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Original Article

Effects of Hatha yoga on cognitive functions in the elderly: a cross-sectional study

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ABSTRACT

This study aimed to investigate the effects of Hatha yoga practice on cognitive functions in the elderly. Thirty healthy older men participated in this study. They belonged to 2 groups. The first group included 15 Hatha yoga practitioners for at least 2 years. The control group involved 15 male older adults who shared the same characteristics (age, years of formal education, and level of physical activity) as the Hatha yoga group but were naive to yoga, meditation, or any mind-body intervention. Neuropsychological tests were applied to measure selective attention, sustained attention, episodic memory, and processing speed. The following tests were administered: The French adaptation of the Victoria Stroop test, the Zazzo's Cancellation Task, the Five Word Test, and a battery of computerized tests to evaluate reaction time. Long-term Hatha yoga practice showed promising results related to executive functions and reaction time, but no significant difference was found between the two groups in episodic memory and sustained attention although a trend of improvement was observed in favor of Hatha yoga practitioners. In conclusion, long-term Hatha yoga practitioners have better cognitive abilities compared to the control group in certain aspects of cognitive functions. Further physiological and psychological variables need to be examined in order to highlight the correlation between yoga intervention and cognitive performance.

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KEYWORDS
Yoga; older adults; executive functions; selective attention; sustained attention; episodic memory; processing speed

1. Introduction

Population ageing is a dominant demographic phenomenon and one of the chief societal problems of this century. Increased life expectancy has obviously engendered physical health problems, psychological deficits, as well as dependency or activity limitations [1]. Age-related diseases have thus increased at an alarming rate in recent decades [2]. Indeed, aging is often associated with structural and functional brain changes that may cause cognitive losses as well as physical and behavioral changes [3–5]. So far, age-related cognitive decline [6], which can affect a wide range of cognitive functions such as memory, processing speed, learning, understanding, and decision making, has become a public health problem [7]. Consequently, concerns have been raised about how to help the elderly maintain their cognitive abilities or at least delay their deterioration.

Scholars have resorted to various approaches like music therapy [8], memory training [9], and exercise therapy [10–12] in order to face the challenges resulting from population ageing. Yet, results have shown that a large proportion of adults are much less active than desired [13,14]. This can be explained by physical limitations, low self-efficacy, and exercise aversion [15].

Mind-body medicine is applied to alleviate the adverse effects of ageing. As one of the various mind-body therapies, yoga is a popular exercise that combines precise Asanas (physical postures), Prāṇāyāmas (breathing exercises), and Dhyāna (meditation). It has significantly helped to improve brain structures and functioning, thus increasing awareness, attention, executive functions, and memory [16,17]. Of the various branches of yoga (e.g. Hindu, Hatha, Raja, and Mantra), Hatha yoga is widely practiced, easy to learn, and does not require any complicated or expensive equipment or any specific training. The practice of Hatha yoga has been shown to enhance an array of cognitive functions such as executive functions, attention, intelligence, memory, and concentration [18].

Previous research confirms that yoga has promising effects on cognitive problems in the elderly [19–21]. In this context, Hariprasad et al. [21] compared yoga and non-yoga practitioners among nursing home residents over 6 months. The yoga intervention group showed significant improvements in attention, episodic memory (Rey's Auditory Verbal Learning Test), executive function (Stroop interference), and processing speed (Trail Making Test-A) compared to the controls. Similarly, Gothe et al. [22] used an eight-week Hatha

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yoga intervention for old community dwellers, noting considerable enhancements of executive function and working memory in the Hatha yoga group. As for Oken et al. [23], no significant improvements in cognitive functions were obtained after a six-month yoga program in healthy seniors.

Despite yoga's wide popularity, most studies have overlooked the positive effects of yogic practices on cognitive functions in the elderly, especially with regard to sustained attention and processing speed. Even existing research has shown mixed results. Therefore, the current study aimed at evaluating the effects of a two-year Hatha yoga practice on selective attention, sustained attention, episodic memory, and processing speed in the elderly.

2. Materials and methods

2.1. Participants

Thirty healthy older men participated in this study. They belonged to 2 groups. The first group included 15 Hatha yoga practitioners supervised by the same qualified instructor for at least 2 years at the rate of twice a week. The control group involved 15 male older adults who shared the same characteristics (age, years of formal education, and level of physical activity, Table 1) as the Hatha yoga group but were naive to yoga, meditation, or any mind-body intervention. In order to determine their level of physical fitness, both groups were required to answer the Dijon Physical Activity Score Questionnaire. All the participants were motivated to take part in this study. They had normal or corrected vision and hearing. Exclusion criteria included substance/drug abuse that may impair cognitive functions, chronic physical or other health problems which can hinder daily activities, clinical history of neurological and/or psychiatric diseases, and color-blindness that can hamper the smooth running of the Stroop test. Informed consent was obtained from all the participants before testing. All experimental procedures were approved by the local research ethics committee of the High Institute of Sport and Physical Education of Sfax, Tunisia (32/2017) and followed the principles outlined in the Declaration of Helsinki.

