

## Research Report

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# The Association Between Emotional Expressivity in Autobiographies from Early Adulthood and the Risk of Dementia in the Context of Written Language Skills

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Received 16 December 2022

Accepted 23 March 2023

Pre-press 10 April 2023

Published 25 April 2023

### Abstract.

**Background:** Risk factors for dementia, such as Alzheimer's disease, are complex and span a lifetime. Exploring novel factors, such as characteristics of writing, may provide insight into dementia risk.

**Objective:** To investigate the association between emotional expressivity and risk of dementia in the context of a previously identified risk factor, written language skills.

**Methods:** The Nun Study recruited 678 religious sisters aged 75+ years. Of these, 149 U.S.-born participants had archived autobiographies handwritten at a mean age of 22 years. The autobiographies were scored for frequency of emotion word usage and language skills (e.g., idea density). The association of emotional expressivity and a four-level composite variable (combining high/low emotional expressivity and high/low idea density) with dementia was assessed using logistic regression models adjusted for age, education, and apolipoprotein E.

**Results:** Within the composite variable, odds of dementia increased incrementally, with opposing effects of emotional expressivity across the two idea density levels. Compared to the referent category (low emotional expressivity/high idea density), the risk of dementia increased in those with high emotional expressivity/high idea density (OR = 2.73, 95% CI = 1.05–7.08), while those with low emotional expressivity/low idea density had the highest risk (OR = 18.58, 95% CI = 4.01–86.09).

**Conclusion:** Dementia risk is better captured by inclusion of multiple measures relating to characteristics of writing. Emotional expressivity may be protective when individuals are at increased risk due to poor written language skills (i.e., low idea density), but detrimental when not at risk (i.e., high idea density). Our findings indicate that emotional expressivity is a contextually-dependent novel risk factor for dementia.

**Keywords:** Alzheimer's disease, cognition, dementia, emotions, language, life course perspective, logistic models, longitudinal studies, risk factors

## INTRODUCTION

Risk factors identified across the life-course have increased the understanding of dementia as a complex condition [1]. Physical, social, psychological,

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and environmental factors in middle-aged and older adulthood have been cited as important contributors to the risk of dementia [1–5]. Early-life predictors of dementia, especially indicators of intellectual ability (e.g., educational attainment, school grades, early-life intelligence) are the focus of a growing body of evidence [1, 3, 6–11]. Such diverse risk factors reveal the complexity of dementia and reflect a need for further insight into contributing factors at various stages of the life-course.

Early-life intellectual pursuits have shown particular promise in positively impacting late-life cognitive outcomes [1, 9, 12], which are dynamic and can fluctuate between normal cognition and varying degrees of impairment within an individual over time [9, 13, 14]. Low education has been associated with a 7% population attributable risk of dementia worldwide, demonstrating the potential impact of early-life intellectual factors to reduce the incidence of dementia [1, 3]. Evidence shows that risk factors do not act in isolation, but rather are contextually dependent on other factors, pointing to the need to explore a variety of risk factors together to better understand their impact on the development of dementia [15–19]. Insight into how various early-life intellectual risk factors interact to protect against, or contribute to, the development of dementia may inform more effective interventions to support cognitive functioning into late life.

Narrative writing, a complex task requiring the coordination of cognitive and psychological processes, can illuminate personal attributes of the author. Writing is cognitively demanding [20] and influenced by executive function [21], and so may be used as one indicator of intellectual capacity. Two measures of written language skill, idea density and grammatical complexity, that were derived from autobiographies written in early adulthood have been highlighted as strong predictors of cognitive function in the Nun Study, a longitudinal study of cognitive ability among older women living in a religious community [22, 23]. Below-average performance in these two measures was associated with cognitive impairment in late adulthood [22], and was a stronger predictor of cognitive impairment than other intellectual factors, including education and multilingualism, in this highly educated sample [15, 17]. As such, these characteristics of narrative writing could be considered within the broader context of intellectual risk factors for dementia.

