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Formal Education, Socioeconomic Status, and the Severity of Aphasia After Stroke

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Abstract

Objective—To determine the role of education and socioeconomic status on the severity of aphasia after stroke.

Design—Cross-sectional study.

Setting—Stroke units of 2 affiliated medical centers.

Participants—Stroke patients (n = 173) within 24 hours of symptom development and hospitalized controls (n = 62) matched for age, education, and socioeconomic status (SES) with normative brain magnetic resonance imaging.

Interventions—Not applicable.

Main Outcome Measures—Percent error on 9 language tasks (auditory and written comprehension, naming [oral, written, and tactile], oral reading, oral spelling, written spelling, and repetition). Education was recorded in years and dichotomized as less than 12 years or 12 years and above for data analysis. Demographic characteristics (age, sex, race) and stroke volume were recorded for adjustment. SES was obtained from census tract data as 2 variables: mean neighborhood household income and family income.

Results—The percentage of errors for participants with 12 or more years of education was significantly lower for auditory and written comprehension, written naming, oral reading, oral spelling, and written spelling of fifth grade vocabulary words, even after adjusting for age, sex, stroke volume, and SES.

Conclusions—These findings suggest that even once learned, access to written word forms may become less vulnerable to disruption by stroke with increasing years of education.

Keywords

Aphasia; Cognitive reserve; Education; Language; Rehabilitation; Social class; Stroke

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Suppliers

Cognitive reserve has been extensively studied in progressive neurologic disease, most prominently dementia and Alzheimer's disease. It has been proposed that people with greater cognitive reserves can use the same brain regions at higher levels, thus having the ability to withstand greater degree of change or pathology while maintaining function.¹ Proposed markers of cognitive reserve include income, occupational attainment, emotional support, social ties, and education.²⁻⁴

Education has long been studied as a measure of cognitive enrichment. The number of years of education is a measure of educational attainment and can be a marker for innate intelligence.² It has been postulated that increasing years of education (an intellectual challenge experienced during life) results in brains with greater synaptic function that are more resilient to aging or pathologic processes.⁵ In Alzheimer's disease, education has been associated with reduced severity and delayed clinical expression of the disease in the presence of similar neurodegeneration.^{6,7} It has also been proposed that education level can affect the cognitive deterioration pattern in Alzheimer's disease.⁸ Evidence for cognitive reserve has also been described in nonfluent progressive aphasia.⁹

Cognitive reserve has seldom been studied in stroke. An article by Elkins et al¹⁰ suggests that education modifies an individual's general cognitive decline after stroke. Cognitive resilience has also been studied in stroke in the context of social integration with 1 study suggesting that social ties provide cognitive reserve after stroke.⁴ A brief retrospective report by Connor et al¹¹ in unilateral left-hemisphere stroke cases reported that lower educational attainment and lower occupational status correlated with increased aphasia severity 4 and 103 months after onset.

In the current study, our goal was to determine the role education might have on the severity of aphasia after stroke before compensatory changes occurred. For that purpose, we studied several language functions to determine if the severity of dysfunction was affected by the individual's educational level. Based on previous studies on cognitive reserve, we hypothesized that individuals with higher education would have lower severity of language dysfunction after stroke. Income has also been associated with cognitive reserve; thus we obtained data on neighborhood family and household income to determine the effect of socioeconomic status (SES) on aphasia severity after stroke.

METHODS

Study Sample

We studied a series of patients (n = 173) consecutively admitted to the Johns Hopkins Hospital or the Johns Hopkins Bayview Medical Center with a diagnosis of acute hemispheric stroke, who agreed to participate in a series of language tests and provided informed consent or whose next-of-kin provided informed consent when appropriate. Inclusion and exclusion criteria included presentation within 24 hours of stroke onset, no history of dementia or previous symptomatic stroke or neurologic disease, no known hearing loss or uncorrected visual impairment, and premorbid English proficiency. Participants with contraindications to magnetic resonance imaging (MRI), pregnancy, altered level of consciousness, hemorrhage on initial scans, global aphasia, or inability to participate in testing were excluded (subjects with global aphasia were unable to assent to participate in the study and were unable to communicate to participate in testing or designate a family member to consent for them). Controls were hospitalized patients with an admitting diagnosis of transient ischemic attack, tested after resolution of their symptoms, with no evidence of infarct on MRI (n = 62). These participants served as excellent controls, because they were similar in age, education, and SES to the stroke patients, had the same

cardiovascular and cerebrovascular risk factors that can affect cognition, and had the same stressors of hospitalization that might affect test results.

