestyle and environment. Bearing in mind the social and economic pressures related to aging populations, the idea that we can modify risk for cognitive impairment and dementia becomes important and appealing. The popularity of all sorts of **'cognitive tools'** such as books, computer games, and programs aiming at keeping our brains 'fit' has exploded in recent years.

For now, research demonstrates that **cognitive activity**, next to physical activity, cardiovascular health and nutrition, could constitute a group of 'protective factors' for cognitive decline and dementia.

The most direct way to boost cognitive health could be 'cognitive activity' as it influences positively brain structure and function however for now it remains underappreciated[48].

The normal aging process comprises both biological and psychosocial aspects, which remain interrelated. Successful aging from a psychosocial point of view implies a high level of social integration which is achieved by maintaining the quality of life. The latter mostly relies on biological aspects of aging, that is good physical and mental status which depend on dignity, finance, access to proper medical services and presence of activities to perform[49].

Cognitive function tends to improve over the first 18 years of life. People tend to experience a peak of cognitive function in their early twenties; thereafter it starts to deteriorate slowly. Lack of adequate nutrition and various stress factors, including diseases, have detrimental effects on the cognitive function of 'healthy' individuals during their lifetime. Most people will suffer at a certain stage of their life from disease and the negative consequences of disease for cognitive function.

A progressive decline in cognition happening due to aging is considered normal, particularly for people past the age of 60 years. Research demonstrates that both reaction time and speed of processing decline progressively throughout adulthood and this has a negative impact on learning abilities later in life[50].

In the absence of other signs and symptoms, learning difficulties observed among age groups of 70 or 80 years do not necessarily imply cognitive difficulty. Such cognitive impairment is called **'age-related cognitive decline'** and its degree varies among individuals. Only in cases when the magnitude of cognitive decline exceeds a certain threshold, an intermediate form of cognitive impairment can be diagnosed[51]. This threshold is either recognized by the affected individual or his caregivers, and requires further assessment by a healthcare professional. Individuals with recognized cases of an intermediate cognitive decline might further require compensating tools, such as lists, maps, or pill boxes, to cope with daily activities and challenges[52].

Evidence demonstrates that cognitive decline during normal aging can be attenuated by a wide variety of factors, such as improved nutrition, appropriate dietary supplementation, increased physical exercise, and the performance of mental exercises[53]. There is also research indicating that the quality of the built environment affects quality of life of older adults[54].

The criteria of **'aging-associated cognitive decline' (AACD)** proposed by the World Health Organization (WHO) includes "the presence of subjective gradual cognitive decline (for at least 6 months) and objective evidence of abnormal performance in any principal domain of cognition, i.e. memory and learning, attention and concentration, thinking, language or visuospatial functioning" [55].

Therefore, the AACD diagnosis identifies persons with subjective and objective evidence of cognitive decline. Cognitive function is assessed by standardized neuropsychological tests and abnormality is defined as performance of at least one standard deviation below age and education norms. Additionally there must be no evidence of any previous medical condition causing cognitive dysfunction[56].

The AACD diagnosis is related to **'age-associated memory impairment' (AAMI)**, a condition characterized in the criteria proposed by a working group of the National Institute of Mental Health. However, the AAMI diagnosis is based on a less comprehensive evaluation which takes into account memory function only[57]. The prevalence of AACD tends to be higher in men (30.1%) than in women (24.4%). Age-specific prevalence rates were:

- 25.2% in the age group 68—70 years,
- 30.5% in the age group 71-74 years,
- 20.5% in the age group 75-78 years[58].

Generally speaking, both higher level of late-life intellectual activity participation[59] and performance of everyday activities[60] were associated with less cognitive decline.

The concept of **'spectrum of cognitive health'** becomes a useful tool which helps to estimate where older adults find themselves on the spectrum of cognitive abilities with regard to their everyday cognitive activity. It helps also define specific preventative (prophylactic) interventions improving cognitive health[61].

Three categories of cognitive functioning can be recognized in older adults: **normal cognitive aging, mild cognitive impairment (MCI), and dementia**. However, these categories are arbitrary since cognitive decline falls along a continuum[62].

Although research on **'normative cognitive aging'** is still determining what changes could constitute a normal aging process, two patterns of change have been noticed so far - some abilities remain relatively stable into old age, while others follow a trajectory of decline.

Among the abilities characterized by the minimal decline there are verbal abilities and comprehension. On the contrary, the abilities such as speed of processing, memory, spatial ability and reasoning decline with aging[63].

The above mentioned aspects of cognitive decline do not affect the ability of older adults to perform daily activities, therefore older adults experiencing 'normative cognitive changes' remain independent unless other medical conditions impede their physical or mental abilities[64].

KEY TAKEAWAY

Cognitive activity can constitute a group of protective factors to prevent cognitive decline and dementia.

Higher level of late-life intellectual activity and performance of everyday activities can aid cognitive decline.

Not all abilities decline equally with age. Speed of processing, memory, spatial ability and reasoning are particularly vulnerable.

DESIGN PROMPTS

HOW CAN DESIGN FEATURES FACILITATE **COGNITIVE ACTIVITY**?

HOW CAN SHARED ENVIRONMENTS SUPPORT A **SPECTRUM OF AGE-RELATED COGNITIVE FUNCTION**?

WHAT ARE SOME CHALLENGES PEOPLE MAY FACE IN THEIR ENVIRONMENTS RELATED TO **ABILITIES PRONE TO COGNITIVE DECLINE**?

48. Hughes. (2010). Promotion of cognitive health through cognitive activity in the aging population. Ageing Health
49. Byoung Hoon Oh, M.D. (2004). Psychosocial Aspects of Normal Ageing. J Korean Med Assoc.
50. Kane et al. (2017). Interventions to Prevent Age-Related Cognitive Decline, Mild Cognitive Impairment, and Clinical Alzheimer's-Type Dementia. Comparative Effectiveness Reviews, No. 188
51. Ibid.
52. Ibid.
53. Miquel et al. (2018). Poor cognitive ageing: Vulnerabilities, mechanisms and the impact of nutritional interventions. Ageing Research Reviews.
54. Raggi et al.
55. Hanninen et al. (1996). Prevalence of Ageing-associated Cognitive Decline in an Elderly Population. Age and Ageing.
56. Ibid.
57. Hanninen et al. (1996).
58. Ibid.
59. Leung, G. Lam, L. C. W. (2011). Examining the association between late-life leisure activity participation and global cognitive decline in community-dwelling elderly Chinese in Hong Kong. International journal of geriatric psychiatry, 26(1), 39-47.Chicago.
60. Zhang, Wei & Niu, Weihua. 2013. Creativity in later life: Factors associated with the creativity of the Chinese elderly. The Journal of Creative Behavior 47: 60-76.
61. Hughes. (2010). Promotion of cognitive health through cognitive activity in the aging population. Ageing Health.
62. Ibid.
63. Ibid.
64. Ibid.

