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Executive functioning in healthy elderly Chinese people

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Abstract

This study aimed to explore the executive function of healthy elderly Chinese people. A sample of 58 healthy Chinese aged 60 and over was recruited from Guangzhou in China. They were divided into two age groups, a younger age group (aged 60–70) and an older age group (aged over 70). Executive function was measured by a battery of seven tests which were assumed to capture specific components of executive function. The tests were initiation (Hayling Sentence Completion Test (HSC)), sustained attention (Monotone Counting Test), switching and flexibility (word fluency and modified Wisconsin Card Sorting Test (WCST)), disinhibition (Modified Six Element Task (SET), Stroop Test, and HSC), attention allocation and planning (SET and modified version of WCST), and updating (Chinese Letter–Number Span). When independent neurocognitive tests were analyzed, there were significant age differences in the WCST (perseverative errors and category completed, $p = 0.025$, 0.023) and the SET (raw score, $p = 0.050$). The older age group tended to do worse in the total profile score of the SET and correct responses of the HSC Part A. However, when these tests were grouped into specific executive function components, a significant difference was found between the two groups in attention allocation and planning ($p = 0.007$) and total component score ($p = 0.026$). Regression analyses also indicated that age accounted for only very little variance of executive function in this narrow band of the elderly, whereas educational level accounted for a large part of the variance in initiation ($R^2 = 0.252$, $p < 0.001$), switching and flexibility ($R^2 = 0.211$, $p < 0.001$), and updating ($R^2 = 0.236$, $p < 0.001$) components of executive function. Our findings suggest that a significant decline in general executive functioning with advancing age was only evident in some putative tests in this sample. In addition, executive functions were selectively affected by older age, with attention location and planning and initiation being the components that were most affected.

Keywords: Executive function; Healthy aging; Chinese

1. Introduction

It is suggested that in normal aging there is a natural process of cognitive decline that is distinct from a pathological aging process such as dementia (Buckner, 2004; Head, Snyder, Girton, Morris, & Buckner, 2005). The frontal hypothesis of cognitive aging assumes that the cerebral cortex deteriorates disproportionately in such a way that aging affects the frontal lobe at first, especially the prefrontal cortex (West, 1996). Neurobiological data (reviewed in Hedden & Gabrieli, 2004) tend to support this hypothesis. The prefrontal cortex (but not the other regions) is associated with a

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decline in the general volume, white matter density, and synaptic densities in the aging brain. Because the prefrontal cortex has been considered to be the seat of executive function, a corresponding decline in executive function has been proposed. Extensive data from cross-sectional and longitudinal studies have demonstrated a robust general decline in executive function among normal elderly (see, for example, Andres & der Linden, 2000; Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000; Grigsby, Kaye, & Robbins, 1995; Royall, Espino, Polk, Palmer, & Markides, 2004; Royall, Palmer, Chiodo, & Polk, 2004; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003).

However, executive function is not a unitary construct and comprises sub-components that are responsible for planning, assembling, coordinating, sequencing, and monitoring other cognitive operations (Burgess & Shallice, 1996a, 1996b; Salthouse, Atkinson, & Berish, 2003; Stuss, Shallice, Alexander, & Picton, 1995). Preliminary evidence suggests that in normal aging there are selective deficits in executive function rather than a general decline. For example, Crawford et al. (2000) found age-related decline in the modified Wisconsin Card Sorting Task (WCST) and Stroop Test, but not in verbal fluency and cognitive estimates, which suggests that planning and control of interference were particularly vulnerable to increasing age. Others (e.g., Plumet, Gil, & Gaonac'h, 2005; Wecker, Kramer, Wisniewski, & Delis, 2000) found an age effect in inhibition and distraction, with switching tasks resistant to aging. These studies suggest that there are differential changes in executive function and that the fractionation of executive function is necessary when studying aging effect.

However, there are several limitations in the studies. First, relatively few studies have focused on the age-related deficits in specific components of executive function. Older participants tended to switch less often than younger ones in the semantic fluency test (Troyer, Moscovitch, & Winocur, 1997). Additionally, older adults were less likely to inhibit a habitual response than younger adults, which was evident in the HSC (Bielak, Mansueti, Strauss, & Dixon, 2005) and Stroop Test (Wecker et al., 2000).

Second, most of the aforementioned studies were based on a traditional set of tests of executive function, without detailing specific components. The conclusions drawn from these studies might be limited by their methodologies. The putative executive measures might not load on a single executive construct, and might overlap with each other (Miyake, Friedman, Emerson, Wilzki, & Howerter, 2000; Royall et al., 2002). In these studies the sub-components of executive function were discussed, but researchers covered only one or two components and did not discuss the executive function as a whole. Therefore, it is necessary to investigate which components the age effect covers.

Third, most of the aforementioned studies were limited to the investigation of the aging effect as a whole. That is, the previous emphasis was on cognitive decline or executive dysfunction with advancing age. However, it is commonly agreed that "old" can be subdivided into different subgroups – young-old, older-old, and oldest-old – and that the subgroups can be characterized by their own cognitive profiles. We speculate that differential executive functioning can be observed among these distinct age subgroups.