Language Testing

A battery of language tests was administered within 24 hours of admission to evaluate various processes underlying lexical tasks. The processes evaluated included access to written and spoken word forms, access to semantic representations in comprehension and naming tasks, and use of sublexical sound-to-print conversion or print-to-sound conversion mechanisms in reading and spelling pseudowords.

The experimental tasks included: (1) oral naming of pictured objects, (2) written naming of pictured objects, (3) oral naming of objects with tactile input (tactile naming), (4) oral reading of words and pseudowords, (5) oral spelling to dictation of words and pseudowords, (6) written spelling to dictation, (7) spoken word-picture verification (ie, auditory comprehension), (8) written word-picture verification (ie, written word comprehension), and (9) repetition of words and pseudowords.

For word-picture verification tasks, the participant had to respond yes or no to verify or deny the correspondence between the picture and the word. The set of pictures was presented as follows: once with the corresponding word (eg, a picture of a cup with the word “cup”), once with a semantic foil (eg, a picture of a cup with the word “plate”), and once with a visually or phonologically related foil (eg, a picture of a cup with “cut”). A correct response is required for both the correct match and both foils to receive credit for understanding the word.¹² Participants were asked to discriminate words versus pseudowords (make a lexical decision) prior to responding in oral reading and dictation tasks. Word frequency, word length in letters and syllables, and grammatical word class were matched across word spelling, reading, picture naming, and comprehension, and repetition tasks. Pseudoword spelling and pronunciation were scored liberally. To exclude the possibility that abnormalities in picture naming were due to visual agnosia naming to tactile input was tested. Norms for these tests were obtained from 50 neurologically healthy controls (mean age $\pm$ SD, 64.7 $\pm$ 10.7y). The median score for healthy controls on all of the tests administered was 100% correct; no normative subject scored below 90%; only participants with at least tenth grade education were administered the reading and spelling tests, as was the case in the present study.¹³

Imaging

Scans were obtained on a 1.5 tesla or 3 tesla, echo-planar imaging (EPI) capable system. Diffusion-weighted imaging (DWI) trace images were obtained using a multislice, isotropic, single-shot EPI sequence, with Bmax of 1000s/mm². At least seventeen 5-mm slices were recorded with a 2-second repetition rate, giving whole brain coverage. Additional sequences included T2, fluid attenuated inversion recovery to rule out previous infarcts, susceptibility weighted images or gradient echo (to rule out hemorrhage), and perfusion-weighted images. Acute stroke was identified as bright on DWI and dark on apparent diffusion coefficient maps. A technologist blinded to the results of cognitive testing determined the lesion volumes (in mm³) on DWI using Image J software.^a The borders of abnormality on each slice were identified on the computer monitor, traced, and the 2-dimensional area of abnormality was calculated. This area was multiplied by the slice thickness to obtain stroke volume.

^a.Image J software. <http://rsbweb.nih.gov/ij>.

Variables

Primary outcome variable and primary predictor—The primary variable of interest was the proportion of errors (% error) on any of the 9 language functions studied. The primary predictor was education, which was recorded at the time of testing in years. For data analysis, education was dichotomized as less than 12 years of education or 12 or more years of education, because 12 years of education (high school education) is the target for formal education in the United States.

Other variables—Demographic characteristics including age, sex, and race were recorded. Using each participant's address, we determined the census tract for that address. From the census tract we determined the mean neighborhood household income and the mean neighborhood family income for each participant (reported by the U.S. Census bureau) as a measure of SES, because SES has also been associated with cognitive reserve. We included stroke volume from the initial MRI images (see Imaging).

Statistical Analysis

Sample characteristics are described for the whole sample, stroke patients and controls (DWI volume > 0 vs DWI = 0) and analyzed using 2 sample tests of proportions, Fisher exact test, or chi-squared test, as applicable. Education was dichotomized into 2 groups: those with less than 12 years of education compared with those with 12 or more years of education. General linear models with a correction for marginal effects (given that the % error data is bound by 0 and 100) were used to adjust for age, sex, and stroke volume. Significance level was set at $P < .05$. Data were analyzed using Intercooled Stata 11.b

RESULTS

Sample Characteristics

The final sample for this study was 235 participants of which 173 had a stroke diagnosis and 62 were neurologically healthy controls. Sample characteristics are detailed in table 1. Of all participants, 49.2% were men. The mean age in this sample was 61.2 years. The racial composition of the sample was consistent with the demographics of the caption area with similar numbers of blacks and whites and with less than 5% being from other racial or ethnic groups. The racial and ethnic composition of the group reflects the population of East Baltimore (the location of Johns Hopkins Hospital), and the age and sex distribution is typical for stroke in this racial and ethnically diverse population.