2.2. Experimental design

The research was thoroughly detailed at a formal meeting and prospective participants were allowed to ask questions and acquaint themselves with the tests to be taken. Tests mainly focused on episodic memory, selective attention, sustained attention, and processing speed. To assure similar experimental conditions, the different tests were administered in the same order to all the participants. The testing session included the Five Word Test (FWT), the Victoria Stroop test, the Zazzo's Cancellation Task (ZCT), and finally the reaction time tests.

Table 1. Main characteristics of the control and Hatha yoga groups.

	Hatha yoga group	Control group
Age (years)	64.00 ± 3.02	65.00 ± 5.11
Years of formal education	17.30 ± 3.12	17.50 ± 3.55
Level of physical activity	24.26 ± 1.27	24.00 ± 2.26

Data are expressed as means ± standard deviations.

Table 2. Sample 60-minute yoga session construction.

Component	Exercises	Approximate duration
Sukṣmavyayama (loosening exercises/warm up)	Greeva Sanchalana (neck movement) Skandha Chakra (shoulder rotation) Kati Chakrasana (hip extension) Janu Chakra (knee movement) Surya Namkaskar (3 rounds)	10 minutes
Asanas (physical postures)	Standing Asanas: e.g. Tadasana, Kati Chakrasana, Virabhadrasana I, II, and III Prone Asanas: e.g. Bhujangasana (cobra pose) and Dhanurasana (bow pose) Supine Asanas: e.g. Setu Bandha Sarvangasana (bridge pose) and Supta Kapotasana (supine pigeon pose)	20 minutes
Prāṇāyāmas	Diaphragmatic breathing	15 minutes
Meditation	Pose: Siddhasana/Savasana	15 minutes

2.2.1. Yoga training program

The twice-weekly 60-minute sessions were conducted in a local yoga studio by the same qualified instructor specialized in teaching yoga to seniors. Hatha yoga employed in this study included Asanas connected with Prāṇāyāmas and a 15-minute guided mindfulness meditation (Table 2).

Participants were recommended to breathe deeply all along the session. According to the yoga instructor, there was an attendance log and in case of absence, there was a catch-up session so that the training was not interrupted.

2.2.2. Five Word Test

The FWT was proposed by Dubois et al. [24] to provide doctors with a tool to rapidly evaluate verbal episodic memory in the elderly. During the FWT, participants were required to learn a list of 5 concrete words. Each word belongs to a specific semantic category but is not prototypical in its class. The FWT is based on inducing particular semantic processing, then controlling encoding to avoid attention deficits, and finally free or cued recalling. Indeed, cued recall aims at helping participants with memory loss. The total number of recalled words during immediate free/cued and delayed free/cued recalls was retained as total recall score.

In this study, the Tunisian Arabic version of the FWT, developed by Khiari Mrabet et al. [25], was used.

2.2.3. French adaptation of the Victoria Stroop test

The French adaptation of the Victoria Stroop test [26] is based on Strauss et al.'s instructions [27]. Twenty-four stimuli were presented on three 35.5 × 10 cm cards, each containing six rows of four items. Four colors were used: blue, green, yellow, and red. Card 1 (C) consisted of colored bars (Color task), card 2 (M) displayed words written in different colors (Word task), and card 3 (I) presented color names written in a different color (e.g. the word 'yellow' was printed in red) (Color-Word task). Words and color bars were ordered horizontally on the cards. Participants completed three tasks. Firstly, they were required to read the names of the colors given on card 1. Then, they were asked to read the colored words on card 2. In the final task, they were asked to name the color used for each colored word displayed on card 3. The third task is considered as an 'interference' task because it reflects the extent to which participants are able to 'shift perceptual set to conform to changing demands' [28]. Participants were required to respond as rapidly as possible.

The two interference indexes (a low interference index and a strong interference index) and the number of errors made ('color errors' and 'interfering errors') were taken into consideration.

Low interference index: Time Card M/Time Card C.

Strong interference index: Time Card I/Time Card C.

