LINGUISTIC COMPLEXITY, CREATIVITY & COVID-19

LINGUISTIC COMPLEXITY AND CREATIVITY ACROSS THE COVID-19 PANDEMIC: A CORPUS ANALYSIS

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Lay abstract

The COVID-19 pandemic has been isolating, and isolation is a mixed bag: being alone promotes self-reflection and overthinking, and doing too much is linked to stress and mental illness. However, more time spent in solitude is also linked to greater creativity. Creativity means more new ideas, which come through as longer, more detailed sentences, with less repetition. This research looked at stories by older adults about their lives, written before and during the pandemic. Surprisingly, the language in the stories became more descriptive and diverse over time—meaning people were being more creative after COVID-19 hit. In the wake of this lonely storm, one silver lining has emerged: whether in spite of or because of this pandemic, creativity is flourishing.

Abstract

The current study investigated the language behaviour of older adults before and during the COVID-19 pandemic. Linguistic complexity (LC)—a measure of lexical and morpho-syntactic richness—is an index of both cognitive functioning and creativity. The increased physical and social isolation during the pandemic yielded reports of heightened levels of creativity as well as cognitive decline, bringing forth two counter-directed predictions: (1) given the threat to cognitive functioning posed by the pandemic, LC may steadily decrease following the onset of the pandemic, or; (2) consistent with the creativity boost reported during lockdowns, LC may be greater after the onset of the pandemic. This work analyzed the syntactic and lexical complexity of texts from the CoSoWELL corpus (v1.0), a collection of personal narratives written by 1028 mature adults (55+) collected at five test sessions spanning before (t1) and after (t2-t5) the beginning of the pandemic. Two lexical variables (type-token ratio; noun-verb ratio) and six syntactic variables (two syntactic variants of type-token ratio; embeddedness; D-ratio; longest dependency path; mean length utterance) were used to calculate LC. All measures saw statistically significant gains from t1 to t2, and further increased across subsequent test sessions. These findings confirmed the second hypothesis and, I argue, support a pandemic-related boost to creativity.

Keywords: aging, COVID-19, creativity, lexical diversity, syntactic complexity

Multimedia abstract

Can a pandemic make you more creative? (Gradflix 2022 Animated Video)

https://tinyurl.com/4ub2nvc5

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1 Introduction

This thesis is an exploratory investigation into changes to the linguistic complexity of written productions elicited from a large group of mature adults before and during the first year of the coronavirus disease 2019 (COVID-19) pandemic. Linguistic complexity—defined in detail below—is a measure of the lexical and morpho-syntactic richness exhibited by writers in their productions. Several social aspects of the pandemic, including the increased physical and social isolation of older adults, bring forward the possibility of drastic changes in the nature and scope of communication in this population group, potentially engendering change in their language use. The primary questions of interest were: (i) has the pandemic affected the complexity of older adults' written language production? That is, do syntactic and lexical complexity vary across test session? And if so, (ii) which particular environmental and cognitive factors might be responsible for this variation?

The evidence base for this thesis is the CoSoWELL (Cognitive and Social Well-being) corpus, a collection of life stories written by older adults (55+ years of age) from Canada and the United States. The project began in 2019 as an initiative to study the relationship between cognitive and social well-being and language use in aging populations. By analyzing language choice and the presence of particular linguistic features, the goal was to measure whether and how language production varies as a function of age and perceived loneliness and social isolation, and a collection of other independent variables. With the onset of the COVID-19 pandemic in March of 2020, the study was extended and data collection resumed for subsequent test sessions (though data collection remains ongoing, only the first five test sessions, t1-t5, are used in the present analysis). This has presented an unprecedented opportunity to study language behaviour as it changes over a period of time corresponding to the

unfolding of a global health crisis—the time frame beginning in pre-pandemic 2019 and extending over the course of the pandemic through 2020 and early 2021. Given the consequential disruptions to nearly all aspects of life brought on by the pandemic, this study sought to know whether written language production, too, would exhibit changes across a corresponding window of time.

The results, discussed in detail later on, show that complexity does indeed differ across stages of the pandemic, trending upward as a function of time. The purpose of the current work is to present and expound upon a theoretical explanation for these findings. In particular, this thesis offers a link between linguistic complexity and creativity in the context of the social and emotional aftermath of the COVID-19 pandemic.

2 Background

2.1 Complexity & Creativity

2.1.1 Linguistic Complexity

Language is the vehicle for the outward expression of one's inner, subjective experience; it constitutes the ability to decode and understand the thoughts of another human being, and, in turn, to communicate and be understood. Utterances and their properties thus reflect internal mental states, and it is these mental realities which both generate and constrain language production (Cohn, Mehl, & Pennebaker, 2004; Eichstaedt et al., 2018; Esmaeelpour & Sasani, 2018; Kyröläinen, Gillett, Karabin, Sonnadara, & Kuperman, accepted; Wei, Finn, Templeton, Wheatley, & Vosoughi, 2021).

Complexity is one well-established property of language used widely in linguistic analysis. Consistent with its lay-meaning, complexity in language can be defined, broadly, as the quality of being intricate, complicated or varied in constitution. The present study investigates the linguistic complexity of CoSoWELL narratives along two dimensions: lexical complexity and syntactic complexity.

Lexical complexity (alternately known as lexical diversity, or lexical richness) refers to the degree of diversity of the language produced in an utterance. In particular, greater lexical complexity reflects a more heterogeneous selection of words, and can be achieved by, for instance, using synonyms or related words (in place of repetition), and more precise rather than generic language, or employing stylistic variation (Ravid, 2005; Smith & Kelly, 2002). Strongly related to expressive vocabulary size, lexical complexity is representative of a person's command of a language insofar as it is an outward indication of the available linguistic content at one's disposal for verbal

communication (Crossley, 2020): low lexical complexity, as found in texts with an excessive repetition of words, is indicative of impoverished language ability, while high lexical complexity signals stronger linguistic capabilities. Lexical complexity also varies by literary genre and modality: formal genres, which are often written in professional settings (e.g., academic publications, news, or magazines), tend to exhibit higher lexical complexity, relative to informal genres (e.g., fiction, spoken language) (Ströbel, Kerz, Wiechmann, & Qiao, 2018). In the course of both first and second language acquisition, lexical complexity sees substantial gains as proficiency increases, in step with the expansion of one's lexical repertoire as knowledge of the new language further accumulates (Kim, 2014; K. Sun & Wang, 2021).

Syntactic complexity reflects the elaborateness or intricacy of the structural composition of an utterance. Measures of length, along with depth and breadth of the hierarchical relations in a structure, point to the amount of information contained in an utterance and to how that information is organized. As it requires the ability to produce grammatically well-formed and multi-tiered branching structures, syntactic—like lexical—complexity is a marker of language proficiency, in addition to cognitive ability (Glasersfeld, 1971; Scontras, Badecker, Shank, Lim, & Fedorenko, 2015). Thus, the overuse of syntactically simple utterances suggests a limited command of the syntactic diversity available in the language. Similarly to its lexical counterpart, syntactic complexity varies by genre (Ströbel et al., 2018) and proficiency level (Crossley, 2020): it is higher in formal written genres and productions from more adept users of a language, with aptitude corresponding to speaker distinctions based on, e.g., development (mature vs. developing); education (more vs. less educated); or language of acquisition (first vs. second; Kim, 2014; Sun & Wang, 2021).

Complex structures and discourses are characterized by more numerous, more variegated, and more structurally intricate components. Under functionalist accounts

of language processing, complexity is more taxing to the system than simplicity. Complex utterances require more resources to produce and comprehend than their simpler counterparts. This results in a tendency of speakers to minimize complexity where possible, in order to reduce cognitive load (Futrell, Mahowald, & Gibson, 2015; Hawkins, 2003; Jaeger & Tily, 2011; Temperley, 2007). The successful handling of complex language thus depends on a speaker's cognitive capabilities. Indeed, language-specific computation is hindered when cognitive functioning is impaired, evident in the simplicity of language produced by speakers with cognitive deficits relative to healthy individuals. The association between cognitive function and linguistic complexity is robustly attested in the literature: results across a number of studies have shown mild cognitive impairment (MCI), Alzheimer's Disease and aphasia to inversely correlate with both lexical and syntactic complexity (Burke & Shafto, 2008; Eyigoz, Mathur, Santamaria, Cecchi, & Naylor, 2020; Le, Lancashire, Hirst, & Jokel, 2011; Pakhomov, Chacon, Wicklund, & Gundel, 2011; Roark, Mitchell, Hosom, Hollingshead, & Kaye, 2011). In other words, with cognitive deficits comes a reduction in the linguistic complexity of a speaker's utterances.

