

A Review Article: Fall Incidents and Interior Architecture— Influence of Executive Function in Normal Ageing

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Abstract

Many ageing people are staying at home, whether they are self-isolating or social distancing, because of the current Covid-19 situation. Fall incidents at home among the ageing are significantly associated with a high level of mortality. Bathrooms are frequently reported as a major environmental hazard in connection with falls. This serious health risk raises the matter of interior architecture. In terms of preventing falls, more architectural research focuses on interior elements e.g., handrail design, and non-slip mat, whilst less attention is paid to the issue of how ageing causes falls. Therefore, this article sheds light on the normal ageing process through an executive function that helps in the fall prevention of ageing people via decision-making and problem-solving. Normal ageing gradually results in declining executive function, including cognitive and motor functions, which limits and reduces day to day activities. The cognitive function (as a system) involves processing speed, accuracy in response, and error response whereas the motor function (as a mechanism) defines both gross and fine motor functions. A combination of cognitive and motor functions reflects conditions that may lead to a fall. Regarding the executive function, interior architecture for preventing falls in normal ageing people is strongly encouraged e.g., clear layout, timesaving activity, simplicity of design, lighting uniformity, short walking distance, cased opening, lightweight fixtures, and fine texture flooring. This article reviews the literature to address the knowledge gaps between interior architecture and human-centred design through ageing ergonomics, and employs a behaviour-focused aspect to interpret results for interior architects. Electronic databases, including Scopus, PubMed, and Google Scholar, were searched to specify appropriate papers, which were restricted to those in the English language. To improve the quality of the elderly's life, this article provides recommendations that could assist interior architects in this challenge.

Keywords

Falls; Interior architecture; Executive function; Ageing ergonomics; Ageing people

1. Introduction

Fall incidents resulting in unintentional injury deaths amongst the ageing population have been increasing (World Health Organization [WHO], 2008), with around 684,000 deaths annually caused by falls worldwide. More than two-thirds of those deaths occur in low- and middle-income countries (World Health Organization [WHO], 2021). Almost half of the falls amongst ageing people occur within their residence. Bathroom, bedroom, kitchen, and staircase areas are frequently noted as environmental fall hazards. Also, designs of flooring, stepping, and lighting are repeatedly reported problems as fall risk factors (Chuangchai, 2017c; Rogers et al., 2004). These serious issues highlight the question of ageing in place design that may be effectively addressed by interior architects. Undeniably, interior architects are in an appropriate position to address these challenges and to be able to deliver with their creative solutions. The solutions for residential interior architecture should ensure that ageing people do not have to decide between a healthy and safe lifestyle and being able to live independently with control over their spaces.

Lifespan for both males and females has extended progressively over the past century due to medical innovation and improvement of living standards (Pothisiri & Quashie, 2018). Many more ageing people are living longer as reflected by the percentage of people aged over 60 years (Pothisiri et al., 2020). The ageing population has rapidly increased across the globe, but the phenomenon is particularly true in Thailand (Chuangchai & Suwanprasert, 2015). Several lines of physiological activities and executive functions decline during the ageing process (Fjell et al., 2016; Gross et al., 2016; Klimova et al., 2017). Degeneration of executive function is one of the challenges for normal ageing as the process of developing and maintaining the functional ability for daily activities and well-being are negatively impacted with ageing. Executive dysfunction refers to both neurocognitive impairment and behavioural symptoms such as psychopathologies and mental disorders. Risk factors of executive dysfunction in normal ageing are associated with genetic and environmental factors in the neurocognitive processes. Ageing people with weak executive function are at a greater risk of accidents and injuries e.g., trip, slip, and fall (Herman et al., 2010; Kearney et al., 2013; Mirelman et al., 2012b). Such accidents and injuries also contribute to a poorer quality of life, disabilities, and mortalities (Chuangchai, 2017a; Rosado-Artalejo et al., 2017).

Fall incidents also illustrate the relationship between normal ageing and residential interior architecture, and its negative impacts on quality of life. We have the opportunity to prove that good design matters, thereby supporting ageing people with provision of a harmless, dignified, and healthy home (Chuangchai, 2017c). One way to minimise the cycle of falling through interior architecture may be approached by a better understanding of age-related changes. Hence, it is important to understand how executive function declines with age in order to design strategies or approaches that could decrease the effects of executive dysfunction, resulting in improved health with a higher quality of life in ageing people. This article, therefore, aims to provide a review of our current understanding with respect to executive function in normal ageing and provide logical criticism derived from surrounding evaluation through ageing ergonomics. The article is useful in providing supportive information for interior architects, experts, specialists, and ergonomists to design a built environment for reducing fall incidents and/or injuries in ageing people with executive function impairment. The paper also adds relevant knowledge to associated health-related areas e.g., universal design, design for disabilities, and ergonomics in design for the future.