2.2.4. Zazzo's Cancellation Task

The ZCT [29], adapted to the elderly, is frequently used to evaluate sustained attention i.e. the ability to simultaneously select stimuli while neglecting distractors. A list of 1000 symbols is presented on a sheet of white paper containing 40 lines of 25 targets. The participants were required to cross out the target stimuli from left to right and line by line as rapidly and accurately as they can. Scoring involves the number of omission errors, the number of commission errors, and the time spent to complete the test.

2.2.5. Reaction time tests

The software 'Reaction' was used for measuring simple reaction time to visual stimuli (i.e. blue square, two identical figures, and yellow triangle) under various conditions [30]. It was designed to assess the subject's ability to inhibit inappropriate reactions. During the test, participants sit at a desk facing a computer screen. They were instructed to click the spacebar each time the appropriate stimulus is presented, as quickly as possible. Each participant had 3 trials. Yet, only three valid simple reaction time trials were retained.

In the first condition (Figure apparition), the participants were asked to identify the imperative stimulus (a blue square) and press the spacebar as quickly as possible. The software measured the time interval between the appearance of the target and pressing the spacebar.

In the second condition (Figure comparison), the participants were required to click the spacebar as soon as two identical figures are displayed, overlooking the two different ones. The time interval between the appearance of figures and pressing the spacebar was measured by the software.

In the third condition (A shape among X), triangles of different colors and positions were displayed on the computer screen. Participants were asked to select a specific model (a yellow triangle) at the moment of its appearance. The software measured the time interval between the appearance of the shape and pressing the spacebar.

In the three conditions, the number of errors and forgets were also retained.

2.3. Statistical analysis

Statistical analyses were performed using Statistica 10 software (StatSoft, France). The Shapiro-Wilk *W*-test for normality revealed that the data were normally distributed. Values are presented as means (± standard deviations). The Student *t*-test was utilized to assess differences between control and yoga groups in all measured variables. Effect sizes were calculated using the Cohen's *d* statistic. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Five Word Test

The *t* test did not reveal any significant difference between the Hatha yoga group (9.26 ± 0.96) and the control group (8.53 ± 1.30) in the total recall score.

3.2. French adaptation of the Victoria Stroop test

The Victoria Stroop test indices are displayed in Table 3.

The *t* test showed a significant difference between the two groups in the number of errors made ($t = -5.4$; $P < 0.001$; $d = -1.97$), with higher values in the control group. However, no significant difference was found for the low interference index and the strong interference index.

3.3. Zazzo's Cancellation Task

The ZCT indices are displayed in Table 4.

Table 3. Indices of the Victoria Stroop test measured in the control and Hatha yoga groups.

	Hatha yoga group	Control group
Low interference index	1.14 ± 0.22	1.20 ± 0.18
High interference index	1.53 ± 0.44	1.75 ± 0.55
Number of errors made	0.66 ± 0.81*	2.53 ± 1.06

Data are expressed as means ± standard deviations.
*: Significantly different compared to the control group.

In the first dim, the number of commission errors was higher in the control group than the Hatha yoga group ($t = -2.95$; $P < 0.01$; $d = -0.67$). Nevertheless, the t test did not reveal any significant difference between the two groups in the time spent to complete the test and the number of omission errors.

In the second dim, the number of commission errors ($t = -3.41$; $P < 0.01$; $d = -1.25$), the number of omission errors ($t = -2.93$; $P < 0.01$; $d = -1.06$), and the time spent to complete the test ($t = -5.30$; $P < 0.001$; $d = -1.93$) were higher in the control group than the Hatha yoga group.

3.4. Reaction time tests

The reaction time tests indices are displayed in Table 5.

In the first condition (Figure apparition), the t test revealed that the reaction time values were higher in the control group than the Hatha yoga group ($t = 2.03$; $P < 0.05$; $d = -0.07$). Likewise, the number of errors ($t = -4{,}15$; $P < 0.001$; $d = -1.39$) and the number of forgets ($t = -3.32$; $P < 0.01$; $d = -0.91$) were higher in the control group.

In the second condition (Figure comparison), the t test revealed that the reaction time values were higher in the control group than the Hatha yoga group ($t = 2.80$; $P < 0.01$; $d = -0.86$). However, no significant difference was observed between the two groups in the number of errors and the number of forgets.

In the third condition (A shape among X), none of the measured indices showed a significant difference between the Hatha yoga group and the control group.

4. Discussion

The present study showed that healthy elderly men who attended yoga sessions for a minimum of 2 years demonstrated better results in some cognitive performance tests than males in the control group. Although the yoga and the control groups shared the same characteristics (age, years of formal education, and level of physical activity), subjects in the yoga group showed slightly better selective attention (executive function), sustained attention, and processing speed (reaction time); but no difference was found in episodic memory after the two-year yoga training.