Fourth, the majority of data that concerns executive function in elderly people was primarily obtained from Western populations. Very few data have been generated from non-Western populations, in particular, the Chinese. Chan, Lam, Wong, and Chiu (2003) found that performance of the modified version of the WCST (Nelson, 1976) by healthy Chinese elderly was associated with age, educational level, and gender. Guo et al. (2003) compared the cognitive functions among elderly of Shanghai, Hong Kong, and San Diego with the Mattis Dementia Rating Scale (DRS) and Mini-Mental State Examination (MMSE).

This study aimed to explore executive function performance in healthy elderly Chinese people. It extended previous studies by examining the potential decline of specific components of executive function in healthy elders. We attempted to examine two age subgroups, the young-old and older-old. We adopted the supervisory attentional system (SAS) (Norman & Shallice, 1986) as the theoretical framework to guide the selection of tests that were used in this study. According to the SAS, there are two cognitive processes that control our actions and thoughts, namely, contention scheduling and the supervisory attentional system. Contention scheduling is responsible for routine overlearned behavior and the performance of everyday tasks. The supervisory attention system is responsible for regulating non-routine and novel tasks. Impairment in the SAS is expected to result in the inability to formulate a goal, to plan, or to choose between alternative sequences of behavior to reach a particular goal.

This model has several advantages over other models. First, this model clearly delineates the specific cognitive processes that are responsible for deficits or dysfunctions in executive function in either healthy or clinical populations (e.g., Burgess & Shallice, 1996a, 1996b; Chan, 2001; Chan, Chen, Cheung, Chen, & Cheung, 2004a, 2004b; Chan, Chen, Cheung, Chen, & Cheung, 2006; Chan, Chen, & Law, 2006; Frith, 1992). In particular, the SAS is responsible for constructing responses in novel situations and for modifying a scheme when the original scheme is inappropriate at that time. Impairment of the SAS will result in the inability to formulate a goal, to plan, or to choose between alternative sequences of behavior to reach a particular goal. Second, several tasks have been developed from this framework to capture specific components of executive function, including initiation, sustaining, switching and flexibility, disinhibition, attention allocation and planning, and online updating (Burgess & Shallice, 1996a, 1996b; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Shallice & Burgess, 1991; Shallice, Burgess, & Frith, 1991). Third, these SAS-based tests have been adapted and applied to the Chinese context and have been shown to have impressive psychometric properties and clinical sensitivity (e.g., Chan, 2001; Chan et al., 2004a, 2004b; Chan, Chen, Cheung, et al., 2006; Chan, Chen, & Law, 2006).

Given the frontal hypothesis of cognitive aging, we expected that there would be a greater decline in executive functioning in older elderly people than in younger elderly people. We also wanted to explore the effects of educational level and gender on executive functioning in this narrow band of elderly participants. Moreover, different components of executive function could also be assessed by a set of tasks that were specifically designed to capture the potential decline of the proposed components. We therefore hypothesized that selective deficits in the attention allocation and planning and initiation components would be demonstrated with increasing age.

2. Methodology

2.1. Participants

Older adults who were 60 years of age or more were recruited from the sample pool of an extensive norming project of neuropsychological testing. They were screened by questionnaires and interviews that were conducted by research assistants. Elders with central nervous system diseases or psychiatric illnesses were excluded from this study. Moreover, all participants were screened by the Chinese version of the Mini-Mental State Examination (Wang, Zhang, Qu, Chen, & Zhao, 1989). The Chinese MMSE has a sensitivity of 92.5% and specificity of 76.5% in detecting subjects with dementia (Chan, Yung, & Pan, 2005). A cut-off score was chosen according to the subject's educational level, as previously suggested (Wang et al., 1989), that is, 18 for illiterate; 20 for 6 years of education; and 24 for more than 6 years of education.

An initial sample of 73 participants was approached. However, 15 cases did not complete all the tests and were deleted from the database. A sample of 58 cases was included in the subsequent data analyses.

2.2. Measures

The tests for the present study were selected from the battery that was used by Chan et al. (2004a); Chan, Chen, Cheung, et al. (2006); and Chan, Chen, and Law (2006) in the Chinese samples. They were either theory-based to capture specific components of executive function or had been proved to be sensitive to prefrontal deficits. They were demonstrated to be able to reflect both the quantitative and qualitative features of the corresponding components of executive function in either a healthy population or clinical group. However, because the subjects were elderly, we knew that the duration of the testing should not be too long; therefore, we chose one or two tests for each component. Details of these tests have been described elsewhere (e.g., Burgess & Shallice, 1996a, 1996b; Chan et al., 2004a; Chan, Chen, Cheung, et al., 2006; Chan, Chen, & Law, 2006). In brief, the test features of each component are as follows.

2.2.1. Initiation

This was measured by the Hayling Sentence Completion Test Part A (HSC Part A) (Burgess & Shallice, 1996a, 1996b; Chinese version, Chan et al., 2004a). Participants were presented with a sentence with the last word omitted, then asked to complete the sentence. The total number of correct responses was converted to a z-score that reflected the initiation component.

2.2.2. Sustained attention

This was measured by the Monotone Counting Test (Wilkins, Shallice, & MaCarthy, 1987). Participants were required to listen to a series of brief pure tones that were generated at a regular pace and asked to report the number of tones that were presented after each trial finished. The number of correct counts was converted to a z-score that reflected the sustained attention component.

