Idea Density Measured in Late Life Predicts Subsequent Cognitive Trajectories: Implications for the Measurement of Cognitive Reserve

Sarah Tomaszewski Farias,1 Vineeta Chand,1 Lisa Bonnici,2 Kathleen Baynes,1 Danielle Harvey,4 Dan Mungas,1 Christa Simon,1 and Bruce Reed1,3

1Department of Neurology, University of California, Davis.
2School of Language and Literature, University of Aberdeen, Scotland.
3Veterans Affairs Northern California Health Care System, Martinez, California.
4Department of Public Health, Division of Biostatistics, University of California, Davis.

Objective. The Nun Study showed that lower linguistic ability in young adulthood, measured by idea density (ID), increased the risk of dementia in late life. The present study examined whether ID measured in late life continues to predict the trajectory of cognitive change.

Method. ID was measured in 81 older adults who were followed longitudinally for an average of 4.3 years. Changes in global cognition and 4 specific neuropsychological domains (episodic memory, semantic memory, spatial abilities, and executive function) were examined as outcomes. Separate random effects models tested the effect of ID on longitudinal change in outcomes, adjusted for age and education.

Results. Lower ID was associated with greater subsequent decline in global cognition, semantic memory, episodic memory, and spatial abilities. When analysis was restricted to only participants without dementia at the time ID was collected, results were similar.

Discussion. Linguistic ability in young adulthood, as measured by ID, has been previously proposed as an index of neurocognitive development and/or cognitive reserve. The present study provides evidence that even when ID is measured in old age, it continues to be associated with subsequent cognitive decline and as such may continue to provide a marker of cognitive reserve.

Key Words: Cognitive aging—Cognitive reserve—Idea density—Linguistic ability.

Aging is characterized, at the population level, by cognitive decline, but individual trajectories of change are highly heterogenous (Wilson et al., 2002). The sources of this individual cognitive variability are not well understood, but clearly there are factors that make one more or less resilient to the effects of aging on cognition—often referred to collectively as “cognitive reserve” (Stern, 2002). Some of these factors are likely to be innate (e.g., genetic), and others are related to lifetime exposures and experiences.

Findings from the Nun Study suggest that linguistic ability in young adulthood predicts cognitive status in old age. Specifically, findings from that study showed that weaker linguistic ability measured during young adulthood was associated with increased likelihood of cognitive impairment and dementia many decades later in old age (Snowdon et al., 1996). These investigators analyzed essays that the sisters had written as young adults, measuring how much information was contained in each sentence relative to the number of words used—referred to as propositional or idea density (ID). ID is distinct from grammatical structure or simply how much is said or written. Prior studies suggest that ID is related to a number of linguistic and other cognitive abilities including vocabulary, general knowledge, reading rate, and verbal fluency (Kemper, Greiner, Marquis, Prenovost, & Mitzer, 2001; Snowdon et al., 1996). ID reflects the complexity of spoken or written communication (including the extent to which individual ideas are interconnected) and overall cognitive processing efficiency (Engelman, Agree, Meoni, & Klag, 2010; Kemper, Greiner, et al., 2001). It has been conceptualized as a reflection of cognitive and brain development (Snowdon et al., 1996). The finding that early life ID appears to moderate the relationship between late life cognitive status and neuropathology (i.e., high ID in early life decreased the association between brain pathology and cognitive status proximal to death) provides particularly strong evidence that ID may be acting as a marker of cognitive reserve (Iacono et al., 2009).

Unfortunately, linguistic samples produced in early adulthood, such as those used in the Nun Study, are rarely available and thus have limited applications. However, there is evidence that ID changes only modestly between the period of young adulthood to old age (Kemper, Greiner, et al., 2001). As a result, ID measured in late life may continue to predict subsequent cognitive change and hence may still provide a useful index of neurocognitive development or cognitive reserve. This would be useful because although
the construct of cognitive reserve is widely referenced, we currently have fairly limited approaches to operationalize and measure it. Educational attainment (in years of education) is the most commonly used proxy for reserve primarily because it is easily quantified. However, it has a number of limitations, given that years of schooling is influenced by many sociological and cultural factors that are unrelated to innate intelligence and cognitive and/or brain development (Knopman, 2011; Manly, Schupf, Tang, & Stern, 2005; Manly, Touradj, Tang, & Stern, 2003).

