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The Psychological Moderating Effect of Olfactory Function on Cognitive Function Changes According to Age in Older People

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Abstract
We conducted this study to verify the regulatory role of olfactory function in age-related cognitive function changes in older people. This study included 140 subjects aged 65 years or older living in region C, South Korea. We conducted an olfactory test and a questionnaire survey. Age significantly affected cognitive function (F=99.115, p<.001), and the explanatory power was 41.4%. The explanatory power with the addition of the olfactory function was significantly increased to 60.8% (F=108.604, p<.001). There was a moderating effect of olfactory function (F=85.135, p<.001), indicating 64.5% explanatory power. Analysis of the conditional effect of olfactory function on cognitive function according to age showed that age had a negative effect on cognitive function when olfactory function is impaired (-1 SD; B=-0.24, se=0.05, t=-4.64, p<.001 and average; B=-0.12, se=0.04, t=-2.69, p=.008). However, age did not appear to have a significant effect on the cognitive function when olfactory function is not impaired (+1 SD; B=0.01, se=0.06, t =0.18, p=.860). We found that olfactory function regulates cognitive function in older people. Therefore, we suggest an intervention program to improve olfactory functions in older people.
Keywords: cognitive function, olfactory function, older people

I. **Introduction**

As of 2020, there were 8.07 million older adults aged 65 years or more in Korea, which is estimated to be 16.5% of the current total population and is expected to increase to 16.98 million by 2040, accounting for over 30% of the total population (Statistics Korea, 2022). Consequently, the incidence and mortality related to geriatric diseases such as cancer, heart disease, pneumonia, cerebrovascular disease, and Alzheimer's disease are increasing. This is an important social issue.

A typical issue observed in older adults is known as cognitive decline. Cognitive function refers to obtaining, manipulating, and using knowledge and understanding the relationship between cause and effect and oneself and the environment (Chu, 2010). Older adults experience cognitive dysfunction (Gomez & Gomez, 1993), accompanied by calculation errors, disorientation disorders, judgment and comprehension disorders, and memory loss (Lehrner et al., 1999). In particular, cognitive decline increases the risk of dementia.

Additionally, cognitive function decreases with age, and the incidences of diseases such as hypertension, diabetes, and stroke increase with age (Oh, 2021), implying a close relationship between aging and decline in cognitive function.

The decrease in olfactory function in older adults seems to result from the inability of the brain to properly recognize sensory signals because of a decrease in the number of olfactory cells with aging and degeneration of the central nervous system (Jung et al., 1993). Older adults may experience a loss of smelldue to a decrease in their cognitive ability to smell (Hsiu-Chiu et al., 1995; Jonathan et al., 1996) and a decrease in the threshold value for olfaction (Min et al., 2006). The olfactory impairment rate in the general population is approximately 24.5%, but in older adults, it is more than 70% (Murphy et al., 2002). Cognitive impairment is significant in older adults with severe olfaction loss (Min et al., 2006). Additionally, impairment of olfactory function appears in the early stages of Alzheimer's disease, which can strongly predict the transition from mild cognitive loss to Alzheimer's disease (Devanand et al., 2013). As age increases, both olfactory and cognitive functions deteriorate (Lee et al., 2007), suggesting a significant relationship between the two functions. Use of olfactory function evaluation tools have increased (Doty et al., 1996), and there is a need for a reliable test to evaluate related functions (Kim, 2014), as decline in olfactory function has emerged as an index for the early diagnosis of diseases such as Alzheimer's disease, dementia, and brain tumors.

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Few studies in Korea have verified the moderating effect of olfactory function on cognitive function in older adults. In older adults with mild cognitive impairment, olfactory function significantly decreased as cognitive function deteriorated (Park, 2021), suggesting the need to understand the correlation between cognitive and olfactory functions from multiple perspectives.

Therefore, the purpose of this study was to examine the moderating effect of olfactory function on cognitive function according to the age of older adults and to identify the changes in olfactory and cognitive functions in older adults at early stages to devise appropriate interventions.

II. Research Method

1. Research Design

This descriptive correlation study aimed to determine whether olfactory function moderates cognitive function according to age in older adults.

2. Research Tool

1) Cognitive Function Evaluation Tool

To evaluate the subjects' cognitive function, we used the Mini-Mental State Examination-Dementia Screening (MMSE-DS) (Kim et al., 2010) an improved version of the existing MMSE test tool, and standardized to reflect the demographic and cultural characteristics of older adults in Korea. The MMSE-DS consists of 19 items with a total score of 30 points, with higher scores indicating better cognitive function. Cronbach's α was 0.864 in this study.