Nun Study autobiographies were also scored for the number of emotion words used, as a measure of emotional expressivity. This measure presents

a unique opportunity to explore the association between emotional expressivity and dementia, which has not been well studied. The number of positive emotion words in these autobiographies predicted longer life approximately six decades after they were written [24], suggesting the potential importance of the emotional content of the autobiographies for predicting other health outcomes, such as dementia, across the life-course. Emotions expressed in writing can reveal various characteristics of the author that have been associated with cognitive outcomes, such as personality and personality disorders (e.g., Parkinsonian personality [25], bipolar disorder [26]), personal history (e.g., adverse childhood events [27, 28]), and ways of experiencing the world (e.g., chronic stress [29, 30], stress management [31]). Emotional expressivity may also reflect cognitive processes and linguistic mastery underlying various thinking styles [32]. In a computerized analysis of text files from a data bank encompassing a variety of writing genres, frequency of use of emotion words was negatively correlated with several cognitively complex linguistic elements (e.g., prepositions) [32], possibly indicating a feature of an uncomplicated writing style that may predict poorer cognitive outcomes.

Since emotional expressivity, idea density, and grammatical complexity represent various characteristics of written communication (e.g., content, style, skill), consideration of these factors together is important to reflect narrative writing more broadly and to further tease out the competing effects of early-life intellectual factors on the risk of late-life cognitive impairment. The current investigation aims to determine the association between emotional content from autobiographies in early adulthood and the risk of dementia in late life in the context of written language skills assessed from these same autobiographies.

## METHODS

### *Study sample*

The Nun Study is a longitudinal study of 678 religious sisters, aged 75 years or older at baseline (1991–1992), living in the United States [22, 33]. Given their unique vocation, all participants were relatively homogeneous in many personal factors including reproductive history and lifestyle behaviors, such as alcohol and tobacco use. All participants provided informed consent to full participation in

the study, including annual assessments of cognitive function and post-mortem brain donation [22].

Eligibility for the current study required availability of an autobiography from the convent archives. These autobiographies (maximum 200 to 300 words) were assigned to provide a sketch of key life details and were completed before formal entry into the religious order [24]. To ensure that they were written personally, only handwritten autobiographies were scored, and they were further restricted to participants born and raised in the United States as a proxy indicator for basic English proficiency [24]. Most autobiographies that met these criteria were found in two convents: Milwaukee, Wisconsin and Baltimore, Maryland. In all, 180 autobiographies from these two locations met the inclusion criteria and were scored for emotional expressivity and written language skills [22, 24]. As such, these 180 individuals (27% of the total sample) were eligible for the study.

### Measures

Narrative writing was assessed based on measures of emotional expressivity, idea density, and grammatical complexity, which were all measured in a single autobiography per participant. Emotional expressivity scores were determined by two independent coders who scored emotional content in the autobiographies by counting the number of words that indicated any emotional experience; a third coder verified each word for accuracy. The coders were blinded to the dementia status of the participant. Coded words were those that directly indicated an experience of emotion and included the emotion word itself (e.g., sadness) or a behavior indicating the emotion (e.g., crying). Examples of emotions included happiness, accomplishment, gratitude, relief, sadness, anger, fear, and shame. Further details of this scoring process are provided elsewhere, including confirmation of acceptable intercoder reliability ( $\kappa=0.83$ ) [24]. The number of emotion words expressed was ranked separately within each convent to control for differences in distribution of expressivity and length of autobiographies [24]. The emotional expressivity variable was dichotomized to reflect “high” (i.e., rank of 50<sup>th</sup> percentile or higher) and “low” (i.e., below the 50<sup>th</sup> percentile) expressivity.

Idea density and grammatical complexity scores reflect different aspects of written language skills [22, 23]. Idea density was operationalized as the average number of ideas expressed per ten words [34, 35]. Grammatical complexity was measured on an eight-

level scale ranging from simple one-clause sentences to complex multi-clause sentences [36]. Aside from raw scores used for descriptive purposes, idea density and grammatical complexity were ranked within convents and categorized as “high” (i.e., upper three quartiles) or “low” (i.e., bottom quartile), consistent with previous studies [9, 15]. Scoring of idea density and grammatical complexity showed high agreement between coders (correlations of 0.88 and 0.93, respectively) [22].

Dementia was diagnosed based on cognitive assessments as described previously [37]. In brief, diagnostic criteria included impairment in memory and at least one other cognitive domain based on normative data from the Consortium to Establish a Registry for Alzheimer’s Disease (CERAD) battery of neuropsychological tests [38], impaired performance in activities of daily living, and decline from a previous level of function [37]. Dementia diagnosis was determined at the last cognitive assessment before death or attrition. All dementia cases were considered incident cases given the early age at which the autobiographies were completed.

