Propositional density in spoken and written language of Czech-speaking patients with mild cognitive impairment

Filip Smolík

Institute of Psychology of the Academy of Science of the Czech Republic

Hana Stepankova

National Institute of Mental Health, Klecany, and Faculty of Arts, Charles University, Prague, Czech Republic

Martin Vyhnálek

Memory Clinic, Department of Neurology, Charles University in Prague, 2nd Faculty of Medicine and University Hospital Motol, Prague, Czech Republic and International Clinical Research Center, St. Anne's University Hospital Brno, Brno, Czech Republic

Tomáš Nikolai

Memory Clinic, Department of Neurology, Charles University in Prague, 2nd Faculty of Medicine and University Hospital Motol, Prague, Czech Republic

Karolína Horáková

National Institute of Mental Health, Klecany, and Faculty of Arts, Charles University in Prague, Czech Republic

Štěpán Matějka

Faculty of Arts, Charles University in Prague, Czech Republic

Author note

Correspondence concerning this article should be addressed to Filip Smolík, Institute of Psychology AS CR, Hybernská 8, 110 00 Praha 1, Czech Republic.

++420 221 403 907 (phone)

++420 222 221 652 (fax)

smolik@praha.psu.cas.cz (e-mail)

Funding

This work was supported by the Grant Agency of Charles University in Prague under Grants GAUK 1332214 and 562412; by Ministry of Health, Czech Republic under Conceptual development of research organization (NUDZ, 00023752); and by the project „National Institute of Mental Health (NIMH-CZ)“, grant number ED2.1.00/03.0078 and the European Regional Development Fund and by MH CZ – DRO, University Hospital Motol, Prague, Czech Republic 00064203 and by by the project FNUSA-ICRC (no. CZ.1.05/1.1.00/02.0123) from the European Regional Development Fund. The first author was supported by the Research organization development scheme RVO 68081740 and CSF grant GA16-15123S.

Date: Prague, August 28, 2015.

ABSTRACT

Purpose: Propositional density (PD) is a measure of content richness in language production that declines in normal aging and more profoundly in dementia. The present study aimed to develop a propositional density scoring system for Czech and use it to compare propositional density in language productions of older people with amnestic mild cognitive impairment (aMCI) and control participants matched on age, gender, and education.

Method: Groups of aMCI patients and cognitively healthy controls (N=20 each) provided short spoken and written language samples. Two samples were elicited for each modality, one describing recent events and one childhood memories. A series of neuropsychological tests were administered. The groups were compared using t-tests, the relations between measures using correlation coefficients.

Results: PD was lower in spoken productions of patients with aMCI, compared to controls, but only in language samples based on remote memories. PD in these samples was related to verbal fluency and education, but not working memory. PD in written samples did not differ in participants with aMCI and controls.

Conclusions: PD in spoken language reflects the cognitive decline in aMCI, but the effect is relatively mild. The results support the existing findings that PD is related to verbal fluency.

Key words: idea density, aging, language, propositional density, language samples

Human aging is accompanied by observable decline in many aspects of cognitive abilities. The decline also affects language abilities, even though some areas of language, such as vocabulary knowledge, remain well-preserved until advanced age (Laumann Long & Shaw, 2000; Lindenberger & Baltes, 1997). Word-finding, naming, and verbal memory difficulties are among the most common problems experienced by older people (Burke & Shafto, 2004; MacKay & James, 2004). The decline of verbal skills may be demonstrated using various psychometric measures, such as tests of vocabulary (Fox, Berry, & Freeman, 2014) , verbal fluency (McDowd et al., 2011), or verbal memory (Lamar, Resnick, & Zonderman, 2003). Alternatively, it is possible to analyze elicited or spontaneous language productions (Kemper, Thompson, & Marquis, 2001; Lyons et al., 1994; Vousden & Maylor, 2006). The analyses of spoken or written language samples demonstrated that linguistic productions of older people changed both in their grammatical form and their semantic content (e. g. Kemper, Greiner, Marquis, Prenovost & Mitzner, 2001), even though these changes may not always result from cognitive limitations. So, Kemper, Kynette, Rash, O'Brien, and Sprott (1989) demonstrated an effect of discourse genre on language production and concluded that older persons, compared to young adults, are more concerned with conveying clear, easily understood, yet interesting statements.

