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Head size and cognitive ability in nondemented older adults are related

Article abstract—In a cross-sectional analysis of 818 healthy older individuals (aged 50 to 81 years), head size was found to be related to performance on tests measuring intelligence, global cognitive functioning, and speed of information processing, but not memory. These relations were not confounded by educational level, socioeconomic background, or height. Large head/brain size may protect elderly people against cognitive deterioration, supporting a reserve hypothesis of brain aging.

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During childhood and adolescence, total brain mass increases and as a consequence so does head size. In the 20s, the volume of the brain starts to decrease, whereas head size remains constant throughout life.¹ Hence, head size is an indicator of maximal mature brain size. Larger brains may contain more neurons and synaptic connections and may therefore provide a greater reserve against cognitive decline when tissue loss or brain damage occurs.^{2,3} In elderly subjects, small head/brain size has been found to be a vulnerability factor for cognitive dysfunctioning. Katzman et al.⁴ found at autopsy that the main difference between 10 nondemented subjects who had signs of Alzheimer brain pathology and subjects without such signs was that the former had heavier brains and more large neurons. The authors suggested that having a larger brain protected these subjects from developing Alzheimer symptomatology. Several studies have found evidence for such an association between head/brain size and cognitive ability.^{5–7} These studies mainly focused on demented subjects. Only one large study⁸ focused on a healthy elderly population (n = 825) and reported that smaller head size was associated with low Mini-Mental State Examination (MMSE) scores.

The goal of the current study was to investigate whether we could corroborate the finding that head

size and cognitive performance are related in a healthy elderly population. We examined global cognitive functioning with MMSE and administered tests that assess the function of specific cognitive domains. All associations were controlled for the potentially confounding influences of height, socioeconomic background, and educational level. To test these hypotheses, we used data from 818 nondemented elderly subjects who participated in the Maastricht Aging Study (MAAS).⁹

Method. *Subjects.* Participants took part in the MAAS, a longitudinal study into the determinants of cognitive aging.⁹ In this study, 1869 subjects, initially nondemented and carefully screened for health problems, will be monitored for 12 years. For the current study, the data of participants 50 years and older (n = 818; 431 men, 387 women) were used.

Measurements. A standard neuropsychological test battery was administered to assess cognitive functioning. A full description of the tests used can be found elsewhere.⁹ In short, global cognitive performance was examined with the MMSE. The Stroop Color-Word Task was used to measure speed of information processing. The Word Learning Task was used to assess the ability to learn (WLT Total) and retrieve (WLT Recall) verbal information. To estimate IQ, four subtests of the Groningen Intelligence Test (GIT; comparable to the Wechsler Adult Intelligence Scale) were used: Arithmetic, Vocabulary, Mental rotation, and Analogies.

Head size (in mm) was determined twice with a tape measure placed around the subjects' head, 0.5 cm above the eyebrows and over the occipital protuberance. The mean of the two values was used for further analysis. Height was measured to the nearest millimeter. Educa-

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Table 1 Association (unstandardized regression coefficients) of head size with cognitive test performance, adjusted for age and sex

Test	Head size, categorical				Head size, continuous
	1 (58.2–62.2 cm)	2 (56.8–58.1 cm)	3 (55.4–56.7 cm)	4 (50.7–55.3 cm)	
GIT					
Arithmetic	(Reference)	-0.96†	-1.56‡	-1.33‡	0.21†
Vocabulary	(Reference)	-0.77†	-0.74*	-0.80*	0.14*
Mental rotation	(Reference)	-0.45	-0.82†	-0.56	0.16†
Analogies	(Reference)	-0.50	-0.46	-0.56	0.09
Stroop 1	(Reference)	1.90†	2.66‡	1.41	-0.21
Stroop 2	(Reference)	2.30†	3.59‡	3.29†	-0.54†
Stroop 3	(Reference)	4.13	8.52‡	8.39†	-1.48†
WLT Total	(Reference)	-0.34	-1.24	0.13	-0.09
WLT Recall	(Reference)	-0.02	-0.08	0.12	-0.04
MMSE	(Reference)	-0.35†	-0.28	-0.37*	0.07*

* $p < 0.10$; † $p < 0.05$; ‡ $p < 0.01$.

GIT = Groningen Intelligence Test; WLT = Word Learning Test; MMSE = Mini-Mental State Examination.

tional level was measured on an eight-point scale, ranging from primary education (1) to higher vocational training or university degree (8). Likewise, socioeconomic background was determined by asking subjects about their father's profession during their childhood, ranging from simple, unskilled work (1) to complex, scientific work (7).