2. Ageing ergonomics

To reduce and prevent fall incidents in interior space amongst ageing people, their limitations and needs should be considered during the pre-design stage. Ageing ergonomics is one of the potential concepts of applied science for interior architecture that is applicable to help prevent fall incidents. It is an interdisciplinary design concept that focuses on age-related changes in aspects of physical activity, physiological function, and psychological circumstance (Cammen & Albayrak, 2019). Moreover, ageing ergonomics is primarily aimed to support ageing people to independently perform an extensive range of activities and instrumental activities of daily living (Righi & Blat, 2017). It not only seeks to alleviate risk factors of falls but also offers innovative solutions for successful ageing (Hignett & Wolf, 2016). It has been determined that when the dwelling is ergonomically designed, then a greater advantage in a safe and healthy living environment will be achieved (Ahasan et al., 2001). These illustrated that ageing ergonomics is associated with the interactions between individuals and built environments to design for maximising well-being and quality of life, (e.g., a barrier-free environment, design for sustainability, or flexibility and adaptability of living space) which makes approaches to ageing ergonomics even more important for housing design. Therefore, the application of ageing ergonomics could improve positive correlations amongst non-fall incidents, the interior architecture of the living environment, and executive function in normal ageing people.

3. Executive function

Executive function considers a set of higher-order operations in the human brain (Ferguson et al., 2021). In addition, it refers to a special pathway for a specific task, particularly in relation to an unpredictable circumstance, such as behavioural control, decision-making and problem-solving (Chuangchai & Siripakarn, 2019). Some of the main purposes of executive function include the ability to effectively manage and pay attention to behaviour or activity with smooth success (Chiu et al., 2018). Besides, the executive function is a part of several abilities e.g., planning and reasoning including mental flexibility (Ferguson et al., 2021). The executive function is highly associated with two processes, which are cognitive and motor functions (Chuangchai & Siripakarn, 2019). The cognitive function plays an important role as a part of higher-order systems of the brain whereas the motor function acts as mechanical systems of the body (Chuangchai, 2017b) as shown in Figure 1. The coordination of these two processes is essential for effective performance in humans. Moreover, the structure, morphology and connectivity of networks (e.g., neurons, dendrites, axons, and synapses) in the brain mostly appear to change with advancing age. These are significantly lost and reduced but do not die. However, the ageing process affects the nervous system as well as the cognitive and motor functions resulting in impairment of executive functions that is frequently linked to falling in various aspects. Previous studies indicated that ageing people showed declining executive functions and were more likely to have the potential to experience a first-time falling accident (Herman et al., 2010; Mirelman et al., 2012). Conversely, successful ageing is more likely to have a much better executive function baseline than ageing with falls (Chuangchai & Siripakarn, 2019). The foregoing discussion suggests that the improvement of executive function through higher-order systems of cognitive function or mechanical systems of motor function could have benefits for the prevention of fall incidents. Therefore, design for enhancing the executive function in ageing people as an intervention focused on removing fall incidents should be considered by interior architects.

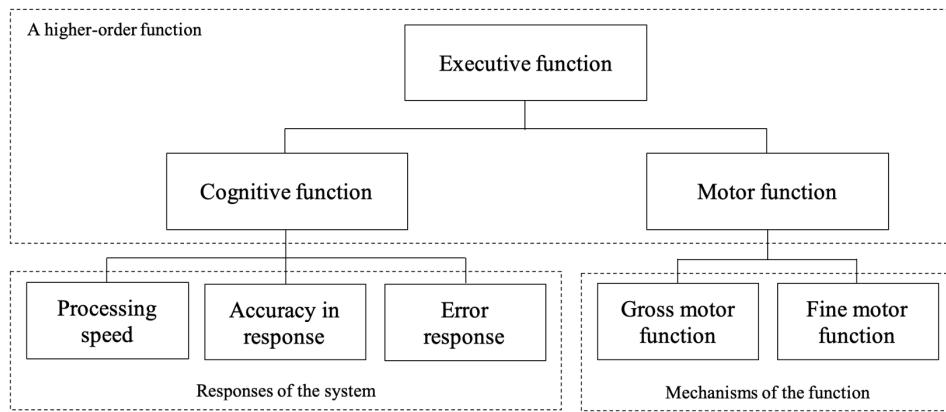


Figure 1. Flow diagram defining an overview of executive function in the article.