The Power of Positivity

From a neurochemical point of view, general cognitive abilities are related to **dopamine receptors** turnover rates in the brain located predominantly within the prefrontal cortex[65]. The body of research suggests that the process of age-related cognitive decline is also linked with a decrease in dopamine receptors[66 67 68], next to slower neurogenesis in various brain regions[69 70].

Ashby, Isen, and Turken's (1999) were among the first ones to put forward the **dopamine hypothesis**[71]. This theory proposes that **positive affect** influences performance on many cognitive tasks and positive affect is associated with increased brain dopamine levels. The theory introduced by Ashby et al. accounts for influences of positive affect on olfaction, the consolidation of long-term (i.e., episodic) memories, working memory, and creative problem solving[72 73 74].

The beneficial effects of induced positive feelings among younger adults are robust, however in older adults, have been studied less[75]. Carpenter et al. (2012) performed studies on a group of 46 older-adult participants (73.9 years, range 63-85). Their results confirm that induced positive feelings can facilitate working-memory capacity and improve decision making among older adults. Positive feelings improve the overall ability of study participants to think carefully and flexibly[76].

Recent studies suggest that changes within the dopaminergic nigrostriatal system are not only a result of dopaminergic neurons loss but they are rather related to the increased vulnerability of neurons to damage[77]. The summary of studies conducted for over 30 years to understand adult age differences in the **dopamine (DA) system** reveal that the DA system declines at around 5% - 10% per decade across adulthood[78].

There is evidence that everyday positive feelings (positive affect) have a facilitative influence on cognitive processes that may be related to decision making and problem solving.

Studies suggest that mild improvements in positive feelings increase specifically cognitive flexibility which help individuals to shift attention among multiple perspectives. This is particularly the case when participants find the task meaningful and engaging[79].

By contrast research confirms that the brain is sensitive to stress. The brain is especially vulnerable during early childhood when it matures and old age when it is prone to degeneration[80].

Exposure to **early-life stress (ES)** was associated with lasting changes in the structure of the adult brain and accelerated cognitive decline. A possible role for epigenetic mechanisms, was suggested, although the underlying molecular mechanisms need to better understood[81]. **Chronic stress** is known to negatively impact brain plasticity. It also triggers dysregulation of the immune system and increases risk of developing brain disorders[82].

KEY TAKEAWAY

For healthy brains, we need less stress and more positivity.

DESIGN PROMPTS

HOW CAN DESIGNED ENVIRONMENTS (EITHER PUBLIC OR PRIVATE) EVOKE **EMOTIONS OF HAPPINESS, CALMNESS, OR CONTEMPLATION**?

WHAT ENVIRONMENTS HAVE YOU EXPERIENCED OR OBSERVED THAT PROVIDE **POSITIVE AFFECT**?

HOW MIGHT DESIGN REDUCE **EARLY-LIFE STRESS OR CHRONIC STRESS**?

65. Wass et al. (2018). Dopamine D1 receptor density in the mPFC responds to cognitive demands and receptor turnover contributes to general cognitive ability in mice. Scientific reports. Nature.
66. Hemby et al. (2003). Neuron-Specific Age-Related Decreases in Dopamine Receptor Subtype mRNAs. J Comp Neurol.
67. Karrer et al. (2017). Reduced dopamine receptors and transporters but not synthesis capacity in normal ageing adults: a meta-analysis. Neurobiology of Ageing.
68. Garrido-Gil et al. (2018). Ageing-related dysregulation in enteric dopamine and angiotensin system interactions: implications for gastrointestinal dysfunction in the elderly. Oncotarget.
69. Galvan & Jin. (2007). Neurogenesis in the aging brain. Clinical Interventions in Ageing
70. Yang et al. (2015). Aging and Exercise Affect Hippocampal Neurogenesis via Different Mechanisms. PLOS One.
71. Ashby et al. (1999). A Neuropsychological Theory of Positive Affect and Its Influence on Cognition. Psychological Review.
72. Ibid.
73. Becker et al. (2016). A network-level analysis of cognitive flexibility reveals a differential influence of the anterior cingulate cortex in bilinguals versus monolinguals. Neuropsychologia
74. Yang et al. (2012).
75. Ibid.
76. Carpenter et al. (2012). Positive feelings facilitate working memory and complex decision making among older adults. Cognition and Emotion
77. Garrido-Gil et al. (2018).
78. Karrer et al. (2017).
79. Carpenter et al. (2012).
80. Prenderville et al. (2015). Adding fuel to the fire: the impact of stress on the ageing brain. Trends Neuroscience.
81. Miquel et al. (2018). Poor cognitive ageing: Vulnerabilities, mechanisms and the impact of nutritional interventions. Ageing Research Reviews.
82. Evans, Gary. (2003). The Built Environment and Mental Health. Journal of Urban Health: Bulletin of the New York Academy of Medicine.

Neurogenesis, Memory & Place

Neurogenesis is the process of the generation of new neurons predominantly observed in the adult **hippocampus**, a region of the brain associated with spatial navigation, memory formation, learning and mood. It is a form of plasticity that persists throughout life in several species including humans. Given that the hippocampus is particularly vulnerable to age-related alterations and neurodegeneration, finding strategies to enhance plasticity in this structure becomes relevant to prevent or alleviate the effects of age-related cognitive decline[83] [84].

Memory systems are not equally affected by aging and some memory functions seem to be more prone to decline than others.

Studies presented by Nilsson in 2003[85] compared five types of memory: **episodic memory, semantic memory, short-term memory, perceptual representation system** and **procedural memory** to reveal that episodic memory (discussed below; see 'Memory, Creativity and Built Environment section) seems to be most affected by age[86], specifically the capability to encode new memories. Research findings suggest also that acquisition of new information declines uniformly with increasing age regardless of education, but recall remains relatively stable throughout age[87].

Two theoretical concepts, 'environmental complexity' and 'cognitive reserve' originating from different empirical roots—the sociology of work and brain injury respectively—provide explanations as to how cognitive activity affects the expression of cognitive impairment. These concepts provide explanations of how cognitive activity may benefit the cognitive system at two complementary levels, one being **psychosocial** ('environmental complexity') and the other being **neurophysiological** ('cognitive reserve'). The complementary nature of these concepts implies also that individuals are able to compensate for age related brain changes and often do not express symptoms of cognitive impairment or dementia[88].

Environmental Complexity hypothesis suggests that environments that have a positive effect on cognitive function are complex, whereas simple environments have a negative impact on cognition. The complexity of the environments depends on the diversity of the stimuli, the number of decisions to be undertaken including the number of considerations included in the decision making process. Complex environments are expected to be rewarding for cognitive effort and they motivate individuals to increase their cognitive and intellectual capacities which could be further used in various scenarios. On the contrary, simple environments could have a detrimental effect on intellectual capabilities[89].

Cognitive Reserve is a concept which could explain differences in cognitive functioning levels between individuals who have similar neurological deficits or similar changes related to aging processes. Two types of cognitive reserve have been proposed to explain these variations: the passive and the active model. The **passive (neuroanatomical) model of cognitive reserve** implies that the brain size or the number of brain neurons and synapses constitute the reserve which is determined genetically, and environment can influence it to a certain degree. The **active (functional) model of reserve** (most commonly used to speak about 'cognitive reserve') is concerned with 'neural processing' and 'synaptic organization' and suggests that they are sensitive to active environmental influences[90].