2.2.3. Switching and flexibility

These were measured by the Word Fluency Test (Spreen & Strauss, 1998) and the perseverative errors in a modified version of the WCST (Nelson, 1976). A composite score was calculated by averaging the value of the summation of the converted z-scores of these two tests.

2.2.4. Disinhibition

This was measured by the HSC Part B, Stroop interference (Victoria version, adapted Chinese version, Lee & Chan, 2000) and the total number of rule-breaks of the modified version of the Six Elements Test (SET) (Wilson, Alderman, Burgess, Emslie, & Evans, 1996). In the HSC Part B, participants were required to complete the sentence with any word that was unrelated to the sentence and would make no sense given the sentence frame. A composite score was calculated by averaging the value of the summation of the converted z-scores of each of these tests.

2.2.5. Attention allocation and planning

These were measured by the raw score and total profile score of the modified version of the SET and the category score of the WCST. A composite score was calculated by averaging the value of the summation of the converted z-scores of these parameters.

2.2.6. Online updating

This was measured by the total number of correct recalls of the Letter–Number Span Test (CLN) (Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997; Chinese version, Chan et al., in press). In this test, participants were required to sort out letters from numbers within a row of alternating letters and numbers that were read to them, and recall the letters and numbers, respectively, in ascending order. There were eight levels, with increasing difficulty from two to nine items. The converted z-score of the number of correct recalls was used to reflect the online updating functioning.

2.3. Data analysis

The sample was divided into two groups according to their age, a younger age group (aged 60–70) and an older age group (aged over 70). MANOVA was used preliminarily to see if there was an age effect in the presence of the collection of all the executive tasks. Therefore, 10 variables that were most representative in capturing specific neurocognitive domains were selected in the analysis. They were: number of correct generated words in word fluency, interference values in the Stroop Test, number of correct responses in the Monotone Counting Test, number of correct items in the CLN, number of perseverative errors and categories achieved in the modified version of the WCST, number of correct responses and total errors in the HSC Part A and B, respectively, and three indices in the SET (raw score, total profile score, and total number of rule breaks). Because of the a priori hypotheses regarding specific group differences in specific components of executive function, post-hoc analyses that used univariate tests were conducted to examine the effect of the age grouping on the individual components. Owing to the small sample size, partial eta square (η^2) and Cohen's d (Cohen, 1988) were calculated to determine the effect sizes in case of insignificant results.

Regression was then used to find how much of the variance in each component or total score was explained by age. In a simple regression, age was the only predictor. In the hierarchical regression model, the number of years of education was entered in the first step, then the gender and age, respectively. If age accounted for a significant increase in the explained variance after controlling for educational level and gender, the hypothesis that age affects executive function would be supported.

3. Results

The mean age and education of the participants was 71.83 years (S.D. = 7.05; ranging from 61 to 85) and 10.54 years (S.D. = 3.91; ranging from 0.5 to 18 years), respectively. The mean score of the MMSE was 26.95 (S.D. = 1.9, ranging from 24 to 30). The demographic description is summarized in Table 1. The two age groups did not differ significantly in gender, $\chi^2(1, N = 58) = 0.225$, $p = 0.634$, or education, $t(56) = 0.558$, $p = 0.579$.

Table 1
Demographic characteristics and MMSE score by age groups

Variable	Younger age ($N=27$, 14/13[a])		Older age ($N=31$, 18/13[a])		Total ($N=58$, 27/31[a])		Difference	
	M	S.D.	M	S.D.	M	S.D.	*t*-value	*p*-value
Age	65.48	2.6	77.37	4.52	71.83	7.05	−12.462	<0.001
Education	10.85	3.42	10.27	4.34	10.54	3.91	0.558	0.579
MMSE	27.15	1.92	26.77	1.96	26.95	1.93	0.732	0.467

Note: MMSE = Mini-Mental State Examination.
[a] Male/female.

3.1. Neurocognitive performances

Results from MANOVA indicated that there was no significant main effect between the age groups ($F(10,47) = 1.068$, $p = 0.407$, partial $\eta^2 = 0.203$). The Wilks' lambda is 0.813, which indicates that the group difference is responsible for only 21% of total variance.

Next, the post-hoc tests of between-group effects showed significant differences in perseverative errors and categories in the WCST, and were marginally significant in the raw score of the SET. Table 2 shows the results for each task.

Moreover, there were moderate effect sizes shown in the HSC Part A and the Six Elements Test (total profile score). This suggests that there is a strong relationship between the age groups and the two tests, that is, the older age group tended to perform significantly worse than the younger age group in these tests.

3.2. Components of executive functions

Table 3 summarizes the standardized scores of the components of executive function for the two age groups. No main effect was found between the two age groups ($F(6, 51) = 1.652$, $p = 0.152$, partial$\eta^2 = 0.163$). However, post-hoc tests showed that there was an age effect on attention allocation and planning ($F = 7.728$, $p = 0.007$, partial $\eta^2 = 0.121$). This effect still persists after controlling for educational level and gender ($F(1, 55) = 7.251$, $p = 0.009$, partial $\eta^2 = 0.116$). The older age group tended to perform worse than the younger age group in initiation ($F(1, 55) = 3.494$, $p = 0.067$, partial $\eta^2 = 0.059$, Cohen's $d = 0.48$). However, there were also small to modest effect sizes of aging on the switching and flexibility ($d = 0.34$) and online updating components ($d = 0.38$).