Note: Adapted from Chuangchai, 2017b.

4. Cognitive function

The cognitive function is associated with brain-based skills that are widely used to indicate differences in intelligence in all ages (Nouchi & Kawashima, 2014). The cognitive functioning involved with various mental processes, include thinking, learning, remembering, reasoning, problem-solving, decision-making, and attention (Fisher et al., 2019). The cognitive function gradually declines over time and is a normal ageing process (Chuangchai & Siripakarn, 2017, 2018a). Processing speed, accuracy in response, and error response are a set of abilities that refers to the function of cognition (Smith & Brewer, 1995). The processing speed is related to the time domain whereas the accuracy and error are related to the frequency domain. The processing speed reflects the time duration of performances. The accuracy and error reflect as correct and incorrect answers respectively, which are registered in multiple units e.g., numbers, counts, rates, or percentages (Vandierendonck, 2017). There is evidence that speed and accuracy are balanced for accomplishment of the most correct answers per unit time in younger participants. In contrast, errors in ageing participants were minimised through slower responses (Starns & Ratcliff, 2010). Together, the processing speed, accuracy, and error contribute a challenge through cognitive function, particularly when it comes to several stimuli and multiple conditions. The difficulty of a task is greater when it has to be managed within a limit of time. These illustrations show better cognitive function may produce quicker decisions, increase the quality of choice selection, and minimise mistakes, collectively which help to avoid fall incidents. However, an interior architecture with several distractions and many choices (e.g., a complex layout with multiple junctions) can exacerbate decline in cognitive function, which can lead to unintentionally falls.

4.1 Processing speed

The speed of processing is a response in performing tasks or activities, which is reflected by reaction time (Ball et al., 2007). There are various causes of slower or delayed processing speed e.g., lack of autonomic responses, poor motor functions, as well as advancing age (Eckert et al., 2010). The slowing of processing speed is reflected by worse test performance on many types of tasks that involve a timed response (Kyllonen & Zu, 2016). Many cognitive tests and neuropsychological tests are used for clinical assessments of processing speed capacities in humans. Previous studies demonstrated that people with healthy ageing have slower processing speed compared with a younger age (Manard et al., 2014; Vallesi et al., 2021). However, it is worth noting that most of the cognitive tests are partially associated with motor function, rather than cognitive function

alone. Since the reaction response reflects processing speed, the interplay of motor response necessarily is a component of this speed (Ebaid et al., 2017). General predictable activities, known as behaviours, are involved with reaction time but do not require the processing speed to complete the tasks. In contrast, unpredictable events, such as fall incidents, require rapid reaction time as reflected by the processing speed in order to successfully navigate the situation. Ageing people with a fast speed of processing are more likely to have a low impact resulting from falls. From another point of view, reducing the number of tasks to perform would decrease reaction time. Unnecessary tasks that are time-consuming should be excluded. Interior architects need to be careful with unnecessary activities that may be related to psychological and mental health in ageing people.

4.2 Accuracy in response

The accuracy in cognition, in general, reflects responding results that fit or are close to an actual value, whereas the precision reflects the consistency of the responding results. Both accuracy and precision are correlated to the frequency domain. The correlations between the accuracy and precision can reflect either parallel or unparallel conditions e.g., accurate and precise, accurate but not precise, not accurate but precise, or not accurate and not precise. Moreover, accuracy is negatively associated with the processing speed and error and somehow falls between the processing speed and error. Besides, as a correct answer, accuracy is opposite to an incorrect answer, which is an error. However, a trade-off between accuracy and processing speed as well as the ratio between accuracy and error may not be applied equally to every task since other related-factors also have an influence e.g., motivation, fatigue, and a prolonged period of testing time (Brébion, 2001; Salthouse, 1979; Selgrade et al., 2020). Regarding the right decision, accuracy alleviates and may even decrease the chance of falls. Given these relationships, interior architects should consider a simple design. An uncomplicated design is a user-friendly design, particularly for ageing people, which reduces opportunities to make wrong decisions. It is emphasised that ageing people need more time for decision than younger people. Thus, the recommendations for interior architecture are a simple design that allows ageing people to make the decision without a time limit to complete their tasks or activities.