Likely, the most accurate explanation of cognitive reserve lies in the combination of passive (Nature) and active (Nurture) models. There is empirical support for the cognitive reserve hypothesis deriving from studies on rodents which have shown that mental stimulation and exercises boost **neurogenesis** (the growth of new neural cells), increases **synaptogenesis** (synaptic formation) and reduces deposition of beta-amyloid plaques involved in Alzheimer's disease. Recent research findings suggest that neurons being a product of adult neurogenesis mature for longer and grow larger compared to neurons created during infancy, suggesting that adult-born neurons may have a more powerful function and may play a critical role in **neuroplasticity**[91].

Studies on humans suggested that cognitive activity can aid structural changes of neurocognitive networks, modulate negative effects of stress hormones (i.e. cortisol) and can increase activity within some brain regions (i.e. prefrontal cortex) responsible for executive functioning (i.e. planning, problem-solving memorizing, self-awareness and self-motivation)[92].

KEY TAKEAWAY

The adult brain does have the capacity to grow and generate new connections (neurogenesis). We must shift from focusing on preventing cognitive decline, to promoting brain health as we age.

DESIGN PROMPTS

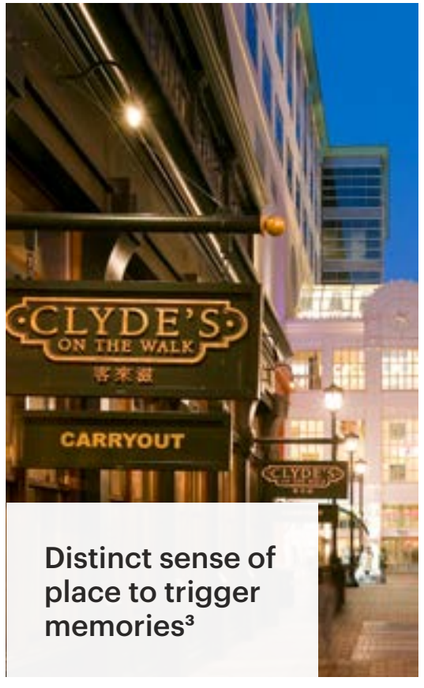
HOW MIGHT AN ENVIRONMENT BE DESIGNED TO ALLOW **CHOICE**, INFORM DECISIONS, AND ENCOURAGE **LEARNING,** TO ACTIVATE THE FRONTAL REGIONS OF THE BRAIN?

CAN A DEEP UNDERSTANDING OF THE FIVE TYPES OF MEMORY INFORM THE DESIGN OF **MEMORY SUPPORT** ENVIRONMENTS?

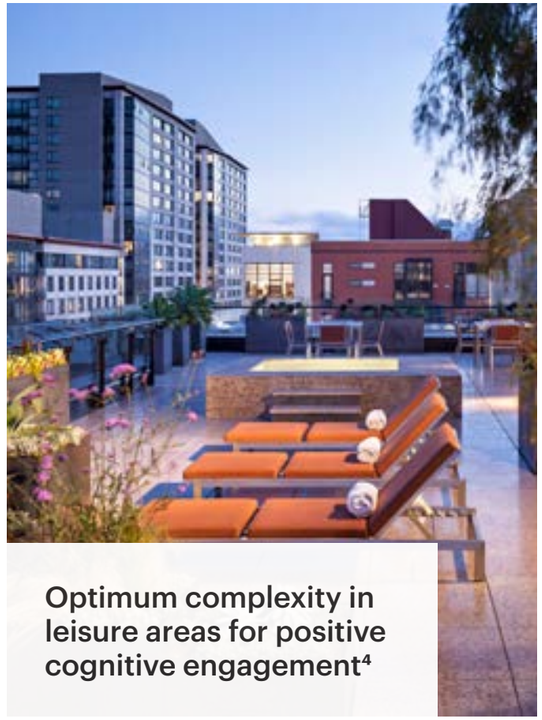
83. Trinchero et al. (2019). Rejuvenating brain with chronic exercise through adult neurogenesis
84. Miquel et al. (2018). Poor cognitive ageing: Vulnerabilities, mechanisms and the impact of nutritional interventions. Ageing Research Reviews
85. Nilsson LG. (2003). Memory function in normal aging. Acta Neurologica Scandinavica. Supplementum
86. Ibid.
87. R. C. Petersen, G. Smith, E. Kokmen, R. J. Ivnik, E. G. (1992) Memory function in normal aging. Tangalos Neurology.
88. Hughes. (2010).
89. Ibid.
90. Ibid.
91. Neuroscience News. (2020). Adult-Born Neurons Grow More Than Their Infancy-Born Counterparts - Neuroscience News. [online]
92. Ibid.

Inclusive intergenerational places to counter ageism & promote positive stereotypes[1]

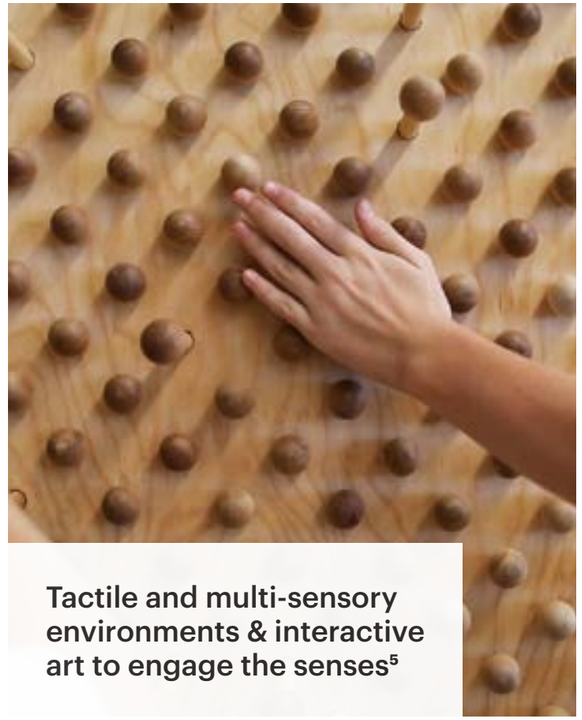
Spatial coherence in clearly delineated living areas to support ease of navigation[2]



Distinct sense of place to trigger memories[3]



Optimum complexity in leisure areas for positive cognitive engagement[4]



Tactile and multi-sensory environments & interactive art to engage the senses[5]

Providing a mix of opportunity for cognitive activity or positive distraction to stimulate the brain and senses or reduce stress[6]