One possible measure of semantic changes in the language of elderly people is the index known as propositional density, or idea density. This can be roughly described as the amount of ideas expressed in a given number of words. It reflects richness of language content, i. e. the amount of information that is communicated. Propositional density (PD) decreases in elderly people, and the scores are related to various psychometric measures of language (Farias et al., 2012; Kemper et al., 2001; Kemper, Hoffman, Schmalzried, Herman, Kieweg, 2011). Moreover, PD is not only a measure of current language skills; Kemper et al. (2001) found that PD in early adulthood predicted cognitive decline in the old age. People whose language in early adulthood showed higher PD were less likely to develop dementia when they got older (Engelman, Agree, Meoni, & Klag, 2010; Kemper et al. 2001; Snowdon et al., 1996). This was so even if their brains contained the neuropathological changes typical for patients with dementia (Iacono et al., 2009). It was also found that PD correlates with a genotype related to the risk of developing familial form of Alzheimer's dementia (Medina et al., 2011). The predictive relation of propositional density to later neuropsychological functioning indicates that the measure taps in important aspects of human cognition, and that it reflects cognitive reserve upon which people draw in advanced age – the brain's mechanism for coping with damage, (Stern, 2002).

Mild cognitive impairment and propositional density

Previous research provided solid evidence that decreased propositional density in early adulthood is related to cognitive decline in aging, especially in dementia. Concurrent relations between propositional density and cognitive status in the old age have also been shown (e. g. Mitzner & Kemper, 2003). However, it is not clear whether PD is also affected in mild cognitive impairment (MCI), which often represents a prodromal stage of Alzheimer's disease. MCI is characterized by decline in cognitive performance that is more pronounced than expected for one's age. MCI symptoms do not fulfill the criteria for dementia and patients are independent in daily life (Petersen et al., 1999). MCI is a heterogenic diagnostic unit encompassing several subtypes with different cognitive profiles: amnestic - with a memory impairment (aMCI), and non-amnestic (naMCI) with impairment limited to other domains than memory (Petersen & Morris, 2005). Libon et al. (2010) identified three subgroups among MCI patients, dysexecutive, amnesic and mixed,. The dysexecutive patients have weakest performance on executive control and verbal fluency tasks, while the memory type is characterized by poor performance in declarative memory tests, particularly on delayed recall and recognition. The mixed type includes some level of impairment in both domains.

Examining free language production and propositional density in people with MCI may clarify the level to which MCI affects spontaneous behavior such as language. One existing study found no differences in PD between people with MCI and cognitively healthy controls (Farias et al., 2012). The oral language samples used in this study were elicited by asking participants for childhood memories. Other evidence suggests that such memories for old, remote events are affected to a lesser extent than memories for recent events in patients with MCI (Leyhe, Müller, Milian, Eschweiler, & Saur, 2009). The good results in PD measures might thus be due to relatively good preservation of remote memories. In contrast, Iacono et al. (2009) showed differences in propositional density of early-life writing samples between the participants of the Nun Study without symptoms of cognitive impairment and those with MCI (as well as with the dementia due to Alzheimer's disease). If the relative score of propositional density in comparison with peers is stable throughout life (Fergusson, Spencer, Craig, & Colyvas, 2014; Spencer, Craig, Ferguson, & Colyvas, 2012), one should expect decreased scores in people with MCI. Examining propositional density in MCI using language sample with different topics could clarify these somewhat conflicting findings. There are additional reasons to expect decreased propositional density in people with MCI. Decreases in PD are related to general cognitive decline in various neuropsychological measures (Mitzner & Sumner, 2001). MCI may be viewed as an early stage of such cognitive decline, and it is thus possible that it will also affect PD. The question is whether the effect is sufficiently strong to be detected. If this is the case, it would validate the concept of MCI as a disorder that affects common daily mental activities such as language communication.