2) Olfactory Function

Cross-Cultural Smell Identification Test (CC-SIT) (Doty et al., 1996) was used for evaluating the olfactory function. The CC-SIT is a test in which the examinee smells a microcapsule containing 12 odors attached to a test strip. Scented parts can be scratched by the examiner or examinee themselves, and the examinee selects the correct answer from four options. The score is the sum of correct answers identifying the 12 odors; higher the score, better the olfactory function. In this study, the researcher scratched the scented parts, allowing the participants to smell them. The subjects who could not read the text were asked to pick the correct answers from four pictorial options. Those who could read were asked to answer independently. The total testing time was approximately 5–10 min.

3. Research Participants and Data Collection

The participants of this study were adults aged 65 years or older, residents of region C of Korea, who could communicate, perform the smell test, and complete the survey questionnaire. Older adults with neurological issues, such as chronic sinusitis, active rhinitis, and stroke, that could affect the smell test were excluded from the study.

The number of participants was calculated using G*power version 3.1.9.2, a program for statistical power analysis. Based on the correlation analysis between olfactory function and other variables, 138 people were calculated as sample size based on two-tailed test, significance level (α)=0.05, power (1-β)=0.95, and median effect size of 0.3.

The institutional review board approved the data collection for this study (IRB No. 1041479-HR-202006-009). The participants were recruited from July 1 to September 30, 2020, using recruitment announcements for older adults in region C in Korea. Considering a dropout rate of 10 %, 151 study participants were recruited. The researchers met the participants in person to explain the purpose of the study. The participants or their guardians signed a consent form to participate in the study and completed the questionnaire and tests. Finally, 140 subjects were included in this study, excluding 11 who discontinued participation, did not complete the questionnaire, or failed to meet the inclusion criteria. The total time required to complete the questionnaire survey and tests was approximately 30–40 min.

4. Data Analysis

The collected data were analyzed using SPSS 25.0 and Hayes' SPSS PROCESS macro 4.0, and the analysis procedure is as follows.

First, frequency analysis and descriptive statistics were performed to determine the distribution and average of participants' age and olfactory and cognitive functions. Second, a simple linear regression was performed to examine the effect of age on cognitive function in older adults. Third, a hierarchical regression analysis was performed to examine the relationship between older adults and the moderating effects of age, cognitive function, and olfactory function. Fourth, the significance of the simple regression line was analyzed using the specific value selection method (Hayes & Matthes, 2009) to examine the moderating effect and significance of olfactory function on the relationship between age and cognitive function in older adults. In other words, to analyze the significance of the moderating effect, the olfactory function values were divided into upper, mean, and lower groups based on the mean and ±1 standard deviation (SD), and the relationship between age and cognitive function was presented as a graph.

III. Results

1. The Olfactory and Cognitive Functions in Older Adults

The study subjects' ages and olfactory and cognitive functions are shown in table 1. The mean age was 75.69±8.92 years, and the average score of the olfactory function was 7.70±2.23 in the range of 0–12, with 64 subjects (45.7%) in the normal group, 38 subjects (27.1%) in the decreased function group, and 38 subjects (27.1%) in the abnormal group. The cognitive function averaged 23.17±5.38 points in the range of 0–30, with 84 subjects (60.0%) in the normal group and 56 subjects (40%) in the cognitive decline group.

Table 1: Olfactory and cognitive functions of the subjects (N=140)

Characteristics	Categories	N(%)	Range	Mean±SD (Min-Max)
Age (year)	65~69	48(34.3)	≥65	75.69±8.92 (65-96)
	70~74	30(21.4)		
	75~79	14(10.0)		
	≥80	48(34.3)		
Olfactory function	normal	64 (45.7)	0-12	7.70±2.23 (3-12)
	deficit relative to younger person	38 (27.1)		
	abnormal relative to age	38 (27.1)		
Cognitive function	normal	84 (60.0)	0-30	23.17±5.38 (9-29)
	cognitive decline	56 (40.0)		

2. Effect of Age on The Cognitive Function in Older Adults

Simple regression analysis was performed to confirm the effect of age on cognitive function in older adults. Age was an independent variable and was found to explain about 41.4% of changes in cognitive function, which was a dependent variable(Table 2). The error independence test was done to determine an autocorrelation between the error terms in the model, no autocorrelation was detected (the Durbin-Watson statistic was 1.657)Significance of the regression model was tested through analysis of variance, and we confirmed the suitability of the regression model (F=99.115, *p*<.001).