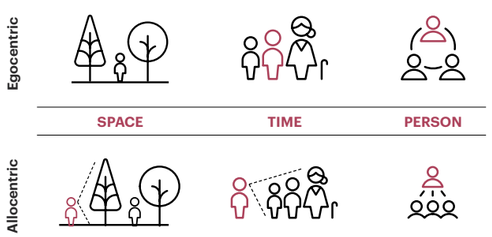
1. Pacific Plaza Pavilion | Dallas, TX, USA
2. The Vista at CC Young | Dallas, TX, USA
3. Gallery Place | Washington DC, USA
4. Arc Light Co. | San Francisco, CA, USA
5. Sensory Wellbeing Hub | Chicago, IL, USA
6. ProMedica Health & Wellness | Sylvania, OH, USA

Enriched Environments

The aging process happening within the hippocampus affects spatial memory and consequently the ability to navigate in space. Research suggests that humans spatial capabilities rely on the construction of predominantly two types of spatial representations:

- **allocentric perspective** constituted by object-to-object representations created based on inferences about spatial relations between objects,
- **egocentric perspective** which involves a self (or body)-to-object representational system[93]

It is allocentric processing that deteriorates with age, and the egocentric tends to remain unaffected[94]. Specifically speaking, the ability to uptake and learn new information about the environment deteriorates, however the old memory of landmarks and general layout remains intact. It implies that memory for the layout of long familiar city landmarks doesn't differ dramatically between young and older participants, however older population tends to make many more errors in learning new routes[95]. Interestingly,



Adapted from Gregory Peters-Founshtein

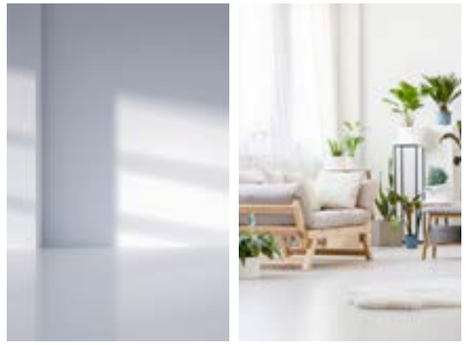
the ability to read maps does not seem to be impaired[96]. Growing evidence suggests that environmental factors often help to preserve cognitive abilities[97].

Neurogenesis and environmentally-mediated neuroplasticity remain the main candidates for a biological foundation explaining how the built environment could support healthy physiological aging. Animal models demonstrate that so-called **'enriched environments'** are capable of stimulating positive behavioral changes[98], i.e. animal's curiosity and exploration[99 100] linked to creativity in humans, and are beneficial in a number of psychiatric and neurodegenerative disorders[101 102 103]. Environmental enrichment (EE), is defined as "housing condition in which animals benefit from the sensory, physical, cognitive and social stimuliation provided, on brain and cognitive functions usually impaired during aging"[104].

The **lifespan theory of human development** created by Paul Baltes and his colleagues[105] distinguishes between two different mechanisms: **'neurobiological mechanics'** (individual genetic makeup, maturation and decline of neurological processes, etc.) and **'socio-cultural pragmatics'** which interact in a reciprocal fashion across the lifespan and constitute human cognitive adaptive balance at all ages. This theory implies also that there is no 'end state' to which an individual aims and that growth and change is possible at all stages of life. Social and environmental input is required to maintain stability[106].

Santiago Ramón y Cajal, a founding pioneer of modern neuroscience and the Nobel Prize winner from 1906, was the first one to propose that mental activity might trigger morphological changes in brain structure. The studies conducted almost 100 years later with the use of magnetic resonance imagining (MRI) demonstrated that experience can affect human brain volume and cortical thickness, as in the famous case of London's cab drivers whose hippocampus were more developed comparing to control group due to navigational demands[107].

STANDARD VS. ENRICHED ENVIRONMENTS



Inspired by "Environmental Enrichment as a Positive Behavioral Intervention Across the Lifespan" 104.

We now know much more about the role of 'place' in memory formation. Memories that involve personal experiences are encoded in a specific time and place. In 1972 a neurocognitive system supporting recollection of such memories was differentiated from other types of memory systems, and named **episodic memory**[108].

Place is an important part of encoding episodic memories and scientists since the 1970s have studied its influence on the process of memory recall[109]. Pieces of information that can trigger the recall are called **retrieval cues**[110]. Physical context is important because it helps to reinstate a memory. When exposed to a large number of retrieval cues from the environment, a person experiences a process of physical reinstatement and remembers a thought encoded together with these cues[111].

Nevertheless it was demonstrated that recall of information improves within so-called **complex-place context** (a combination of environmental cues and individual internal factors related to a performed task, i.e. motivation, engagement) comparing to **simple-place context** (reliance on surroundings only)[112].

This finding implies that engagement with place can potentially improve the process of recall of information.

KEY TAKEAWAY

Spatial coherence and engagement with the physical context of place can help with memory retrieval.

Sensory, physical, cognitive & social stimulation create enriched environments.

Enriched environments can preserve cognitive abilities.

Recall of information improves with complex-place context, environmental cues, and internal engagement.

DESIGN PROMPTS

HOW CAN WAY-FINDING DESIGN OR PROGRAMMING AND MASTER PLAN STRATEGIES CATER TO BOTH **ALLOCENTRIC AND EGOCENTRIC** PERSPECTIVES?

HOW MIGHT DESIGN ENFORCE **SPATIAL COHERENCE**?

HOW CAN A DESIGN ENGAGE MULTIPLE FORMS OF **INTERACTION** (SPATIAL, SENSORY, SOCIAL, EMOTIONAL...)?

HOW MIGHT WE EXPAND OUR THINKING ABOUT **PLACE-MAKING** TO INCLUDE ACTIVE **ENGAGEMENT WITH PHYSICAL CONTEXT**?

93. Ekstrom & Isham. (2017). Human spatial navigation: Representations across dimensions and scales. Curr Opin Behav Sci
94. Rosenbaum R Shayna, Winocur Gordon, Binns Malcolm, Moscovitch Morris (2012) Remote spatial memory in aging: all is not lost. Frontiers in Aging Neuroscience
95. Rosenbaum et al. (2012). Remote spatial memory in aging: all is not lost. Front. Aging Neurosci.
96. Wolbers Thomas, Dudchenko Paul, Wood Emma (2014) Spatial memory—a unique window into healthy and pathological aging. Frontiers in Aging Neuroscience.
97. Carpenter et al. (2012). Positive feelings facilitate working memory and complex decision making among older adults. Cognition and Emotion.
98. Sampedro-Piquero & Begega. (2017). Environmental Enrichment as a Positive Behavioral Intervention Across the Lifespan. Current Neuropharmacology
99. Lambert et al. (2005). Different types of environmental enrichment have discrepant effects on spatial memory and synaptophysin levels in female mice. Neurobiol. Learn. Mem.
100. Casarrubea et al. (2013). The temporal structure of the rats' behaviour in an elevated plus maze test. Behav. Brain Res.
101. Laviola et al. (2008). Effects of enriched environment on animal models of neurodegenerative diseases and psychiatric disorders. Neurobiology of Disease
102. Anastasía et al. (2009). Enriched environment protects the nigrostriatal dopaminergic system and induces an astroglial reaction in the 6-OHDA rat model of Parkinson's disease. J. Neurochem.
103. Nithianantharajah et al. (2008). Gene-environment interactions modulating cognitive function and molecular correlates of synaptic plasticity in Huntington's disease transgenic mice. Neurobiol. Dis.
104. P. Sampedro-Piquero and A. Begega, "Environmental Enrichment as a Positive Behavioral Intervention Across the Lifespan", Current Neuropharmacology (2017) 15:459.
105. Baltes, Paul B. (2006).
106. Coen and Rugg. (2019).
107. Brozzoli et al. (2017).
108. Tulving, E. (1972).
109. Godden, D.R. and Baddeley, A.D. (1975). Context dependent memory in two natural environments: on land and underwater. British Journal of Psychology
110. Tulving, E., & Thomson, D. M. (1973).