Mental well-being also has important implications for complexity in language production. The presence of stress, anxiety and depression are predictive of lower-complexity productions as well as lower cognitive performance in general (Esmaeelpour & Sasani, 2018; Pue et al., 2021; Wei et al., 2021; Zhong, Chen, & Conwell, 2016). These links, considered together with the relationship between cognitive function and linguistic complexity, reveal emotional and cognitive well-being as important factors to consider when to the question of how and why the complexity of a speaker's written productions might change over time.

2.1.2 Creativity

Linguistic complexity is also a measure of creativity. The generative linguistics notion of linguistic creativity, initially proposed by Chomsky (1969), constitutes the ability to use and combine a finite quantity of items in an infinite number of ways (Adger, 2019; Chomsky, 1969)—that is, to produce novelty (in language) within established parameters (e.g., the grammatical conventions of a language). T. Ward, Smith, and Vaid (1997) state that "[c]reativity may even be better thought of as the entire system by which processes operate on structures to produce outcomes that are novel but nevertheless rooted in existing knowledge". 'Existing knowledge' and 'structures' serve as the basis for creativity (in language, one's lexical inventory and grasp of grammatical relationships), while 'processes' refer to the cognitive events involved in generating creativity, and 'outcomes' refer to the products of creativity (Zawada, 2006). To put this framework into fresh terms, these correspond to the palette (existing knowledge base → lexicon/grammar), the brushes and techniques (processes → cognitive events), and the finished painting (outcomes → creative products), respectively.

In line with these distinctions and across its wide disciplinary scope, creativity is explored via two primary veins of research: creative processes and creative products. Creative products are tangible or material outputs which are novel, original and meaningful[1]; creative processes, meanwhile, are the cognitive and neural states and

[1]Novelty and originality are undisputed key characteristics of creative products. However, it should be noted that a number of accounts also list usefulness or value as a criterion for creativity (e.g., Beghetto and Kaufman, 2007; Helfand, Kaufman, and Beghetto, 2016; Marron and Faust, 2018; Marron et al., 2018; T. B. Ward, 2007), in spite of numerous compelling reasons against its inclusion, most obvious of which is the highly subjective and changeable nature of value judgments, not only from individual to individual but also from era to era, where the notion of value shifts with changing cultural values, practices and beliefs (e.g., Weisberg, 2015). More recent work (Helfand et al., 2016) amended the older definition, characterized by the two prongs of novelty and usefulness, to include meaningfulness as a property interchangeable with or in place of usefulness. Hence, a product that is both novel and meaningful is one which is creative. And while usefulness may indeed be a beneficial by-product of many creative works, it should not be a necessary condition for recognition as such.

actions involved in the generation and production of creative products. The research that is the subject of this paper taps into both: this study analyzes creative products (the CoSoWELL texts), and discusses what these results might tell us about the creative processes involved in the production of these (creative) products.

The Four-C model of creativity (Beghetto & Kaufman, 2007; Helfand et al., 2016; Kaufman & Beghetto, 2009) offers a framework for situating creativity research according to what the authors term 'creative magnitude'. This classification scheme gauges creativity (of products, across modes of expression) primarily by the skill level of the creator and the scope or reach of the creative products, in addition to the requisite qualities of novelty and meaningfulness. The model thus delineates four levels of creativity: Big-C, Pro-c, little-c, and mini-c. While the first three distinguish and categorize creative products by their creative magnitude (e.g., the creator's technical aptitude and/or degree of mastery; the quantity of their outputs; how successful or widely-accepted the idea is), the last, mini-c, is qualitatively different. Mini-c is defined as the "novel and personally meaningful interpretations of experiences, actions and events" (Beghetto & Kaufman, 2007). Importantly, the category of mini-c encompasses creative processes which are present at every instance and every level of creativity (Kaufman & Beghetto, 2009). It is the creative process which is the focus of mini-c creativity, such that intrapersonal insights, interpretations and constructions are understood as creative acts per se. Mini-c is highly intrapersonal, and it is on this dimension that mini-c is most distinct from the other strata of creativity (i.e., little-c, Pro-c, Big-C), membership to which relies almost solely on interpersonal or externally-sourced appraisals of creative products (with respect to both their novelty and meaningfulness–to qualify as creative in the first place–and their creative magnitude, the ultimate determinant of their rank within the model). Mini-c creative expression is neither bound nor influenced by the evaluations of magnitude required

for classification at the other levels of creativity in the Four-C model. Linguistic complexity, considered through this lens as a dimension of creativity, falls under the mini-c designation.

One theory in creativity research from cognitive science explores the processes at the heart of mini-c more explicitly. The creative cognition approach holds that novel ideas or products "emerge from the application of ordinary, fundamental cognitive processes to existing knowledge structures" (T. B. Ward, 2007). In other words, the focus of creative cognition research is understanding which cognitive mechanisms enable creative thought and behaviour. In particular, creative thought depends on two cognitive factors: executive (control) processes and associative (spontaneous) processes. Control processes are those governed by conscious direction, whereas spontaneous processes reflect processing occurring automatically. Both types are necessary for creative cognition.

The literature outlines several processes that facilitate the generation of creative ideas, or *creative cognitions*: divergent thinking, convergent thinking, and remote semantic-conceptual association (henceforth RSCA). Divergent thinking is described as the generation of novel or unique ideas from diverse domains, while convergent thinking captures the process of producing (i.e., converging on) one solution, evaluated on its correctness or appropriateness (Marron & Faust, 2018; Marron et al., 2018; Mason et al., 2021); RSCA describes the ideational combination of concepts which do not frequently co-occur. Inherent to creative thought are the notions of divergence (or diversity) of concepts and novelty in the way they are combined and used. Both divergent thinking and RSCA reference novelty, and much like the previously-introduced concept of linguistic complexity, are measures of diversity. Indeed, conceptual diversity and linguistic diversity are in fact analogous: language consists of the lexical and

syntactic packaging of concepts, and greater linguistic diversity signals the activation of a greater number of concepts or mental representations. In essence, divergent thinking is to a creative idea as linguistic complexity is to a text (while convergent thinking is to a creative solution as linguistic/grammatical convention is to a text).

By merging the generative definition of creativity, denoting the richness, diversity and novelty of forms and constructions in language production with creative cognition concepts such as divergent and convergent thinking, we arrive at a more complete understanding of linguistic complexity as a lower-level dimension of creativity, mapping onto the Four-C Model's mini-c level (reflecting novelty and meaningfulness in an intrapersonal context). The current project thus explores linguistic complexity (operationalized in section 3.6) as a proxy for linguistic creativity.

Recalling that mini-c creativity considers intrapersonal insights and interpretations as creative acts, the life stories which are the basis for this investigation are in fact classifiable as creative products in their own right, irrespective of further analysis: the texts are novel, original, and personally meaningful interpretations of life experiences. It should be noted that for this study, we have access to the products (this study examines language data, with no e.g., neuroimaging), and as such we make inferences about the underlying processes involved by looking at the products' properties. The question of interest in the present study is whether the texts became more or less complex across the pandemic, where higher or lower linguistic complexity may reflect either a surge or a drop in creativity, respectively.

In sum, linguistic complexity's associations with cognitive and emotional wellness on the one hand, and creativity on the other, lead us to two counter-directed predictions, outlined in the following section.

2.2 Psychosocial consequences of the COVID-19 pandemic

The Covid-19 pandemic has been the single largest and most impactful global event of the twenty-first century. Its effects have been far-reaching and devastating: as of January 2021, over 98 million people had contracted the virus since the outbreak began, and more than 2.1 million lost their lives. Just one year later, the death toll is more than twofold what it was, and the number of cases has nearly tripled (*Weekly Epidemiological Update*, 2021, 2022).

Epidemics are known to have negative psychological effects in addition to and independently of symptoms arising from having contracted the disease, and Covid-19 is no exception (Hossain, Tasnim, et al., 2020; Ji et al., 2017). Older adults, who are at a higher risk of death and serious illness from Covid-19, must bear the heavy emotional burden of fear and anxiety in addition to the greater physical toll of sickness. Meanwhile, the protective countermeasures enacted to reduce viral spread and prevent the collapse of public health systems have themselves had a host of adverse collateral effects.

In response to Covid-19, daily life was transformed as a result of sweeping shutdowns of public and interpersonal spheres, stay-at-home orders and physical distancing protocols, and the restriction of access to both essential and non-essential services. Such measures—characterized by social isolation—remained the most effective widely-available tools for slowing and preventing viral transmission over the first year of the pandemic. However, the limiting and in some cases total prohibition of extra-household socialization has proven challenging. People were largely relegated to their homes for periods of weeks or months, cut off from social activities—from larger events to small gatherings to brief but routine interactions—which would have been central constituents of pre-pandemic quotidian life.