Other covariates of interest for this study included age at last cognitive assessment, education, and apolipoprotein E (*APOE*) genotype. Educational level was represented as the highest level achieved (i.e., grade school, high school, Bachelor’s degree, Master’s degree or higher). *APOE* genotype was determined, blinded to cognitive status, through genetic testing of DNA obtained from buccal swabs and from brain tissue according to standard techniques [39].

### Data analysis

The emotional expressivity of participants was explored through univariate and bivariate analyses (i.e., Pearson correlations, *t*-tests, chi-square tests). Both raw scores and dichotomous rankings of the emotional expressivity and linguistic measures were analyzed. Bivariate analyses tested factors associated with dementia, including emotional expressivity and other covariates (i.e., idea density, grammatical complexity, age at last cognitive assessment, level of education, and presence of an *APOE*  $\epsilon 4$  allele). Multivariable logistic regression analysis assessed the association of dementia with emotional expressivity, adjusted for the same covariates.

Given that a strong effect of idea density on the risk of dementia was found in the initial multivariable logistic regression models, a four-level composite

variable was created to test the effect of high and low emotional expressivity within the context of high and low idea density. Dementia prevalence and other covariates were compared across the four groups (i.e., high/low emotional expressivity with high/low idea density) using chi-square tests with *post hoc* Fisher's exact contrasts and ANOVAs, where appropriate. A logistic regression model, adjusted for age, education, *APOE*  $\epsilon 4$  carrier status, and grammatical complexity tested the association of this four-level composite variable with the risk of dementia. The low emotional expressivity/high idea density subgroup was used as the referent group because they had the lowest prevalence of dementia. Diagnostic tests were performed to assess influential outliers and multicollinearity. All analyses were completed using SAS statistical software, versions 9.2–9.4 (SAS Institute Inc., Cary, NC). Ethics clearance was granted by research ethics committees at the University of Kentucky for the original Nun Study and at the University of Waterloo for the current study.

## RESULTS

The final sample included 149 (82.8% of eligible) individuals after exclusions. Sixteen individuals were excluded because of missing data on *APOE*. An additional 15 individuals whose highest level of education attained was a high school diploma were excluded given this low prevalence in the sample and subse-

quent implications of small cell sizes in multivariable analyses.

Table 1 provides a description of the sample. Approximately one-third of participants ( $n=47$ ) were diagnosed with dementia at their last cognitive assessment. The mean age was 21.9 years (standard deviation [SD]=2.6) when the autobiographies were written and 88.1 years (SD=5.0) at the last cognitive assessment, with a mean difference of 66.2 years (SD=5.2) between writing the autobiography and the last cognitive assessment. Individuals with dementia did not differ from those without dementia in age, years between writing the autobiography and last cognitive assessment, or education, but a significantly higher proportion had at least one *APOE*  $\epsilon 4$  allele (40.4% versus 19.6%,  $\chi^2=7.21$ ,  $p=0.007$ ).

Emotion word usage was highly variable. On average, participants used 8.8 (SD=7.4) emotion words in their autobiographies, ranging from 0 to 32 words (Table 1). The mean number of emotion words in the low emotional expressivity subgroup was significantly lower (mean=4.3, SD=3.9) than that of the high emotional expressivity subgroup (mean=12.6, SD=7.5;  $p<0.001$ ). The presence of high emotional expressivity did not differ significantly by dementia status (59.6% with dementia versus 51.0% without dementia,  $\chi^2=0.96$ ,  $p=0.33$ ).

Emotion word usage was associated with both measures of written language skills as raw counts but not after collapsing them into high/low categories.