Sample Characteristics and Language Test Performance by Stroke Volume

Table 2 details the characteristics of stroke patients (DWI volume > 0) and controls (DWI volume = 0). No statistically significant differences in sex, age, racial distribution, education, neighborhood mean household income, or neighborhood mean family income were found between stroke patients and controls. Statistically significant differences were found for all the language functions evaluated with the proportion of errors being greater in the stroke group.

Education

The proportion of errors in oral spelling to dictation and written spelling to dictation differed between participants with lower and higher education (table 3). In the oral spelling to dictation task, participants with less than 12 years of education had 59.6% errors compared

^b.Stata Corp, 4905 Lakeway Dr, College Park, TX 77845.

with 33.2% errors performed by participants with 12 or more years of education ($P < .001$). Similarly, when comparing participants with less than 12 years of education versus 12 or more years of education performing a written spelling to dictation task, the proportion of errors were 69.6% and 31.9%, respectively ($P < .001$). Adjusting for age, sex, and stroke volume did not alter these associations.

On written naming, the rate of errors were 45.7% and 29.4% for participants with less than 12 years of education versus 12 or more years of education, respectively ($P = .052$). Adjusting for age, sex, and stroke volume strengthened this association ($P = .024$) slightly.

Significant differences, albeit of smaller magnitude, were also found in written word and auditory word comprehension (see table 3) by education years. Participants with less than 12 years of education versus 12 or more years of education had error rates of 22.9% and 14.8% ($P = .038$) on auditory word comprehension, respectively, and 29.6% and 19.1% ($P = .022$) on written word comprehension, respectively. These associations were still present after adjustment for demographic characteristics and stroke volume (see table 3).

The rate of errors on the oral reading task were 30.5% and 23.6% for participants with less than 12 years of education, versus 12 or more years of education, respectively ($P = .255$). After adjusting for age, gender, and stroke volume this association was statistically significant ($P = .030$).

No statistically significant differences were found in oral naming, tactile naming, and repetition tasks by education years.

Socioeconomic Status

Neighborhood household income and family income had a modest but significant association with errors on oral spelling and written spelling to dictation. For every \$10,000 increase in mean neighborhood household income or mean family income, the mean rate of errors in oral spelling to dictation decreased by 4% ($P = .002$ for both household and family income). After adjusting for stroke volume, age, and sex these associations were still statistically significant ($P = .005$ for household income and $P = .004$ for family income).

Errors in written spelling to dictation also decreased by 4% for every \$10,000 increase in neighborhood household income or family income ($P = .009$ and $P = .012$, respectively). After accounting for stroke volume, age, and sex, the magnitude of the reduction in errors/\$10,000 increase in income decreased to 3% for both household and family incomes ($P = .041$ and $P = .054$, respectively).

Neither neighborhood household income nor family income had a significant effect on errors in naming (oral, tactile, or written), repetition, comprehension (written word or auditory), or oral reading (data not presented).

Education and SES

Adjusting for SES in addition to age, sex, and stroke volume did not affect the associations between specific language functions and education described above (% error reduction changed by approximately 1%–2% in some cases) (see table 3).

DISCUSSION

In this sample, education at a high school level or above was associated with significant reductions in the proportion of errors made on several language tasks including written spelling to dictation, oral spelling to dictation, and written naming. More modest but

significant reductions in errors were also identified in auditory word comprehension, written word comprehension, and oral reading of words and pseudowords. Education had no significant effect on oral naming, tactile naming, or repetition.

SES as measured by mean neighborhood household income or family income had modest error reducing effects in the 3% to 4% range and only for tasks involving dictation (oral spelling to dictation and written spelling to dictation).

These findings suggest that access to written words may become less vulnerable to disruption by stroke with increasing years of education. Increasing years of education (in this case 12 years of education) resulted in decreased severity of aphasia after stroke in tasks that involved access to written words. These findings are particularly striking in view that all stimuli are considered within fifth grade vocabulary, and that spelling or reading tasks were administered only to participants with at least tenth grade education. Therefore, we assume that participants were able to read the words prior to stroke, but made errors after stroke (consistent with high performance by controls).

Education has long been used as a measure for cognitive reserve. In the absence of pathology, educational level predicts performance on neuropsychologic and language testing.¹⁴ It is reasonable to assert that the effect of education on the brain provides resilience to injury by increasing the number of functional connections that provide access to written word forms. People with at least a twelfth grade education may read more frequently or may be involved in activities requiring more frequent cognitive engagement. More frequent access to written word forms (orthographic representations of words) may strengthen the synapses associated with this process, or may increase the number of synapses capable of supporting this process, making it less vulnerable to brain damage or immediate spontaneous reorganization.

