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Executive function, episodic memory and Medicare expenditures

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Abstract

INTRODUCTION—We examined the relationship between healthcare expenditures and cognition, focusing on differences across cognitive systems defined by global cognition, executive function, or episodic memory.

METHODS—We used linear regression models to compare annual health expenditures by cognitive status in 8,125 Nurses' Health Study participants who completed a cognitive battery and were enrolled in Medicare parts A and B.

RESULTS—Adjusting for demographics and comorbidity, executive impairment was associated with higher total annual expenditures of \$1,488 per person ($p < .01$) compared to those without impairment. No association for episodic memory impairment was found. Expenditures exhibited a linear relationship with executive function, but not episodic memory (\$584 higher for every 1 standard deviation decrement in executive function; $p < .01$).

DISCUSSION—Impairment in executive function is specifically and linearly associated with higher healthcare expenditures. Focusing on management strategies that address early losses in executive function may be effective in reducing costly services.

Keywords

Medicare; dementia; cognition; aging; executive function; episodic memory; healthcare spending

1. Introduction

Cognitive impairment is a primary feature of many neurodegenerative diseases, including Alzheimer's disease (AD) [1–7]. With the aging population, the prevalence of cognitive

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impairment is likely to increase [2,8]. Yet, the relationship between healthcare costs and cognitive impairment is not well understood.

Recent studies have demonstrated that a diagnosis of dementia is associated with increased healthcare utilization [8,9]. In 2010, Medicare costs attributable to dementia were estimated to be \$11 billion [2,8,9]. In order to develop strategies to manage these expanding costs, it is essential to better understand this relationship. Impairment in episodic memory versus executive function may be a useful distinction. While episodic memory is impaired early in AD, impairment in executive function often predominates in vascular disease; the two co-occur as well [3,10–12]. A second fundamental question is whether healthcare utilization exhibits a continuous relationship with cognitive function, or if it is not until a certain threshold level is reached when cognitive impairment begins to influence spending. Such a distinction could have important implications for timing the initiation of interventions.

In this study, we linked Medicare claims to cognitive data from the Nurses' Health Study (NHS) to investigate the association between impairment in specific cognitive systems and healthcare utilization. The NHS is a large, prospective, epidemiological study of female nurses with cognitive data collected via validated telephone assessments [13,14]. We performed a cross-sectional analysis of NHS participants to evaluate the association between Medicare expenditures and global, episodic and executive function, adjusting for demographic characteristics and chronic comorbid conditions.

2. Methods

2.1. Study Population

The Nurses' Health Study (NHS) is a longitudinal study of female nurses across 11 U.S. states that began in 1976 [13]. The NHS is approved by the Partners Human Research Committee (Boston, MA). From 1995 to 2001, a telephone-based cognitive assessment was initiated in subjects who were at least 70 years of age and free of stroke (93% of those eligible participated). Three follow-up assessments were performed every 2 years (with >90% follow-up rate) [15]. The final cognitive assessment was conducted from 2005 through 2008 and was completed by 8,890 nurses. In this study, only cognitive data from the final assessment were used since Medicare claims data were available starting in 2006.

2.2. Cognitive Assessment

The cognitive battery was administered over the telephone and included the following: Telephone Interview for Cognitive Status (TICS); a delayed recall of the TICS 10-word list; immediate and delayed recall of the East Boston Memory test (EBMT); digit span backwards; and category fluency (animal naming). The TICS is a telephone version of the Mini-Mental State Examination and assesses global cognitive function [16–18]. The EBMT tests paragraph recall and the TICS 10-word list assesses word list recall [19,20]. The category fluency task and digit span backwards both assess aspects of executive function [21–23].

We utilized Z-scores to calculate composite scores to measure global cognitive function, executive function, and episodic memory. The global score was the mean of the Z-scores for

all 6 cognitive tests. The episodic score was the mean of the Z-scores of: the immediate and delayed recall of the TICS 10-word list and the immediate and delayed recall of the EBMT; and the executive score was the mean of the Z-scores of digit span backwards and category fluency.

