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Age-Related Changes in Executive Function Abilities: A Cross-sectional study

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Cognitive decline is a well-known aspect of the healthy aging process, which adversely affects cognitive abilities, and frequently reflects a decline in executive functioning. To gain a better knowledge of executive functions over the lifetime, a cross-sectional design was utilized to examine the age-related changes in executive function across young adults (n=20; Age range= 18 to 30 years; Mean Age = 24.85 years; S.D = 2.97) and old adults (n=20; Age range=60 to 90 years; Mean Age = 74.10 years; S.D = 7.46). The Executive Function Module of the Neuropsychological Assessment Battery was administered. The results indicate that aging has a major impact on executive functions. The older age group performed worse on Executive function tasks highlighting the challenges with planning, psychomotor speed, ineffective problem solving, diminished capacity for decision-making, lower mental flexibility and response set, and diminished generativity or verbal fluency than the young adults. The results of this study suggest that age-related differences in executive functions exist and that measuring the rate at which cognitive decline occurs can be a useful diagnostic strategy for dementia and other conditions.

Keywords: Cognitive abilities, executive function, old adults and young adults.

The term "age-related cognitive decline" describes the slow, normal reduction in cognitive function that comes with aging, especially in later adulthood. Although a certain amount of cognitive loss is thought to be a typical aspect of aging, each person's experience with the condition and its effects will differ greatly. A person's education level, genetics, lifestyle choices (food, exercise, social interaction, and cognitive stimulation), medical conditions (hypertension, diabetes, and cardiovascular disease), and exposure to environmental toxins are some of the factors that can affect the course and severity of age-related cognitive decline. The study of cognitive aging looks at these processes as people age. It looks at how people's cognition varies over time both inside and between individuals. Previous studies have demonstrated that older persons do worse than younger adults on cognitive tasks, such as attention, working memory, and episodic memory assessments (Park et al.,2009; Salthouse, 2010; Hedden, & Gabrieli, J. 2004; Grady, 2012; Craik, & Bialystok, 2006). When it comes to skills like judgment and problem-solving assessments, where they may apply their life experience and wisdom, older folks typically outperform younger adults.

Cognitive decline henceforth leads to decrease in the Executive functioning of the individuals. Executive Functions are said to stand for skills that are essential for handling new tasks and adjusting to changing surroundings. (Anderson et al.,2008; De Luca et al.,2003; Duncan et al.,1995). Individuals with deficiencies in executive functions may experience difficulties with memory, focus and attention, processing speed, language, and verbal ability. It is implicitly assumed that tasks measuring fluency, working memory, concept formation, set shifting, inhibition, organization, abstract reasoning, and novel problem solving, either separately or in different combinations, measure the same construct when they are used as indicators of executive functioning. It's critical to comprehend age-related cognitive loss in order to differentiate between normal alterations and more serious conditions like dementia or cognitive impairment.

The central executive system (CES) of the Working Memory model put forth by Baddeley and Hitch (1974) may also be connected to these distinct regions that are activated during the particular Executive Function processing, which could explain the varying population decline rates. According to Baddeley (2000), this system directs, plans, manages, and incorporates new data into and among the episodic buffer slave systems, the visuospatial sketchpad (VSSP), and the phonological loop (PL).

The executive decline hypothesis (Dempster & Vegas, 1992; Luszcz & Bryan, 1999; Moscovitch & Winocur, 1992; Parkinson, 1996, 1997; Parkin & Walter, 1992; Troyer, Graves, & Cullum, 1994) postulates that declines in executive functions, which are indicative of higher order, goal-directed, and strategic cognitive activity, are the cause of age-related declines in memory. It is believed that these executive functions dominate other facets of cognitive functioning. Research indicates that the cognitive abilities of elderly persons exhibit heterogeneous change trajectories and do not alter consistently with time (Zaninotto et al., 2018). Cognitive aging may be viewed as a heterogeneous process through the involvement of various physiological and cognitive processes affecting cognition. Schonfield (1965) found that while older persons performed similarly well in recognition as younger ones, they had significantly worse recollection (however other studies, such as those by Erber (1974) and Harwood & Naylor (1969), suggest that older adults do worse in both recognition and recall).