Finally, we added up the standardized scores of each component into one single index and found that there was a significant difference between the two groups ($t(56) = 2.290$, $p = 0.026$), with the younger age group scoring higher than the older age group.

Table 2
Comparison of executive function performances between the two age groups

	Younger old, 60–70 ($N=27$)	Older old, ≥70 ($N=31$)	*F*-value	*p*-value	Partial η^2	Cohen's *d*
	Mean (S.D.)	Mean (S.D.)				
Stroop (interference score)	14.67 (8.61)	13.87 (8.23)	0.131	0.719	0.002	0.09
Word fluence (no. of correct names)	16.96 (4.90)	16.58 (5.10)	0.084	0.773	0.001	0.07
CLN (no. of correct response)	10.70 (4.11)	9.29 (3.21)	2.158	0.147	0.037	0.38
Monotone (no. of correct response)	11.81 (0.62)	11.87 (0.34)	0.188	0.666	0.003	0.12
WCST perseverative error	4.44 (5.03)	7.87 (6.14)	5.300	0.025	0.086	0.60
WCST category	4.33 (1.84)	3.13 (2.05)	5.490	0.023	0.089	0.61
HSC Part A (no. of correct response)	14.63 (0.74)	14.23 (0.88)	3.494	0.067	0.059	0.48
HSC Part B (no. of total errors)	7.22 (4.55)	6.81 (4.92)	0.111	0.741	0.002	0.09
SET (raw score)	5.26 (1.10)	4.58 (1.43)	4.013	0.05	0.067	0.52
SET (no. of total rule break)	0.93 (1.80)	2.00 (4.99)	1.123	0.294	0.020	−0.28
SET (total profile)	3.37 (0.79)	2.90 (1.11)	3.327	0.073	0.056	0.48

Note: CLN = Chinese Letter–Number Span Test; WCST = Modified Card Sorting Task; HSC = Hayling Sentence Completion Test; SET = Modified Six Element Task.

Table 3
Comparison of specific executive function performances between the two age groups

Components	Younger old, 60–70 ($N=27$)		Older old, ≥70 ($N=31$)		F-value	p-value	Partial η^2	Cohen's d
	Mean	S.D.	Mean	S.D.				
Initiation	0.26	0.88	−0.22	1.05	3.494	0.067	0.059	0.48
Sustain	−0.06	1.27	0.05	0.7	0.188	0.666	0.003	0.11
Switching and flexibility	0.18	0.74	−0.15	0.9	2.296	0.135	0.039	0.34
Disinhibition	0.02	0.49	−0.01	0.68	0.04	0.842	0.001	0.03
Attention allocation and planning	0.28	0.7	−0.24	0.74	7.728	0.007	0.121	0.56
Online updating	0.2	1.11	−0.18	0.87	2.158	0.147	0.037	0.38

Table 4
R^2 and changed R^2 of age in simple and hierarchical regression within a narrow band of elderly participants

Variable	Simple regression[a]				Hierarchical regression[b]			
	R^2	F	d.f.	p-value	ΔR^2	ΔF	d.f.	Δp
Total	0.051	2.997	1.56	0.089	0.050	3.655	1.54	0.061
Initiation	0.038	2.207	1.56	0.143	0.032	2.071	1.54	0.156
Sustain	0.013	0.74	1.56	0.393	0.016	0.918	1.54	0.342
Switching and flexibility	0.008	0.441	1.56	0.510	0.012	0.933	1.54	0.338
Disinhibition	0.001	0.042	1.56	0.839	0.001	0.047	1.54	0.829
Attention allocation and planning	0.171	11.538	1.56	0.001	0.176	12.551	1.54	0.001
Online updating	0.022	1.282	1.56	0.262	0.023	1.727	1.54	0.194

[a] Predictor is age.
[b] Predictor is education, gender and age, entered in step.

3.3. Regression with age, education, and gender

Age accounted for some variance in the components of executive function. The results of regression are summarized in Table 4. The amount of age-related variance was only statistically significant in the component of attention allocation and planning, in which age accounted for a 17.1% variance ($F(1, 56) = 11.538$, $p = 0.001$), with the older age group scoring lower in this component. This effect still persisted after controlling for educational level and gender. Age accounted for an additional 17.6% of the variance ($\Delta F(1, 54) = 12.551$, $p = 0.001$). Fig. 1 shows the regression line of this component.