Table 1  
Participant characteristics by dementia status ( $n=149$ )

Characteristic	Total	Dementia <sup>†</sup>	
		No	Yes
N	149	102	47
Age at Last Cognitive Assessment, Mean Years (SD)	88.1 (5.0)	88.2 (5.0)	88.0 (4.9)
Level of Education, %			
Bachelor's Degree	42.3	42.2	42.6
$\geq$ Master's Degree	57.7	57.8	57.4
Presence of <i>APOE</i> $\epsilon 4$ , %	26.2	19.6	40.4**
Autobiography Measures			
Emotional Expressivity			
Raw Word Count <sup>‡</sup>			
Mean (SD)	8.8 (7.4)	8.3 (7.3)	9.8 (7.5)
Median (Range)	7.0 (0–32)	6.0 (0–32)	8.0 (0–29)
High Emotional Expressivity <sup>§</sup> , %	53.7	51.0	59.6
High Idea Density <sup>¶</sup> , %	80.5	91.2	57.5**
High Grammatical Complexity <sup>¶</sup> , %	78.5	83.3	68.1*

\* $p<0.05$ ; \*\* $p<0.01$ . <sup>†</sup>Based on diagnosis of dementia at the last cognitive assessment.

<sup>‡</sup>Autobiographies were required to be no more than one page in length, providing an approximate standard length for comparison. <sup>§</sup> $\geq 50^{\text{th}}$  percentile ranking within convent. <sup>¶</sup>Upper three quartiles. *APOE*  $\epsilon 4$ , apolipoprotein E  $\epsilon 4$  allele; SD, standard deviation.

The raw number of emotion words within the autobiographies was correlated in opposite directions with idea density and grammatical complexity scores: a negative association was found with idea density ( $r = -0.40$ ;  $p < 0.001$ ), whereas a positive association was found with grammatical complexity ( $r = 0.46$ ;  $p < 0.001$ ). When controlling for between-convent differences in the autobiographies by ranking these scores by convent and collapsing them into high and low categories, chi-square tests did not show a significant association of emotional expressivity with either idea density or grammatical complexity.

Emotional expressivity as an independent variable was not significantly associated with dementia in the logistic regression analyses (Table 2). While the fully adjusted model indicated increased odds of developing dementia with high emotional expressivity, this association was not significant (odds ratio [OR] = 1.82; 95% confidence interval [CI] = 0.82–4.18). Both high idea density (OR = 0.14, CI = 0.05–0.36) and high grammatical complexity (OR = 0.46, CI = 0.18–1.23) were protective against development of dementia, but only idea density was significant in the fully adjusted model.

Bivariate analyses comparing the characteristics of the four emotional expressivity/idea density subgroups revealed differences by dementia and *APOE* ε4 carrier status (Table 3). Dementia incidence increased in a stepwise fashion across the four groups with the lowest incidence among the low emotional expressivity/high idea density subgroup (14.6%). Incidence was twice as high (i.e., 29.2% versus 14.6%) among the high emotional expressivity/high idea density subgroup and reached statistical significance at over four times as high in the high emotional expressivity/low idea density (60.0%) and low emotional expressivity/low idea density (78.6%) subgroups. The prevalence of *APOE* ε4 carrier status also increased in a stepwise fashion across the groups, but the high emotional expressivity/high idea density subgroup had the lowest proportion of *APOE* ε4 carriers (16.9%) and low emotional expressivity/low idea density had the highest (57.1%): only these two subgroups were significantly different from each other in proportion of *APOE* ε4 carriers. The four subgroups did not differ in age at last cognitive assessment, level of education, or the grammatical complexity of their autobiographies.

Table 2  
The association between emotional expressivity and dementia ( $n = 149$ )

Variable	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
High Emotional Expressivity (versus low) <sup>†</sup>	1.65 (0.80–3.50)	1.72 (0.79–3.90)	1.74 (0.83–3.75)	1.82 (0.82–4.18)
Age at Last Cognitive Assessment, y	1.00 (0.93–1.08)	1.04 (0.96–1.12)	1.02 (0.94–1.10)	1.05 (0.97–1.15)
Education (Master’s versus Bachelor’s Degree)	0.93 (0.45–1.93)	1.12 (0.51–2.51)	0.99 (0.47–2.08)	1.18 (0.53–2.67)
<i>APOE</i> ε4 (Presence versus Absence)	<b>3.04 (1.39–6.74)</b>	2.26 (0.95–5.37)	<b>2.97 (1.34–6.69)</b>	2.26 (0.94–5.45)
High Idea Density (versus low) <sup>‡</sup>		<b>0.13 (0.05–0.34)</b>		<b>0.14 (0.05–0.36)</b>
High Grammatical Complexity (versus low) <sup>‡</sup>			<b>0.41 (0.17–0.98)</b>	0.46 (0.18–1.23)

<sup>†</sup>High: ≥ 50<sup>th</sup> percentile ranking within convent; low: < 50<sup>th</sup> percentile ranking. <sup>‡</sup>High: upper three quartiles; low: bottom quartile. *APOE* ε4, apolipoprotein E ε4 allele; CI, confidence interval; OR, odds ratio. Bolded values indicate statistical significance,  $p < 0.05$ .