Much research on propositional density focused on its use as a marker of cognitive reserve, following the findings of its predictive value. Not many studies examined concurrent relations between propositional density and other cognitive measures. One such analysis used structural equation modeling to examine the structure of verbal abilities as reflected by a range of tests and spontaneous language measures (Kemper & Sumner, 2001). This analysis revealed three interrelated factors, vocabulary, working memory and processing. Propositional density was a part of the processing factor, along with measures of verbal fluency (both initial letter and category), reading rate and mean length of utterance. Also other findings revealed relations between propositional density and verbal fluency (Snowdon et al., 1996). The contrast between processing efficiency and working memory has also been documented by van der Linden et al. (1999).

Propositional density and language samples

The idea of analyzing language productions originated in sample-based measures of grammatical complexity in child language, such as Mean Length of Utterance (R. Brown, 1973). Grammatical complexity in language productions tends to decline in older age, particularly in dementia (Kemper et al., 2001; Lyons et al., 1994). On the other hand, grammatical structure of spoken language does not disintegrate, the basic structure of sentences is preserved even in relatively advanced stages of Alzheimer's disease (Kemper et al., 1993). Preservation of grammatical structure, however, is accompanied by decreases in the information content, which is reflected by decreased propositional density (Kemper, 1992)

Originally, propositional density was scored by human raters according to a set of detailed rules for identifying individual propositions. According to Turner and Greene (1978), propositions are units that connect a relation and one or more arguments so that the result is a single idea. The three main types of relations are predication, modification, and connection. In predication, the core of the proposition is an assertion or statement about the subject of the proposition, i. e. about one (possibly the only) of its arguments. For example, the sentence

John is running contains one predicative proposition that can be written as RUN (JOHN), meaning that John is the subject of the predicate *run*. Modification propositions include relations such as adjectival or adverbial modification, quantification, generally attributing a property or a quantity to some argument. So, *Peter is smart* expresses the proposition SMART(PETER). The third type of propositions are connective propositions that reflect relations between ideas, such as conjunction or disjunction. The original approach to propositional density has relied on manual classification and identification of individual propositional relations in the text, and calculated their count (C. Brown, Snodgrass, Kemper, Herman, & Covington, 2008).

In recent research, an alternative approach is often used. This relies on the analysis of parts of speech, often using the computer application CPIDR – Computerized Propositional Idea Density Rater (Brown, Snodgrass, Kemper, Herman, & Covington, 2008; a version of CPIDR is now a part of the CLAN suite of transcript analysis tools available from the TalkBank, http://talkbank.org/, see MacWhinney, 2016). In this approach, propositions or ideas are not counted directly but the number of propositions is approximated by the number of words from specific part-of-speech categories. This relies on the fact that some parts of speech typically signal the presence of a proposition: lexical verbs are predicates, adjectives or adverbs modifiers, numerals are used for quantification, connectives for connecting ideas. Even though the overlap between part-of-speech category of a word and its function in expressing propositions is not perfect, it can be used to approximate the numbers of propositions, and the resulting numbers are very close to ratings provided by human raters. The advantage of this approach is that scoring can be done using a simpler set of rules applied in a more consistent manner, resulting in higher reliability. If there is an automatic part-of-speech tagger available, propositional density can be scored automatically using this approach, which is the case of CPIDR.