2.3. Medicare Expenditures and Utilization

A crosswalk was generated by the Center for Medicare and Medicaid Services to link NHS participants to their beneficiary ID on the Medicare claims held at Dartmouth. Medicare claims data were obtained for beneficiaries in 2006 through 2009 using the Standard Analytic File (SAF). Medicare expenditures were price-standardized to account for variation in the price of services across areas [24]. Total expenditures and expenditures by category (inpatient, outpatient, physician services, home health, hospice, and durable medical equipment) were measured. Data on all-cause hospitalizations, obtained from the Medicare Provider Analysis and Review (MedPAR) file, were also used to determine the number of hospitalizations, average length of hospital stay, and total hospital days.

2.4. Covariates

Age and race were obtained from NHS questionnaires at the time of cognitive assessment. Comorbid illnesses were obtained from the Medicare claims files using the Elixhauser comorbidity score [25]. Elixhauser score is a summary measure of comorbidity generated from the presence of diagnoses indicated by Medicare International Classification of Disease-9 or Diagnosis-Related Groups codes. We required one inpatient claim or two outpatient claims to identify the presence of a comorbid disease. Year of utilization measurement was also included as a covariate to account for any differences in potential time trends.

2.5. Analysis

Cognitive scores for global, episodic and executive function were the main independent variables. In initial analyses, cognitive scores were categorized as either impaired or not impaired for each domain, where impaired was defined as the worst 10% of the distribution of the study population. The primary outcome measures were annual Medicare expenditures and hospitalization rates for the year following the participant's cognitive assessment. Unless specified otherwise, only subjects with Medicare claims data for the full year following the cognitive assessment were included. A secondary analysis was also performed to include subjects who died prior to the end of the year with additional adjustment for the time (in months) between the start of the claims year and date of death.

In the initial analyses, the association of Medicare expenditures with impairment in each cognitive domain (global, episodic, and executive) was tested. Multiple linear regression with heteroscedasticity-consistent standard errors was used to model expenditures as a function of cognitive status (impaired or not impaired). The association of cognitive function on expenditures was further explored by grouping cognitive scores into deciles, and marginal means were generated to estimate Medicare expenditures separately for each level of cognitive function. Finally, cognitive function (in Z-scores) was modeled as a continuous variable in a linear model.

To test the association of impairment with hospitalization rates, a generalized linear model with a Poisson distribution and log link function was used to model hospitalizations, total hospital days, and length of hospital stay as a function of cognitive status (impaired or not impaired).

Since impairment in different cognitive systems may co-occur, we also created four mutually-exclusive categories to represent the impairment type. Subjects were grouped into one of four categories as follows: neither episodic nor executive impairment (Neither); episodic impairment but not executive impairment (Episodic Only); executive impairment but not episodic impairment (Executive Only); or both episodic and executive impairment (Both). This designation was then included in the model as the independent categorical variable with reference to Neither.

3. Results

3.1. Participant Characteristics

Among 8,890 NHS participants who completed cognitive assessments between 2005 and 2008, 8,125 were enrolled in Medicare parts A and B during the year following their assessment, or until date of death (Supplementary Fig. 1). Ages ranged from 76 to 88 years at the time of cognitive assessment (mean=80.8 years) and the majority of participants were white (98.5%; Table 1). Most participants had two or less comorbidities (72.7% with 0 to 2 comorbidities), with the most common conditions being hypertension (in 64.4% of subjects), diabetes (17.7%) and hypothyroidism (15.9%). Deaths occurred in 215 subjects (2.7%) prior to the end of the claims year.

3.2. Medicare Expenditures

In unadjusted analyses, global, episodic, and executive impairment were all significantly associated with higher annual standardized expenditures compared to subjects without each of those impairments (Supplementary Table 1). The higher expenditures appeared greatest for impairment in executive function, rather than episodic memory. Specifically, executive impairment was associated with higher total annual expenditures of \$2,983 per person (41% higher, $p<.01$) compared to subjects without impairment, while episodic impairment was associated with an increment of \$1,269 (17%, $p<.05$). The higher expenditures were largely driven by significant inpatient and home health spending. Executive impairment was associated with greater annual inpatient expenditures of \$2,233 (70%, $p<.01$), while episodic impairment was associated with greater expenditures of \$1,032 (31%, $p<.05$). Home health expenditures contributed to a lesser extent but were also significantly higher in subjects with impairment (global, \$687, $p<.01$; episodic, \$577, $p<.01$; executive, \$534, $p<.01$).

