DO PULMONARY FUNCTION AND SMOKING BEHAVIOR PREDICT COGNITIVE FUNCTION? FINDINGS FROM A BRITISH SAMPLE

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(Received 27 October, 1995)

The relationship of smoking behavior, pulmonary function, and four measures of cognitive function was studied in a sample of 4,399 men and women (mean age = 44.7 ± 17.1 years; age range: 18 to 94 years) randomly selected from British electoral registers. Each subject was assessed with a face-to-face structured interview (including demographic data, smoking history, and health-related questions) as well as cognitive testing [simple reaction time (SRT), choice reaction time (CRT), incidental memory, and spatial reasoning] and pulmonary function testing. Results indicated that smoking was associated with somewhat better performance on the CRT and memory tasks, and that smoking behavior was not associated with decrements in cognitive performance. Impaired pulmonary function was generally associated with poorer cognitive performance on all of the cognitive measures, suggesting that pulmonary function may be a relevant factor to consider in experimental studies of smoking and cognitive function among healthy adults.

Keywords: Smoking history, pulmonary function, cognitive function.

Past studies of the acute effects of smoking on cognitive performance suggest that smoking may enhance performance on speeded tasks (Hasenfratz and Battig, 1992; Warburton, Rusted and Fowler, 1992; West and Hack, 1991), paired associate learning (Mangan, 1983), and verbal memory (Warburton et al., 1986). However, equivocal results have been reported in studies evaluating the cumulative effects of chronic smoking, in which cognitive performance of non-smokers is compared with performance among regular smokers or among individuals with a long smoking history (Spilich, June and Renner, 1992; Hill, 1989). Although performance on less complex cognitive tasks (e.g., simple reaction time) may not be affected by smoking (Carter, 1974; Spilich et al., 1992), there is evidence of impaired functioning among regular smokers on more complex measures of psychomotor speed and working memory (Hill, 1989; Spilich,

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et al.). Frasure-Smith and Rolicz-Woloszyk (1982) have proposed that smoking may have a short-term enhancing effect on cognitive functioning, but may have an overall negative effect on cognitive function. Spilich et al., in a series of five studies, provide compelling evidence for an association of smoking with impaired performance on more complex tasks, such as text comprehension and driver simulation, requiring attention as well as active use of both working memory and long-term memory stores.

In a related line of inquiry, recent epidemiological data from individuals with a family history of Alzheimer’s disease indicated that the risk of developing Alzheimer’s disease decreased as the number of cigarettes smoked increased (van Duijn and Hofman, 1991). Also, subcutaneous administration of nicotine to patients with Alzheimer’s disease has resulted in improvements in visual attention, reaction time, and perception, although not in short-term memory (Jones et al., 1992). Longitudinal data among non-demented community-residing older adults indicates no consistent association of smoking with cognitive decline (Hebert et al., 1993).

Thus, a number of studies suggest that smoking may benefit at least some aspects of cognitive function in some individuals. It has been suggested that smoking may enhance cognitive functioning via a stimulating effect of nicotine on nicotinic receptors in the brain (Jones, Sahakian, Levy, Warburton and Gray, 1992) or nicotine-related neuuropeptide release (Pomerleau, Fertig, Seyler and Jaffe, 1983). Alternatively, it has also been suggested that improved cognitive performance following smoking may result from relieving the symptoms of smoking abstinence rather than from a primary effect of nicotine on the brain (Le Houezec and Benowitz, 1991).

Past studies of smoking and cognitive function have been limited by confounds, such as lack of experimental control of age or pulmonary status, and no attempt to control for the effects of education. Pulmonary status may be particularly relevant, since research on hypoxic patients with chronic obstructive pulmonary disease (COPD) has documented the presence of mild decrements in cognitive functioning (Grant, Prigatano, Heaton, McSweeney, Wright and Adams, 1987). Because smoking history is a primary risk factor for COPD and other lung disorders, smoking may have an indirect effect on cognitive function through its impact on pulmonary function. Age may compound the observed cognitive deficits among pulmonary patients because most patients with impaired lung functioning are older, and studies have found consistent changes in cognitive functioning associated with age. Previous studies have not evaluated the relationship of pulmonary function, smoking, and cognitive function in healthy adults.