Such isolation can have a detrimental impact on mental health outcomes. A systematic review by Hossain, Sultana, and Purohit (2020) reported a heavy toll of mental illness and related psychological problems among individuals who underwent quarantine or isolation, citing depression, anxiety, mood disorders, and psychological distress among the observed negative mental health outcomes. Another review by Luo et al. (2020) echoed these findings, reporting that the onset of a number of adverse psychological symptoms—including anxiety, depression, despair and loneliness—coincided with (and subsequently extended beyond) the start of a quarantine period. Further reports on the effects of the conditions brought on by pandemic restrictions described decreased cognitive functioning and overall well-being in addition to higher rates of depression and anxiety (Banerjee & Rai, 2020; Hossain, Tasnim, et al., 2020; Pue et al., 2021).

From this arises the first prediction of the current study: Given the Covid-19 pandemic's deleterious effects on mental health and well-being, we expected cognitive skills to deteriorate and, consequently, for linguistic complexity to decrease in the course of the pandemic. In addition, that these conditions and their effects manifest linguistically has already been corroborated in earlier analyses of the same dataset (the CoSoWELL corpus) targeting the topical structure of the narratives as well as their affective and sensorimotor characteristics (Kyröläinen & Kuperman, n.d.; Kyröläinen et al., accepted).

While its negative repercussions are numerous and oft-discussed, social isolation also has lesser-known positive effects. A multitude of recent studies have reported an increase in creativity since the first lockdowns in early 2020 (Du et al., 2021; Karwowski et al., 2021; Lopez-Persem, Bieth, Guiet, Ovando-Tellez, & Volle, 2021; Mercier et al., 2021; Pauly, Chu, Zambrano, Gerstorf, & Hoppmann, 2021; Wang, Zhao, Yuan, & Shi, 2021). These studies, spanning a range of countries, cultures,

and age groups, converged in their (respective) findings that participants engaged in more modes of creative expression, and did so more frequently, during the pandemic compared to their pre-pandemic baseline of creative activity. As to the mechanism responsible for this shift, there are two primary contenders. One proposed possibility is that negative affect and mixed or variable emotions—such as those experienced widely during the pandemic's protracted waves of severely limited social contact—are in fact facilitatory (if not necessary) conditions for heightened creativity (Karwowski et al., 2021; Lopez-Persem et al., 2021; Wang et al., 2021) (see also George and Zhou, 2002; Bledow, Rosing, and Frese, 2013). Notably, however, the other prominent view focuses on creativity as the fruit of isolation itself, attributing the observed change in creative activity to prolonged periods of time spent alone (Du et al., 2021; Pauly et al., 2021). Solitude (i.e., time to oneself)[2], gives rise to internally-directed thought, encompassing introspection, mind-wandering, and both reflection and rumination, all of which have been linked to increased levels of creative thought and expression. These two accounts are certainly not mutually exclusive, and both may in fact play a part in the boost to creativity recorded during this time.

The second prediction lies in direct opposition to the first: in keeping with the recent evidence pointing to a pandemic-related creativity surge, we hypothesized that the extended periods of isolation—irrespective of the exact mechanism—could have facilitated a boost to creativity, and thus we expected greater complexity of the language in the CoSoWELL texts following the onset of the pandemic. To test these predictions, eight measures of linguistic complexity were calculated for each of the texts analyzed in this study, and will be discussed in the section to follow.

[2][Note on usage] Some work makes a distinction between two related yet emotionally divergent experiences arising from isolation: (i) solitude, defined as time alone marked by introspection and reflection, and; (ii) loneliness, the subjective experience of aloneness characterized by negative affect. I will not be making this distinction, and use solitude interchangeably with isolation, i.e., time spent alone and not in the company of other people.

3 Method

3.1 Overview

This thesis uses data from the CoSoWELL (Cognitive Social Well-being) corpus. Comprised of over 1.2 million tokens, the CoSoWELL corpus consists of extensive language data whose creation and collection span before and after the onset of the COVID-19 pandemic. The corpus contains life stories written by older adults (age $\geq$ 55 years), whose themes draw on various facets of autobiographical memory[3] (Kyröläinen et al., accepted).

3.2 Participants

Participants were recruited and their data collected via web surveys on Amazon Mechanical Turk (MTurk; mturk.com) and online crowd-sourcing platform Prolific (prolific.co) at multiple stages over a two-year period beginning in March 2019 (t1, the pre-pandemic baseline); the four pandemic testing sessions, t2-t5, occurred in April, July, and October of 2020 and February of 2021. The current project uses the responses of 1,028 individuals who took part in the study. Some participants did not complete both of the writing and survey components (described below); these participants were excluded from the present analysis (i.e., only those participants who completed both the narrative writing task and the survey were included).

[3]Autobiographical memory is the memory system that integrates and maintains one's life events, memories and emotions with a persisting and cohesive sense of self. Past psycholinguistic work has identified specific topics and themes that reflect the different sectors of autobiographical memory (past, present and future self), divisions corroborated by the results of Kyröläinen et al. (accepted)'s topic model. Each CoSoWELL story type can be said to reflect a different facet of autobiographical memory via the distinctive topics that are present and predominate in the texts corresponding to each type. For a more in-depth discussion of the methodological validity of the corpus, see Kyröläinen et al. (accepted).

Participants (n = 1028; 693 female, 332 male, 3 no gender specified; mean age = 62.9; age range = 55-83 years; SD = 5.3) were 55 years of age or older, and were native English speakers born and currently residing in either Canada or the United States, as per the experiment inclusion criteria. Written informed consent was obtained prior to participation and all participants were remunerated through AmazonTurk and Prolific following the experiment. The study received approval from the McMaster Research Ethics Board (ethics protocol #0606).

All participants responded to two components: (i) a writing task, where participants were asked to produce four thematically different texts[4], and; (ii) a survey, consisting of demographic questions and cognitive-emotional self-evaluations. The four thematic conditions consist of the following:

(1) a story about an event that occurred in the writer's distant past ("past");

(2) a story about an event that occurred in the writer's recent past ("yesterday");

(3) a story about what the writer would like to do in the future ("future"); and

(4) a description of the "cookie theft" image ("cookie") from the Boston Diagnostic Aphasia Examination (BDAE).

Overall, 487 participants completed the writing task at one test session, 291 at two sessions, 248 at three sessions, and 2 at four sessions. See Table 1 for the sample size by test session and for a breakdown of the descriptive statistics of the CoSoWELL corpus across test sessions.

[4]Note that the terms *text* and *story* are used interchangeably to refer to an individual written piece (e.g., participant *n*'s "cookie" story) while *story type* and *theme* refer to the thematic condition (e.g., "past", "yesterday", "future", or "cookie").

Table 1: Descriptive statistics of the corpus by test session.

Test session	Token	Type	Lemma	Narrative	Sentence	Participant
t1	158,656	9,394	7,728	832	9,127	208
t2	326,118	13,252	10,978	1,727	18,429	317
t3	256,606	12,427	10,272	1,604	14,371	401
t4	224,696	11,407	9,483	1,480	12,274	370
t5	256,957	12,378	10,251	1,640	14,105	388
Total	1,223,033	58,858	48,712	7,283	68,306	1,684* (1,028)

The number marked by * represents the total number of participants across test sessions, counting participation in each test session separately. The number in parentheses represents the unique number of participants across all test sessions.

The design with respect to participants is mixed: the corpus consists of between-participants as well as within-participants data. Some individuals ($n = 656$) participated at multiple test sessions, and thus have contributed multiple sets of narratives to the corpus. In the context of this thesis, both are interesting and can in theory be considered together, but a concern remained about the possibility of observing a potential effect resulting not from the dependent variables but from (a difference in) practice or writing development (i.e., someone who has written two or more sets of narratives might show changes in their output as a consequence of the repetition of the task itself). Two sets of data were thus compared: the total dataset containing all texts (written by participants who met the criteria defined above) and the subset containing only the first set of texts written by participants, whether or not they contributed at more than one instance of t, in order to control for practice/repetition effects. The analysis was run with both sets and no difference was found; the number of times an individual had participated (i.e., contribution *instance*) did not affect the results, therefore the complete dataset is the one used for the present purposes.

3.3 Materials

The following prompts were presented to each participant, for each respective narrative in the writing task:

> **Story 1**: Write a story about a significant life event that occurred in your distant past.
>
> **Story 2**: Write a story about a personal life event that occurred yesterday.
>
> **Story 3**: Write a story about a personal life event that will take place in your future.
>
> **Story 4**: Write a story about the event described in the picture.