When adjusting for age, race, comorbidity, and claims year, similar results were found (Table 2 and Supplementary Fig. 2). Executive impairment was strongly associated with higher total Medicare expenditures of \$1,488 (20% higher, $p<.01$) compared to those without impairment. In contrast, episodic impairment was not significantly associated with a difference in total expenditures ($p>.05$). The higher expenditures due to executive impairment were driven primarily by greater annual inpatient expenditures of \$1,262 (38%,

$p < .01$) and higher home health expenditures of \$413 (102%, $p < .01$) compared to subjects without impairment. Interestingly, while total, inpatient, and home health expenditures were higher, impairment in all cognitive domains was associated with lower expenditures for physician services of approximately 15% (global, $-\$458$, $p < .01$; episodic, $-\$417$, $p < .01$; executive, $-\$345$, $p < .01$), suggesting that patients may be neglecting physician visits and then are eventually hospitalized. Hospice, durable medical equipment (DME) and outpatient expenditures did not show any considerable association with cognitive status in either adjusted or unadjusted analyses.

A secondary analysis was performed to include subjects who died during the claims year and who therefore had varying exposure times during the year (Supplementary Table 2). To account for this, we adjusted for the time (in months) between the start of the claims year and the date of death. Consistent with prior results, executive impairment was associated with significantly greater total expenditures of \$1,010 ($p < .05$) compared to no impairment, while no significant association was found with episodic impairment ($p > .05$).

To further characterize the relationship between the continuum of cognitive function and expenditures, we grouped cognitive scores into deciles for each domain. The estimated marginal means for annual expenditures are displayed in Fig. 1. Notably, expenditures were incrementally greater across the entire range of scores for executive function. Therefore, we next examined the association between cognitive function and expenditures in a linear model using the composite Z-scores in a continuous variable for each cognitive domain (Table 3). Confirming prior results, total annual expenditures were \$584 higher for every 1 standard deviation decrement in executive function ($p < .01$). In contrast, we found no significant relationship for episodic memory ($p > .05$).

3.3. Hospitalizations

With the observation that inpatient costs were the largest single component of the higher total expenditures observed with cognitive impairment, we next investigated the relationship between cognitive impairment and hospitalization rates (Supplementary Table 3). Compared to subjects without impairment, both episodic and executive impairment were associated with a significantly higher annual rate of hospitalization. This corresponded to a 14.3% ($p < .05$) higher incidence rate for episodic impairment and 18.0% ($p < .01$) for executive impairment. In addition, impairment in all domains was associated with significantly greater total days spent in the hospital during the year; again, the largest effect was observed with executive impairment (global, 11.5%, $p < .01$; episodic, 18%, $p < .01$; executive, 23.4%, $p < .01$). There was no significant association between cognitive impairment and the average length of stay per hospitalization ($p > .05$).

3.4. Episodic vs. Executive Impairment

In a final analysis, since some participants had both episodic and executive impairment, we separately examined the association of episodic versus executive impairment with healthcare expenditures (e.g. of the 813 subjects identified to have episodic impairment, 337 of them also had executive impairment). We created four mutually-exclusive categories for impairment status: Neither, Episodic Only, Executive Only, or Both. In this analysis, a stark

contrast between episodic and executive impairment was further revealed (Fig. 2 and Supplementary Table 4). Selective impairment in episodic memory (Episodic Only) had no association with total expenditures ($p>.05$). Yet, impairment in executive function (Executive Only) was significantly associated with higher expenditures (\$1,358, $p<.05$). The higher total expenditures due to executive impairment were again largely driven by higher inpatient costs (\$1,113, $p<.05$). While episodic impairment contributed significantly to higher home health expenditures (\$308, $p<.01$), this was offset by the lower expenditures for physician services ($-\$364$, $p<.01$).

4. Discussion

Women with cognitive impairment, especially those with decrements in executive function, had significantly higher annual healthcare expenditures and hospital use than those with better cognition. The higher total expenditures were attributed predominantly to higher inpatient and home health spending, while spending for physician services was lower. This suggests that patients may be neglecting physician visits and subsequently are hospitalized; indeed, women with executive function impairment had a nearly 20% greater risk of hospitalization and 25% greater number of days per year hospitalized. Importantly, we demonstrated a clear linear association between executive function and total annual expenditures, indicating that the health services impact of cognitive status likely extends substantially further than previously indicated by studies which focused only on the extreme of dementia.