This study was designed to explore the association of cognitive functioning with smoking and pulmonary function, and to evaluate the relative contribution of smoking and pulmonary factors in cognitive performance. The study utilized data from the Health and Lifestyle Survey (HALS), a representative sample of adults (aged 18-94 years) in Great Britain (Cox et al., 1987). The HALS is the largest survey of its kind conducted in Britain, and included data on cognitive functioning, physical health and functioning, psychological well-being, activity levels, and lifestyle. The following hypotheses were evaluated: (1) smoking would not be associated with performance on a less complex reaction time task, but would be associated with impaired performance on more complex tasks, and (2) pulmonary function would be positively correlated with cognitive performance. In addition, the data were analyzed to explore (3) the association of cognitive performance with cumulative effects of smoking, as assessed by smoking history, and (4) among smokers, the association of cognitive performance with amount of time elapsed since the subject last smoked.
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METHODS

Sample
Random selection procedures were utilized to select 12,254 addresses of individuals
18 years and older from English, Welsh and Scottish Electoral Registers. Of the 12,254
individuals contacted, 3,251 individuals were unwilling to participate or were
available. HALS was then conducted with the remaining 9,003 adults, who were
found to provide a representative sample of the British population as compared with
recent Census data (Cox et al., 1987).

The HALS was conducted in three stages, the first of which was a face-to-face
interview completed in the subject's home, including questions about the subject's
home and family life, social support, self-reported health, attitudes about health, dietary
habits, exercise and leisure activities, smoking habits and alcohol consumption.

The second stage of HALS required a home visit by a community nurse for the
purpose of physiological measurements including pulmonary function, height, weight,
and blood pressure, as well as simple tests of cognitive function (reaction time,
memory, and spatial reasoning). At the conclusion of the nurse's visit, subjects were
given a booklet, including three self-completion psychological questionnaires, and
were asked to return them by mail. Of the 9,003 subjects initially interviewed, 1,589
refused the follow-up visit, yielding 7,414 subjects for the nurse's visit, of whom 6,572
completed the mail-in questionnaire.

The sample was further limited by (1) random missing values for independent and
dependent variables, and (2) exclusion of current and ex-smokers who reported
smoking less than ten cigarettes per day, to be consistent with prior studies of smoking
(e.g., Pomerleau et al., 1983; Sherwood, Kerr, and Hindmarch, 1992). Thus, this study
was conducted on a subset of 4,399 subjects for whom complete data were available.
The sample was approximately evenly divided by gender (45% male, 55% female),
with a mean age of 44.7 (± 17.1) years (range: 18 to 94 years). Approximately half
of the sample (49%) had achieved at least the equivalent of a tenth grade education.
Most subjects (51%) rated their own health as 'good', with 21% reporting 'excellent',
23% 'fair', and 5% 'poor'.

Measures
The complete survey included extensive questions regarding social support, health
beliefs, and health practices, in addition to standard psychological questionnaires and
cognitive measures. This study utilized the pulmonary function measure, body weight,
and cognitive function assessed during the nurse's visit, in addition to demographic
variables and smoking history.

Education
In addition to age and gender, it was important to account for the effects of education
on cognitive performance. However, evaluation of educational level was complicated
because the educational system in Great Britain has undergone several significant
changes during the past 60 years, including a reorganization of State or Church schools
after 1944. Thus, no meaningful continuous variable (such as grades of school
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and those who had received less than a tenth grade education \((n = 2224, 51\%)\). The number of subjects in the sample with no education was negligible \((n = 3)\), hence those subjects were included in the latter (less than tenth grade) education group.

**Smoking Status**

The questionnaire included extensive questions regarding present and past smoking behavior. Based on the self-report data, subjects were initially categorized into three groups: never smoked \((n = 2013)\), past smokers (quit at least one year ago and smoked at least ten cigarettes per day, \(n = 843\)), and current smokers (smoking at least ten cigarettes per day, \(n = 1543\)).

Categorization of smokers and ex-smokers was intended to maintain consistency with prior studies of smoking behavior (e.g., Hill, 1989; Pomerleau et al., 1983; Sherwood et al., 1992). There were no significant differences in age, gender, or education among the three smoking groups.