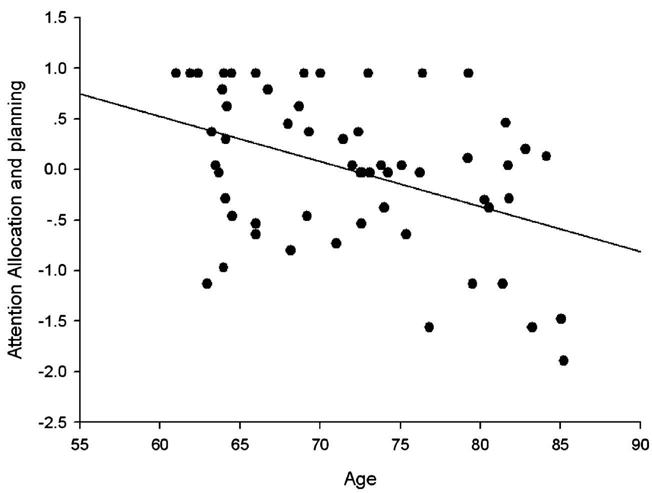

Fig. 1. Prediction of age within the narrow band of elderly participants by the attention allocation and planning component.

Table 5
Regression for executive components with education as predictor

Variable	R^2	$F(1, 56)$	p-value
Total	0.252	18.834	0.001
Initiation	0.119	7.558	0.008
Sustain	0.006	0.352	0.555
Switching and flexibility	0.211	14.980	0.001
Disinhibition	0.009	0.493	0.486
Attention allocation and planning	0.058	3.458	0.068
Online updating	0.236	17.328	0.001

Educational level accounted for a large part of the variance in initiation, switching and flexibility, and updating (see Table 5). It was also responsible for 25.2% of the variance of the total components score ($F(1, 56) = 18.834$, $p < 0.001$). These results demonstrated that the effect of educational level on executive function was stronger than the effect of age.

Adding gender as an additional predictor only significantly increased the explained variance in switching and flexibility ($\Delta R^2 = 0.080$, $\Delta F(1, 55) = 6.222$, $p = 0.016$). It was found that men outperformed women in this component.

4. Discussion

This study extends previous studies on age-related executive function decline among healthy elderly people. The major findings of this study are summarized as follows.

1. There were age-related deficits in the performance in the WCST (perseverative errors and categories completed) and the SET (raw score) for elderly who were 60–85 years old. The total profile score in the SET and correct responses in the HSC Part A also implied some age-related decline when the effect size was taken into consideration.
2. In our sample, attention allocation and planning and initiation were found to be the specific components of executive function that were most affected by the aging process.
3. Age explained a small amount of the variance in executive function, while educational level effected significant changes in specific components of executive function, including initiation, switching and flexibility, and online updating. There might also be a gender effect on switching and flexibility.

4.1. Age effect

There was no significant general age effect on executive function in our sample. However, a look at the effect size showed that there were moderate to modest decrements of performance in the CLN, WCST (perseverative and category scores), SET (raw score, number of rule breaks, and total profile), and HSC Part A. This suggests that aging may be associated with a decrement in executive function, at least for those within the age range from 60 to 85 years. Moreover, when looking into the specific components, the findings showed clear differential decrements in executive function, which indicates that there might be an aging effect on the attention allocation, and planning component and initiation component. These findings were consistent with those of previous studies that used similar tests. The attention allocation and planning component was determined by the WCST and SET. In the WCST, older participants tended to commit more perseverative errors and achieved fewer categories than their younger counterparts. This confirmed the prior well-known age effect in favor of younger adults on these scores (Fristoe, Salthouse, & Woodard, 1997; Rhodes, 2004; Rhodes & Kelly, 2005).

In the SET, the raw score reflected the higher level of attention control in regulating the output of performance, while the number of rule breaks captured the disinhibition of action and attention (Chan et al., 2004a). The results showed a distinct effect on these two scores, which suggests that there is an age-related deficit in attention allocation but not in disinhibition. Phillips, Smith, and Gilhooly (2002) used another executive function task, the Tower of London, and found that older adults showed greater planning impairment than younger adults did in both the positive and negative mood conditions. Allain et al. (2005) used an ecological planning task, the "Zoo Map Test," and showed that elderly participants demonstrated difficulty in developing logical strategies to complete the task. These findings suggest that there is quite a robust relation between age and attention allocation and planning.

In addition, small to modest effects were found between the two age groups in the switching and flexibility and the online updating components – findings which are consistent with those of previous studies that used similar tasks (e.g., Amieva, Phillips, & Della, 2003; Wecker, Kramer, Hallam, & Delis, 2005).

For the sustained attention component and the disinhibition component, neither the *p*-values nor the effect sizes showed an age effect. The Monotone Counting Test was the only task that was used to assess sustained attention, which plays an important role in daily activities. However, this test was found to be irrelevant to age in this study. One possibility is that the test was too easy for our present sample; only seven participants missed one or two trials. By using a more rigorous criterion, the Monotone Counting Test may not actually capture higher level executive functioning, though some studies have shown a significant relationship between this task and other executive attention tasks (e.g., Chan et al., 2004a, 2004b; Chan, Chen, Cheung, et al., 2006; Chan, Chen, & Law, 2006; Robertson et al., 1997). Several studies found an aging effect on the test by using vigilance tasks (reviewed in Giambra, 1997), which may be more difficult than the Monotone Counting tasks. Berardi, Parasuraman, and Haxby (2001) adopted a digit-discrimination task and found no age-related difference in sustained attention capacity either. It is suggested that sustained attention depends on the characteristics of the task and on intrinsic and extrinsic motivational factors.