Table 2: Effect of age on cognitive function in older adults

Dependent variable	Independent variable	Unstandardized coefficient		Standardized coefficient	t(*p*)
		B	S.E.	β	
Cognitive function	(Constant)	52.693	2.986		17.648***
	Age	-0.390	0.039	-0.647	-9.956***
F=99.115*, Adjusted R^2=0.414**					

***p<.001

3. Moderating Effect of the Olfactory Function

Hierarchical regression analysis was performed to examine whether the relationship between age and cognitive function changes with olfactory function in older adults (Table 3). First, to solve the multicollinearity problem in the hierarchical regression analysis, an interaction term was established by mean-centering age, an independent variable, and the olfactory function score, a moderating variable. In step 1, the effect of age on cognitive function was analyzed, and the explanatory power was 41.4%. In Step 2, the moderating variable, olfactory function, was added to the independent variable (age) for analysis; the explanatory power was significantly increased to 60.8% (F= 108.604, *p*<.001). In step 3, an interaction term was added along with the independent and moderating variables to verify the moderating effect. The explanatory power was 64.5%, indicating an increase in the explanatory power compared to before the interaction term was added. This confirmed the moderating effect of olfactory function (F=85.135, *p*<.001).

Table 3: Moderating effect of olfactory function on the relationship between age and cognitive function.

Dependant variable: Cognitive function												
	Step 1				Step 2				Step 3			
	A→C				A, B→C				A, B, A*B→C			
	B	SE	β	T(*p*)	B	SE	β	T(*p*)	B	SE	β	T(*p*)
(Constant)	52.693	2.986		17.648***	23.171	0.285		80.301***	23.952	0.336		71.210***
A	-0.390	0.039	-.647	-9.956	-0.126	0.045	-0.209	-2.797**	-0.116	0.043	-0.192	-2.687**
B					1.503	0.181	0.622	8.316***	1.351	0.176	0.559	7.670***
A*B									0.056	0.014	0.212	3.923***
F	99.115***				108.604***				85.135***			
R^2	0.418				0.613				0.653			
Adj. R^2	0.414				0.608				0.645			

***p<.001, **p<.01

4. Exploring the conditional effect of olfactory function on changes in cognitive function according to age

As the interaction term between age and olfactory function was significant, the conditional effect of olfactory function was explored using the SPSS Process macro to select specific values of the moderating variable (-1 SD, mean, +1 SD). Table 4 presents the results of this analysis.

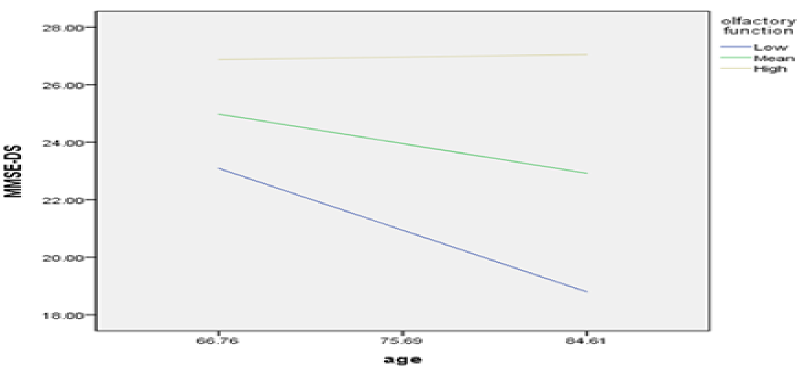
Table 4: Testing the conditional effect of the moderating effect of olfactory function

		Olfactory	**Effect**	**SE**	**t**	**LLCI**	**ULCI**
Olfactory function	-1 SD	5.4730	-2.4080	0.0519	-4.6384***	-0.3435	-0.1381
	Mean	7.7000	-0.1155	0.0430	-2.6871**	-0.2006	-0.0305
	+1 SD	9.9270	0.0097	0.0552	0.1767	-0.0993	0.1188

***p<.001, **p<.01

The interaction diagram depicts the method proposed by Aiken and West (Aiken et al., 1991), and the regression equation of age as the independent variable and cognitive function as the dependent variable when the moderating variables were 0, -1 SD, and +1 SD was estimated and expressed as a simple slope. In other words, analyzing the conditional effect of age on cognitive function according to the olfactory function of older adults, the olfactory function of -1 SD was expressed as low, average as mean, and +1 SD as high. When olfactory function was -1 SD (B=-0.24, se=0.05, t=-4.64, p<.001) and average (B=-0.12, se=0.04, t=-2.69, p=.008) the age of the older adults had a negative effect on cognitive function; when olfactory function was +1 SD (B=0.01, se=0.06, t=0.18, p=.860), there was no significant effect. This means that age does not affect cognitive function when older adults have good olfactory function; however, when olfactory function is below average, the negative effect of age on cognitive function is revealed. A graph of the moderating effect estimated through this is as shown in figure 1.