**Pulmonary Function**

During the nurse’s visit, standard measurements of pulmonary function were assessed with an electronic spirometer (Micro Medical Ltd., London, England), which was chosen for its accuracy, reproducibility, and simplicity of use. The spirometer is a hand-held device with a large circular mouthpiece. Subjects were instructed to take a very deep breath and to blow into the mouthpiece as forcefully as possible, sustaining the exhalation for as long a time as possible. The spirometer recorded three measurements, one of which was used in this study: forced expiratory volume in one second \((FEV_1)\). \(FEV_1\) is the volume of air in liters expelled during the first second of exhalation into the spirometer. \(FEV_1\), one of the most frequently used measures of lung functioning and a useful indicator of airway obstruction, \(FEV_1\), was associated with younger age \((r = .62, p < .001)\), male gender \([F(1, 4397) = 929.04, p < .001]\), and greater education \([F(1, 4397) = 517.87, p < .001]\). \(FEV_1\) did not differ significantly across the three smoking groups.

**Cognitive Functioning**

The cognitive test battery was developed for HALS to assess mental speed, short-term memory, and problem-solving ability (Cox et al., 1987). The battery included two measures of reaction time \((RT)\), a measure of incidental memory, and a measure of spatial reasoning. Prior analyses indicated that the reaction time and spatial reasoning tasks have adequate reliability (Cronbach’s alpha for spatial reasoning = .76), but that reliability of the incidental memory task is low (Cronbach’s alpha = .42; Emery, Huppert, and Schein, 1995).

1) RT was assessed with a portable unit, consisting of a small display screen under which there were five keys, labelled from left to right, 1, 2, 0, 3, 4, (Batvale Electronics, Cambridge, England). Subjects rested the dominant hand on the keyboard, and numerals were displayed on a small screen. The apparatus allowed measurement of simple reaction time \((SRT)\) and choice reaction time \((CRT)\). SRT was measured as the time taken to respond to a single, known target numeral. Subjects were given 8 practice trials followed by 20 test trials, with the time between each response and the next digit randomly varied between one and three seconds. For each SRT trial, only the digit ‘0’ appeared, and subjects pressed the center key labelled ‘0’ with the second finger of

the dominant hand. Faster reaction times indicate

\[ p < .001 \]

2) CRT was then advanced to include the presentation of both present and non-present digit. Subjects were divided into two groups in order to present the digits in a random order which were to be remembered. The subjects were asked to press the response to the target digit as quickly as possible, but were also asked to remember the non-target digit. The subjects were then asked to recall the digits in the order presented.

3) Inclusion of the digit was presented in a list of digits, which were then divided into two groups, one including apples and the other bananas. The subject was then asked to perform the CRT as quickly as possible \((4397)\).

4) Spatial reasoning was assessed using the Benton Visual Retention Test, which measures spatial orientation and consists of a series of interrelated drawings. Subjects were asked to recall the drawings in the correct order, which was scored as an index of spatial orientation and memory. Incorrect responses were recorded, and the scores were used to assess the association with cognitive functioning.

**Data Analysis**

To address the effects of education, gender, smoking status, and incident, associations to establish the reliability of the tests were analyzed. Smoking status was included in the analyses to explore the relationships between education, incident, and the intensity of smoking behavior.
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5 to assess mental speed, short-term memory, and a measure of reaction time and spatial reasoning or spatial reasoning (Cr). Subjects were given two tasks. One task involved remembering a series of words, and the other task involved remembering a series of numbers. The results showed that subjects with lower FEV₁ scores performed worse on the spatial reasoning task than did subjects with higher FEV₁ scores.

Data Analysis

To address the first two experimental hypotheses, each of the four cognitive measures was regressed onto pulmonary function (FEV₁), after first entering age, gender, height, education, and smoking status into the analysis, to control for the association of age, gender, and education with cognitive function, and education with cognitive function, as well as the potential association of height and smoking status with pulmonary function. Follow-up regression analyses were conducted to investigate the interactions of Age x Pulmonary Function and of Smoking Status x Pulmonary Function on cognitive function. The third and fourth exploratory hypotheses were addressed with hierarchical multivariate regression analyses predicting cognitive performance from measures of smoking frequency and intensity, as described below.
Analysis of missing subjects

Preliminary analyses of demographic, smoking, and pulmonary function data for the 4604 subjects with incomplete or excluded data revealed that the missing subjects were older (difference in mean age = 2.3 years) [F(1, 9001) = 39.2, p < .001], were more likely to be female (58% vs. 55%) [X^2(1) = 9.1, p < .01], and were less likely to have been educated beyond tenth grade (51% vs. 56%) [X^2(1) = 23.2, p < .001]. Missing subjects were less likely to report current smoking than study subjects (29% vs. 35%) and more of them had never smoked (52% vs. 46%) [X^2(2) = 37.8, p < .001]. No difference in pulmonary function was observed between the two groups [F(1, 6743) = 1.61, p > .2].