Participants typed responses into a text box beneath the given instruction. The fourth story (i.e., the "cookie" story) served as the study's control condition, being a narrative that would be shared by all participants[5]. Thus cookie stories provided a baseline for comparing texts between participants. In this condition, all participants were presented with and asked to write a story about an image depicting the *Cookie Theft* scene, taken from the Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2001). Instructions were identical for each data collection period (henceforth *test session*).

3.4 Procedure

Upon beginning the experiment, participants read the letter of information and provided consent by pressing the "Continue" button. The next step presented the writing task instructions (see section 3.3) and participants typed their responses into a text box beneath the given instruction. Responses were recorded when participants clicked

[5]The validity of cookie controls was validated by Kyröläinen et al. (accepted)'s topic model, which was able to differentiate between story types with a 96% accuracy rate.

the "Submit" button upon completion of the task. There was no limit on the length of time allowed to complete the task nor on the length of the written responses.

For the first two test sessions (t1 and t2), both the recruitment process and the experiment were run through Amazon Mechanical Turk, while all subsequent test sessions (t3-t5) used Prolific for recruitment of participants. For participants from t1 and t2, the task was thus programmed, delivered and completed via MTurk; participants in t3 onward (i.e., t3, t4, and t5) were directed from Prolific to LimeSurvey, the online platform hosting the writing task. At each test session participants were paid $7 USD as compensation for their time.

Approximately one week following the completion of the writing task, participants received an invitation to the second part of the study: a survey including demographic questions about their age (birth month, year), gender (female; male; other; prefer not to say), highest level of education completed (some high school; high school graduate; some college, no degree; associate's degree; bachelor's degree; master's degree; doctorate), and retirement status (retired: yes/no). Additional cognitive-emotional participant data was collected via questions about perceived (i.e., self-rated) loneliness, social isolation and memory functioning. The total questionnaire took, on average, between 10 and 15 minutes to complete, and respondents were compensated $2 USD for their participation. (For an in-depth description of the experimental procedures, refer to Kyröläinen et al. (accepted).)

3.5 Measuring linguistic complexity under the Dependency Grammar framework

In the present study, linguistic complexity is explored and measured through the lens of dependency relations. In linguistic analysis, there exist several competing architectures of grammar, each with different structural scaffolding to enable the parsing of natural language. One of these is dependency grammar, conceived in its modern form by linguist Lucien Tesnière (1959/2015). Dependency grammar is the framework often employed for the computational analysis of language in natural language processing (Debusmann, 2000; Marneffe and Nivre, 2018; Tesnière, 1959/2015). Dependency parsing constitutes the mapping of the linguistic units (i.e., words) in a sentence to grammatical roles, building out a model that contains both the syntactic function and lexical properties of each individual word, as well as its structural relation to the other words in the sentence. The basic linguistic unit is the *node*, analogous to the construct of a "word" (unlike, e.g., Phrase Structure Grammar (PSG), which takes phrases and phrasal nodes to be the basic units of language). Dependency parsing is based on the *dependency relation*, or the notion that all linguistic units are connected via directed links called (syntactic) dependencies. A dependency is a structurally asymmetric relationship wherein one element governs another. All nodes exist in dependency relations, as either:

(i) a dependent, a node which is governed by another sentential node corresponding to the role of the head (see (ii));

(ii) a head, the governor in a dependency relation and which may have one or more dependents; or

(iii) both.

Within a dependency framework, the predicate is the root of the structure, and it is from this root that all subsequent nodes branch. With the exception of the root—which itself is not a dependent—every node has exactly one head, but a single head may have multiple dependents (as is often the case with roots). Every structurally delineated entity (i.e., node) corresponds to a pronounceable element (i.e., a word) in a sentence[6]. We use the dependency grammar framework to define our dependent variables.

3.6 Dependent Variables

This analysis explored the degree of lexico-syntactic complexity in each of the collected texts via eight dependent variables, of which many are commonly used in both computational-linguistic and psycholinguistic analysis of texts (Baayen, 2001; Graesser, McNamara, & Kulikowich, 2011; Jagaiah, Olinghouse, & Kearns, 2020; Nippold, Cramond, & Hayward-Mayhew, 2014; Vermeer, 2000; Webb, 2020): the lexical variables included Noun-to-Verb Ratio (NVR) and Type-Token-Ratio (TTR); the syntactic variables included two additional variants of TTR, depth, embeddedness, D-ratio, and mean utterance length (MLU), as further described below.

3.6.1 Lexical Variables

Noun-to-Verb Ratio (NVR) was calculated for each narrative by dividing the total number of nouns by the combined number of nouns and verbs in the text. Nouns and verbs have differences in their distributional properties, which affect the production and comprehension of the items from each respective grammatical class (Vigliocco et al., 2011) and are linked to neurodegenerative or age-related language impairments,

[6]This stands in contrast to the approach of PSG, for example, which postulates an abstract phrase level and contains a number of covert and unpronounceable nodes at various levels of the structure.

associated with the less frequent use of verbs relative to nouns (Burke & Shafto, 2008; Le et al., 2011).

The Type-Token Ratio (TTR), originally proposed by Johnson (1944) as a metric of lexical diversity in a language, traditionally consists of the number of unique words, i.e., *types*, divided by the total number of words (whether unique or repeated), i.e., *tokens*. The second lexical variable considered, TTR-w, aligns with the standard calculation of TTR (dealing with word types and tokens; punctuation excluded). An increase in TTR-w can be interpreted as an increase in lexical diversity, indicating higher linguistic productivity of an author/participant in a given narrative.

3.6.2 Syntactic Variables

Here we considered two additional and related but distinct variants of the original TTR operationalization. When calculating the standard TTR (here, TTR-w), the tokens in question (and the types derived from them) are words. The TTR variants introduced here consider particular syntactic features associated with each word as 'tokens' (in place of the words themselves): TTR-p is based on the part-of-speech category (e.g., noun, verb, adjective, preposition, etc.) to which a word belongs, and TTR-d is based on the dependency relation assigned to a given word. The dependency relation category provides information about the functional and structural role of a word in the context of the dependency relation in which it exists. For example, the label NSUBJ indicates that the item in question is the nominal subject of a clause, while OBJ denotes a verbal object, and CCOMP indicates the item is a clausal complement of a verb or adjective. The presence of more unique dependency relations in a text signals the usage of a wider variety of grammatical constructions and functions. For both of these measures, the unit of analysis was a given written narrative. As with TTR-w, an increase in either of the syntactic TTR measures (TTR-p and TTR-d) can

be interpreted as an increase in syntactic diversity, again signaling greater linguistic productivity.

A second set of variables tapped into the syntactic complexity of a sentence, which has been shown to affect language comprehension (Gibson, 1998, 2000; Levy, 2007) and constrain language production (Ferreira, 1991; Nippold et al., 2014; Scontras et al., 2015; Szmrecsányi, 2004).

The first variable in this particular set is D-ratio, a measure of the distribution of the syntactic dependencies in a sentence. D-ratio represents the number of heads for every dependent, thus capturing the degree of elaborateness of the structures in a given sentence: it reflects the additional detail provided at an existing level of the structure; that is, it reflects the presence of adjunct structures and higher valenced verbs (i.e., taking a greater number of arguments). In a dependency parse, there will always be n-1 dependencies, where n is the number of words; we subtract one because the root is ungoverned (i.e., is never itself a dependent within any relation). Thus, the hard number of dependencies (and dependents) in a sentence will vary linearly with length since every word except the root must be a dependent. It is the presence of modifiers at the same level as complements which increases values of this measure[7]. The formula for the measure that we will refer to as d-Ratio was:

$$D = 1 - \frac{n \text{ heads}}{n \text{ nodes (total)}} \tag{1}$$

A higher D-ratio indicates that a sentence contains more modifiers, and is thus a

[7]Two dependent nodes can be said to exist at the same structural level if they share the same head.

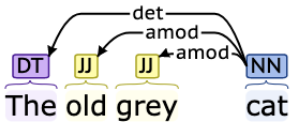

Figure 1: Visual representation of nominal modifiers (*old, grey*) at the same level in the dependency tree (both are dependents of the noun, *cat*).

measure of sentence elaborateness[8]. This measure was calculated for every sentence and then averaged for each narrative.

The second variable in this set operationalized syntactic complexity in a given sentence by calculating the longest path in a dependency tree for a given sentence, corresponding to its maximum structural depth. This measure follows the notion that longer dependency relations are more effortful to process (Gibson, 1998, 2000) and there is a general tendency to minimize dependency distances in language production (Futrell et al., 2015; Temperley, 2007). To facilitate efficient computation time, a given dependency tree was treated as a directed acyclic graph (Oya, 2011; Yadav, Husain, & Futrell, 2019) and the longest path was calculated using the diameter function in the R package igraph, version 1.2.6, i.e., the length of the longest shortest path ($\max_{u,v} d(u, v)$ between any two nodes (u, v), where $d(u, v)$ is a distance) (Csárdi & Nepusz, 2006). Similar to D-ratio, this variable was calculated for each sentence and averaged across the sentences for a given narrative. We will refer to this variable as the longest dependency path (LDP) in this study.