The disinhibition component comprised the rule-breaking behavior of the SET and HSC Part A, and the interference effect observed in the Stroop Test. In many studies, researchers have claimed that older participants were much slower or made more errors in incongruent conditions than did younger ones in performing the Stroop Test, which was due to the relative impairment in concentration and ability to ignore distraction (Libon et al., 1994; Wecker et al., 2000). Recently, however, a study among healthy older adults aged over 65 years showed that an age effect on Stroop interference for the picture–word test, but not for the color–word test (Graf & Uttl, 1995). With regard to the HSC, Bielak et al. (2005) found that the impact of age was greater in the second than in the first section of the HSC, which was contrary to our findings. These differences in empirical data could result from cultural influences. In this study, our participants had difficulties in understanding the "irrelevant" answers. Moreover, our participants needed much urging to respond, at the expense of more errors in this test.

4.2. Education and gender effect

Age-related selective decline in executive function supported the fractionation of executive function in healthy elderly, but age itself was not responsible for most executive changes in our sample. Educational level played an important role in the changes in executive function, particularly in initiation, switching and flexibility, and updating, tests for which semantic abilities were required and age showed little relevance. The semantic knowledge that was required was mainly acquired through formal education, thus the educational level of a participant directly affected the individual's performance, a finding which supports the findings of others (Chan et al., 2003; Xu, Sun, & Wu, 1989). Specifically, several studies have demonstrated that executive functions were mediated by educational level (Plumet et al., 2005). It seems that elderly people with a low level of education are more likely to suffer executive function decline, and that those with a high level of education are less likely to experience cognitive aging.

Gender-related variance only existed in the switching and flexibility component. de Luca et al. (2003) found that males outperformed females in executive function over a lifespan. In fact, the question of gender differences in executive function is still in debate and warrants further study (Tisserand & Jolles, 2003). The gender difference may derive from biological characteristics, different lifestyles, and daily activities.

The effect of educational level and gender suggested that individual factors determine executive decline. Factors that cause variability in individual differences may include education, emotion, memory, and genetic characteristics (Christensen, 2001). Moreover, there may be some factors that contribute to "successful aging" and prevent cognitive decline (Tisserand & Jolles, 2003). Therefore, it is reasonable to find only a few decrements in executive function, because many of our participants may not yet have suffered decline.

4.3. Limitations

Our findings are subject to the limitations shared by cross-sectional studies, particularly in terms of potential cohort effects. Moreover, we only recruited a relatively small sample in this study, thereby limiting the power of analysis.

Thus, we do not know if the negative findings of aging effect might persist if we recruited a larger sample. Nevertheless, the effect size, which is relatively less dependent on the sample size, may provide partial support for our results. The participants whom we recruited in this study were limited to healthy elderly people. We did not include healthy young adults as the comparison group to examine the "true" aging effect, if any, across the lifespan continuum. Besides, the executive function deficits may occur outside the sample age range, so we would not be able to detect age-related decline. Some lifespan studies have reported a decline in subjects as young as 50 years of age (de Luca et al., 2003), whereas other studies have suggested that such a decline does not occur until people are in their early 70s (Mack et al., 2005). Therefore, our sample has not included an age range that is wide enough to detect this cognitive decline. Furthermore, our sample comprised a relatively large portion of highly educated elderly. These elderly may be involved in a wide range of daily activities that demand cognitive engagement. In so doing, their brains may be more resistant to degeneration.

In our study, the components were derived from the classification of Chan et al. (2004a); Chan, Chen, Cheung, et al. (2006); and Chan, Chen, and Law (2006), but the tests were not exactly the same as those in the original set, with some tests not being included owing to the relatively low endurance of the elderly. We did not adopt a more rigorous approach to defining the components in this study. For example, the Stroop Test assesses reading, naming, and inhibition. In order to obtain more isolated measures of disinhibition, contrast scores need to be developed that parse out performance on the baseline tasks from that of the higher level tasks. However, because of the time constraints in testing the participants, we did not implement the baseline tasks of the Stroop Test, only the interference condition. The word fluency tests and Wisconsin Card Sorting Test may also be insufficient in testing the component of switching and flexibility. Moreover, the number of tests for each component was not equal, with some components including only one test, so the results may be biased to some extent. The sensitivity of these tests is also a problem. Therefore, the findings of selective decline of executive function need further validation.

Moreover, we did not control other cognitive abilities that could mediate between age and executive function. A number of studies have taken perceptual speed into account, because it may be a more primitive ability that is affected by age (Crawford et al., 2000; Fristoe et al., 1997; Salthouse et al., 2003). Therefore, future studies should include tasks that test perceptual speed.

References

Allain, P., Nicoleau, S., Pinon, K., Etcharry-Bouyx, F., Barre, J., Berrut, G., et al. (2005). Executive functioning in normal aging: A study of action planning using the Zoo Map Test. *Brain and Cognition*, *57*, 4–7.

Amieva, H., Phillips, L., & Della, S. S. (2003). Behavioral dysexecutive symptoms in normal aging. *Brain Cognition*, *53*(2), 129–132.

Andres, P., & der Linden, M. V. (2000). Age-related differences in supervisory attentional system functions. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *55*, 373–380 (Abstract).

Berardi, A., Parasuraman, R., & Haxby, J. V. (2001). Overall vigilance and sustained attention decrements in healthy aging. *Experimental Aging Research*, *27*(1), 19–39 (Abstract).