RESULTS

Hierarchical multiple regression analysis indicated that pulmonary function was a significant predictor of SRT [F(1, 4392) = 66.75, p < .001], after controlling for the contribution of age, gender, height, education, and smoking status, as shown in Table 1. Analysis of CRT indicated that faster CRT was associated with smoking [F(1, 4393) = 5.32, p < .05] and with better pulmonary function [F(1, 4392) = 101.81, p < .001].

Regression of the memory scores indicated that smoking behavior and pulmonary function were associated with memory task performance, although the amount of variance after entering the other variables was negligible [Smoking R^2 change = .0012, F(1, 4393) = 5.99, p < .05; Pulmonary function R^2 change = .0066, F(1, 4392) = 32.44, p < .001]. Similarly, pulmonary function accounted for a very small but significant amount of variance in spatial reasoning performance [F(1, 4392) = 43.26, p < .001], as shown in Table 1.

Regression analyses indicated significant interactions of Age x Pulmonary Function for all four cognitive variables, but no interaction of Smoking x Pulmonary Function for any of the cognitive variables, as shown in Table 2. The Age x Pulmonary Function interactions indicated that pulmonary function was more strongly associated with cognitive function among older subjects than among younger subjects.

Table 1 Hierarchical regression of cognitive function for total sample (n = 4399)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>SRT R^2</th>
<th>CRT R^2</th>
<th>Memory B</th>
<th>Spatial Reasoning B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>.2824</td>
<td>.1362***</td>
<td>.5222</td>
<td>-.2028</td>
</tr>
<tr>
<td>Gender</td>
<td>.0572</td>
<td>.0305</td>
<td>.1592</td>
<td>-.1787</td>
</tr>
<tr>
<td>Height</td>
<td>.0100</td>
<td>.0273</td>
<td>-.0439</td>
<td>-.0177</td>
</tr>
<tr>
<td>Education</td>
<td>-.1602</td>
<td>-.1869</td>
<td>.1361</td>
<td>.1696</td>
</tr>
<tr>
<td>2. Smoking</td>
<td>-.0100</td>
<td>.1364</td>
<td>-.0277</td>
<td>.3681*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.0350</td>
</tr>
<tr>
<td>3. FEV_1</td>
<td>-.1773</td>
<td>.1493***</td>
<td>-.1865</td>
<td>.3825***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.1264</td>
</tr>
</tbody>
</table>

* p < .05; ** p < .01; *** p < .001
Note: p-values reflect significance of R^2 change for each step
SRT = simple reaction time; CRT = choice reaction time; Spatial Reasoning = spatial reasoning

Table 2 Results of Predictors

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Age x FEV_1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Height</td>
</tr>
<tr>
<td>Education</td>
<td>Smoking</td>
</tr>
<tr>
<td>FEV_1</td>
<td>Smoking x FEV_1</td>
</tr>
</tbody>
</table>

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The calculation by subjects period. Missing were not so

To evaluate four cognitive education, significant Table 3. We analyses, p

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<table>
<thead>
<tr>
<th>Predictors</th>
<th>SRT R²</th>
<th>CRT R²</th>
<th>Memory B</th>
<th>Spatial Reasoning B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>.2824</td>
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<td>.1592</td>
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<td>.0273</td>
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<td>1.3611</td>
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<td>Education</td>
<td>-.1602</td>
<td>-.1869</td>
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<td>3. FEV₁</td>
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<td>.1493***</td>
<td>-.1865</td>
<td>.3825***</td>
</tr>
</tbody>
</table>

* p < .05; ** p < .01; *** p < .001
Note: p-values reflect significance of \( R^2 \) change for each step
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To evaluate the effects of smoking on cognitive function, the calculated values were not statistically significant. To evaluate the impact of education on cognitive function, the regression analyses were not performed. The regression analysis of current smoking and cognitive function \( [F(1, 4392) < .001] \) did not yield significant results.
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### Table 2 Regression analysis of age, smoking status, and pulmonary function on cognitive function (\( n = 4399 \))