Creativity as a Design Strategy

Creativity enforces engagement. Based on the complex-place context theory we hypothesize that interaction with space in a creative way can strengthen the cue-target association and ease the recall of information.

Episodic memory has been reported to be affected by aging more than other memory systems[113]. In comparative studies of processing contextual information between older and younger adults it was shown that older adults have more difficulties with integration of information and context into an ensemble, even though they process associated context[114]. Thus based on the previous studies we hypothesize that engagement constitutes an important element affecting the processing of contextual information.

Creating age-friendly, and more importantly “aging-friendly" environments is a significant opportunity for the built environment—ranging from how we design the interiors of our buildings, to the design of our cities. This is not about creating simple replicas of distant pasts, but rather meaningful and engaging environments that allow creative explorations to promote healthy aging of both body and brain.

Mental simulation underlies some of the most fundamental cognitive skills. It is related with brain areas involved in operations such as episodic memory, future thinking, and problem solving[115].

Episodic future thinking, relying on episodic memory[116], produces performance benefits, including decision making, emotion regulation, prospective memory, and spatial navigation[117].

The cognitive mechanisms underlying creativity have long been discussed in relation to operations of **declarative memory** (or explicit memory), that is a neurocognitive system concerned with our ability to consciously recollect facts (semantic memory) and episodic information (episodic memory)[118] [119] .

Individual differences in creativity tasks performance were previously linked with a variety of ways in which ideas or concepts are accessed and associated with one another.[120] [121] [122]

Some studies highlight the role of episodic memory in **divergent creative thinking**[123] and suggest that some aspects of creativity depend on recall processes linked with this memory type[124].

Other studies on creativity in aging population indicate that creativity can also lessen effects of depression and dementia and increase social support. Hope, better emotional regulation, and improved communication are mentioned among positive effects of art and music therapies[125].

Research conducted on a group of patients with Alzheimer’s disease encourages the view that performing creative tasks has the potential of improving memory, reading, writing, and word games. It can increase one's vocabulary and defend against memory loss[126]. The process of idea generation can be understood as a state of focused internally-directed attention (reflective attention) and involves controlled semantic retrieval. The generation of new ideas, as opposed to the retrieval of old ideas, was associated with stronger activation within a brain region (left inferior parietal cortex) known to be involved in mental simulation, imagining, and future thought[127].

Scientists believe that practice might help to minimize negative effects of cognitive decline e.g. in the area of episodic memory and memory encoding[128]. Tests on how cognitive training is affecting memory are ongoing and showing promising results. Nevertheless the amount of research is still not large enough to come to a definite conclusion on their influence[129]. Art therapy also shows promising results in positive influence on cognitive decline and memory deterioration[130] [131].

KEY TAKEAWAY

Meaningful, engaging environments that allow creative explorations promote healthy aging.

DESIGN PROMPTS

HOW CAN A DESIGN FOSTER **ENGAGEMENT THROUGH CREATIVITY**?

HOW CAN A DESIGN STRATEGICALLY **INCORPORATE THE ARTS** (MUSIC, SCULPTURE, PAINTING, POETRY...) TO PROVIDE COGNITIVE ACTIVITIES?

111. Isarida, Takeo & Isarida, T.K.. (2014). Environmental context-dependent memory.
112. Ibid.
113. Nilsson LG. (2003). Memory function in normal aging. Acta Neurologica Scandinavica. Supplementum.
114. Ute J. Bayen, Matthew P. Phelps, Julia Spaniol, (2000) Age-Related Differences in the Use of Contextual Information in Recognition Memory: A Global Matching Approach, The Journals of Gerontology.
115. Landriscina, Franco. (2014). The role of mental simulation in understanding and in creating scientific concepts.
116. Wang, T., Yue, T., & Huang, X. T. (2016). Episodic and Semantic Memory Contribute to Familiar and Novel Episodic Future Thinking. Frontiers in Psychology.
117. Schacter, D. L., Benoit, R. G., & Szpunar, K. K. (2017). Episodic Future Thinking: Mechanisms and Functions. Current opinion in behavioral sciences,
118. Abraham A. (2016). Commentary: Creativity and Memory: Effects of an Episodic-Specificity Induction on Divergent Thinking. Front. Psychol.
119. Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson, Organization of memory. Academic Press.
120. Abraham A. (2016). Commentary: Creativity and Memory: Effects of an Episodic-Specificity Induction on Divergent Thinking. Front. Psychol.
121. Mednick, S. (1962). The associative basis of the creative process. Psychological Review
122. Mendelsohn G. A. (1974). Associative and attentional processes in creative performance. J. Pers.
123. Madore et al. (2015). Creativity and memory: effects of an episodic-specificity induction on divergent thinking. Psychol. Sci.
124. Ibid.
125. Price, K. A., & Tinker, A. M. (2014). Creativity in later life. Maturitas, 78(4), 281-286.
126. Hannemann, Beat Ted. 2006. Creativity with dementia patients. Gerontology 52: 59-65.
127. Benedek, Mathias & Jauk, Emanuel & Fink, Andreas & Koschutnig, Karl & Reishofer, Gernot & Ebner, Franz & Neubauer, Aljoscha. (2013). To create or to recall? Neural mechanisms underlying the generation of creative new ideas. NeuroImage.
128. Mahncke HW, Connor BB, Appelman J, Ahsanuddin ON, Hardy JL, Wood RA, Joyce NM, Boniske T, Atkins SM, Merzenich MM. (2006) Memory enhancement in healthy older adults using a brain plasticity-based training program: a randomized, controlled study. Proc Natl Acad Sci USA.
129. Ranganath, C., Flegal, K. E., & Kelly, L. L. (2011). Can cognitive training improve episodic memory?. Neuron, 72(5), 688–691. https://doi.org/10.1016/j.neuron.2011.10.022
130. Mahendran, R., Gandhi, M., Moorakonda, R.B. et al. (2018) Art therapy is associated with sustained improvement in cognitive function in the elderly with mild neurocognitive disorder: findings from a pilot randomized controlled trial for art therapy and music reminiscence activity versus usual care. Trials.

KEY TAKEAWAYS

Due to the high costs of long-term care and associated physical, mental, and emotional stress it has on older adults and their family members, any kind of community interventions keeping people participating in the community for as long as possible become an important investment [139].