Building upon previous findings, the present study sought to determine whether ID measured in late life predicts subsequent trajectories of cognitive change. Previous work examining ID and the development of cognitive impairment focused on very specific groups of older adults (e.g., nuns), which may not well represent the larger population of older adults. The present study focuses on a much more demographically diverse sample of older adults. It was predicted that lower ID in late life would be associated with increased rate of subsequent cognitive decline. Previous studies examining the association between ID in young adulthood and cognition in late life have examined cognition primarily in terms of categorical syndromes (e.g., normal cognition, mild cognitive impairment [MCI], and dementia). To our knowledge, no previous study has examined the association between ID and longitudinal trajectories using continuous measures of cognition. As such, we did not have an a priori reason to believe that ID would differentially relate to specific neurocognitive outcomes. We chose to include multiple cognitive outcomes (measuring both global cognitive function and specific neuropsychological domains) primarily as a means to test the robustness of any observed effect.

**METHOD**

**Participants**

Participants were evaluated by the University of California, Davis, Alzheimer’s Disease Research Center as part of an ongoing longitudinal study of cognitive impairment, which has been previously described (Farias, Mungas, Reed, Harvey, & DeCarli, 2009; Mungas et al., 2010). Recruitment into the cohort utilizes a rolling enrollment approach and therefore has differing years of follow-up. All participants signed informed consent, and all human subject involvement was approved by the institutional review boards.

**Diagnostic Evaluation**

All participants received an annual multidisciplinary diagnostic evaluation, including medical history, physical exam, neurological exam, labs, neuroimaging, and clinical neuropsychological testing. Diagnosis of cognitive syndrome (Normal, MCI, Dementia) was made according to standardized criteria and methods. Dementia was diagnosed using DSM-III R (American Psychiatric Association, 1987) criteria for dementia. Individuals with less severe cognitive changes not meeting criteria for a dementia were diagnosed with MCI. All diagnoses were made blind to the outcome measures used in this study.

**Idea Density**

ID is a measure of how much information is packed into a narrative relative to the number of words it contains, reflecting how efficiently an individual conveys novel and on-topic information (Kemper, Thompson, & Marquis, 2001). High scores indicate an economy of expression, whereas low scores indicate vague and/or repetitious language (Examples 1 and 2 in the Appendix 1 show the idea breakdown and word count for two abbreviated narratives, which have high and low ID scores, respectively). Ideas correspond to elementary propositions, typically verbs, adjectives, adverbs, prepositional phrases, and complex propositions that state or infer causal, temporal, or other relationships between propositions. Thus, ideas represent semantic concepts and relations between them.

**Linguistic Data Collection and ID Analysis**

Oral speech samples were obtained by having participants answer a series of three open-ended questions of which the third was typically analyzed. The first two prompts were used as “warm-ups” to allow the participant to become comfortable with the task. The prompt that was analyzed asked participants to “Tell me what it was like to grow up in your home town.” Broadly, responses were digitally recorded, transcribed, broken down into individual utterances, and then decomposed into constituent ideas. Transcripts of grossly unequal length may themselves introduce analytic bias: Individuals with more cognitive impairment are more likely to produce shorter narratives, and it is unclear how narrative length itself may affect ID scores. Raw word count has not been explored or even documented in previous research on ID. Although the Nun Study papers corrected for this by only examining the final 10 sentences of each narrative, this criteria is problematic for oral samples, given that utterances tend to be shorter than written sentences (Chafe & Tannen, 1987). Thus, in order to avoid introducing analytic bias based on narrative length, the entire narrative was analyzed, the exception being that transcription of longer samples was halted at the end of the utterance containing the 400th word.

Transcription followed standard spelling, but not orthographic conventions, with the goal of maintaining integrity between the original audio and subsequent transcripts. Orthographically, transcripts of oral language can deviate from standard writing samples by including lexical and nonlexical fillers (e.g., you know and um, respectively) and metadiscourse, which is defined as language which pertains to the interview context, not the narrative topic (e.g., Is that enough? or Can I have a tissue?). Instances of metadiscourse
and nonlexical fillers were initially transcribed but then omitted from the analysis of ideas and from word count totals. Utterances were operationally defined through narrative segmentation, which relied on several factors including topic, pauses, intonation, content, and the larger context of the language sample to determine utterance boundaries. Utterances thus can correspond not only to grammatical sentences but also to interjections, fillers, and fragments. Utterance segmentation in a subsample of language samples (N = 35) showed high interrater consistency across independent coders (Interclass Correlation Coefficient [ICC] = .97). Importantly, although narrative segmentation is a necessary aspect of transcription and can provide cues to the original oral presentation, utterance boundaries do not affect overall ID scores, which are computed as the average number of ideas per 10 words across the entire narrative, following Kemper, Greiner, and colleagues (2001).