<table>
<thead>
<tr>
<th>Predicators</th>
<th>B</th>
<th>SRT</th>
<th>R²</th>
<th>CRT</th>
<th>R²</th>
<th>Memory</th>
<th>R²</th>
<th>Spatial Reasoning</th>
<th>R²</th>
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<tbody>
<tr>
<td>1. Gender</td>
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<tr>
<td>Age x FEV₁</td>
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<td>.5222</td>
<td>.3674***</td>
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<td>.0819***</td>
<td></td>
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<tr>
<td>3. FEV₁</td>
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<td>.1492***</td>
<td>-.1874</td>
<td>.3818***</td>
<td>.1276</td>
<td>.1087***</td>
<td>.1475</td>
<td>.0908***</td>
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<tr>
<td>4. Age x FEV₁</td>
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<td>.1743***</td>
<td>-.3731</td>
<td>.4032***</td>
<td>.1789</td>
<td>.1136***</td>
<td>.1814</td>
<td>.0959***</td>
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<tr>
<td>Smoking x FEV₁</td>
<td>-.0074</td>
<td>.0638</td>
<td>-.0181</td>
<td>.1199</td>
<td>.0313</td>
<td>.0656*</td>
<td>-.0004</td>
<td>.0745</td>
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<td>3. FEV₁</td>
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<td>-.4899</td>
<td>.2966**</td>
<td>.2208</td>
<td>.1015**</td>
<td>.1488</td>
<td>.0908***</td>
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<tr>
<td>4. S x FEV₁</td>
<td>-.0574</td>
<td>.1337</td>
<td>-.0354</td>
<td>.2967</td>
<td>-.0118</td>
<td>.1015</td>
<td>.0503</td>
<td>.0910</td>
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* \( p < .05 \); ** \( p < .01 \); *** \( p < .001 \)
Note: \( p \)-values reflect significance of \( R^2 \) change for each step
FEV₁ = forced expiratory volume in one second; SRT = simple reaction time;
CRT = choice reaction time

To evaluate the extent to which cognitive performance was associated with extent of smoking behavior, hierarchical multivariate regression analyses were conducted on data from the subset of current and past smokers \( (n = 2386) \). Pack-years of smoking was computed for all subjects using the following standard formula:

\[
\text{(# packs/day)} \times \text{(# of years smoked)} = \text{pack-years}.
\]

The calculation of pack-years took account of periods of smoking abstinence reported by subjects, as well as variations in amount of smoking during the reported smoking period. Mean pack-years of current smokers (24.4 ± 17.5) and ex-smokers (25.5 ± 26.3) were not significantly different \( F(1, 2384) = 1.73, p > .15 \).

To evaluate the association of pack-years with cognitive performance, each of the four cognitive variables was then regressed on the covariates age, gender, height, and education, followed by pack-years. The regressions revealed that pack-years did not significantly predict performance on any of the cognitive variables, as shown in Table 3. When smoking status and pulmonary function were entered into the regression analyses, pack-years still did not account for a significant share of the variance in cognitive performance.

The regressions were then repeated for the current smokers \( (n = 1543) \), substituting number of cigarettes smoked per day instead of pack-years to further discriminate current effects of smoking from cumulative effects of lifetime smoking exposure. The analyses revealed that amount of smoking was a significant predictor of spatial reasoning performance, even when controlling for the contribution of pulmonary function \( F(1, 1536) = 9.99, p < .01 \), but it accounted for less than 1% of the variance in performance. Smoking was not a significant predictor of any of the other cognitive variables.
Table 3  Hierarchical regression of cognitive function among current and ex-smokers (n = 2386)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>SRT B</th>
<th>SRT R²</th>
<th>CRT B</th>
<th>CRT R²</th>
<th>Memory B</th>
<th>Memory R²</th>
<th>Spatial Reasoning B</th>
<th>Spatial Reasoning R²</th>
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<td>.0261</td>
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<td><strong>Model 2</strong></td>
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<td>.0808</td>
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<tr>
<td>3. FEV₁</td>
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<td>.1472***</td>
<td>-.1812</td>
<td>.3963***</td>
<td>.1150</td>
<td>.1062***</td>
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<td>4. Pack-Years</td>
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<td>-.0011</td>
<td>.0890</td>
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</table>