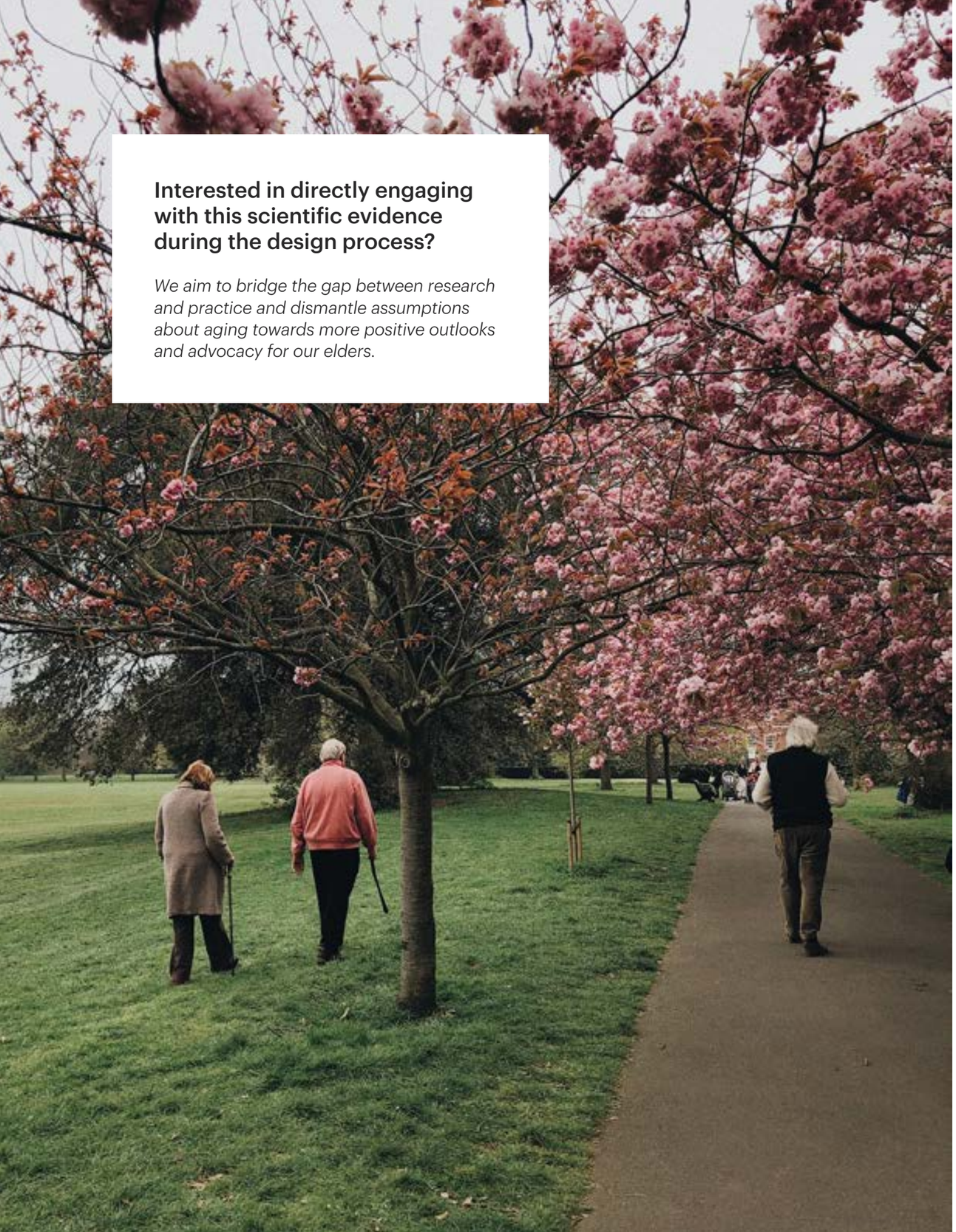
Built environments could become a prophylactic tool supporting healthy and successful aging, by offering opportunities to engage in activities preventing cognitive decline.

Throughout this document we have explored the neurobiological underpinnings of 'age-related cognitive decline' and the significance of 'enriched environments' in mitigation of cognitive impairment.

1. **Aging is a global trend- and affects ALL of us. We must avoid stereotypes associated with Aging**
2. **Not all abilities decline equally with age. Speed of processing, memory, spatial ability and reasoning are particularly vulnerable.**
3. **During COVID, our seniors have been disproportionately affected, and there is a risk going forward that we address only physical rather than social and cognitive needs.**
4. **The brain is plastic and can generate new connections through neurogenesis**
5. **Enriched environments that promote sensory, motor, cognitive and social, engagement can aid neurogenesis and prevent cognitive decline**
6. **Complex-place contexts (enrichment + engagement), and positive associations can help with cognitive activity and reduced stress. Engagement with place via creativity and art can create complex-place context to aid memory retrieval.**

ENRICHED + ENGAGING ENVIRONMENTS	→	COGNITIVE OUTCOMES	→	HEALTHY AGING
SENSORY + MOTOR + COGNITIVE + SOCIAL STIMULI OPTIMAL COMPLEXITY SPATIAL COHERENCE POSITIVE ASSOCIATION		PREVENT COGNITIVE DECLINE PROMOTE BRAIN HEALTH AND GROWTH		QUALITY OF LIFE PHYSICAL, COGNITIVE, AND EMOTIONAL WELLBEING

139 Sykes, Kathleen E. & Robinson, Kristen N. 2014. Making the right moves: promoting smart growth and active ageing in communities. Journal of ageing & social policy.



Interested in directly engaging with this scientific evidence during the design process?

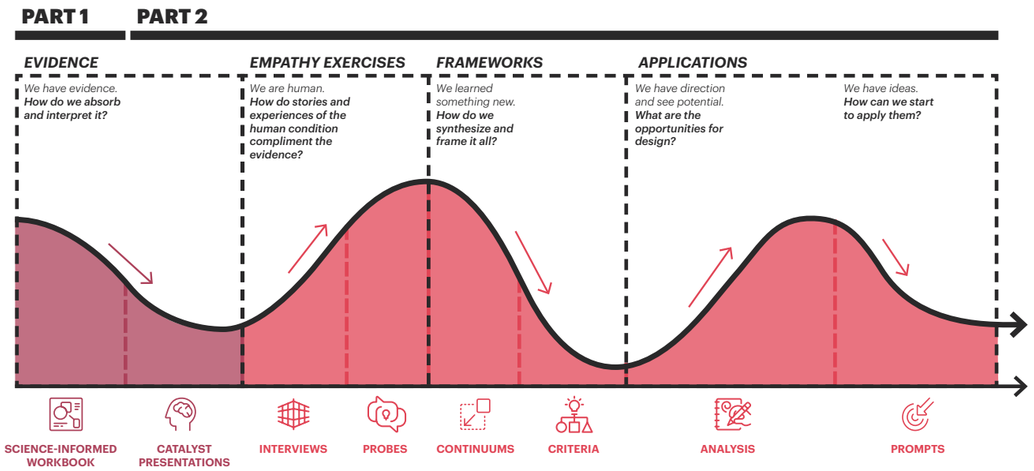
We aim to bridge the gap between research and practice and dismantle assumptions about aging towards more positive outlooks and advocacy for our elders.