Word count, although seemingly straightforward, also requires standardization. Acronyms, possessives, and multiword numbers are each treated as a single word in the word count. Each element of a multiword proper noun, idiomatic phrase, or lexical filler is counted as a separate word. Contractions are treated as two words, whereas compounds that are written as a single word or that are hyphenated count as a single word. Word count consistency was also very high across raters (ICC = .98).

Methods used to identify individual ideas were based on those described elsewhere by Kemper and colleagues (Kemper, Kynette, Rash, & O’Brien, 1989; Snowdon et al., 1996). However, it was necessary to develop more explicit coding guidelines to ensure consistency across raters. Broadly, we separated and systematically counted meaningful phrasal and utterance level syntactic groupings, which functionally conveyed new on-topic content to the listener (Armstrong, 2005; Martin & Rose, 2003). By focusing on the phrasal level, units with different internal syntactic structures and word counts are systematically handled to more directly tap semantically meaningful units rather than syntactic constructions. For example, prepositions serve a variety of syntactic and semantic functions: They can introduce a location or direction (e.g., in the Bronx) and are then counted as a separate idea, although they can also, in conjunction with a verb, functionally instantiate a single predicative meaning (e.g., prepositional particles are not counted as a separate idea when they are functionally part of a predicate, he passed out, i.e., he fainted, and no one acted up, i.e., no one misbehaved). Interrater reliability for the identification of individual ideas was high (ICC = .97) in our sample.

Cognitive Outcomes

Global cognitive function.—The Clinical Dementia Rating (CDR) Scale (Morris, 1993) is a widely used measure of global cognitive and functional impairment or disease severity. The CDR is based on a structured caregiver/informant interview. Scores are obtained in six different domains (memory, orientation, judgment and problem solving, community affairs, home and hobbies, and personal care). Previous studies show that it has good interrater reliability (e.g., agreement across raters is above 80%; Burke et al., 1988). It discriminates between diagnostic groups (Morris, McKeel, Fulling, Torack, & Berg, 1988; Morris & Rubin, 1991) and has been shown to be related to postmortem neuropathological findings (Berg et al., 1984). The “sum of boxes” score is the arithmetic sum of the six subscores (Daly et al., 2000) and was used in the primary analysis (CDRsum).

Neuropsychological domains.—Specific domains of neuropsychological function were measured using the Spanish and English Neuropsychological Assessment Scales (SENAS). The SENAS have undergone extensive development as a battery of cognitive tests relevant to diseases of aging (Mungas, Reed, Crane, Haan, & Gonzales, 2004; Mungas, Reed, Farias, & DeCarli, 2005; Mungas, Reed, Marshall, & Gonzales, 2000). This study used a subset of SENAS scores assessing four cognitive domains: episodic memory, semantic memory, visuospatial abilities, and executive function. The episodic memory measure is a composite score derived from a multitrial word list learning test (Gonzales, Mungas, & Haan, 2002). Alternate forms of the word list learning task were used in the annual assessments to control for practice effects. Semantic memory is a composite of highly correlated verbal and nonverbal tasks. Spatial ability was measured by the Spatial Localization subtest of the SENAS, a task that involves reproducing spatial relationships among objects on a stimulus page. Executive function is a composite of category fluency, phonemic fluency, and working memory. SENAS development and psychometric characteristics have been reported in detail in previous publications (Mungas et al., 2004; Mungas, Reed, Farias, et al., 2005; Mungas et al., 2000). These measures do not have appreciable floor or ceiling effects and have linear measurement properties across a broad ability range. All four neuropsychological indices have similar psychometric measurement properties (e.g., equivalent reliability and sensitivity), which facilitate unambiguous interpretation of any potential differential effects of ID on the specific neuropsychological trajectories. The SENAS composite scales have been shown to have good to excellent reliability (Mungas et al., 2004). SENAS measures relate to clinical diagnosis and independent function (Mungas, Reed, Farias, et al., 2005; Mungas, Reed, Haan, & Gonzales, 2005) and to structural brain imaging indices (Carmichael et al., 2010; Farias, Mungas, Reed, et al., in press).