To our knowledge, this is the first study to use the continuum of cognitive scores, rather than clinical diagnoses, to investigate the relationship between impairment and healthcare spending. Our results support, and extend, findings in prior studies that have focused on the healthcare costs of clinically-diagnosed dementia. Overall, we observed that Medicare expenditures were as high as \$1500 per person greater for the year in those with cognitive impairment, or 20% greater than subjects without impairment. While this is less than the estimates of a 2015 report [8], which found that a diagnosis of dementia was associated with an increase of about \$2700 in total Medicare spending, we defined impairment more broadly (the lowest 10% of the study population) rather than limiting it to a subset of subjects with diagnosed dementia who are likely to have the most severe impairment. Interestingly, we found that inpatient spending was the single largest contributor to the higher total expenditures, in agreement with a 2004 study of dementia in the general Medicare population [9]. Thus, increased hospitalization is an important contributor to the higher expenditures observed with impairment, and may be an effective target for developing programs aimed at reducing healthcare costs in these patients.

To begin to achieve a more detailed understanding of this relationship, we separated cognitive status by domain into those representing episodic memory or executive function. In all analyses, the higher healthcare expenditures were disproportionately attributed to impairment in executive function, rather than episodic memory. Even the smaller increases in total expenditures that were observed with episodic memory impairment could be explained by co-existing executive impairment; when subjects with co-existing impairment were segregated, the effect of episodic memory on total expenditures was eliminated (Fig.

2). Again, in public health terms, this may suggest that focusing on older patients with decrements in executive function could be especially important in efforts to reduce healthcare spending associated with cognitive impairment. In addition, when expenditures were analyzed across the full range of cognitive scores, executive function clearly exhibited a continuous and linear relationship with spending, demonstrating that costs begin to rise even at the earliest stages of cognitive decrements. These findings strongly suggest that current estimates of healthcare expenditures associated with the extreme of dementia underestimate total cost as they do not consider these pre-clinical states; thus, earlier monitoring and management of executive impairment has the potential to produce significant cost-savings.

There are many possible explanations for the large effect of executive impairment on healthcare spending. It is possible that lower executive functioning leads to poor decisions regarding care or planning at home and fewer physician visits; executive impairment may lead to poorer management of other chronic illnesses, either through reduced ability to coordinate care or to follow and manage their care plans. These all may result in more hospitalizations. Additionally, falls in the elderly are a significant cause of emergency room visits, hospitalizations and disability [26], and impairment in executive function has been identified as a significant risk factor for falls [27–29]. In comparison, memory impairment is not a predictor of falls in these studies [30,31]. Thus, executive impairment may have both direct and indirect impact on healthcare costs and utilization.

An important strength of this study is the large sample size and the unique dataset linking neuropsychological test scores, as opposed to diagnostic codes, to healthcare expenditures captured in Medicare claims. This approach allowed us to consider the full spectrum of cognition and to investigate effects specific to the domain of function, and it has more complete expenditure data than can be achieved with self-reported data. This study also has limitations. First, since this study focused only on expenditures from Medicare parts A and B, we cannot make any conclusions about the effects on out-of-pocket costs or costs for patients with managed care plans. Second, cognitive function in this study was measured by telephone assessments. While this departs from traditional neuropsychological testing approaches, these assessments have been validated in multiple studies; they show both high inter-interviewer reliability and are highly correlated to results from in-person interviews [32–35]. Third, since this is a cross-sectional analysis, this study does not demonstrate causality as we cannot establish that cognitive impairment preceded healthcare utilization; however, it seems unlikely that increased utilization causes cognitive impairment rather than the reverse.

An additional consideration is that the study sample is primarily white and composed of female nurses. Participants in this study have all achieved advanced education, and are likely to have better average cognition than the general population due to their education; thus, we may be underestimating the impact cognitive impairment would have on healthcare expenditures in the general population [36,37]. It is also possible that their level of professional and educational attainment influences their healthcare utilization. However, even if nurses have different patterns of use from the general population, the association between cognition and utilization in this sample remains internally valid and provides strong

evidence regarding the differential effect of executive function and episodic memory, as well as the linear relation of cognition to healthcare costs and utilization. In addition, although our population is all female, women live longer than men and have a higher prevalence of dementia, and therefore better understanding of healthcare utilization in women remains especially important. The homogeneity of our population in terms of education, occupation, and sex may also reduce the potential for confounding, which can be problematic in observational studies.