There are many theories which explains cognitive decline in people. A basic theory that explained many age impairments was reduced processing speed after Birren's early study (Birren, 1965) revealed that participants' processing times for a variety of cognitive tasks was progressively slower with age. Salthouse (1996) had given two mechanisms by which older adults struggle in Executive function tasks : a limited time mechanism, whereby older adults find it more difficult to perform higher-level tasks because it takes them longer to process early operations; and a simultaneity mechanism, whereby older adults find it difficult to consider as many task-relevant components at once as younger adults do because the results of earlier processing might not be available once ongoing processing is finished. Hasher and Zacks (1988) introduced the inhibition deficit theory, which postulates that older people' diminished attentional control makes them more vulnerable to the effects of distracting interference when performing cognitive tasks. According to the prefrontal-executive theory put forth by Dempster and Vegas (1992) and confirmed by West (1996), Executive Function loss is brought on by structural and functional alterations in the prefrontal cortex (PFC) areas that are seen with aging and in neurodegenerative diseases. Bailey et al. (2009) proposed the strategy-deficit hypothesis, which explains how older people' inadequate or ineffective use of strategies results in additional age-related performance losses. They struggle to come up with and apply the right encoding techniques for information that could be needed to finish a task that hampers their daily routine.

Not every study concentrates on variations in executive function capacities. According to a study by Hasher and Zacks (1979), older persons showed worse recall for the words themselves, whereas younger adults had comparable memory for word frequency and word position. Research indicates that the cognitive abilities of elderly persons exhibit heterogeneous change trajectories and do not alter consistently with time (Zaninotto et al., 2018). There is a lack of research dealing with the differences in interindividual variability according to age. In order to provide individualized, timely interventions, it is crucial to look into how older adults' cognitive ability varies over time. Despite its importance, there isn't much research done worldwide on this subject. Hence, this study intends to compare the differences based on age, the precise nature and extent of these changes remain the subject of ongoing investigation.

Executive Functions are all seemingly impacted by aging to different degrees. It's unclear, meanwhile, if they are all impacted equally or if some are more so than others. The current investigation examined the individual decline rates of various EFs as a result of aging. Based on the available literature following two hypotheses framed as older adults would demonstrate lower performance on executive function abilities as compared to young adults and that there will be differences in certain executive function abilities as we age.

Method

Participants

40 participants, 20 young adult (Age range= 18 to 30 years; Mean Age= 24.85 years; S.D. = 2.97) and 20 old adults (Age range= 60 to 90 years; Mean Age= 74.10 years; S.D. = 7.46), of Varanasi district of Uttar Pradesh were selected using convenience sampling technique. Participant had normal or corrected to normal eyesight with normal range of hearing ability, and none of them had a history of any neurological conditions or under any sort of medications.

Tools

The following two screening tests were performed on the participants to screen out cognitively healthier individuals.

Montreal Cognitive Assessment (MoCA): It takes around ten minutes to administer the MoCA, a pen and paper screening tool for cognitive decline. name, memory, attention, language, abstraction, delayed recall, orientation, and visuospatial/executive function are its eight domains. Accuracy performance determines scores, which go from 0 to 30. (Nasreddine et al., 2005) Scores above 25 indicate normal cognition, 20 to 25 moderate cognitive impairment (MCI), 19 to 14 early-stage dementia, and below 14 dementia.

Mini Mental State Examination (MMSE): The MMSE tool is a pen and paper screening test that takes around ten minutes to give in order to identify cognitive deterioration. This straightforward cognitive function exam has a maximum achievable score of 30 points. Orientation, concentration, attention, verbal memory, naming, and visuospatial skills are its six domains. According to Folstein et al. (1975), scores of 28–30 indicate normal cognition, 25–27 MCI, 19–24 mild dementia, 10–18 moderate dementia, and 0–9 severe dementia.

Finally, Executive Function Module of Neuropsychological Assessment Battery® (NAB®) was administered to evaluate cognitive abilities in people with suspected or confirmed central nervous system diseases.