Statistical Analysis

Simple Pearson correlation coefficients were used to estimate the relationship between ID and various demographic
variables. Planned comparisons using t tests were used to compare ID across the three diagnostic groups. Repeated measures random effects models (Laird & Ware, 1982) were used to assess associations between ID (collected at a single time point and measured by the average number of ideas per 10 words) and change in each of the outcome variables including the CDRsum and the four neuropsychological variables. These models use all of the available outcome assessments for each person and allow for differences in the number of observations per person as well as differences in the lag between observations. Predictors include ID, a time-varying measurement of time since the visit when ID was obtained, calculated for each assessment, and the interaction between time and ID. The coefficient for ID is interpreted as the average difference in baseline level of the outcome associated with a one unit change in ID. The coefficient for time is the average annual change for an individual with average ID, average age and education, and the coefficient for the interaction represents the modification to that change associated with a one unit difference in ID. Each outcome was modeled separately. Due to the skewness of the distribution of the CDRsum, the model assumption of constant variance of the residual terms was violated in our initial fit of the models. We therefore considered two alternative transformations, the square root and the natural logarithm initial fit of the models. We therefore considered two alternative transformations, the square root and the natural logarithm of one plus the CDRsum (to avoid taking the logarithm of zero). Ultimately, we determined that using the square root of the CDRsum better met the assumptions of the models. Form differences for the episodic memory variable (e.g., the list learning task) were included as a time-varying covariate term; this form effect accounts for within person variability in episodic memory that is related to the test form but is independent of systematic trends across time. All models were adjusted for age (at the time ID was obtained) and education. Model assumptions were met by the data. Analyses were first conducted on all participants with more than one annual assessment and ID data. Secondary analyses (a) assessed differences across diagnostic groups in how ID influenced trajectories and (b) excluded those subjects who had dementia at the time ID was measured. Finally, for comparison purposes, we also ran similar repeated measures, random effects models to assess the association between years of education (the most commonly used proxy for cognitive reserve) and change in the cognitive outcome variables.

### RESULTS

#### Participant Characteristics

A total of 81 subjects had ID scores in addition to longitudinal data on the outcome variables. The average age of the sample was 76.3 ($SD = 6.86$), and the average years of education was 14.4 ($SD = 3.60$). Fifty-three percent of the sample was female. The majority of the sample (74.1%) was Caucasian, 13.6% were African American, 9.9% were Hispanic, and 2.5% were of another ethnic background. All language samples were collected in English, the dominant language of all participants. At the time language samples were collected and ID measured, 37 participants were cognitively normal, 21 had MCI, and 23 had a dementia syndrome. The three groups did not significantly differ in total word count of their speech sample (mean length of words per sample = 188.4 (75.6) in the dementia group, 221.9 (105.5) in the MCI group, and 179.3 (86.4) in the normal group). Number of longitudinal cognitive assessments ranged from two to seven (81 participants had at least two assessments, 72 had at least three, 57 had at least four, 35 had at least five, 15 had at least six, and the rest had seven follow-up assessments). The average number of annual assessment visits for the sample was 4.26. Table 1 includes the means, standard deviations and ranges for ID as well as the outcome measures presented by diagnostic group.

#### Association With Demographics, Cognitive Outcomes, and Diagnosis

We first examined whether ID was associated with various demographic and outcome variables. Neither age nor sex was significantly related to ID ($ps = .59$ and .74, respectively). There was only a modest relationship between ID and education ($r = .17, p = .12$), suggesting that these two variables are measuring different things (e.g., possibly different aspects of cognitive reserve). ID was minimally to moderately correlated with our other cognitive variables (episodic memory: $r = .19, p = .08$; executive function: $r = .38, p < .001$; semantic memory: $r = .39, p < .001$; spatial abilities: $r = .43, p < .001$), suggesting that ID while having some overlap with these other cognitive abilities is also substantially different from them. A subgroup of subjects ($N = 19$) also received a measure of reading literacy (American