Table 3  
Description of the four-level composite variable combining emotional expressivity and idea density ( $n = 149$ )

Emotional Expressivity <sup>†</sup>	Low	High	Low	High
Idea Density <sup>‡</sup>	High	High	Low	Low
N	55	65	14	15
Dementia diagnosis <sup>§</sup> , %	14.6 <sup>a</sup>	29.2 <sup>a</sup>	78.6 <sup>b</sup>	60.0 <sup>b</sup>
Age at Last Cognitive Assessment, Mean Years (SD)	88.1 (5.2)	89.0 (4.5)	86.0 (6.2)	86.4 (4.5)
Level of Education, %				
Bachelor’s Degree	43.6	36.9	42.9	60.0
≥ Master’s Degree	56.4	63.1	57.1	40.0
Presence of <i>APOE</i> ε4, %	25.4 <sup>a,b</sup>	16.9 <sup>a</sup>	57.1 <sup>b</sup>	40.0 <sup>a,b</sup>
High Grammatical Complexity <sup>‡</sup> , %	80.0	84.6	57.1	66.7

<sup>a,b</sup>Subgroups with the same letter superscript are not significantly different,  $p < 0.05$ . There was no significant difference where no letter superscripts appear. <sup>†</sup>High: ≥ 50<sup>th</sup> percentile ranking within convent; low: < 50<sup>th</sup> percentile ranking. <sup>‡</sup>High: upper three quartiles; low: bottom quartile. <sup>§</sup>Based on diagnosis of dementia at the last cognitive assessment. *APOE* ε4, apolipoprotein E ε4 allele; EE, emotional expressivity; ID, idea density; SD, standard deviation.

Table 4

The association of dementia with the four-level composite variable combining emotional expressivity and idea density ( $n = 149$ )

Variable	Unadjusted OR (95% CI)	Fully Adjusted OR (95% CI)
Emotional Expressivity <sup>†</sup> and Idea Density <sup>‡</sup> Composite Variable		
Low EE / High ID <sup>§</sup>	1.00	1.00
High EE / High ID	2.43 (0.97–6.09)	<b>2.73 (1.05–7.08)</b>
Low EE / Low ID	<b>21.54 (4.90–94.66)</b>	<b>18.58 (4.01–86.09)</b>
High EE / Low ID	<b>8.81 (2.46–31.58)</b>	<b>9.02 (2.33–34.87)</b>
Age at Last Cognitive Assessment, y		1.05 (0.96–1.15)
Education (Master's versus Bachelor's Degree)		1.10 (0.49–2.48)
APOE $\epsilon$ 4 Allele Status (Presence versus Absence)		2.25 (0.92–5.47)
High Grammatical Complexity (versus low) <sup>‡</sup>		0.47 (0.18–1.24)

Bolded values indicate statistical significance,  $p < 0.05$ . <sup>†</sup>Emotional expressivity: high =  $\geq 50^{\text{th}}$  percentile ranking within cohort; low =  $< 50^{\text{th}}$  percentile ranking. <sup>‡</sup>Idea density and grammatical complexity: high = upper three quartiles; low = bottom quartile. APOE  $\epsilon$ 4, apolipoprotein E- $\epsilon$ 4 allele; CI, confidence interval; EE, emotional expressivity; ID, idea density; OR, odds ratio; <sup>§</sup>Referent category.