4.3 Error response

In cognitive ageing, error processing is an important aspect to explain behavioural control and adaptation (Kolev et al., 2005). The error in cognition refers to an incorrect response via a wrong decision, but not due to a lack of knowledge (Sitzman et al., 2015). Mostly, the decision in ageing is slower, and tends towards avoiding errors, whereas decision in younger ages is quicker and more accepting of errors (Starns & Ratcliff, 2010). Loss of attention, which is an inability to focus or concentrate on specific information, also leads to cognitive errors (Harada & Suto, 2006). In terms of attention, there are two models of error that frequently occur in cognitive tests e.g., errors with selective attention and errors with divided attention (Reve & Bruin, 2014). First, the errors with selective attention are incorrect answers that are caused by specific focus on one selected task whilst surrounded with multiple stimuli (either of relevant, or irrelevant, or mixed stimuli) (Zanto & Gazzaley, 2017). Second, the errors with divided attention are incorrect answers that are caused by limited ability to concentrate on more than one task at the same time (multitasking). The tasks can either be the same or not the same, or mixed. The latter model could be more complicated since the divided attention requires abilities to momentarily hold information of every single task whilst simultaneously manipulating another task, and then getting back to the task at hand again (either orderly or randomly) (Ballesteros & Mayas, 2015).

Moreover, there are many other aspects of cognitive errors e.g., errors when thinking or doing backwards, and errors with error-tolerance. Inattention with ageing people can lead to a significantly increased risk of fall incidents. The preceding discussion suggests that design with consistency or mitigation of distractions through context such as lighting uniformity are useful for ageing people to avoid falls. Moreover, use of material and colour similarities should be wisely selected. There is a possibility that sameness could create errors through misinterpretation. Besides, the contrast in design should not be abandoned for ageing people since the contrast could contribute to visibility, whether from near or far distances, which directs attention to specific information. Thus, interior architects have to examine and optimise the proportion between conformity and contrast.

5. Motor function

Ageing people normally experience declining motor function, which is associated with a greater risk of fall, disability and mortality (Buchman et al., 2009). Decreased muscle strength by various factors (such as degeneration of neurotransmitter systems, age-related atrophy of the motor cortical regions in brain, and motor deficits) is one of the main reasons for restricted movements and lower performances (Liu et al., 2014; Seidler et al., 2010). Motor function consists of two main systems, the central nervous system and the peripheral nervous system. Generally, the central nervous system controls the core functions of the body whereas the peripheral nervous system controls the minor functions, including the gross and fine motor functions (Camicoli et al., 1999). Both gross and fine motor functions collectively influence the ability to perform tasks. Proprioception, which is an ability to recognise the surrounding space and volume including perception of the object's location, also works concurrently with gross and fine motor functions in the navigation of tasks (Chuangchai, 2017c; Kattenstroth et al., 2010). These indicate motor performance. Physical activities in daily life such as walking, bathing, and getting up or down from the stairs are governed by the motor performance (Giulio et al., 2020). Regarding ageing, reduction of daily functional activities is positively associated with a low level of motor performance through changes in the neuromuscular system e.g., motor nerves and muscle fibres (Vandervoort, 2002). Research has indicated that motor function is significantly diminished between the ages of 75 and 80 years. In addition, slower movement and velocity, and higher fatigability with less muscle strength accelerate rapidly at very old ages (over 80 years) (Hunter et al., 2016). Moreover, the performance of motor function was different for ageing people who had a history of falls as compared to non-fallers, where the non-fallers group exhibited better motor performance (Chuangchai & Siripakarn, 2019). These factors indicate that a higher level of motor performance could reduce the chance of falls. Interior architecture that facilitates ageing people to perform activities effortlessly will make their living healthier. It also helps to prevent fall incidents by including short walking distance, arched opening (or cased opening), and lightweight fixtures and equipment to overcome obstacles.

5.1 Gross motor function

The gross motor function is involved with the capabilities of body movements and postural controls through balance and coordination (Berryman et al., 2014). The gross motor function controls the core and major parts of the body e.g., trunk, neck, arms, legs, and ankles (Song & Park, 2016). A more complete motion of the gross motor function offers the motor skill. This skill mechanism can be developed by learning repeatedly. More motor skill use contributes to new behaviour (Voelcker-Rehage, 2008). Ageing people, however, naturally experience a loss of gross motor function. It broadly shows in the physical activities of daily life that are

performed with less smooth and/or narrow movements e.g., self-dressing (Spedden et al., 2017). Moreover, some gross motors cooperate with fine motors, via sensorimotor, to perform complicated tasks, such as eye-hand coordination as well as eye-foot coordination when dancing with partners, driving cars, or playing sports (Chuangchai & Siripakarn, 2018b). Gross motor function and coordination are key to whole-body control in avoiding fall incidents such as increasing stance width when losing stability or by reaching a handrail in the bathroom when losing balance. For falls prevention, the role of interior architecture not only refers to the human dimensions and range of motion but also is related to the limitations of gross motor functions. Fall incidents occur within a short period of time and restriction of movements is highly recommended as a priority for ageing people.