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal</th>
<th>MCI</th>
<th>Demented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideas/10 words</td>
<td>$M (SD)$</td>
<td>$SD$</td>
<td>$Min, Max$</td>
</tr>
<tr>
<td>CDRsum</td>
<td>0.5 (0.7)</td>
<td>0.2 (1.0)</td>
<td>2.0 (2.6)</td>
</tr>
<tr>
<td>Episodic memory</td>
<td>0.7 (0.9)</td>
<td>0.5 (0.9)</td>
<td>0.3 (1.0)</td>
</tr>
<tr>
<td>Executive function</td>
<td>0.7 (0.9)</td>
<td>0.5 (0.9)</td>
<td>0.3 (1.0)</td>
</tr>
<tr>
<td>Semantic memory</td>
<td>0.2 (1.0)</td>
<td>0.2 (1.0)</td>
<td>0.2 (1.0)</td>
</tr>
<tr>
<td>Spatial abilities</td>
<td>0.3 (0.6)</td>
<td>0.5 (1.8)</td>
<td>0.3 (0.6)</td>
</tr>
</tbody>
</table>

Note. All of the neuropsychological outcomes are reported as z scores based on the current sample. CDRsum = Clinical Dementia Rating scale sum of boxes; ID = idea density; MCI = mild cognitive impairment.
IDEA DENSITY PREDICTS COGNITIVE CHANGE

Table 2. Longitudinal Models Showing the Association Between Idea Density and Change in Global Cognition As Measured by the Clinical Dementia Rating Scale Sum of Boxes (CDRsum) (square root) and the Neuropsychological Outcomes As Measured by the Spanish and English Neuropsychological Assessment Scales, Adjusted for Age and Education

<table>
<thead>
<tr>
<th>Variable</th>
<th>β-estimate</th>
<th>SE</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDRsum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideas/10 words</td>
<td>−0.46</td>
<td>0.21</td>
<td>.03</td>
</tr>
<tr>
<td>Time</td>
<td>0.11</td>
<td>0.04</td>
<td>.004</td>
</tr>
<tr>
<td>Ideas/10 words × time</td>
<td>−0.16</td>
<td>0.06</td>
<td>.005</td>
</tr>
<tr>
<td>Semantic memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideas/10 words</td>
<td>0.79</td>
<td>0.21</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time</td>
<td>−0.12</td>
<td>0.04</td>
<td>.002</td>
</tr>
<tr>
<td>Ideas/10 words × time</td>
<td>0.14</td>
<td>0.06</td>
<td>.03</td>
</tr>
<tr>
<td>Episodic memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideas/10 words</td>
<td>0.32</td>
<td>0.22</td>
<td>.15</td>
</tr>
<tr>
<td>Time</td>
<td>−0.14</td>
<td>0.03</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Ideas/10 words × time</td>
<td>0.15</td>
<td>0.05</td>
<td>.004</td>
</tr>
<tr>
<td>Spatial abilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideas/10 words</td>
<td>0.74</td>
<td>0.25</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time</td>
<td>−0.23</td>
<td>0.1</td>
<td>.02</td>
</tr>
<tr>
<td>Ideas/10 words × time</td>
<td>0.32</td>
<td>0.15</td>
<td>.04</td>
</tr>
<tr>
<td>Executive function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideas/10 words</td>
<td>0.71</td>
<td>0.20</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Time</td>
<td>−0.18</td>
<td>0.04</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Ideas/10 words × time</td>
<td>0.11</td>
<td>0.06</td>
<td>.10</td>
</tr>
</tbody>
</table>

National Adult Reading Test [AMNART]; Grober & Sliwinski, 1991); previous investigators have suggested that measures of literacy may be a better marker of cognitive reserve than years of education because it is a more direct measure of educational attainment (Manly et al., 2003, 2005). Consistent with this idea, a stronger correlation was observed between the AMNART and ID ($r = .46, p = .05$) than ID and education.

We next examined whether ID varied as a function of diagnostic group at the time the language sample was collected (normal, MCI, or dementia). Planned comparisons revealed that the dementia group showed significantly lower ID than either the normal group ($p = .04$) or the MCI group ($p = .005$). However, the MCI group and the cognitively normal group, which together constituted 84% of the sample, did not differ from one another in terms of ID ($p = .15$).