The present study was based on the Stroop test to assess the executive function considered as one of the cognitive functions which can be damaged due to ageing [31,32]. This test is the most frequently applied method for evaluating executive functions, particularly inhibition, in the elderly [23,33–40]. There is a wide variety of Stroop test versions [41]. Yet, the French adaptation of the Victoria Stroop test [26] was adopted in this study since it seems to be the most appropriate version for the geriatric population. Indeed, it is briefly administered (~5 minutes) and easily understood thanks to the addition of an example line in each card.

The present study showed a significant difference between the two groups in the number of errors

Table 4. Indices of the Zazzo's Cancellation Task measured in the control and Hatha yoga groups.

	Dim 1		Dim 2	
	Hatha yoga group	Control group	Hatha yoga group	Control group
Time (s)	5.00 ± 1.16	5.85 ± 1.61	10.91 ± 1.59*	15.62 ± 3.05
Number of omission errors	9.60 ± 7.10	15.73 ± 9.65	16.07 ± 6.67*	23.27 ± 6.79
Number of commission errors	0.00 ± 0.00*	1.27 ± 2.66	0.33 ± 0.72*	1.60 ± 1.24

Data are expressed as means ± standard deviations.
*: Significantly different compared to the control group.

Table 5. Indices of the reaction time tests measured in the control and Hatha yoga groups.

		Hatha yoga group	Control group
First condition (Figure apparition)	Time (ms)	313.99 ± 49.65*	318.64 ± 68.13
	Number of errors	0.20 ± 0.24*	1.82 ± 1.63
	Number of forgets	0.02 ± 0.00*	1.15 ± 1.74
Second condition (Figure comparison)	Time (ms)	653.74 ± 87.45*	719.97 ± 63.41
	Number of errors	1.84 ± 1.32	2.75 ± 0.89
	Number of forgets	0.93 ± 0.30	1.15 ± 1.20
Third condition (A shape among X)	Time (ms)	533.29 ± 60.87	562.19 ± 86.05
	Number of errors	1.82 ± 0.92	2.02 ± 1.53
	Number of forgets	0.64 ± 0.50	1.00 ± 1.06

Data are expressed as means ± standard deviations.
*: Significantly different compared to the control group.

made. In fact, 50% of the Hatha yoga group against 100% of the control group made errors during the execution of the interfering task, showing difficulty in ignoring the distractor and inhibiting it. However, no significant difference was found in the interference indexes. The present results corroborate previous findings [36,37,39] showing that participants in the mind-body exercise had better Stroop test results in comparison with the control group. In this context, yoga intervention, or any other mind-body exercise, may enhance executive functions in seniors [42] and lead to positive changes in brain structure, especially in the frontal lobe regulating the executive functions [43,44]. Yoga intervention covers a variety of components ranging from skeletal muscles stretching and relaxation to the coordinated body and regular breathing movements [45]. Particularly, during yoga Asana practice, engagement of skeletal muscles for a given time interval is likely to result in a greater attentional capacity. Similar results were obtained *via* meditation [46,47]. In fact, previous studies showed that meditation practice can enhance selective attention as it correlates with increased oxyhemoglobin concentrations in the prefrontal cortex given the increased blood flow in that area [48,49]. Likewise, compared to non-meditators, meditation practitioners showed better selective attention and greater inhibitory control [50]. Another study conducted by MacLean et al. [51] showed that even novice meditators demonstrated improved attention and vigilance during a visual attention task. Lazar et al. [52] provided a detailed account of all the previously mentioned research showing that meditators had thicker brain areas involved in attention and interoception, as well as in sensory processing in the prefrontal cortex (Brodmann areas 9 and 10), the auditory cortex, the somatosensory cortex, and the right anterior insula.

Nevertheless, Oken et al. [23] revealed that a six-month Iyengar yoga intervention did not produce any significant improvement in inhibitory control assessed using the Stroop task. Similarly, Kapalabhati breathing (breathing is a very important part of Hatha yoga) had no notable effect on female adults' selective attention [53].

Contradiction between the findings could be attributed to the different forms of yoga interventions utilized in the studies, the adoption of only one yoga component (meditation), or the lack of proper clarification and intervention.

Afterwards, as for sustained attentional ability, the participants in the Hatha yoga group made fewer commission errors, while no notable difference was detected in omission errors and performance speed between the two groups. The findings of the current study do not support the previous research [53] which found no significant changes in sustained attention assessed using the six-letter cancellation task after a three-month Kapalabhati breathing training program.