Statistical analysis. Head size was treated both as a categorical variable based on quartiles and as a continuous variable. In both instances, ordinary least-squares regression was used, adjusted for age and sex. Dependent variables included the intelligence and cognitive measures. To test whether the associations with head size still existed after correction for potential confounders, analyses were repeated after separately entering educational level, socio-

economic background, and height into the regression model. Significance was defined as $p < 0.05$. Relations with p levels of <0.10 were considered marginally significant.

Results. The mean age of the participants was 63.2 years (SD 9.0, range 50 to 81). The mean head size was 56.8 cm (SD 2.0, range 50.7 to 62.2). Women had smaller heads than men (55.5 vs 58.0 cm, $p < 0.01$). Age and head size were not related (Pearson $r = -0.04$, $p = 0.32$). Head size and education were associated (Pearson $r = 0.15$, $p < 0.01$). Table 1 shows the association between head size and measures of intelligence and other cognitive functions, adjusted for age and sex. In the categorical analyses, head size was consistently related ($p < 0.05$) to performance on one GIT subtest (Arithmetic), whereas head size as a continuous variable was associated with performance on two intelligence subtests (Arithmetic and Mental rotation). In the other subtests, the relation was in the expected direction but did not reach significance. Furthermore, small head size (both categorical and continuous) was associated with decreased performance on the Stroop task ($p < 0.05$) and with lower scores on the MMSE ($p < 0.10$). Head size and memory performance were not related. The influence of educational level, socioeconomic background, and height were examined in separate analyses (table 2). Adjusting for educational level did not change the relation between head size and cognitive performance. Correcting for both socioeconomic background and height only slightly weakened the associations.

Discussion. In this cross-sectional analysis, smaller head size was found to be associated with lower intelligence, lower general cognitive functioning (MMSE), and slower speed of information processing. No relation was found between head size and memory function. A large brain reserve capacity² may protect older persons against cognitive decline. Head size, reflecting the maximum mature brain

Table 2 Association (unstandardized regression coefficients) of head size (continuous measures) with cognitive test performance, adjusted for age and sex (Model 1) with additional adjustment for socioeconomic background (Model 2), height (Model 3), or educational level (Model 4)

Test	Model 1	Model 2	Model 3	Model 4
GIT				
Arithmetic	0.21†	0.18*	0.18*	0.19†
Vocabulary	0.14*	0.13*	0.07	0.12*
Mental rotation	0.16†	0.12*	0.12*	0.15†
Analogies	0.09	0.06	0.01	0.07
Stroop 1	-0.21	-0.10	-0.12	-0.18
Stroop 2	-0.54†	-0.42*	-0.36	-0.51†
Stroop 3	-1.48†	-1.24†	-1.18†	-1.37†
WLT Total	-0.09	-0.14	-0.16	-0.11
WLT Recall	-0.04	-0.05	-0.07	-0.04
MMSE	0.07*	0.06	0.04	0.06*

* $p < 0.10$; † $p < 0.05$.

GIT = Groningen Intelligence Test; WLT = Word Learning Test; MMSE = Mini-Mental State Examination.

size, represents an indirect measure of this concept. In studies of patients with AD, smaller head/brain size was found to be associated with an increased risk of developing dementia.⁵⁻⁷ A relation between head size and global cognitive functioning has also been found in healthy subjects.⁸ However, an alternative explanation is that the head size–cognition association is based on differences in educational level. In the current study, educational level and head size were significantly related (see also references 1 and 6, although others^{7,8} did not find such a relation). This possibly implies that not large head size but high educational level protects against cognitive decline.¹⁰ Therefore, we investigated the head size–cognition relation both with and without adjustment for educational level. This did not alter the associations, indicating that educational level is not a (strong) mediator of the relation between head size and cognitive performance.

Several other factors may influence the relation between head size and cognitive ability. Small head size may reflect exposure during the process of brain maturation to detrimental factors, such as nutritional deficits or low socioeconomic background. We investigated the effect of paternal profession (reflecting socioeconomic background) and height (possibly reflecting nutritional and other developmental factors during early life) on the head size–cognition relation. Only a subtle decrease in the association was found when height or socioeconomic background was included in the model. This implies that the association between head size and cognitive ability is not substantially confounded by the effects of socioeconomic background or height.

It will be interesting to reconsider these findings using prospective data of the MAAS,⁹ which are being collected. In this way, we may be able to examine whether small head size is a vulnerability factor for cognitive deterioration.

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