**ID As a Predictor of Cognitive Change**

Of primary interest was whether ID predicts subsequent longitudinal change in cognitive function. First we examined whether ID was associated with change in global cognition as measured by the CDRsum. Results showed that higher ID predicted a slower rate of decline in global cognition as measured by the CDRsum. For example, an individual of average age and education expressing the average number of ideas per 10 words (−3.8) declines by 0.11 points per year. An increase of 1 idea per 10 words was associated with a −0.16 point difference in annual change of the CDRsum (a negative coefficient corresponds to improvement on the CDRsum because lower scores mean better global cognitive function), so that someone with an ID measured one unit above the mean actually improves slightly each year ($0.11 − 0.16 = −0.05$; see Table 2). Figure 1 provides a plot of three hypothetical individuals of average age and education who differ only on their ID score to demonstrate how ID measured in late life influences the CDRsum trajectories. Follow-up analysis assessing differences in how ID was associated with change in CDRsum across diagnostic groups showed an overall difference by diagnostic group ($p = .03$) with a greater impact of ID in the MCI group relative to the demented group ($p = .008$). The impact of ID on change in CDRsum was similar in the normals as compared with the MCI group. Figure 2 illustrates this interaction effect.

The association between ID and change in four neuropsychological domains was also evaluated. ID was significantly associated with change in semantic memory, episodic memory, and spatial abilities (see Table 2). In each case, higher ID was associated with a slower decline in these three cognitive outcomes. On average, an individual of average age and education expressing the average number of ideas per 10 words (−3.8) declined 0.12 points per year on the semantic memory index, 0.14 points per year on the episodic memory index, and 0.23 points per year on the spatial abilities index. An increase of 1 idea per 10 words was associated with decline that is 0.14 units slower on semantic memory, 0.15 units slower on episodic memory, and 0.32 points slower on spatial abilities. Figure 3 provides a plot of three hypothetical individuals of average age and education who differ only on their ID score to demonstrate...
how ID influences the episodic memory trajectories (Plots for semantic memory and spatial abilities are similar and so are not included.). ID was not statistically significantly associated with change in executive function ($\beta = .11, SE = .06, p = .10$). None of the differences between diagnostic groups and how ID was associated with change in the specific neuropsychological domains reached statistical significance (episodic memory: $p = .35$; executive function: $p = .12$; semantic memory: $p = .40$; spatial abilities: $p = .9$).

In all of the above models, education (which is often used a proxy for cognitive reserve and has been shown in some studies to impact cognitive function) was also included as a predictor. In this way, we were able to examine the effect of ID on the trajectories of cognitive change independent of years of education. In the above models, education was a significant unique predictor only of change in CDRsum ($p = .02$) but not in any of the other models (episodic memory: $p = .77$; semantic memory: $p = .44$; executive function: $p = .1$; spatial ability: $p = .39$). For comparison, we also ran models that only considered age and education; in the present sample, education was not quite statistically significantly associated with change in CDRsum ($p = .07$) and was not significantly associated with change in any of the SENAS outcomes (episodic memory: $p = .73$; executive function: $p = .17$; semantic memory: $p = .63$; spatial abilities: $p = .2$).

**Secondary Analysis Excluding Dementia Cases**

The above analysis was based on the entire sample, which included participants with normal cognition as well as those with MCI and dementia. It is possible that ID predicted subsequent trajectories of cognitive change primarily because ID is sensitive to the presence of a dementia. For this reason, in a set of secondary analyses, we excluded the dementia cases. Both individuals with normal cognition and those with MCI were included because neither group differed in terms of their ID score. Overall, the results remained similar to the primary analysis that included all participants. Specifically, ID remained significantly associated with change in CDRsum ($\beta = -0.17, SE = 0.07, p = .02$) and change in spatial abilities ($\beta = .33, SE = 0.16, p = .04$). The association between ID and change in semantic memory ($\beta = .11, SE = 0.06, p = .08$) and change in episodic memory ($\beta = .09, SE = 0.05, p = .06$) fell just short of reaching statistical significance, likely a function of the reduced sample size. The association between ID and change in executive function remained nonsignificant ($p = .76$).