Study Limitations

From these data, we can make no conclusions as to the role of education in aphasia recovery, as participants with aphasia were tested within 24 hours of symptom onset. It is plausible that the resilience provided by a more robust neural network underlying language also facilitates recovery after injury. The role of education in recovery from aphasia (controlling for stroke volume, age, sex, SES, and time postonset of stroke) should be the focus of future studies. Previous studies of the role of education in aphasia recovery have reported conflicting results, perhaps because of the failure to control for these additional variables.^{11,15–20}

CONCLUSIONS

Education (> 12y) was associated with reduced rate of errors in multiple (mostly written) language tasks with fifth grade vocabulary after stroke, indicating that education provides resilience in spite of injury when access to written word forms is needed. These findings further support the previously reported association between education and cognitive reserve.

Acknowledgments

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List of Abbreviations

DWI diffusion-weighted imaging

EPI	echo-planar imaging
MRI	magnetic resonance imaging
SES	socioeconomic status

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Table 1

Sample Characteristics (N=235)

Characteristic	Estimate
Men, n (%)	115 (49.2)
Age *	61.2±15.8
Race, n (%)	
White	107 (45.5)
Black	117 (49.8)
Other/unknown	11 (4.7)
Education * (y)	12.3±3.3
Median ± SE	12±0.41
Mean household income *	38,743±22,477
Median ± SE	34,846±1684
Mean family income *	44,325±24,103
Median ± SE	40,625±1921
DWI volume, mm ³ ± SD	14,731±38,005
Median ± SE	1857±474

* Mean ± SD.

Table 2

Characteristics of Stroke Cases (stroke volume=0) and Controls (stroke volume>0) (N=235)

Characteristic	Stroke Volume=0 (n=62)	Stroke Volume>0 (n=173)	P
Men, n (%)	25 (40.9)	90 (52.0)	.14
Age, mean $\pm$ SD	63.0 $\pm$ 14.4	60.6 $\pm$ 16.3	.30
Race, n (%)			.63
White	25 (40.3)	82 (47.4)	NA
Black	34 (54.8)	83 (48.0)	NA
Other/unknown	3 (4.9)	8 (4.6)	NA
Education, mean $\pm$ SD	12.7 $\pm$ 2.8	12.1 $\pm$ 3.4	.27
Household income, * mean dollars $\pm$ SD	36,338 $\pm$ 21,697	39,563 $\pm$ 22,741	.35
Family Income, † mean dollars $\pm$ SD	43,048 $\pm$ 23,052	44,760 $\pm$ 24,502	.64
Language test, % error $\pm$ SD			
Auditory comprehension	10.1 $\pm$ 19.3	20.0 $\pm$ 29.0	.01
Written word comprehension	13.2 $\pm$ 22.2	25.4 $\pm$ 31.0	.006
Oral naming	10.7 $\pm$ 19.4	27.5 $\pm$ 34.3	.001
Written naming	19.9 $\pm$ 24.5	37.5 $\pm$ 36.2	.02
Tactile naming	11.4 $\pm$ 23.4	25.2 $\pm$ 35.8	.02
Oral reading of words and pseudowords	15.7 $\pm$ 21.7	29.4 $\pm$ 35.9	.01
Oral spelling to dictation	29.0 $\pm$ 26.3	43.4 $\pm$ 36.5	.04
Written comprehension to dictation	26.2 $\pm$ 25.8	43.8 $\pm$ 39.5	.04
Repetition	11.1 $\pm$ 19.1	19.7 $\pm$ 28.6	.01

Abbreviation: NA, not applicable.

* Mean neighborhood household income.

† Mean neighborhood family income.

Table 3

Effect on Education on the Error Rates for Specific Language Tasks, Crude and Adjusted (regression models)

Language Function	No. Tested	%	% Error (mean $\pm$ SD)	Education Effect P Crude	Education Effect P Adjusted*	Education Effect P Adjusted (2) [†]
Auditory comprehension	222	94	17.3 $\pm$ 27.0	.397	.198	.164
Written word comprehension	208	89	21.9 $\pm$ 29.3	.084	.033	.049
Oral naming	189	80	23.1 $\pm$ 32.0	.869	.764	.291
Written naming	101	43	32.7 $\pm$ 34.3	.122	.063	.193
Tactile naming	176	75	21.6 $\pm$ 33.5	.525	.730	.591
Oral reading of words and pseudowords	161	69	25.3 $\pm$ 32.9	.284	.022	.019
Oral spelling to dictation	122	52	39.3 $\pm$ 34.4	.001	.001	.015
Written comprehension to dictation	86	37	38.1 $\pm$ 36.4	.002	<.0001	.001
Repetition	122	52	17.2 $\pm$ 26.4	.161	.086	.006

* Adjusted for stroke age, sex, and stroke volume.

[†] Adjusted for stroke age, sex, stroke volume, and mean neighborhood family income.