The third and final variable within this set, labelled embeddedness, considered the notion of syntactic complexity by focusing on the use of complex clauses, such as those containing coordination and subordination, relative to syntactically simplex

[8]The highest d-ratio values correspond to "run-on" sentences, where a greater number of dependents exist at the same level (i.e., are dependents of a single head). This is largely due to the fact that chaining (e.g.,) four or more clauses together in a run-on fashion will result in the root (the first main verb in the first clause of the utterance, typically) as the governor in at least three dependency relationships, and therefore fewer unique heads. In this way, d-ratio also captures information measured more precisely by MLU and clauses per sentence.

ones (Beaman, 1984; Givón, 1991). For the purposes of the present study, a wide range of syntactic constructions were considered to constitute degree of embeddedness, not just coordinating and subordinating clauses. The presence of one of the following nine dependency relations was used to mark a sentence as complex listed below, otherwise a sentence was considered as simplex. The definitions used below follow the UD schema used in this study.

- parataxis: parataxis
- xcomp: a clausal complement of a verb or an adjective functioning as a predicative or clausal complement without its own subject
- ccomp: a clausal complement of a verb or adjective with a dependent clause which is a core argument
- advcl: an adverbial clause modifier
- acl:relcl: a relative clause modifier
- acl: finite and non-finite clauses modifying a nominal
- conj: a coordinating conjunction
- cc: a conjunct and a preceding coordinating conjunction
- mark: a word marking a clause as subordinate to another clause

For a given narrative, the number of simplex and complex sentences were calculated and the sums were divided to compute a ratio ($1 - \frac{n_{simplex}}{n_{complex}}$) where higher values indicated that a given story had relatively more complex sentences.

The final variable considered in this study is mean length of utterance (MLU), originally proposed by Brown (1973). MLU reflects the average sentence length in

a text. It was calculated for each story by adding the length of (i.e., the number of tokens in) each sentence and dividing by the number of sentences in the story. Sentence length is an indicator of syntactic complexity, as the longer the sentence, the more syntactic content in the structure (Glasersfeld, 1971). MLU has been used extensively to study linguistic productions in children (see Rice et al., 2010, and citations therein) and adults (see Nippold et al., 2014, and citations therein).

3.7 Independent Variables

The goal of the study was to track the temporal trajectory of change across lexical and syntactic complexity. As such, the critical independent variable that this study considered was test session, with levels labelled t1-t5. Collected in March 2019, t1 serves as the pre-pandemic baseline against which to compare the data collected during the pandemic (i.e., t2-t5).

Another independent variable in the dataset was story type, with levels corresponding to a narrative's thematic condition (i.e., "past", "yesterday", "future", "cookie"). Prior work on this corpus Kyröläinen et al. (accepted) did not find any relation between this variable and the lexico-syntactic complexity of the CoSoWELL texts, and in the present analysis all story types are considered jointly.

Additional independent variables included demographic characteristics, such as age, gender, educational level, and retirement status. This study also considered one psychological independent variable: perceived loneliness. This variable is calculated based on the three-item loneliness scale (Hughes, Waite, Hawkley, & Cacioppo, 2004), with a range from 3 to 9 points, where a higher score on the scale reflects a higher subjective level of perceived loneliness. None of these characteristics were found to affect lexico-syntactic complexity in a systematic way, and they are not reported in

the analysis below.

All texts were labeled by instance, an ordinal number representing the test session in which a given respondent completed the writing task, and this variable accounted for repeated measures collected from some participants. Since practice and repeated exposure to tasks have been shown to increase creativity (Beaty & Silvia, 2012), it was important to control for this possibility in the context of the current work. However, the instance variable did not have any effect in the regression models, and considering only participants' first submission of written narratives did not change any critical findings of this study. All narratives were thus considered jointly, regardless of the order of submission indicated by instance.

A total of eight stories were removed from the data due to undefined values in calculating the eight lexico-syntactic variables. Thus, the data used in this section consisted of 7,275 life stories written by 1,028 participants. The summary information of the lexico-syntactic variables across test sessions is given in Table 4 in Appendix A.

3.8 Statistical Considerations

Analyses below were carried out in the statistical platform R, version 4.1.0 (R Core Team, 2020). Generalized linear mixed-effects regression models with the Gaussian family were fitted to each of the 8 dependent variables described above. All models included test session as a predictor and by-participant random intercepts. The resulting models are reported in Appendix A. Models were fitted using lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017). Visualization of the estimated effects was done using the package effects (Fox & Weisberg, 2018) and ggplot2 (Wickham, 2011).

4 Results

A total of 1028 unique participants produced a total of 7283 narratives over 5 test sessions (t1: 832 narratives, t2: 1727 narratives, t3: 1604 narratives, t4: 1480 narratives, and t5: 1640 narratives) and submitted demographic and psychological surveys during one of the test sessions. Figure 2 visualizes the temporal trajectory of change in each dependent variable, by plotting partial effects of test session. Respective regression models are reported in Appendix A, and the inferential statistic for each critical effect is reported above panels of Figure 2.

The general pattern of change was clear-cut, consistent and statistically significant (all ps < 0.01, except depth, $p = 0.04$) across all measures of lexical and syntactic complexity. Narratives produced during the pandemic (test sessions t2–t5) were lexically and structurally more diverse and richer than those recorded one year before the global lockdown (t1). Moreover, all measures showed a further increase in linguistic complexity during the pandemic, compared to t2, the test session initiated in the first month of the lockdown in North America (i.e., in April 2020). Of the syntactic measures, D-ratio, longest dependency path (LDP), and mean length of utterance (MLU) demonstrated a monotonic increase across all test sessions. We also observed a steep increase in lexical (type-token-ratio based on words TTR-w, and Noun-to-Verb ratio) or syntactic (TTR-p, TTR-d) complexity between test sessions t2 and t3, roughly 3 months after the global lockdown, followed by stable high levels of complexity from June 2020 to February 2021 (t3–t5). This distinctive temporal signature aligns with the trajectories observed by Kyröläinen and Kuperman (n.d.) in their affective and sensorimotor analyses of the CoSoWELL texts: narratives had higher valence and concreteness before and at the beginning of the pandemic, t1–t2, followed by a plateau of relative pessimism and abstractness from t3 to t5. The one