Figure 1: The simple slope of the cognitive function changes by age at three different levels of olfactory function



IV. Discussion

This study examined the moderating effect of olfactory function on the cognitive function changes according to the age of older adults.

Age of older adults significantly affected their cognitive function, and the explanatory power was 41.4%. This result is similar to previous studies that suggested that the cognitive function of adults aged 85 years or older with mild cognitive impairment was significantly lower than that in adults aged 65–84 years (Park, et al., 2021), and while the incidence of dementia increased because of the decline in cognitive function with aging, the incidence of dementia in people over 80 years of age increased by 25–35% compared to those over 65 years of age (Small, 2001). Therefore, it can be predicted that cognitive function decreases with age and may progress to dementia. Thus, it is crucial to assess cognitive function according to age and to actively utilize age-specific cognitive function improvement programs.

In this study, when the olfactory function,the moderating variable,was added to the analysis along with age, the explanatory power significantly increased to 60.8%, and when the moderating effect was tested in the next step, the explanatory power was 64.5%. These results indicated a moderating effect of the olfactory function. Similar results have been reported in previous studies. In an olfactory function test conducted on 80 adults aged 65 years or more, most participants showed mild (weak smell perception) loss of olfaction (Min et al., 2006), and the olfactory cognitive function of adults aged 85 years or older was significantly decreased compared to those aged 65–84 years (Park et al., 2021). Additionally, the more severe the dementia, the greater the deterioration of the olfactory function (Murphy et al., 2002; Serby et al., 1991). This study confirmed that loss of olfaction could lead to cognitive decline, and it is necessary to seek health promotion methods for maintaining olfactory function in older adults.

Additionally, as a result of exploring the conditional effect of olfactory function on age-related changes in cognitive function, age did not affect cognitive function in older adults with good olfactory function. However, when olfactory function was below average, the effect of age on cognitive function was significant. This result is consistent with a previous study that reported no difference in cognitive function among older adults with mild to moderate olfaction loss and normal olfactory function, but a significant cognitive impairment in older adults with severe olfaction loss, indicating the possibility of cognitive impairment through olfaction loss in older adults (Min et al., 2006). Additionally, as the cognitive function deteriorates, the olfactory cognitive function also decreases (Park et al., 2021), and the olfactory cognitive function of people with memory deterioration decreases with increasing age (Lee et al., 2007). The decline of cognitive and olfactory functions associated with Alzheimer's disease patients worsens with age (Serby et al., 1991). Our results are consistent with these studies and show that olfactory function moderates changes in cognitive function according to the age of older adults.

The olfactory nerve is responsible for distinguishing substances through smell in daily life. Neurofibrillary tangles and senile plaques, known as pathological features of Alzheimer's disease, are found in the nerve cells of the olfactory epithelium (Morris, 2001), and the olfactory nerve can recognize approximately 2,000–4,000 odors (Seoul Asan Hospital Health Information, 2022). Cognitive function, which smells, distinguishes, and expresses it, is directly related to olfactory function; therefore, these two main functions are considered to have a close correlation. This study verified that olfactory function has a moderating effect on cognitive function changes. Therefore, older adults with a lower-than-average sense of olfaction require an institutional system that can assess them through health checkups or community programs. Additionally, it is necessary to develop an effective health promotion intervention before olfactory impairement leads to cognitive decline that could eventually progress to geriatric diseases, such as dementia.

Although this study has a limitation in generalizing the results because it was conducted on older adults from just one region of Korea. However, it is still significant to establish the moderating effect of olfactory function on cognitive function according to the age of older adults.

Based on the results of this study, our suggestions are as follows:

First, we suggest the necessity of an intervention program to improve olfactory and cognitive functions in older adults.

Second, additional research is needed on health promotion systems that help older adults periodically identify and maintain their olfactory and cognitive functions.

Third, expanded research using related studies and a large number of subjects is needed on the mechanism of changes in the cognitive function with the moderating effect of the regulation of the olfactory function.

V. Conclusion

The results of this study confirmed that cognitive function declines according to the age of older people, which can progress to dementia, and loss of smell can lead to cognitive decline. In particular, when olfactory function was below average, the effect of age on cognitive function was significant. And, in this study, we verified that the olfactory function has a modulating effect in the cognitive function change according to the age of the older people. Therefore, it is necessary to evaluate changes in cognitive function according to age at an early stage, to actively utilize age-specific cognitive function improvement programs, and to seek health promotion methods for maintaining olfactory function in older people. In particular, it is considered that it is necessary to establish an institutional system for the initial assessment of older adults with lower-than-average olfactory function and to develop an effective health promotion intervention method before progressing to geriatric diseases such as dementia.

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