Neuropsychological Assessment Battery® – *Executive Function Module*: The NAB® is a modular battery of neuropsychological tests designed to evaluate cognitive abilities in people with suspected or confirmed central nervous system diseases (White & Stern, 2003). The NAB® in its original form and its German adaption have five domain-specific modules (attention, language, memory, spatial, and EFs) in addition to a screening module (Buczylowska et al., 2013). In this particular study we were interested in Executive function abilities.

Procedure

The participants were explained about the test briefly and informed consent was taken from all the participants. They were asked to fill the socio-demographic details. Montreal Cognitive assessment (MoCA) and Mini Mental State Examination (MMSE) were performed to screen out cognitively healthier individuals. Thereafter, Executive Function module of Neuropsychological Assessment Battery® (NAB®) was administered on Cognitively healthier participants after giving proper instructions. The time taken by the participants and non-verbal activities were noted by the administrator. At the end of the test, feedback of the participants was obtained and they were thanked for their participation and cooperation.

Statistical Analyses

The research design used in this study was cross-sectional. The raw scores of the NAB sample were used to compare two age groups (below 30 and above 60) on all four subtests of the Executive Functions Module. For both age group, the mean and standard deviation were calculated. The data was analysed using t-test to measure the mean differences between performance of young adults and older adults on Executive Function Abilities.

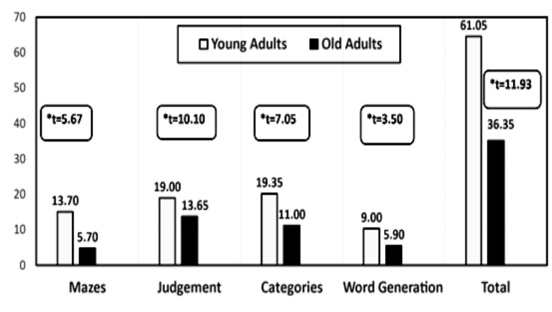
Table 1. Executive function abilities: cross-sectional analysis between the young and older adults.

Tasks	N	Age	Mean	S.D.	t	df	p-value
Mazes	20	Young	13.70	5.51	5.67	38	.000
	20	Old	5.70	3.04			
Judgement	20	Young	19.00	1.21	10.10	38	.000
	20	Old	13.65	2.03			
Categories	20	Young	19.35	3.75	7.05	38	.000
	20	Old	11.00	3.72			
Word Generation	20	Young	9.00	3.46	3.50	38	.000
	20	Old	5.90	1.91			
Total	20	Young	61.05	6.42	11.93	38	.000
	20	Old	36.35	6.65			

Results

Independent samples *t*-test for two different age groups i.e, old age and young adults was applied to see whether there was any statistical difference between the them. Table 1 shows the results of t-test for the Executive Function abilities. The mean performance score on all the executive function abilities (i.e., Total Score) by the young adults was higher (M=61.05, S.D = 6.42) in comparison to old age adults (M = 36.35, S.D = 6.65); (t = 11.93, df = 38, P > 0.01) (see Figure 1).

Figure 1
Decline in executive function abilities as a function of age.



Note: *t-values are significant at 0.000 level

A significant difference was found between young adults and older adults on the subtest of ‘Mazes’: Young adults scored higher (M = 13.70, S.D =5.51) than the older adults (M = 5.70, S.D = 3.04), (t = 5.76, df = 38, P > 0.01). This shows that young adults have better planning, impulse control and psychomotor speed than older adults.

A significant difference was found between young adults and older adults on the subtest of ‘Judgement’, Young adults performed higher (M = 19.00, S.D =1.21) than the older adults (M = 13.65 and S.D = 2.03), (t = 10.10, df = 38, P > 0.01) showing judgement and decisional capacities of about issues and situations in daily life are encountered effectively by Young Adults than the older adults.

A significant difference was found between young adults and older adults on the subtest of ‘Categories’, young adults’ performance was better (M = 19.35 and S.D = 3.75) than the older adults (M = 11.00 and S.D = 3.72), (t = 7.05, df = 38, P > 0.01). showing concept formation, cognitive response set and mental flexibility of young adults are better than the older adults.