5.2 Fine motor function

The fine motor function occurs when performing specific tasks e.g., press a small button with one finger, pick a tiny object up with two fingers, or threading a needle (Shafizadeh et al., 2019). The fine motor function requires sensorimotor in cooperating functions, and often is involved with the somatosensory function e.g., tactile sensation (García-Piqueras et al., 2019). The tactile sensation, or the sense of touch, is stimulated via several forms of information that contact with the body surfaces e.g., pressure, vibration, and temperature (Wickremaratchi & Llewelyn, 2006). Loss of tactile sensation of palms and feet soles in ageing people is normal. Loss of tactile sensation plays an important role in the degeneration of fine motor function (Logue et al., 2020) and is indicative of fine motor skill decline in ageing people (Hoogendam et al., 2014). Moreover, fine motor skill deficits are not only associated with the impairments of motor function but also cognitive function (Curreli et al., 2018). By increasing fine motor function of foot sole skin sensitivity, risk of fall incidents could be reduced. Ageing people with greater fine motor function of feet soles have better balance and lower fall incidents since they could firmly recognise their centre of masses (Chuangchai & Siripakarn, 2018b). Interior architects should consider the design of flooring. For example, textures could motivate fine motor function for normal ageing whereby the fine motor function could be improved, reducing the possibility of fall incidents.

6. Conclusions and recommendations

Fall incidents amongst ageing people are more likely to result in disability and mortality. As a crucial environmental health hazard, fall incidents often occur within elderly houses. One of the most important causes linked to falls in normal ageing is the decline of executive function, which slows the pathway to make a critical decision through cognitive and motor functions. The cognitive ageing process is not only closely correlated with processing speed and accuracy in response, but also correlated with error response. Besides, the motor ageing process is associated with declines in gross and fine motor functions. The interplay between cognitive and motor functions increases the probability of fall incidents and injuries.

In conclusion, design recommendations are that the interior architecture should work to minimise junctions, time-consuming tasks, complex planning, design with inconsistency, long walking distance, multiple doors, heavyweight equipment, and flooring without textures as summarised in Table 1. These recommendations are addressed in order to guide interior architects in the ageing ergonomics knowledge of residential design for ageing people. It is, therefore, beneficial and useful for interior architects to understand how executive function changes with age as supportive information in creating a successful environment to postpone the detrimental impact of falls. Moreover, this article will help interior architects to communicate and work with geriatrics

healthcare professionals and related medical specialists for great benefit in fall prevention through design. It will provide information about safe design for all ages and risk- and hazard-free design for ageing people.

Table 1. A summary of the normal changes in ageing people and the implications for interior design.

Executive function	Degeneration	Design recommendation
Cognitive function	Poor decision making	A non-complex layout, clear planning, and fewer junctions are suggested.
Processing speed	Slow reaction time	Unnecessary tasks and non-value-added activities should be avoided.
Accuracy in response	Low accuracy in response	An uncomplicated design should be considered. Being able to pause or have no time limit while making a decision should also be an option.
Error response	Loss of attention	Design with consistency e.g., lighting uniformity
Motor function	Low level of motor performance	Short walking distance, arched opening, and lightweight fixtures and equipment are recommended.
Gross motor function	Uncoordinated movement	Not only human dimension but also range of motion should be integrated into design.
Fine motor function	Loss of tactile sensation	Flooring design with fine texture

The world population is ageing and will continue to do so for decades more. The number of ageing with executive function impairment will increase and this has implications for residential building design. In the near future, residential buildings may require a design-enhancing executive function as a strategy in reducing fall incidents. This article provides a brief review to introduce interior architects to the concepts of ageing ergonomics. Future work should consider a more detailed evaluation of executive function and ageing processes related to functions of heart rate variability, pulse transit time, and autonomic nervous system (Chuangchai, 2020; Chuangchai & Pothisiri, 2021; Chuangchai et al., 2021). Additionally, more work on developing design guidelines in contributing to the executive function is recommended.

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Author Contributions

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Conflicts of interest

The authors declare no conflict of interest.

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