**DISCUSSION**

There has been increasing interest in identifying factors present throughout the life span that relate to cognitive aging trajectories. The Nun Study was the first to show that low linguistic ability (measured by ID) in young adulthood is associated with susceptibility to cognitive impairment and dementia in late life (Iacono et al., 2009; Kemper, Greiner, et al., 2001; Riley, Snowdon, Desrosier, & Markesbery, 2005; Snowdon et al., 1996). Recently, the correlation between early life ID and late life cognition has been replicated in an entirely different sample (primarily male medical students), further strengthening such findings (Engelman et al., 2010). The present study extends this previous work by examining
ID measured in late life as a predictor of subsequent trajectory of cognitive change. Our results are the first to show that even when ID is measured in late life, it may still provide a useful marker of cognitive reserve that can be used to help understand individual variability in late life cognitive change. Specifically, we found that lower ID was associated with steeper subsequent decline in cognitive function.

In particular, we found that ID was associated with change in a global measure of cognitive function (the CDRsum) as well with longitudinal trajectories across a number of specific neuropsychological domains. More specifically in terms of the neuropsychological domains, ID was significantly related to change in three of the four domains examined: episodic memory, semantic memory, and spatial abilities. Such findings suggest that the effects of ID on subsequent cognitive change tend to be fairly broad based. Examination of the standardized estimates does suggest that ID was most strongly associated with change in spatial ability and about equally related to change in episodic and semantic memory (as well as to change in global cognition as measured by the CDR). The relationship between ID and executive function trajectories was not statistically significant ($p = .10$). Although such results suggest that ID may have differential relationships to subsequent change depending on the cognitive domain measured, further investigation will be needed to confirm this. Findings from the Nun Study found that ID collected in early life was associated with a fairly wide variety of cognitive tests when measured at one time point in late life (Snowdon et al., 1996). In that case, ID was related to memory (most strongly), confrontation naming, verbal fluency, and spatial/constructional abilities, but other measures of executive functioning were not included.

The primary analysis was based on the entire sample, which was comprised of individuals with varying levels of cognitive ability (46% normal, 26% MCI, and 28% dementia). When an interaction term was included in the model to examine whether the effect of ID on the cognitive outcomes varied by diagnostic group, results were somewhat mixed. There was no significant effect of diagnostic group membership on the neuropsychological outcomes. However, when using global cognition (CDR) as an outcome, the results did differ by group in that ID showed a stronger relationship to cognitive change in the MCI group as compared with the demented group (the effect of ID on global cognition was similar in the MCI and normal groups). These findings suggest that the impact of ID on subsequent cognitive change may differ depending on disease stage, such that ID has more of an association with rate of cognitive change early in disease (e.g., when a person has only mild cognitive impairment or is still technically cognitively normal) but may be less associated with subsequent trajectories of cognitive change once a person has clear dementia. Similarly, excluding the dementia group from the analysis did not substantially alter the pattern of associations between ID and the cognitive outcomes.

ID was moderately correlated with another, previously established marker of reserve—reading literacy as measured by the AMNART. In contrast, we found a low nonsignificant relationship between ID and years of education. Although education is a commonly used marker of reserve, it is a complex variable with wide ranging effects on health and social position, and many of these effects have nothing to do with reserve. In this study, ID provides unique information above and beyond education in terms of predicting cognitive change (ID was an independent predictor when education was also included in the model). As such, ID may be measuring a different aspect of cognitive reserve than education. Interestingly, in the present sample, education when included by itself (i.e., without ID but controlling for age) was not a significant predictor of subsequent cognitive change.

The MCI group did not differ significantly in their mean ID score from the normal older adult group. This suggests that ID does not appear to be substantially altered in the early stages of a neurodegenerative disease process. Conversely, ID in the dementia group was significantly lower than either the normal or MCI groups. Other measures of baseline intelligence have also been shown to decline little in the early stages of a dementia (e.g., single word reading measures), so the finding that ID is also not affected by early disease, is not entirely surprising. Importantly, findings suggest that ID may continue to serve as a useful measure of reserve even in individuals who already have mild cognitive impairment, although it may be less useful in those who already have dementia.

The current results should be considered preliminary. The sample size was small, although similar in number to the Nun Study and considerably larger than in the study of Engelman and colleagues. Although the current study provides support for the assertion that ID collected in late life serves as a marker of reserve, ultimately the examination of whether late life ID modifies the relationship between biological markers of disease (e.g., postmortem neuropathological findings or in vivo biomarkers) and cognitive function will provide more definitive evidence for this. Another limitation to this study is that the methods used to extract ID (both in this study and in the original Nun Study) are fairly time and training intensive. The recent development of an automated freely available software program for calculating ID (Brown, Snodgrass, Kemper, Herman, & Covington, 2008) may facilitate a wider application of this variable in the study of cognitive aging.