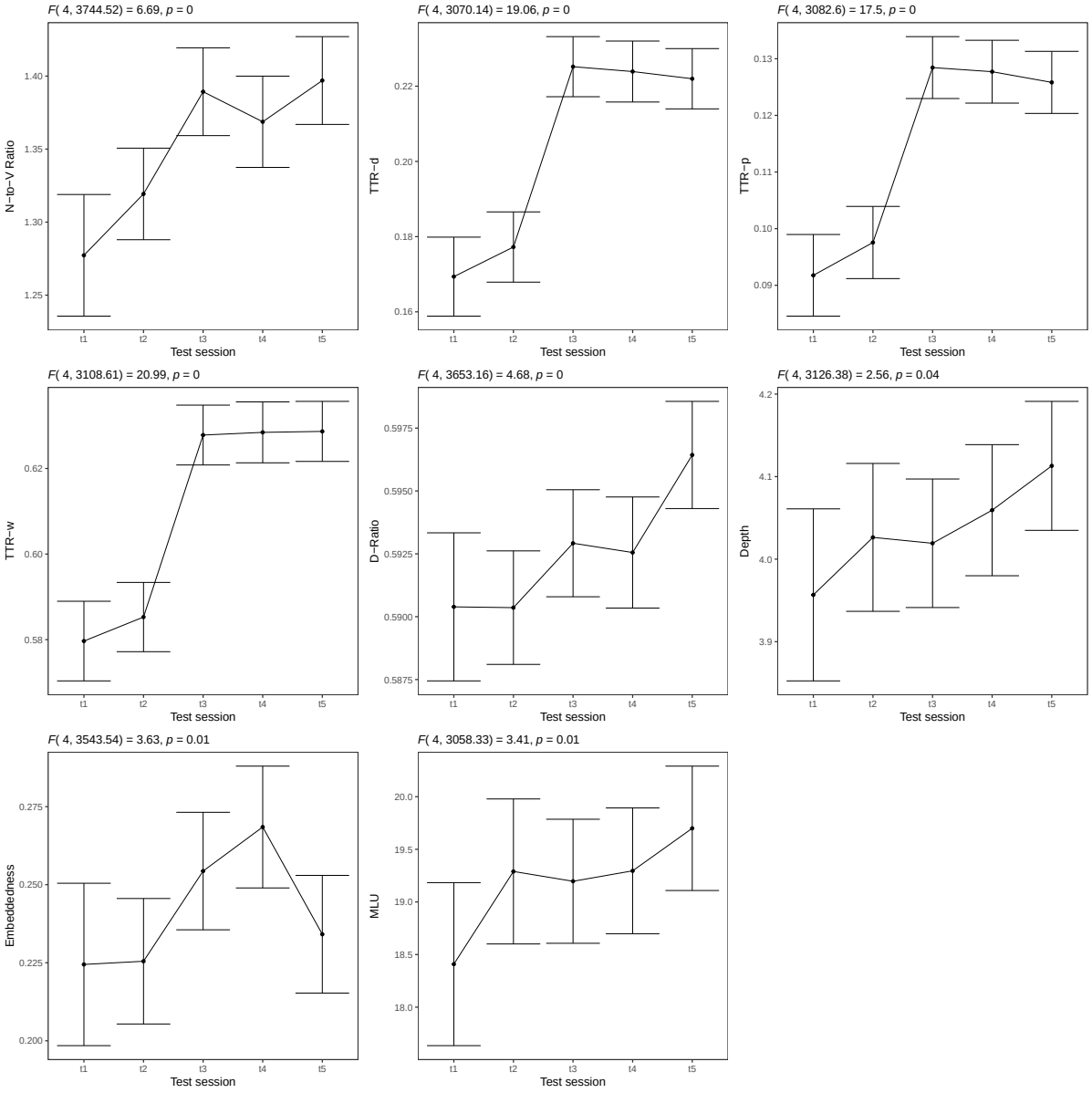

Figure 2: Effect of test session on measures of lexical and syntactic complexity. Error bars stand for ±1 SE. Outcomes of the F-test are reported on top of each panel.

minor deviation from the two major patterns—a monotonic increase or an increase followed by a plateau—is on the metric of syntactic embeddedness, where increasing levels of complexity in t1–t4 came with a further decrease in t5.

To estimate effect sizes, we compared distributions of values of lexical and syntactic complexity between the initial and the final available test sessions, t1 and t5. Specifically, we calculated the difference between the percentile in a t1 distribution of a given variable that corresponds to the median of that variable at t5. The increase in linguistic complexity over time was the largest in the type-token ratio variables (TTR-w 16, TTR-d and TTR-p 18 percentile points), somewhat smaller in MLU, syntactic depth (both 10 percentile points) and Noun-to-Verb ratio (9 percentile points) and small in D-ratio and embeddedness (around 5 percentile points).

We did not observe any main effects of loneliness, age or other demographic variables on levels of lexical and syntactic complexity, nor did these variables interact with test session. Thus, the data do not point to substantial variability between participants either at the individual level (e.g., driven by loneliness) or group level (e.g., driven by age, gender, education, or retirement status). Across the entire sample of participants, the data provide a strong indication that linguistic productivity, diversity and richness strengthen throughout the pandemic period.

5 Discussion

5.1 Overview

This study sought to advance psychological research into the effects of the COVID-19 pandemic on the language behaviour and mental states of older adults. To achieve this, we focused on patterns of language use in the Cognitive and Social WELL-being (CoSoWELL) corpus, a collection of written texts produced (in response to the prompts outlined in Section 3.3) by mature adults (age 55+) at one or more data collection periods, or *test sessions*. Five test sessions were included in this analysis: t1, in March 2019, corresponding to the pre-pandemic baseline; and t2-t5, in April, July, and October of 2020 and February of 2021, respectively. The time-series nature of the data allowed for the observation and analysis of changes in the linguistic properties of the narratives over time: we modeled the relationship between changes in language behaviour and both the temporal progression of the pandemic as well as the self-reported demographic and psychological data on the writers.

In earlier studies, CoSoWELL data proved both reliable and insightful for the investigation of changes to emotional well-being and topical content of concern for older adults (Kyröläinen et al., accepted; see Kyröläinen and Kuperman, n.d., for a general discussion about the role of affect in production and comprehension in adulthood across languages). The study that is the topic of this thesis targeted yet another facet of the CoSoWELL stories: linguistic complexity, a measure of morphological and syntactic richness that is related to both cognitive functioning and creativity, two major domains of human behaviour. The goal of the study was to track changes in lexico-syntactic complexity across the pandemic as an index of potential changes in cognitive functioning and creativity.

Here, a number of different variables were examined across both structural and

lexical linguistic features for a total of eight measures of linguistic complexity. Two metrics of lexical complexity were used to quantify the richness, diversity and productivity of the utterances produced by CoSoWELL authors in their written narratives; six metrics of syntactic complexity tapped into structural variation and elaborateness within the texts. The proposed links between linguistic complexity, cognitive function, and creativity—in particular how each of these areas was affected during the pandemic—bring forth two counter-directed predictions, which are briefly reiterated below.

The existing body of literature views both dimensions of linguistic complexity as reliable markers of cognitive functioning (Burke & Shafto, 2008; Eyigoz et al., 2020; Le et al., 2011; Pakhomov et al., 2011; Roark et al., 2011). Lower cognitive ability is typically signalled by lower complexity scores, indicating impoverished vocabulary and a relative dearth of grammatical knowledge and ability. The first prediction stemmed from the initial, oft-reported suggestion—and later evidence—of the threat posed by the COVID-19 pandemic to cognitive functioning in older adults: given this possible cognitive blow, the linguistic complexity of the CoSoWELL narratives will be lower during (corresponding to test sessions t2-t5) relative to before (corresponding to t1) the pandemic, and complexity may continue to decrease throughout the first year of the pandemic.

The second prediction comes from the association of linguistic complexity with creativity—looking to theories of creativity (e.g., creative cognition), as well as ideas from generative linguistics, and reports of creativity during COVID-19—to understand how linguistic complexity may have been affected across the pandemic. Creativity is defined in the literature as involving novelty and meaningfulness; one dimension outlined by the Four-C model of creativity (Beghetto & Kaufman, 2007; Helfand et al., 2016; Kaufman & Beghetto, 2009), mini-c creativity, encompasses both creative products

and processes. The membership criteria for a creative process or output as mini-c creativity consists of two things: (1) that it be novel, and (2) that it be personally meaningful. In this study, both the narratives from which the data are drawn and the degree of creativity in the language comprising them—assessed by measures of linguistic complexity—fall under the umbrella of mini-c creativity. As reviewed in the Introduction, creative activities have seen a somewhat counter-intuitive boost during the pandemic, both in their frequency and scope. This reported increase concerns the intrapersonal domain of creativity (Beghetto & Kaufman, 2007), which describes creative processes and interpretations that are meaningful for the individual's construction of personal knowledge and understanding of the world (i.e., mini-c; see the Introduction for more discussion). As earlier stated, we link linguistic complexity in CoSoWELL narratives to this domain of creativity, labeled mini-c (Kaufman & Beghetto, 2009). In addition, the prompts we provided for participants were generic and did not place a special emphasis on creativity; participants were aware that their identities are anonymized and that researchers were the only projected readers of these texts. These experimental conditions would be expected to only support the facet of creativity that is individually meaningful for the writer (i.e., mini-c) and not driven by external (e.g., professional, artistic or reputational) goals or subjective judgments. Finally, the prediction stemming from the reported boost to creativity was that linguistic complexity during the pandemic will be more developed than prior to the pandemic, and it may increase further as the pandemic progresses.

Analyses of both lexical and syntactic measures of linguistic complexity, summarized in Figure 2, unequivocally supported the second prediction. All these measures showed a higher level of richness and diversity during the pandemic (test sessions t2–t5) as compared to the pre-pandemic level (t1). Furthermore, all the measures saw an increase across the pandemic, either in a monotonous fashion (throughout

t1–t5) or in a step-wise fashion (a steep increase between t2–t3, i.e., April and July 2020). The step-wise increase is in line with previous analyses of CoSoWELL data, where a similar increase between test session t2 and t3 was observed in levels of pessimism, abstract ideation and loneliness (Kyröläinen & Kuperman, n.d.), as well as a shift in topics of relevance for older adults (Kyröläinen et al., accepted). While demographic variables, including age and gender, as well as perceived loneliness were considered as covariates in regression models, none of them had a significant independent effect on any metric of linguistic complexity. Interactions between these variables and test session did not influence linguistic complexity either. These findings suggest that the increase in lexical and syntactic complexity was general and did not vary substantially across demographic subgroups or levels of perceived loneliness.