Evidence-based Ideation Workshop

Designing for Brain Health in Older Adults

HKS provides intensive and comprehensive workshops where a team of design researchers and experienced practitioners walk novice or experienced designers, owners, and operators through neuroscience-based evidence, provocative catalyst presentations, and interactive empathy exercises to ideate and develop applicable design concepts that can change the conversation around designing for aging from preventing cognitive decline to promoting brain health to achieve systemic outcomes for healthy aging.

Contact HKS Research at research@hksinc.com for a four hour intensive or two day comprehensive guided explorations workshop that combines evidence & empathy - and results in new innovative ideas to promote brain health BY design in older adults.



References

Abraham A. (2016). Commentary: Creativity and Memory: Effects of an Episodic-Specificity Induction on Divergent Thinking. Front. Psychol.

Abrams et al. (2006). "An age apart: the effects of intergenerational contact and stereotype threat on performance and intergroup bias," Psychology and Aging

Anastasia et al. (2009). Enriched environment protects the nigrostriatal dopaminergic system and induces an astroglial reaction in the 6-OHDA rat model of Parkinson's disease. J. Neurochem.

Ashby et al. (1999). A Neuropsychological Theory of Positive Affect and Its Influence on Cognition. Psychological Review

Baltes, Paul B. (2006). Lifespan development and the brain. Cambridge, UK: Cambridge University Press

Becker et al. (2016). A network-level analysis of cognitive flexibility reveals a differential influence of the anterior cingulate cortex in bilinguals versus monolinguals. Neuropsychologia

Benedek, Mathias & Jauk, Emanuel & Fink, Andreas & Koschutnig, Karl & Reishofer, Gernot & Ebner, Franz & Neubauer, Aljoscha. (2013). To create or to recall? Neural mechanisms underlying the generation of creative new ideas. NeuroImage.

Brozzoli et al. (2017). Expansion and Renormalization of Human Brain Structure During Skill Acquisition. Trends in Cognitive Sciences

Burdick, G. (2019). The Workforce Is Aging—We Need to Keep It Healthy and Safe - EHS Daily Advisor. EHS Daily Advisor.

Byoung Hoon Oh, M.D. (2004). Psychosocial Aspects of Normal Ageing. J Korean Med Assoc.

Caballero et al. (2016). Advanced analytical methodologies for measuring healthy ageing and its determinants, using factor analysis and machine learning techniques: the ATHLOS project. Nature

Casarrubea et al. (2013). The temporal structure of the rats' behaviour in an elevated plus maze test. Behav. Brain Res.

Carpenter et al. (2012). Positive feelings facilitate working memory and complex decision making among older adults. Cognition and Emotion

Coen and Rugg. (2019). Neural Dedifferentiation in the Aging Brain. Trends in Cognitive Sciences

Corley et al. (2009). Age-associated cognitive decline. British Medical Bulletin

Corner et al. (2004). Social aspects of ageing. Psychiatry

Corner et al. (2006). Social aspects of ageing. Women's Health Medicine

Craik & Bialystok. (2006). Cognition through the lifespan: mechanisms of change. Trends in Cognitive Sciences

Dionigi, R. A. (2015). Stereotypes of Aging: Their Effects on the Health of Older Adults. Journal of Geriatrics, 2015, 1–9. doi: 10.1155/2015/954027

Ekstrom & Isham. (2017). Human spatial navigation: Representations across dimensions and scales. Curr Opin Behav Sci

Evans, Gary. (2003). The Built Environment and Mental Health. Journal of Urban Health: Bulletin of the New York Academy of Medicine

Fassino, Secondo, Leombruni, Paolo, Daga, Giovanni Abbate, Brustolin, Annalisa, Rovera, Giovanni Giacomo & Fabris, Fabrizio. 2002. Quality of life in dependent older adults living at home. Archives of gerontology and geriatrics 35: 9-20.

Galvan & Jin. (2007). Neurogenesis in the aging brain. Clinical Interventions in Ageing.

Garrido-Gil et al. (2018). Ageing-related dysregulation in enteric dopamine and angiotensin system interactions: implications for gastrointestinal dysfunction in the elderly. Oncotarget

Garris et al. (2002). Games, Motivation, and Learning: A Research and Practice Model. SAGE Journals.

Giles-Corti, Billie & King, Abby C. 2009. Creating active environments across the life course:"thinking outside the square". British journal of sports medicine 43: 109-113.

Godden, D.R. and Baddeley, A.D. (1975), Context- dependent memory in two natural environments: on land and underwater. British Journal of Psychology

Gureje et al. (2015). 'Profile and determinants of successful ageing in The Ibadan Study of Ageing'. J Am Geriatr Soc

Hannemann, Beat Ted. 2006. Creativity with dementia patients. Gerontology 52: 59-65.

Hanninen et al. (1996). Prevalence of Ageing-associated Cognitive Decline in an Elderly Population. Age and Ageing

References (Continued)

Harrison, S., 2020. Some Nursing Homes Escaped Covid-19—Here's What They Did Right. [online] Wired. Available at: <https://www.wired.com/story/some-nursing-homes-escaped-covid-19-heres-what-they-did-right/> [Accessed August 2020].

Hemby et al. (2003). Neuron-Specific Age-Related Decreases in Dopamine Receptor Subtype mRNAs. J Comp Neurol.

Holt, Nicolette R; Neumann, Johannes T; McNeil, John J; Cheng, Allen C. (2020). Implications of COVID-19 in an ageing population. Published online: 6 May 2020. Med J Aust

Hughes. (2010). Promotion of cognitive health through cognitive activity in the aging population. Ageing Health

Isarida, Takeo & Isarida, T.K.. (2014). Environmental context-dependent memory.

J. M. Hausdorff, B. R. Levy, and J. Y. Wei, "The power of ageism on physical function of older persons: reversibility of age-related gait changes," Journal of the American Geriatrics Society, vol. 47, no. 11, pp. 1346–1349, 1999.

Johnson, Richard W., 2003. Changing The Age Of Medicare Eligibility. [online] Urban Institute. Available at: <https://www.urban.org/research/publication/changing-age-medicare-eligibility/view/full_report> [Accessed August 2020].

Kane et al. (2017). Interventions to Prevent Age-Related Cognitive Decline, Mild Cognitive Impairment, and Clinical Alzheimer's-Type Dementia. Comparative Effectiveness Reviews, No. 188

Karrer et al. (2017). Reduced dopamine receptors and transporters but not synthesis capacity in normal ageing adults: a meta-analysis. Neurobiology of Ageing

Kravitz et al. (2012). Cognitive Decline and Dementia in the Oldest-Old. Rambam Maimonides Med J

Lambert et al. (2005). Different types of environmental enrichment have discrepant effects on spatial memory and synaptophysin levels in female mice. Neurobiol. Learn. Mem.

Landriscina, Franco. (2014). The role of mental simulation in understanding and in creating scientific concepts.