Although the current study only examined one particular linguistic variable—ID—it is possible that other linguistic abilities (e.g., word frequency and content vs. function word ratios; Biber, Johansson, Leech, Conrad, & Finegan, 1999) and text coherency (e.g., Graesser, McNamara, Louwerse, & Cai, 2004) may also be useful in predicting increased risk of cognitive decline. Future studies should examine the
specificity of ID as a marker of cognitive reserve compared with other linguistic measures. It will also be important to develop a more complete understanding of the cognitive correlates that contribute to supporting and promoting more efficient communication (and hence higher ID). For example, one could imagine that other measures that tap cognitive processing efficiency should be related to ID. Additionally, investigations into approaches to enhance efficiency in cognitive processing and communication (e.g., more emphasis on communications skills in early education) may ultimately help to promote more successful cognitive aging.

In summary, the results of the current study suggest that late life linguistic ability, as measured by ID, helps to explain some of the variability in subsequent trajectories of cognitive change. Specifically, higher ID was associated with a slower rate of subsequent decline on a global measure of cognitive function as well as several specific neuropsychological domains. The widely reported finding from the Nun Study had previously demonstrated that lower ID, measured from autobiographies written in early life, was associated with increased risk of cognitive impairment and dementia decades later. This has been interpreted to mean that ID in early life serves as some marker of one’s “baseline” level of cognitive reserve. The present findings provide support for the supposition that ID—even when measured in late life—continues to be associated with subsequent trajectories of cognitive change. As such, it may provide another approach to quantifying this reserve capacity. Stern (2009) has suggested that cognitive reserve may, in part, relate to neural organization that influence how individuals respond to numerous challenges. Language efficiency may be a direct reflection of this organizing principle, which remains powerful throughout life, and permits resilience in the context of cognitive aging.

**Funding**

This study was funded by the following grants from the NIH: AG002151-01A1, AG031563-01A2, AG010220, AG031563, and P30 AG 10129.

**Conflict of Interest**

None of the authors of this study have any financial or other conflicts of interest.

**Correspondence**

Correspondence should be addressed to Sarah Tomaszewski Farias, PhD, Department of Neurology, University of California, 4860 Y Street, Suite 3700, Davis, CA 95617. E-mail: sarah.farias@ucdmc.ucdavis.edu.

**References**


APPENDIX 1.

Example 1. High ID extract with analysis. 22 ideas, 59 words, ID score of 3.729

It was right in the the m- depression. And everybody felt it except that my father had a job. And that was sacred. You know those people came to our back door and begged for work or food or to be paid in food. They didn’t care if they had money but they they really needed food.

Example 1.1. Ideas breakdown per utterance. Repeated ideas (marked with REP) are not included in the total idea count

It was right in the the m- depression.
1. was, it
2. in the depression
3. in, right

And everybody felt it except that my father had a job.
1. felt, everybody, it
2. except that 3
3. had, my, father, a job
4. and that was sacred.
1. was, that, sacred

You know those people came to our back door and begged for work or food or to be paid in food.
1. came, those people
2. to our door
3. door, back
4. and (then)
5. begged, these people
6. for work
7. for food
8. to be paid
9. in food

They didn’t care if they had money but they they really needed food.
1. did care, they
2. NEG it’s
3. if 4 but 5
4. had, they, money
5. needed, they, food
6. needed, really

Example 2. Low ID extract with analysis. 7 ideas, 57 words, ID score of 1.296

It’s all you know they had all you know they these all these ah vegetables you know around there they’re right there you know. All the way around there’s lot of vegetables because we. My dad was usually uh do some irrigating or something it was on a tractor you know. And and same thing.

Example 2.1. Ideas breakdown per utterance. Repeated ideas (marked with REP) are not included in the total idea count

It’s all you know they had all you know they these all these ah vegetables you know around there they’re right there you know.
All the way around there’s lot of vegetables because we.

My dad was usually uh do some irrigating or something it was on a tractor you know.

And and and same thing.

[no ideas]