*p < .05; **p < .01; ***p < .001
Note: p-values reflect significance of R² change for each step
SRT = simple reaction time; CRT = choice reaction time

To assess effects of smoking recency on cognitive performance, analyses were conducted of time since last cigarette for the current smokers. This variable was not available for all current smokers, hence a smaller sample was used (n = 1259). Regression analyses, entering the covariates followed by time since last cigarette, revealed no effect of smoking recency on any of the cognitive measures, as shown in Table 4. When pulmonary function and pack-years were entered into the equation prior to smoking recency, smoking recency still did not predict cognitive performance.

DISCUSSION

The data suggest a very mild relationship of smoking with cognitive performance. Smokers demonstrated no impairment on more complex tasks (CRT, memory, and spatial reasoning), and, in fact, performed somewhat better than ex-smokers on the CRT and memory tasks. The results thus differ from those of Spilich et al. (1992) suggesting that smokers have more difficulty than non-smokers or ex-smokers on tasks of greater cognitive complexity. One possible explanation for the present finding is that the cognitive tasks in this study were of less complexity than the tasks used by Spilich et al. Another possible explanation is that the ex-smokers in this study may have had significant health problems that had forced them to quit smoking and that might also affect cognitive function. However, significant health problems would be inconsistent with subjects' self-ratings of health. Also, only 19% (n = 843) of the sample was described as ex-smokers.

Results of this study may also be somewhat affected by subject attrition. Despite initial success recruiting a representative sample of 9,003 subjects, complete data were available only for a sample of 4,399 subjects. The bias toward somewhat younger males, with more education and more smoking behavior limits the generalizability of the results pulmonary...
of the results. The strength of the study rests in the evaluation of cognitive function, pulmonary function, and smoking in a large sample of community-residing adults. Although the regression analyses indicated that smoking status was a statistically significant predictor of reaction time and memory performance, the clinical relevance of the association is questionable. The amount of variance explained by smoking status was minimal when controlling for the covariates (< 1%), while the regressions indicated no facilitation of cognitive performance associated with amount of smoking, and only minimal facilitation associated with recency of smoking (spatial reasoning). The data were limited by self-report measures of smoking behavior and the use of pack-years as a measure of smoking behavior. Although pack-years is commonly used in clinical medical settings, it may not reflect accurately variations in smoking frequency and smoking style (e.g., inhaling vs. not inhaling) which, in turn, may be relevant for evaluating the relationship between pulmonary function and cognitive function.

The relationship of cognitive function with pulmonary function was the most striking and consistent result of the study, although the amount of variance in cognitive performance explained by pulmonary function was also relatively small. The study did not include any other objective pulmonary function measure, such as blood-oxygen saturation levels, that would be potentially relevant to cognitive performance. However, it is possible that oxygen saturation or other biological markers, unexplained by these data, account for the significant association. Also, the relationship may be attributable to more general differences in speed of processing, since the pulmonary function testing required that subjects follow directions carefully and exhale as fast as possible. Although the association of cognitive function and pulmonary function was statistically significant, the results must be interpreted cautiously. The clinical significance of the data must be determined by further empirical investigation.
Overall, the results suggest a relationship between pulmonary function and cognitive function that may not be mediated by smoking behavior. Instead, age may be a much more important factor, with pulmonary function and cognitive function more strongly associated among older adults than among younger adults. In addition, environmental factors and individual differences may be important to evaluate further in understanding the relationships among smoking behavior, pulmonary function, and cognitive performance. For example, the utility of pulmonary function data has been confirmed in studies of cognitive functioning among COPD patients, but further studies are needed to explore the utility of pulmonary function data for predicting functional outcomes among healthy adults. Small sample experimental studies, with tighter control over intervening variables, will help to elucidate the nature of these relationships. Laboratory studies of smoking effects on a wide range of cognitive tasks are also needed to further understand the relationship of smoking with cognitive performance.

Author's Notes

This work was supported by a Fulbright Fellowship awarded to Dr. Emery, and by grants from the National Heart Lung and Blood Institute (HL45290) and the National Institute on Aging (AG00029). We are grateful for the support of the Health and Lifestyle Survey staff, especially for the technical assistance of Judith A. Nickson and A. Toby Prevost.

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