Despite the importance of sustained attention for the daily lives of older adults, few studies have explored this type of attention. Even existing research has shown no effects of age-related deficits on sustained attention [54–56]. It turns out that this cognitive ability may be sensitive to age if the stimulation frequency is high and the items location is random, as indicated by Berardi et al. [56] using the high event rate digit-discrimination task at six levels of stimulus degradation.

According to the present study, no significant difference between the Hatha yoga group and the control group was observed in episodic memory outcome measures. This finding is contrary to previous studies showing that any form of yoga training positively affects episodic memory. In fact, Eyre et al. [57] reported that both Kundalini yoga and memory enhancement training improved verbal memory performance at 12- and 24-weeks follow-up. In another study, Cinalli et al. [58] found that yoga practice has a beneficial effect on cognitive functions such as verbal episodic memory assessed by the Hopkins Verbal Learning Test. Likewise, a six-month yoga intervention improved verbal episodic memory evaluated using the Rey Auditory Verbal Learning Test in older adults [21]. Moreover, Erickson et al. [59] confirmed that interventions, including aerobic exercises like yoga practice, are correlated with enhancement of episodic memory.

Given that participants may increase their hippocampus volume following yoga practice, a possible explanation for the latter results may be the significant relationship between the hippocampal volume and memory function [60,61], in addition to the involvement of the default mode network in memory retrieval and encoding [62,63]. Furthermore, extensive meditation training led to stronger functional connectivity between certain default mode network regions, possibly reflecting strengthened present-moment awareness [64].

Also, yoga improves neuroplasticity processes and increases telomerase activity [65]. Additionally, movement-based mind-body practices are associated with improvement in episodic memory and structural changes in different brain regions involved in cognitive functions [66] such as higher cortical thickness, as well as increased gray matter volume [67,68] and hippocampal volume [69]. Other previous research showed that interventions, including mind-body exercise, are associated with moderate improvement in episodic memory [21,36,70]. Nevertheless, Bhattacharyya et al. [71] reported that engaging in movement-based mind-body practices was independently associated with a smaller decline in episodic memory.

The inconsistency between the present findings and those of previous studies may be due to the effect of yoga on only certain aspects of cognitive functions and the presence of the ceiling effects.

This study confirms that Hatha yoga intervention positively affects processing speed assessed by the reaction time tests. In fact, the Hatha yoga group showed better scores in 'Figure apparition' and 'Figure comparison' conditions; but there was no significant difference between the two groups regarding the 'Shape among X' condition. The difference in reaction time values between the two groups may be attributed to the decline of sensory awareness and attention span in the elderly. These results are relatively in agreement with those of Hariprasad [21], who indicated that the six-month yoga group showed a better improvement than the control group in processing speed assessed by the Trail Making Test-A. Similarly, Lutz et al. [72] and Slagter et al. [73] confirmed that long-term meditation training could boost processing speed. Another study by Telles et al. [74] reported an enhancement of processing speed and effectiveness after a three-month yoga breathing intervention. Nevertheless, Oken et al. [23] revealed that the yoga intervention and the aerobic exercise did not produce any improvement in processing speed compared to the control group, indicating that a short-term exercise intervention does not affect cognitive functions in the elderly.

5. Study limitations

Additional variables need to be recorded before taking the Stroop test, e.g. the anxiety state, since anxiety is commonly linked to a general decline in attention and focus [75]. Furthermore, despite the fact that Hatha yoga practice can improve certain aspects of cognitive functioning such as selective attention and processing speed, other factors which are difficult to control but deserve mentioning may implicitly intervene in these cognitive improvements. These factors include, first, socialization (it takes place in the Hatha yoga session during the long-term period of 2 years) which may affect especially the elderly as they suffer from loneliness and isolation. Second, the placebo effect, self-efficacy, and expectancy can affect results [76,77]. Third, the yoga group had been practicing yoga for two years and were motivated to do so outside of a research study. It is possible that the yoga group was generally healthier than the control group on many factors (e.g. cardiovascular health, diet) and that this explains the cognitive superiority of the yoga group.

Besides, the small sample size and the homogeneity (only males) of participants prevent a valuable generalization of the obtained results. Finally, this study does not involve a specific Hatha yoga design and type, which may engender mixed results.

6. Conclusion

Healthy seniors attending Hatha yoga training for at least two years performed better than a control group owing to an improvement in certain aspects of cognitive functions. Since it incorporates postures, breathing, and meditative exercises, Hatha yoga can preserve cognitive capacities in long-term practitioners compared to controls. Improvements in cognitive performance after long-term interventions are not based on sufficient evidence. Thus, future studies regarding the role of Hatha yoga would be worthwhile.

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