Written productions during the pandemic reveal clear evidence in favor of increased creativity and sophistication of writing. If the progress of the pandemic has led to partial loss in cognitive functioning among older adults, as one of the possible predictions suggest, this negative effect on linguistic complexity was not strong enough or perhaps not prevalent enough in the population of older adults to reverse the positive effect of creativity. In the remainder of this section, we elaborate on possible counterarguments to this conclusion and implications of our findings.

Our finding of a reliable increase in creativity during the pandemic converges with several prior reports (Du et al., 2021; Karwowski et al., 2021; Lopez-Persem et al., 2021; Mercier et al., 2021; Pauly et al., 2021). Yet we argue that it offers novelty and methodological advantages that some of those reports do not provide. First, unlike one-time cross-sectional measurements, CoSoWELL is a time-series that affords a detailed insight into the temporal dynamics of psychology and behavior during the first year of the pandemic, as well as at the pre-pandemic control. Second, most prior research on the topic so far has administered scales of self-reported creativity, or

questionnaires and diaries about the frequency and nature of creative behavior. This direct and explicit interrogation of how the pandemic affected their creativity may have led to a response bias in participants, perhaps to demonstrate greater resilience to the psychological fallout of the lockdown, or perhaps because creativity is widely viewed as a positive and desirable characteristic. One could argue that a similar response bias may underlie our findings as well. Even though an individual writer is partly able to consciously control the richness and diversity of their prose, the next paragraph outlines why this response bias is unlikely to have occurred in the present study.

As previously noted, our study does not mention nor does it require a specific focus on creativity or creative activities. Roughly one half of our participants contributed narratives only in one of the five test sessions, and these participants would have no frame of reference as to what level of linguistic complexity is expected or how their productions compare to those submitted by other authors in earlier test sessions. Given that the prompts and instructions (see the Methods section) were identical throughout the study, there is also no a priori reason to expect that participants showed a consistently stronger response bias towards demonstrating greater linguistic complexity in later sessions compared to earlier ones. Moreover, the creative cognition approach outlines both control (executive) and spontaneous (associative) processes as necessary for creativity (Marron & Faust, 2018; Marron et al., 2018; Mason et al., 2021). Through this lens, conscious direction alone (i.e., trying to be more creative) could not wholly account for the rise in creativity, since unconscious and thus inaccessible mechanisms remain central to creative processes. Another possible reason for the increased creativity that we observed over time would be a well-established serial order effect (i.e., "practice effect") in creative tasks: once the technical requirements

of the task have been learned, further attempts at the task provide more creative outcomes (Beaty & Silvia, 2012). Since we observe all critical patterns even when only considering the first contribution by each participant, the serial order effect cannot explain these patterns away.

5.2 Theoretical Interpretations

A question we have not yet addressed is *why* our participants show increasingly more sophisticated and variegated writing throughout the pandemic. What drives them to tap into more remote corners of their mental lexicon and grammatical knowledge? As earlier suggested, part of the reason is a greater need for a personally meaningful and novel interpretation of drastically changing and challenging experiences that the COVID-19 pandemic and the global lockdowns engender (Mercier et al., 2021). Recall that linguistic complexity can be understood as a manifestation of creativity: it reflects the activation of (and access to) a wider range of associations. This is analogous to the concept of divergent thinking in theories of creative cognition, wherein divergent thinking involves the generation of many unique ideas from different domains. It is possible that a major critical event such as a pandemic could trigger the casting of a wider linguistic net, as well as engender a cross-pollination of concepts and ideas, especially when significant paradigm and behavioural shifts are involved. It should be noted that it is likely individual writers are not aware of their expanding palette of linguistic expression, nor do they consciously mobilize ever greater creative resources as the pandemic progresses. Either way, the written narrative data enable this cognitive change to be charted objectively, regardless of the writers' awareness.

Another possibility in the literature is that heightened creativity is fueled by negative emotions, which have become increasingly prevalent during the pandemic and

lockdowns (Du et al., 2021; Wang et al., 2021). Indeed, this could explain creativity prevailing (i.e., our finding of increased linguistic complexity) rather than diminishing in the face of stressful pandemic-related conditions (as described in the Introduction section). Previous research has already explored the link between creativity and negative affect or mental illness (i.e., chronic negative affect), as discussed below.

One study by Bledow et al. (2013) found that employee creativity increased as a function of dynamic affective experiences, wherein higher creativity was reported after a period of low affect that was followed by a subsequent rise in affect. This bears a keen resemblance to the emotional yo-yo effect of the alternating imposing and lifting of pandemic restrictions experienced across our data collection periods. In another study looking at high school students during the pandemic, higher creative performance was predictive of intrusive rumination (Wang et al., 2021). Interestingly, this relationship was modulated by emotional resilience, whereby creativity was lower when emotional resilience was higher, and vice versa—supporting an account of creativity as influenced, even enhanced, by negative affect. In light of these findings, perhaps the observed creativity boost in the present analysis actually reflects depleted emotional stores. Indeed, this aligns with Kyröläinen and Kuperman (n.d.)'s findings of increasingly negative affect in the CoSoWELL texts throughout the pandemic. For the current study, we had initially predicted that weakened emotional resilience would lead to lower linguistic complexity, but it is possible that the anticipated cognitive blow resulting from stress and negative emotional experiences was buffered by alternate, creativity-related effects of negative emotionality. Even though worsened emotional well-being can predict impaired cognition (Pue et al., 2021; Zhong et al., 2016) and lower complexity in language (Esmaeelpour & Sasani, 2018; Wei et al., 2021), under certain circumstances, this might be mitigated—or even reversed—in situations where creativity (and in particular the cognitive mechanisms facilitating

creativity) is bolstered.

A final proposed reason for increased creativity is a greater availability of relevant neurocognitive and attentional resources. The widely reported experience of physical and social isolation afforded individuals greater stretches of time alone, leading both to increasing feelings of loneliness (Kyröläinen & Kuperman, n.d.) and to more frequent and deeper introspection, reflection and rumination (Wang et al., 2021). Storr (1989) argues that solitude sets the stage for new ways of thinking by putting one in contact with one's inner, mental world. In the absence of the typical abundance of external stimuli to redirect attention outwards, a person is able to become more keenly attuned to inner mental activity of this kind. Thus, various researchers (Long & Averill, 2003; Storr, 1989) contend, separating a person from their typical external (e.g. social and physical) environments enables the relation and combination of previously discrete or unrelated thoughts and feelings—in other words, such a separation promotes mini-c creativity and creative processes such as divergent thinking. Long and Averill (2003) outline two primary ways in which solitude effects creativity: (1) by stimulating "imaginative involvement in multiple realities"; and (2) by adopting alternate identities via projection of the self (e.g., theory of mind perspective-taking). Importantly, it is these alternate modes of reality via self-projection which our experiment (via the writing task) probes. It is possible that the pandemic-related isolation yielded just the conditions of solitude described by Storr (1989) and Long and Averill (2003), and that more time alone, more often, has resulted in the advantageous engagement of the cognitive processes involved in creative thought. This, in turn, is responsible for the greater linguistic complexity of the CoSoWELL texts, i.e., the creative products analyzed in this study.

5.2.1 Exploring a neural basis for creativity: the default mode network

There is a possible neural mechanism for this last possibility—a direction which may prove fruitful in further investigation in future work on this topic: default mode network activation. While not engaged in tasks of focused attention, the brain exhibits a characteristic pattern of activation within the default mode network (DMN), a neural network comprised of the posterior cingulate cortex (PCC), the medial prefrontal cortex (mPFC), the hippocampal formation, and the precuneus (Baror, Aminoff, & Bar, 2021). The default mode network mediates, among other functions, autobiographical and episodic memory, projection, mind wandering and imagination (Baror et al., 2021; Buckner & Carroll, 2007; Spreng, Mar, & Kim, 2009; Wise & Braga, 2014). Default network activity is anticorrelated with activity in the cognitive control network, a task-related network active during focused, task-oriented behaviours (Kühn et al., 2014; Raichle et al., 2001). However, it is not the case that the default network, or its associated subregions, are active exclusively during rest[9] (i.e., while not engaged in a task). Baror et al. (2021) found that tasks of contextual association elicit activity in the same regions that are active in resting states, and conclude that default activation can therefore be characterized as context-based associative processing. Associative processing constitutes the foundation for each of the core functions of the DMN (e.g., mentalizing, projecting the self, memory retrieval); each function requires the activation and retrieval of information stored across networks in the brain. If this sounds similar to the components of creativity and divergent thinking described thus far, there is good reason: the DMN is shown to be centrally involved in creative ideation and activity.

[9] "Rest" refers to a state characterized by non-engagement in any directed task requiring sustained and focused attention, though this term is rather a misnomer, since the brain continues to be nearly equally as active during such states (see, e.g., Raichle et al., 2001).