Most, if not all, existing studies using propositional density as an index of cognitive decline examined language productions in English. The challenge in using propositional density in a language other than English is that each language has a unique way of expressing ideas and organizing them in grammatical structures. Some functions performed by words of a certain type, e. g. prepositions, in one language may be fulfilled by different linguistic devices in other languages. So, some English prepositions (e. g. *of*) would be often expressed by case forms in Czech (genitive). If coding is based on parts of speech in the way used in CPIDR (C. Brown et al., 2008), prepositions in English would be counted, while case forms of nouns in Czech would not. The strategy for scoring propositional density must thus be developed separately in each language, reflecting its specifics. A system of coding rules for Czech was developed in this study. Because there was no automatic part-of-speech tagging software available at the beginning of the project, the coding rules were designed for manual coding. We followed the strategy of coding parts of speech rather than propositions directly, and using the proportion of certain parts of speech as an approximation of PD. The major difference between the coding principles in CPIDR (C. Brown et al., 2008) and in the current system was that nouns in some case forms were counted as propositions. This was the case for the genitive, dative, and instrumental case forms in Czech. These case forms often express meanings that are marked by prepositions in English (*of* for genitive, *for* or *to* for dative, or *with* for instrumental), or with other semantic or syntactic devices, e. g. adjectives or adverbs. Because prepositions, adjectives or adverbs are marked as propositions in the English coding system, Czech nouns in these case forms were also coded as propositions. The following sentence provides an example of the analysis, with words printed in italics contributing to the propositional density count.

1. *Náš* zeť *naštípal* dříví *sekerou*.

   our$_{\text{_NominativeSg}}$ son-in-law$_{\text{_NominativeSg}}$ split$_{\text{_PastMasculine}}$ wood$_{\text{_AccusativeSg}}$ axe$_{\text{_InstrumentalSg}}$

Our son in law split the wood with an axe.

In this sentence, the possessive pronoun *our*, the verb *split*, and the instrumental case noun *axe* are counted as propositions. This is in line with the usual scoring in English as the pronoun attributes possession to the subject (son in law), the verb is the main predicate of the sentence. The noun is counted because the instrumental case expresses the manner attribute, and would be marked using the preposition *with* in English**.**

Goals and hypotheses

The present study was planned with three goals. The first was to test a scheme for scoring propositional density in Czech. The second was to compare propositional density in participants with no cognitive impairment and persons with MCI, using closely matched samples. The third goal was to test relations between propositional density and selected neuropsychological measures.

Our expectation was that persons with MCI would show lower propositional density than the cognitively healthy matched controls. Given the null finding by Farias et al. (2012), we suspected that the difference in PD between people with and without MCI may be absent in language samples based on remote, childhood memories. To test this possibility, we collected separate language samples based on recent and remote memories from each participant. In addition to the oral samples, participants were asked for written language samples, both for recent and remote memories. Written samples were included because previous research suggested that written productions may be more closely related to cognitive measures than spoken productions (Kemper et al., 1989; Mitzner & Kemper, 2003). Even though the primary focus of the present study was on the oral language, the data made it possible to compare language samples with different topics and in different modalities.

Independently of the comparisons between healthy participants and those with MCI, we aimed to test relations between propositional density and neuropsychological measures, in particular, measures of verbal working memory and verbal fluency. Given the existing research (Kemper & Sumner, 2001; Snowdon et al., 1996), we expected that PD would be specifically related to measures of verbal fluency. At the same time, the language decline in older age is also related to changes in working memory, even though this is more closely related to grammatical than semantic language measures (Kemper & Sumner, 2001). However, to control for the possible relation between PD and working memory, backward digit span was included (Wechsler, 1997).

METHODS

Participants

The study examined and compared two groups (N=20 in each), patients with amnestic MCI (aMCI) and healthy control group (HC). All participants signed informed consent forms approved by the local ethics committees. All aMCI participants were recruited from referrals to the Memory Disorders Clinic at Motol Hospital, an affiliate of Charles University in Prague. They underwent standard protocol which consisted of magnetic resonance imaging, neurological, medical and laboratory evaluation, questionnaires and complex neuropsychological assessment. The patients met the revised Petersen‘s criteria for aMCI (Petersen, 2004). They or their caregivers reported cognitive complaints, and were impaired on objective memory tasks. The patients did not have dementia, and had largely intact functional activities with CDR (Clinical Dementia Rating scale) of 0.5. Of the 20 broadly defined aMCI cases, only 3 had pure amnestic single-domain MCI (i. e. all non-memory tests were within the normal range – aMCIsd). The remaining 17 participants suffered from other subtle semantic, visuoconstructive or attention-executive function deficits besides the amnestic deficit (i.e. multiple-domain amnestic MCI; aMCImd).