In the multivariable logistic regression analysis, the composite emotional expressivity/idea density variable was significantly associated with dementia (Table 4). Compared to participants with low emotional expressivity/high idea density, all other subgroups had significantly higher risk of dementia in the fully adjusted model. Comparing the two groups with high idea density, a significantly greater risk of dementia was found for individuals with high emotional expressivity/high idea density (OR = 2.73; 95% CI = 1.05–7.08) relative to low emotional expressivity/high idea density after adjustment for potential confounders. Strong effects were also found in both low idea density subgroups relative to the referent group. However, in contrast to the increased risk of dementia found with high emotional expressivity among individuals with high idea density, the strongest effect was found with low emotional expressivity among individuals with low idea density. That is, individuals with low emotional expressivity/low idea density had the highest risk of dementia (OR = 18.58; 95% CI = 4.01–86.09) while those with high emotional expressivity/low idea density had a comparatively smaller magnitude of risk (OR = 9.02; 95% CI = 2.33–34.87) relative to the referent group.

## DISCUSSION

Our findings show that the emotional content from autobiographies handwritten in early adulthood was associated with the risk of dementia in late life within the context of a measure of written language skill (i.e., idea density) from these same autobiographies. Emotional expressivity, when combined into a composite variable with idea density, was predictive of

dementia over 50 years later among American women living in a religious community. Compared to the referent group (i.e., low emotional expressivity/high idea density), high emotional expressivity/high idea density was associated with a three-fold increased risk of dementia after also adjusting for other related factors, including education. As expected, given the established strong association between low idea density and dementia, the risk of dementia was greatest among the low emotional expressivity/low idea density and high emotional expressivity/low idea density subgroups, but the added effect of emotional expressivity was opposite to what may have been expected. Among these two groups, individuals with high emotional expressivity/low idea density had a nine-fold increased risk of dementia and those with low emotional expressivity/low idea density had a nineteen-fold increased risk compared to the referent group. Grammatical complexity was neither associated with dementia when idea density was included in the models, nor did it have a significant effect on the association between emotional expressivity and dementia.

These results point to the importance of considering novel early-life factors in the context of other established risk factors to understand the complexity of dementia risk more fully. The Nun Study autobiographies provide a unique window into the early lives of participants, presenting emotional expressivity as another element of writing style, in addition to well-established measures of written language skills (i.e., idea density and grammatical complexity) that predict cognitive outcomes [9, 22, 23].

Theoretical interpretation of the different components of narrative writing reveals specific cognitive

and personal characteristics of the writer. Emotion words are a measure of written content and describe a particular aspect of individual experience, revealing personality, perspective, and coping styles [32]. Idea density is related to the content of writing. It is a measure of language processing and is a function of education, general knowledge, vocabulary and reading comprehension [40, 41]. Idea-dense writing efficiently communicates conceptually rich information, whereas writing that is low in idea density is vague or repetitious [42]. In contrast, grammatical complexity reflects the structure rather than the content of the written text. As a measure of working memory [36, 43], grammatical complexity indicates overall intellectual aptitude and fluid intelligence [44], and demonstrates the capacity to retain and manipulate multiple syntactic elements [43]. In the context of the current findings, the distinctions between these interpretations suggest that the content (i.e., idea density, emotional expressivity) may be more important than the structure (i.e., grammatical complexity) of writing in predicting dementia.

The current findings, specifically the combined effect of emotional expressivity and idea density scores as measures of the written content, suggest underlying factors interact to predict the risk of dementia. In our analysis, individuals with low emotional expressivity and high idea density were considered at lowest risk and thus treated as the referent group, given the established protective effect of high idea density and consistent with evidence that low emotional expressivity may be correlated with cognitively complex writing [32]. Indeed, individuals with high emotional expressivity and high idea density had a greater risk of dementia compared to the referent group and, as expected, both low idea density subgroups had even higher odds of developing dementia. However, between the two low idea density subgroups, individuals with low emotional expressivity were at greatest risk, which was opposite to what was expected based on the direction of association between the two high idea density subgroups and the previously cited literature [32]. This contradiction suggests that single measures (e.g., idea density) are not sufficient to capture the complexity of dementia risk. Emotional expressivity may be protective when individuals are at increased risk of dementia due to poor written language skills (i.e., when idea density is low), but detrimental when not at increased risk (i.e., when idea density is high). This is consistent with other studies that show the importance of context when considering the protective effect of

intellectual factors on cognitive impairment, such as evidence that cognitively demanding skills (e.g., multilingualism) may be protective when individuals are at increased risk of poor cognitive outcomes due to low levels of education [16, 19, 45] or other cognitive leisure activities [18].