A significant difference was also found between young adults and older adults on the subtest of ‘Word Generation’, young adults performed better (M = 9.00 and S.D = 3.46) than the older adults (M = 5.90 and S.D = 1.91), (t = 3.50, df = 38, P > 0.01). showing better verbal fluency and generativity than the older adults.

Discussion

The findings from this cross-sectional study provide valuable insights into the trajectory of age-related changes in executive function abilities. While certain aspects of executive function exhibit pronounced declines with age, others, may show more variable patterns. These results underscore the importance of considering the multifaceted nature of executive function when examining cognitive aging processes. This study used the executive function module of the Neuropsychological assessment Battery to measure age decline on a variety of tasks testing the executive function abilities between young and older persons. The findings showed that in a number of executive function tasks, including Mazes, Judgment, Categories, and Word generation, older persons underperformed compared to young adults. The findings support the aging literature by indicating that subclinical executive impairments may occur with aging and may affect daily functioning (Ready, Ott, Grace, & Cahn-Weiner, 2003; Albert, Moss, Tanzi, & Jones, 2001).

Younger people had the greatest scores, while older participants had lower scores in all the subtests of Executive Function Abilities. Hence, Executive function skills are significantly impacted by age. Older adults demonstrate poorer performance on ‘Mazes’ subtest of Executive function abilities than young adults showing not proper planning and indicating with increasing difficulty their performance deteriorate. They took more time to complete the mazes.

Participants may have unique characteristics that are difficult to regulate but yet affect how well they do on the test. The performance of older adults is comparatively better on 'Judgement' than 'Mazes' and 'Word Generation' showing better decisional capacity and competence among them. The findings were supported by Craik and Salthouse (2000). As we age, our ability to process information efficiently decreases, which leads to a reallocation of certain cognitive processes to improve performance. This is the fundamental executive system of the WM model, as outlined by Baddeley and Hitch (1974). The reason behind this could be in older brains, dedifferentiation and neuronal remodelling in the Pre-Frontal Cortex cause Executive Functions to become less distinct and merge, which reduces response selectivity and results in more homogenous responses (Grady, 2012).

In young adults the maximum performance came out in 'Judgement' and 'Categories' subtest of executive function module showing younger adults are efficient in forming concepts, establishing relationships, making decisions and cognitive flexibility in novel situations.

Future Directions

The present study utilized a cross-sectional design, which limits our ability to draw causal inferences about age-related changes in executive function. Future longitudinal studies are needed to elucidate the trajectories of executive function across the lifespan. While the battery of neuropsychological tests used in this study provided a comprehensive assessment of executive function, additional measures and tasks targeting specific components may offer further insights into age-related changes. The findings of this study may be influenced by sample characteristics such as education level, socioeconomic status, and health status. Future research should aim to replicate these findings in more diverse populations. Also, the researches should continue to investigate the mechanisms underlying age-related changes in executive function and evaluate the effectiveness of interventions aimed at preserving cognitive function in older adults.

Conclusion

Numerous lifestyle factors that may enhance cognition and lead to more effective brain functioning in both men and women have been studied. Modifiable lifestyle factors, such as exercise, cognitive training, diet, yoga, tai chi, mindfulness, and social engagement, have been investigated for their possible advantages on cognition in aging.

Furthermore, understanding the specific areas of executive function that are most vulnerable to age-related changes can inform the development of targeted interventions to support cognitive health in older adults. In conclusion, this cross-sectional study highlights age-related changes in executive function abilities, with older adults demonstrating impairments in inhibition, working memory, cognitive flexibility, and planning compared to younger counterparts. These findings contribute to our understanding of cognitive aging processes and have implications for the development of interventions aimed at preserving cognitive function in older adults. By examining differences across different age groups, we have identified specific components of executive function that are particularly susceptible to the effects of aging. These findings have implications for interventions aimed at preserving cognitive health and promoting successful aging in older adults.

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