In summary, cognitive impairment is associated with significantly higher healthcare expenditures and hospital use, and these effects are disproportionately attributed to impairment in executive function, rather than episodic memory. Focusing on management strategies that address executive impairment may be most effective in producing cost savings among those with cognitive impairment. Importantly, expenditures increased incrementally with worsening executive function, implying that pre-clinical recognition of impairment, may be key in helping to stem the greater expenditures that we observed. Overall, our findings provide a framework for future studies to determine the causes for higher costs in patients with executive impairment and to evaluate strategies to deliver earlier care more effectively, thus producing substantial savings to the healthcare system.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Executive impairment was associated with higher Medicare expenditures.
- Higher expenditures were driven by higher hospitalization rates and inpatient costs.
- Executive function, across all levels, had a linear relationship with expenditures.
- No association was found with episodic memory.
- Impairment in executive function, not memory, drives higher healthcare costs.

Research in Context

1. Systematic review: Prior studies on the relationship between cognitive impairment and healthcare spending have been appropriately cited. They demonstrate that a diagnosis of dementia is associated with higher healthcare costs, independently of other comorbidities, and that hospitalizations are an important contributor to the higher costs.
2. Interpretation: Our findings extend prior results in two important ways. By investigating separate domains of cognition, we show that impairment in executive function, not episodic memory, drives higher spending. Second, by considering the full spectrum of cognition, we find that a linear relationship exists between executive function and expenditures, implying that earlier recognition of impairment has the potential to produce significant cost-savings.
3. Future directions: Future studies will be needed to determine the causes of higher spending (e.g. hospitalizations) in those with executive impairment, and to investigate strategies for both improving care and reducing costs in this population.

Fig. 1.

Adjusted mean annual Medicare expenditures stratified by level of cognitive function (in deciles). Cognitive scores for Global, Episodic, and Executive domains were stratified into deciles, with “1” representing subjects with the highest 10% of cognitive scores and “10” representing subjects with the lowest 10%. Estimated marginal means are displayed for total annual Medicare expenditures, adjusting for age, race, comorbidity and claims year. Error bars represent standard error of the mean.

Fig. 2.

Adjusted mean annual Medicare expenditures attributed to cognitive impairment in episodic or executive domains. Cognitive impairment was coded as one of four mutually-exclusive categories: neither episodic nor executive impairment (“Neither”); episodic but not executive impairment (“Episodic Only”); executive but not episodic impairment (“Executive Only”); or both episodic and executive impairment (“Both”). Each bar indicates the difference in Medicare expenditures for subjects with impairment referenced to those in the “Neither” category, adjusted for age, race, comorbidity and claims year. See Supplementary Table 4 for p values.

Table 1

Characteristics of NHS participants

Characteristic	All Subjects	Global Impairment	Episodic Impairment	Executive Impairment
N	8125	811	813	833
Year of Cognitive Assessment (%)				
2005	33.02	34.90	34.93	35.05
2006	41.42	41.18	42.44	38.66
2007	24.54	23.06	21.77	25.33
2008	1.02	0.86	0.86	0.96
Age				
mean	80.78	81.72	81.58	81.48
SD	2.39	2.30	2.33	2.33
range	76–88	77–87	76–87	77–87
Race (% white)	98.45	97.53	97.54	97.36
Deaths in year (%)	2.65	5.30	4.06	4.92
Comorbidities (sum score)				
mean	1.90	2.10	2.04	2.18
sd	1.74	1.90	1.90	1.93
range	0–14	0–11	0–11	0–11
# Comorbidities (%):				
0	19.64	18.61	19.53	16.65
1	30.18	28.54	28.31	28.07
2	22.86	20.22	21.88	21.63
3	12.37	13.52	12.61	13.73
4	6.92	7.82	7.54	8.51
5+	8.00	11.29	10.14	11.42

Table 2

Adjusted Medicare parts A & B annual spending for NHS participants with and without cognitive impairment*