Bielak, A. A. M., Mansueti, L., Strauss, E., & Dixon, R. A. (2005). Performance on the Hayling and Brixton tests in older adults: Norms and correlates. *Archives of Clinical Neuropsychology*, *21*, 141–149.

Buckner, R. L. (2004). Memory and executive function in aging and AD: Multiple factors that cause decline and reserve factors that compensate. *Neuron*, *44*, 195–208.

Burgess, P. W., & Shallice, T. (1996a). Response suppression, initiation and strategy use following frontal love lesions. *Neuropsychologia*, *4*, 263–273.

Burgess, P. W., & Shallice, T. (1996b). Bizarre responses, rule detection, and frontal lobe lesions. *Cortex*, *32*, 1–19.

Chan, R. C. K. (2001). Dysexecutive symptoms among the non-clinical sample: A study with the use of the Dysexecutive Questionnaire. *British Journal of Psychology*, *92*(3), 551–565.

Chan, R. C. K., Chen, E. Y. H., Cheung, E. F. C., Chen, R. Y. L., & Cheung, H. K. (2004a). Executive dysfunctions in schizophrenia: Relationships to clinical manifestations. *European Archives of Psychiatry and Clinical Neuroscience*, *254*, 256–262.

Chan, R. C. K., Chen, E. Y. H., Cheung, E. F. C., Chen, R. Y. L., & Cheung, H. K. (2004b). A study of sensitivity of the sustained attention to response task in patients with schizophrenia. *Clinical Neuropsychologist*, *18*(1), 114–121.

Chan, R. C. K., Chen, E. Y. H., Cheung, E. F. C., Chen, R. Y. L., & Cheung, H. K. (2006). The components of executive functioning in a cohort of patients with chronic schizophrenia: A multiple single-case study design. *Schizophrenia Research*, *81*, 173–189.

Chan, R. C. K., Chen, E. Y. H., & Law, C. W. (2006). Specific executive dysfunction in patients with first-episode medication-naïve schizophrenia. *Schizophrenia Research*, *82*, 51–64.

Chan, C. W. Y., Lam, L. C. W., Wong, T. C. W., & Chiu, H. F. K. (2003). Modified card sorting test performance among community dwelling elderly Chinese people. *Hong Kong Journal of Psychiatry*, *13*(2), 2–7.

Chan, R. C. K., Wang, Y., Deng, Y., Zhang, Y., Yiao, X., & Zhang, C. (in press). The development of the Chinese equivalence version of Letter-Number Span Test: Validity, reliability and clinical discrimination. *Clinical Neuropsychologist*.

Chan, C. C., Yung, C. Y., & Pan, P. C. (2005). Screening of dementia in Chinese elderly adults by the clock drawing test and the time and change test. *Hong Kong Journal of Medical*, *11*, 13–19.

Christensen, H. (2001). What cognitive changes can be expected with normal ageing? *Australian and New Zealand Journal of Psychiatry*, *35*, 768–775.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. New York: Academic Press.

Crawford, J. R., Bryan, J., Luszcz, M. A., Obonsawin, M. C., & Stewart, L. (2000). The executive decline hypothesis of cognitive aging: Do executive deficits qualify as differential deficits and do they mediate age-related memory decline? *Aging, Neuropsychology and Cognition*, *7*, 9–31.

de Luca, C. R., Wood, S. J., Anderson, V., Buchanan, Jo-A., Proffitt, T. M., Mahony, K., et al. (2003). Normative data from the Cantab. I: Development of executive function over lifespan. *Journal of Clinical and Experimental Neuropsychology*, *25*, 242–254.

Fristoe, N. M., Salthouse, T. A., & Woodard, J. L. (1997). Examination of age-related deficits on the Wisconsin card sorting test. *Neuropsychology*, *11*, 428–436.

Frith, C. D. (1992). *The cognitive neuropsychology of schizophrenia*. UK: Erlbaum: Hove.

Giambra, L. M. (1997). Sustained attention and aging: Overcoming the decrement? *Experimental Aging Research*, *23*(2), 145–161.

Guo, Q. H., Hong, Z., Chen, R. Y., Ding, D., Yu, H., & Lv, C. Z. (2003). Comparison for cognitive functions between Chinese elderly and Americans. *Journal of Chinese Mental Health*, *17*, 731–733 (Chinese).

Gold, J. M., Carpenter, C., Randolph, C., Goldberg, T. E., & Weinberger, D. R. (1997). Auditory working memory and Wisconsin Card Sorting Test performance in schizophrenia. *Archives of General Psychiatry*, *54*(2), 159–165 (Abstract).

Graf, P., & Uttl, B. (1995). Color- and picture- word stroop tests: Performance changes in old age. *Journal of Clinical and Experimental Neuropsychology*, *17*(3), 390–415.

Grigsby, J., Kaye, K., & Robbins, L. J. (1995). Behavioral disturbance and impairment of executive functions among the elderly. *Archives of Gerontology and Geriatrics*, *21*, 167–177.

Head, D., Snyder, A. Z., Girton, L. E., Morris, J. C., & Buckner, R. L. (2005). Frontal-hippocampal double dissociation between normal aging and Alzheimer's disease. *Cerebral Cortex*, *15*, 732–739.