Laviola et al. (2008). Effects of enriched environment on animal models of neurodegenerative diseases and psychiatric disorders. Neurobiology of Disease

Lee, R., Wong, J., Shoon, W., Gandhi, M., Feng, L., et al. (2018). Art therapy for the prevention of cognitive decline. The Arts in Psychotherapy.

Leung, G. Lam, L. C. W. (2011). Examining the association between late-life leisure activity participation and global cognitive decline in community-dwelling elderly Chinese in Hong Kong. International journal of geriatric psychiatry, 26(1), 39-47.Chicago

Löckenhoff et al. (2009). Perceptions of aging across 26 cultures and their culture-level associates.Psychology and Aging

Lupien, S. J., & Wan, N. (2004). Successful ageing: from cell to self. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 359(1449), 1413–1426. https://doi.org/10.1098/rstb.2004.1516

Madore et al. (2015). Creativity and memory: effects of an episodic-specificity induction on divergent thinking. Psychol. Sci.

Mahendran, R., Gandhi, M., Moorakonda, R.B. et al. (2018) Art therapy is associated with sustained improvement in cognitive function in the elderly with mild neurocognitive disorder: findings from a pilot randomized controlled trial for art therapy and music reminiscence activity versus usual care. Trials

Mahncke HW, Connor BB, Appelman J, Ahsanuddin ON, Hardy JL, Wood RA, Joyce NM, Boniske T, Atkins SM, Merzenich MM. (2006) Memory enhancement in healthy older adults using a brain plasticity-based training program: a randomized, controlled study. Proc Natl Acad Sci USA

McEvoy, J., 2020. Nursing Homes Account For Over 40% Of U.S. Coronavirus Deaths. [online] Forbes. Available at: <https://www.forbes.com/sites/jemimamcevoy/2020/06/16/nursing-homes-account-for-over-40-of-us-coronavirus-deaths/#1204e975300b> [Accessed August 2020].

Mednick, S. (1962). The associative basis of the creative process. Psychological Review

Mendelsohn G. A. (1974). Associative and attentional processes in creative performance. J. Pers.

Miquel et al. (2018). Poor cognitive ageing: Vulnerabilities, mechanisms and the impact of nutritional interventions. Ageing Research Reviews

Neuroscience News. 2020. Adult-Born Neurons Grow More Than Their Infancy-Born Counterparts - Neuroscience News. [online] Available at: <https://neurosciencenews.com/adult-neuron-growth-16569/> [Accessed August 2020].

Nilsson LG. (2003). Memory function in normal aging. Acta Neurologica Scandinavica. Supplementum

Nithianantharajah et al. (2008). Gene-environment interactions modulating cognitive function and molecular correlates of synaptic plasticity in Huntington's disease transgenic mice. Neurobiol. Dis.

Overview - Population - Eurostat. [online] Available at: <https://ec.europa.eu/eurostat/web/population> [Accessed August 2020].

Price, K. A., & Tinker, A. M. (2014). Creativity in later life. Maturitas, 78(4), 281-286.

Prenderville et al. (2015). Adding fuel to the fire: the impact of stress on the ageing brain. Trends Neuroscience

Poscia et al. (2016). Workplace health promotion for older workers: a systematic literature review. BMC Health Services Research

R. C. Petersen, G. Smith, E. Kokmen, R. J. Ivnik, E. G. (1992) Memory function in normal aging. Tangalos Neurology

Raggi et al. (2016) Determinants of Quality of Life in Ageing Populations: Results from a Cross-Sectional Study in Finland, Poland and Spain. PLoS ONE

Ranganath, C., Flegal, K. E., & Kelly, L. L. (2011). Can cognitive training improve episodic memory?. Neuron, 72(5), 688–691. https://doi.org/10.1016/j.neuron.2011.10.022

Rosenbaum R Shayna, Winocur Gordon, Binns Malcolm, Moscovitch Morris (2012) Remote spatial memory in aging: all is not lost. Frontiers in Aging Neuroscience

Rosenbaum et al. (2012). Remote spatial memory in aging: all is not lost. Front. Aging Neurosci.

Poscia et al. (2016). Workplace health promotion for older workers: a systematic literature review. BMC Health Services Research

Sampedro-Piquero & Begega. (2017). Environmental Enrichment as a Positive Behavioral Intervention Across the Lifespan. Current Neuropharmacology

Schacter, D. L., Benoit, R. G., & Szpunar, K. K. (2017). Episodic Future Thinking: Mechanisms and Functions. Current opinion in behavioral sciences,

Scott, A. & David, J. (April, 2020). The interaction between Covid-19 and an ageing society. https://voxeu.org/article/interaction-between-covid-19-and-ageing-society

Sykes, Kathleen E. & Robinson, Kristen N. 2014. Making the right moves: promoting smart growth and active ageing in communities. Journal of ageing & social policy

Trinchero et al. (2019). Rejuvenating brain with chronic exercise through adult neurogenesis

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson, Organization of memory. Academic Press.

United Nations ESCAP, Social Development Division. 2016 Population Data Sheet. 9 September 2016 revision.

UNFPA EECARO. (April, 2020). Ageing populations & COVID-19 risk.

Ute J. Bayen, Matthew P. Phelps, Julia Spaniol, (2000) Age-Related Differences in the Use of Contextual Information in Recognition Memory: A Global Matching Approach, The Journals of Gerontology

Wang, T., Yue, T., & Huang, X. T. (2016). Episodic and Semantic Memory Contribute to Familiar and Novel Episodic Future Thinking. Frontiers in psychology

Wass et al. (2018). Dopamine D1 receptor density in the mPFC responds to cognitive demands and receptor turnover contributes to general cognitive ability in mice. Scientific reports. Nature

What Is Healthy Ageing. Available online: http://www.who.int/ageing/healthy-ageing/en/

Wolbers Thomas, Dudchenko Paul, Wood Emma (2014) Spatial memory—a unique window into healthy and pathological aging. Frontiers in Aging Neuroscience

Wong, R. (2018). A New Strategic Approach to Successful Aging and Healthy Aging. Geriatrics

World Population Ageing. Highlights. (2017). United Nations

Yang et al. (2015). Aging and Exercise Affect Hippocampal Neurogenesis via Different Mechanisms. PLOS One

Yang et al. (2012). Positive affect improves working memory: Implications for controlled cognitive processing. Cognition and Emotion

Zhang, Wei & Niu, Weihua. 2013. Creativity in later life: Factors associated with the creativity of the Chinese elderly. The Journal of Creative Behavior 47: 60-76.

WORLD HEADQUARTERS

350 N. St. Paul, Suite 100
Dallas, Texas 75201

ABOUT HKS

HKS is a global firm of architects, designers, advisors and makers driven by curiosity and devoted to creating places that combine beauty with performance. Our 1,350 people in 23 locations are united by our shared culture and sense of purpose. We value honesty, diversity and inclusion and we celebrate creative thinking across our firm. In partnership with each other, our clients and our partners, we craft powerful ideas and solutions. Together we create places that stand apart.

research@hksinc.com
www.hksinc.com

HKS