Category	Global			Episodic			Executive		
	Not Impaired	Impaired	Difference	Not Impaired	Impaired	Difference	Not Impaired	Impaired	Difference
Total									
Mean	\$7,566.72	\$8,459.21	\$892.49	\$7,602.04	\$8,326.41	\$724.37	\$7,505.20	\$8,993.04	\$1,487.84
95% CI			-44.28 to 1829.25			-157.90 to 1606.63			515.48 to 2460.19
p value			0.062			0.108			0.003
Inpatient									
Mean	\$3,349.79	\$4,030.93	\$681.14	\$3,359.75	\$3,998.10	\$638.35	\$3,290.20	\$4,552.50	\$1,262.30
95% CI			-28.48 to 1390.77			-37.88 to 1314.59			510.69 to 2013.91
p value			0.060			0.064			0.001
Home Health									
Mean	\$387.36	\$991.74	\$604.39	\$396.44	\$916.94	\$520.50	\$404.96	\$818.08	\$413.12
95% CI			405.57 to 803.21			331.09 to 709.91			232.83 to 593.40
p value			0.000			0.000			0.000
Hospice									
Mean	\$68.15	\$149.42	\$81.27	\$72.20	\$109.67	\$37.47	\$70.41	\$126.97	\$56.56
95% CI			-101.14 to 263.69			-86.52 to 161.46			-116.30 to 229.42
p value			0.382			0.554			0.521
DME									
Mean	\$159.85	\$188.03	\$28.18	\$157.84	\$206.71	\$48.87	\$157.50	\$208.63	\$51.13
95% CI			-19.92 to 76.28			0.130 to 97.61			-0.71 to 102.98
p value			0.251			0.049			0.053
Outpatient									
Mean	\$844.33	\$800.10	-\$44.22	\$850.64	\$747.09	-\$103.55	\$835.09	\$884.55	\$49.46
95% CI			-201.22 to 112.77			-257.93 to 50.84			-126.46 to 225.38
p value			0.581			0.189			0.582
Physician									
Mean	\$2,757.25	\$2,298.98	-\$458.27	\$2,765.18	\$2,347.91	-\$417.28	\$2,747.04	\$2,402.30	-\$344.74
95% CI			-670.68 to -245.86			-614.73 to -219.83			-542.19 to -147.28

* adjusted for age, race, comorbidity, and claims year

Category	Global			Episodic			Executive		
	Not Impaired	Impaired	Difference	Not Impaired	Impaired	Difference	Not Impaired	Impaired	Difference
p value			0.000			0.000			0.001

Table 3

Association of Medicare parts A & B annual spending with cognitive function*

Category	Global	Episodic	Executive
Total			
Coeff *	-\$435.05	-\$170.38	-\$584.34
95% CI	-759.03 to -111.07	-454.09 to 113.34	-892.04 to -276.65
p value	0.008	0.239	0.000
Inpatient			
Coeff	-\$323.13	-\$147.68	-\$406.05
95% CI	-566.16 to -80.09	-361.41 to 66.04	-636.17 to -175.94
p value	0.009	0.176	0.001
Home Health			
Coeff	-\$212.32	-\$153.95	-\$161.27
95% CI	-275.56 to -149.08	-207.08 to -100.82	-211.93 to -110.60
p value	0.000	0.000	0.000
Hospice			
Coeff	-\$35.95	-\$8.99	-\$40.82
95% CI	-96.15 to 24.26	-50.13 to 32.16	-90.47 to 8.83
p value	0.242	0.669	0.107
DME			
Coeff	-\$17.45	-\$9.31	-\$22.28
95% CI	-34.87 to -0.02	-24.91 to 6.29	-37.03 to -7.53
p value	0.050	0.242	0.003
Outpatient			
Coeff	-\$33.92	-\$12.33	-\$68.95
95% CI	-91.13 to 23.29	-63.65 to 39.00	-120.15 to -17.75
p value	0.245	0.638	0.008
Physician			
Coeff	\$187.71	\$161.88	\$115.03
95% CI	101.50 to 273.92	84.18 to 239.59	22.19 to 207.87
p value	0.000	0.000	0.015

* cognitive scores were computed as Z-scores; higher scores represent higher cognitive functioning; analysis is adjusted for age, race, comorbidity, and claims year

** "Coeff" represents the mean change in expenditures for one unit change (in Z-scores) of the cognitive variable