Hedden, T., & Gabrieli, D. E. (2004). Insights into the ageing mind: A view from cognitive neuroscience. *Nature Reviews: Neuroscience*, *5*, 87–94.

Lee, T. M. C., & Chan, C. C. H. (2000). Stroop interference in Chinese and English. *Journal of Clinical and Experimental Neuropsychology*, *22*, 465–471.

Libon, D. J., Glosser, G., Malamut, B. L., Kaplan, E., Goldberg, E., Swenson, R., et al. (1994). Age, executive functions, and visuospatial functioning in healthy older adults. *Neuropsychology*, *8*, 38–43.

Mack, W. J., Teng, E., Zheng, L., Paz, S., Chui, H., & Varma, R. (2005). Category fluency in a Latino sample: Associations with age, education, gender, and language. *Journal of Clinical and Experimental Neuropsychology*, *27*, 591–598.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). Contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.

Nelson, H. E. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, *12*, 313–324.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (2nd ed., Vol. 4, pp. 1–18). New York: Plenum.

Phillips, L. H., Smith, L., & Gilhooly, K. (2002). The effects of adults aging and induced positive and negative mood on planning. *Emotion*, *2*(3), 263–272.

Plumet, J., Gil, R., & Gaonac'h, D. (2005). Neuropsychological assessment of executive functions in women: Effects of age and education. *Neuropsychology*, *19*, 566–577.

Rhodes, M. G. (2004). Age-related difference in performance on the Wisconsin card sorting test: A meta-analytic review. *Psychology and Aging*, *19*, 482–494.

Rhodes, M. G., & Kelly, C. M. (2005). Executive processes, memory accuracy, and memory monitoring: An aging and individual difference analysis. *Journal of Memory and Language*, *52*, 578–594.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). Oops!: Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), 747–758.

Royall, D. R., Espino, D. V., Polk, M. J., Palmer, R. F., & Markides, K. S. (2004). Prevalence and patterns of executive impairment in community dwelling Mexican Americans: Results from the Hispanic EPESE study. *International Journal of Geriatric Psychiatry*, *19*, 926–934.

Royall, D. R., Lauterbach, E. C., Cummings, J. L., Reeve, A., Rummans, T. A., Kaufer, D. I., et al. (2002). Executive control function: A review of its promise and challenges for clinical research. *Journal of Neuropsychiatry and Clinical Neurosciences*, *14*, 377–405.

Royall, D. R., Palmer, R., Chiodo, L. K., & Polk, M. J. (2004). Declining executive control in normal aging predicts change in function status: The freedom house study. *Journal of American Geriatrics Society*, *52*, 346–352.

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive function as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology: General*, *132*, 566–594.

Shallice, T., & Burgess, P. W. (1991). Higher-order cognitive impairments and frontal lobe lesions. In H. S. Levin, H. M. Eisenberg, & A. L. Benton (Eds.), *Frontal lobe function and dysfunction* (pp. 125–138). Oxford: Oxford University Press.

Shallice, T., Burgess, P. W., & Frith, C. D. (1991). Can the neuropsychological case-study approach be applied to schizophrenia? *Psychological Medicine*, *21*, 661–673.

Singer, T., Verhaeghen, P., Ghisletta, P., Lindenberger, U., & Baltes, P. B. (2003). The fate of cognition in very old age: Six-year longitudinal findings in the Berlin Aging Study (BASE). *Psychology and Aging*, *18*, 318–331.

Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests: Administration, norms and commentary* (2nd ed.). New York: Oxford University Press.

Stuss, D. T., Shallice, T., Alexander, M. P., & Picton, T. W. (1995). A multidisciplinary approach to anterior attentional functions. *Annals of the New York Academy of Sciences*, *769*, 191–211.

Tisserand, D. J., & Jolles, J. (2003). On the involvement of prefrontal networks in cognitive aging. *Cortex*, *39*(4–5), 1107–1128.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology*, *11*(1), 138–146.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin*, *120*, 272–292.

Wecker, N. S., Kramer, J. H., Wisniewski, A., & Delis, D. C. (2000). Age effects on executive ability. *Neuropsychology*, *14*(3), 409–414.

Wecker, N. S., Kramer, J. H. K., Hallam, B. J., & Delis, D. C. (2005). Mental flexibility: Age effects on switching. *Neuropsychology*, *19*, 345–352.

Wilkins, A. J., Shallice, T., & McCarthy, R. (1987). Frontal lesions and sustained attention. *Neuropsychologia*, *25*, 359–365.

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (1996). *Behavioural assessment of the dysexecutive syndrome (BADS). Thames Valley Test Company*. UK: Bury St. Edmunds.

Xu, S. L., Sun, H. K., & Wu, Z. P. (1989). Word fluency: Age difference in adulthood and relationship with word memory. *Acta Psychologica Sinica*, *21*(4), 337–345 (Chinese).

Wang, Z. Y., Zhang, M. Y., Qu, G. Y., Chen, J. X., & Zhao, J. (1989). The application of the Chinese version of Mini Mental State Examination. *Shanghai Psychiatry Medicine*, *7*(3), 108–111 (Chinese).