Alternatively, the added significance of emotional expressivity combined with the idea density measure in predicting dementia may simply be an artefact of the idea density measure, given the inverse correlation found between idea density and emotional expressivity. That is, a high number of emotion words would increase the total number of words written (i.e., the denominator of the idea density score) without contributing to the number of ideas expressed (i.e., the numerator), thus driving down the idea density score. Further exploration of the effects of written language characteristics, including emotion, would be useful to confirm whether the emotional expressivity variable measures a similar construct to idea density, or if the effect is altogether different.

Autobiographical narrative writing is a rich source of data associated with various personal characteristics of the writer. These characteristics, such as executive function, psychological processes, social status, and physical health outcomes [21, 32, 46], may be related to risk of dementia, potentially explaining the significant association between emotional expressivity in the autobiographies and dementia in the current study. For example, the emotional expressivity score may reveal the emotional qualities of an individual, such as emotional tendencies (e.g., positive/negative), lived experiences, emotional intelligence, or ability to regulate expression of emotions to match the context of the written assignment. These factors may be associated with dementia through various mechanisms, including cognitive processes, stress or high reactivity, emotional intelligence, and emotional regulation [5, 47–49]. Given that many of these factors are potentially modifiable, the mechanism underlying the association between emotional expressivity and dementia is worthy of further investigation.

The unique study population and data sources are valuable contributions to this novel research. The relative homogeneity of demographic characteristics and lifestyles of participants in adulthood serves as a natural control for potential confounding factors (e.g., socioeconomic status, marital status, reproductive history, tobacco and alcohol use), and rigorous control of the effect of education through restriction and multivariable analysis allows for clearer

etiologic conclusions to be drawn. Cognitive data were comprehensive and based on a standard battery of neuropsychological tests. In addition, autobiographies written in early adulthood provided a unique source of data where several aspects of written language could be analyzed, and a temporal association established. Obtaining all measures from the same autobiography allowed for control of acute factors potentially affecting the composition of the autobiographies.

Conversely, the homogeneity of participants and the restriction of the analysis to those with a post-secondary degree limit the generalizability of the results. Participants were 75 years or older at the beginning of data collection, potentially introducing survival bias. While methodological approaches to address related left-truncation issues are being developed [50], similar to other longitudinal studies of aging we were not able to assess the impact of survival bias on our results because outcome data were only available for study participants. Members of our religious order cohort who died prior to recruitment into the study may have had different patterns of emotional expressivity related to higher risk of early death, particularly given the association of positive emotions with longevity in this sample [24]. Furthermore, only the final cognitive assessment before death or the end of the data collection period was considered in the analyses, so transient diagnoses were not captured. In addition, the representativeness of the autobiographies across a lifetime was unknown in that they were written at a single time point.

The results suggest that further exploration of the relationship between dementia and written communication is warranted. In our analysis, autobiographies were coded manually through a validated process, providing an overall summary of writing style. Technological advancements in computerized text analysis, such as Linguistic Inquiry and Word Count (LIWC), demonstrate how even individual word selection can convey psychological meaning [32]. Analysis of various sources of text using this newer technology and application to other populations could further link written language to dementia and could be extended to other outcomes across the life-course. Future research would also be useful in clarifying the meaning of the emotional expressivity variable. For example, the association of positive and negative expressivity with dementia may be explored given substantial evidence suggesting differences in physiological and cognitive processes involved in positive and negative emotions [51]. Considering our findings

from a life-course perspective, the effects of written communication on cognitive trajectories could be explored in the context of cognitive reserve theory [52].

The current investigation indicates that components of narrative writing, particularly emotional expressivity and idea density, from autobiographies written in early adulthood are predictive of dementia more than half a century later. These findings add to the growing body of evidence suggesting the importance of context when evaluating the effect of early-life factors on dementia risk, and demonstrate the potential for emotions among other writing characteristics to predict the risk of dementia across the life-course.

## ACKNOWLEDGMENTS

The authors have no acknowledgments to report.

## FUNDING

The Nun Study (University of Kentucky): NIA #R01AG09862, K04AG00553, P50AG05144, and the Kleberg Foundation. This work: Canadian Institutes of Health Research (CIHR) #137035 awarded to ST.

## CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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