Creativity is both functionally and structurally linked to the default network. Both Kühn et al. (2014) and Huo et al. (2020) found a positive association between performance on creativity tasks and functional connectivity between core DMN hubs. Kühn et al. (2014)'s study additionally found grey matter volume in DMN subregions to be correlated with creativity scores: the more grey matter, the better the scores. Tasks of association are also effective predictors of creativity: (free) chain association predicts cognitive flexibility and originality, and continuous association predicts originality along with ideational fluency (Marron et al., 2018). Unsurprisingly, conditions which facilitate associative thinking enhance performance on creativity tests (Marron & Faust, 2018). As discussed in the Introduction, associative thinking can lead to unusual combinations between ideas, which can generate creative ideas or a creative solution to a particular problem (for an in-depth discussion of this see Marron and Faust, 2018). Moreover, divergent thinking training has been found to produce functional and structural changes in the brain, in addition to improving both the fluency and the originality of divergent thinking (J. Sun et al., 2016). Thus consistently engaging particular networks over an extended period of time as a result of behavioural changes can in fact lead to both neural adaptation and changes in performance. Given this, increased DMN activation remains an open possibility as to the mechanism for the rise in linguistic complexity observed across test sessions. Though occurring in the absence of formal training or direction, with more time alone and fewer directed tasks (in general, far fewer things to do, places to go and people to see) for a prolonged duration, people may have been inadvertently "training" their brains to engage self-referential and associative thought more readily—thus strengthening default network activation by consistently reinforcing it. Spending more time mentally projecting oneself and imagining alternate realities—including ruminating or reflecting on memories—means more time spent inhabiting a cognitive state characterized

by rich mental representations of the imagined or projected objects. Our study asked for stories relating to various modes of self-projection (*past*, *yesterday*, *future*, and *cookie*, each corresponding respectively to different facets of autobiographical memory, see Kyröläinen et al., accepted, but also to episodic memory, prospection, and theory of mind/imagination; see Buckner and Carroll, 2007). It is possible that people are more linguistically creative at each subsequent session because their internal self-referential modes of thinking are further primed after increasingly long periods of time spent alone, with daily social and physical isolation becoming the norm. (This is, of course, the deep-dive neurocognitive counterpart to the general effects of solitude on creativity, as discussed above.)

One clear caveat: the data set used in this study enables linguistic analysis, from which we can make inferences about cognitive states and processes, but to answer this question—and establish whether default network activity plays a central role—more data will be necessary. Such data is not available at this point, and thus ascertaining the involvement of particular brain networks in linguistic creativity lies outside the scope of what can be definitively answered by this work. That said, there is a fascinating story here which is well worth illustrating, and can serve as a starting point for future ventures deeper into this topic.

This thesis is predicated on linguistic complexity as a facet of creativity (mini-c creativity, on the Four-C model scale), based on theoretical and empirical work linking these constructs (see the Introduction, at Section 2.1.2, for a discussion of these links). Future work may yet probe the relationship between creativity and linguistic complexity more directly by using neuroimaging to capture and monitor DMN activation and connectivity while engaging in a task similar to the one employed in the present study (involving e.g., the production of a writing sample whose topical content requires the engagement of autobiographical memory and self-projection systems). Such

an investigation could provide more conclusive answers as to the neurocognitive mechanism responsible for the pandemic-driven creativity upsurge observed in the current analysis, and help to confirm or refute the explanations tentatively proposed in this discussion.

In conclusion, the CoSoWELL data make it possible to detect a trend in the data but not to link the observed increase in linguistic complexity and mini-c creativity with any specific configuration of underlying mechanisms. Targeted studies, possibly using mixed methods like questionnaires, creative tasks, and neuroimaging, will be required to obtain more definitive answers as to the origin of the creativity boost. There is no doubt that while linguistic creativity during the COVID-19 pandemic is a complex and dynamic issue with many layers to unpack, it is a rich and worthwhile avenue for further exploration.

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A Supplementary Materials

This appendix contains linear mixed-effects multiple regression models fitted to the eight metrics of lexical and syntactic complexity discussed in this thesis. In all models, the sole predictor was testing session (t1–t5). Random intercepts were used by participant. Model outcomes are presented in two formats. Table 2 lists coefficients for the categorical variable testing session as well as measures of goodness-of-fit and variance of random effects. The variable is treatment contrast-coded with the pre-pandemic test session t1 as a reference level. Table 3 additionally reports results of the Type III Analysis of Variance Table with Satterthwaite's method, with test session effect as a multilevel categorical variable. These inferential estimates are also reflected in Figure 2 in the main paper. Table 4 contains the (raw) descriptive statistics for each measure of linguistic complexity calculated.

	N-to$_V$ *Ratio*	TTR-d	TTR-p	TTR-w	D-ratio	Depth	Embed	MLU
(Intercept)	1.28***	0.17***	0.09***	0.58***	0.59***	3.96***	0.22***	18.41***
	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)	(0.05)	(0.01)	(0.40)
phaset2	0.04	0.01	0.01	0.01	−0.00	0.07	0.00	0.88**
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.01)	(0.33)
phaset3	0.11***	0.06***	0.04***	0.05***	0.00	0.06	0.03	0.79
	(0.03)	(0.01)	(0.00)	(0.01)	(0.00)	(0.07)	(0.02)	(0.50)
phaset4	0.09***	0.05***	0.04***	0.05***	0.00	0.10	0.04**	0.89
	(0.03)	(0.01)	(0.00)	(0.01)	(0.00)	(0.07)	(0.02)	(0.50)
phaset5	0.12***	0.05***	0.03***	0.05***	0.01**	0.16*	0.01	1.29**
	(0.03)	(0.01)	(0.00)	(0.01)	(0.00)	(0.07)	(0.02)	(0.50)
AIC	11737.42	−14533.38	−19693.18	−15163.49	−27282.30	20477.72	4152.69	47935.63
BIC	11785.66	−14485.14	−19644.94	−15115.25	−27234.05	20525.97	4200.93	47983.87
Log Likelihood	−5861.71	7273.69	9853.59	7588.75	13648.15	−10231.86	−2069.34	−23960.81
Num. obs.	7272	7272	7272	7272	7272	7272	7272	7272
Num. groups: id	1028	1028	1028	1028	1028	1028	1028	1028
Var: id (Intercept)	0.03	0.01	0.00	0.01	0.00	0.61	0.02	40.34
Var: Residual	0.27	0.01	0.00	0.01	0.00	0.75	0.09	31.07

*]5

[

Table 2: Mixed-effects regression models fitted to metrics of linguistic complexity with participant id as a random effect. Pre-pandemic t1 is the reference level.

	Dependent variable	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
1	N-to-V Ratio	7.23	1.81	4.00	3744.52	6.69	<0.001
2	TTR-d	0.44	0.11	4.00	3070.14	19.06	<0.001
3	TTR-p	0.20	0.05	4.00	3082.60	17.50	<0.001
4	TTR-w	0.46	0.11	4.00	3108.61	20.99	<0.001
5	D-Ratio	0.02	0.01	4.00	3653.16	4.68	0.0009
6	Depth	7.70	1.92	4.00	3126.38	2.56	0.0368
7	Embeddedness	1.34	0.33	4.00	3543.54	3.63	0.0059
8	MLU	423.45	105.86	4.00	3058.33	3.41	0.0087

*]5

Table 3: Type III Analysis of Variance Table with Satterthwaite's method for regression models fitted to metrics of lexical and syntactic complexity.

session	n_to_v_ratio	ttr_d	ttr_p	ttr	d_ratio	depth	embeddedness	mlu
t1	1.28 (0.42)	0.17 (0.08)	0.09 (0.05)	0.58 (0.09)	0.59 (0.03)	3.94 (0.81)	0.22 (0.27)	18.43 (6.55)
t2	1.32 (0.48)	0.18 (0.1)	0.1 (0.06)	0.59 (0.1)	0.59 (0.03)	4 (1.14)	0.23 (0.32)	19.03 (8.8)
t3	1.39 (0.57)	0.22 (0.12)	0.13 (0.09)	0.63 (0.11)	0.59 (0.04)	3.98 (1.06)	0.26 (0.35)	18.84 (7.37)
t4	1.37 (0.6)	0.23 (0.13)	0.13 (0.09)	0.63 (0.11)	0.59 (0.04)	4.1 (1.24)	0.27 (0.36)	19.54 (8.3)
t5	1.4 (0.6)	0.22 (0.12)	0.12 (0.08)	0.63 (0.11)	0.6 (0.04)	4.12 (1.32)	0.23 (0.32)	19.8 (9.47)

Table 4: Descriptive statistics of lexical and syntactic complexity measures by test session: Mean (SD)