Healthy control participants were recruited and assessed at Prague Psychiatric Center (now transformed into the National Institute of Mental Health, Klecany). The members of the HC group participated in a larger set of neuropsychological studies, all scored within normal range in cognitive tests. They reported no cognitive problems, which was subsequently confirmed by neuropsychological testing. Healthy participants were individually matched with members of the patient group based on age, education, and gender (see Table 1).

Neuropsychological measures

For the purposes of this study, we used the participants' results on the following tests: Mini-mental State Examination (Folstein, Folstein, McHugh, & Fanjiang, 2001; Štěpánková et al., 2015) as a general cognitive status measure; Rey Auditory Verbal Learning Test – RAVLT (Bezdicek et al., 2014; Rey, 1958) for episodic memory; Digit Span Forward and Backward (Wechsler, 1997) for working memory;phonemic (K, P) and category verbal fluency (animals) test (Kopeček & Štěpánková, 2009; Nikolai et al., 2015; Tombaugh, Kozak, & Rees, 1999; Shao, Janse, Visser, & Meyer, 2014) for language and executive functions. All aMCI patients underwent a standard neurological examination with cognitive testing by an experienced cognitive neurologist (MV); the language samples for oral PD analysis were collected at this occasion. Patients also underwent a brain MRI and standard laboratory testing,. The healthy control participants were examined by psychologists at the Prague Psychiatric Center.

Language sample measures

Spoken samples: After neuropsychological examination, all participants were asked to talk about two topics, recent and past. For the recent topic, the instruction was: *Now please* *tell me about how you spent the last weekend, what you did and what it was like. Further you can talk about how you spend your time overall in the last couple of weeks, what you do and what you think about. Please talk until I ask you for some details or until I stop you.* For the topic from the past, the instruction was: *Now please tell me about your childhood and youth. Talk until I ask you for some details or until I stop you.* If participants hesitated or were not able to proceed, they were prompted to go on. The topics were chosen so that they would be sufficiently familiar for the participants, and would not require extensive effort or fabulation. Following the analyses of the Nun Study data (e. g. Kemper et al., 2001; Mitzner & Kemper, 2003), we aimed to analyze 10 sentences from each participant. Even though it would be more informative to have a longer sample available, the use of such a short segment made it easier to collect and transcribe the samples in clinical settings, especially for the group of people with aMCI. When eliciting the oral productions, the goal was to collect at least 12 sentences, of which the initial two would be dropped as a “warm-up”, and the subsequent 10 used for the analysis. In all but one spoken sample, it was possible to collect enough material to analyze a complete sample of 10 utterances. The productions were recorded using a small digital recorder and transcribed by one of the authors (HS, KH) or a trained research assistant.

Written samples: Written productions were collected using response forms that were given to the participants at the end of the assessment session, along with postmarked and addressed envelopes. Participants were asked to write two stories of 12 to 15 sentences, using the same prompts as for the spoken samples.

Propositional density was coded manually according to a set of rules that was based on parts of speech rather than on the actual idea count (Štěpánková & Smolík, 2013). This is a similar approach to that used in the automatic PD coder CPIDR (C. Brown et al., 2008). Parts of speech have simpler definitions than idea units, and even though the counts based on ideas and parts of speech may not be identical, they are closely related (C. Brown et al., 2008). The present scheme counted as propositions all main verbs, adjectives, adverbs, prepositions, numerals, and connectives. Also included were nouns that were not in nominative or accusative case, if not introduced by prepositions. This was because nouns in oblique cases often serve similar functions as prepositional phrases in English. Excluded were connectives *and, or* if they were used in the beginning of an utterance (and thus lacked their connective function), and an arbitrary list of words, mostly adverbs, that are often used as empty, parasitic words. Propositional density was calculated as the proportion of propositions to the number of words in the language sample. Word fragments and sentence fragments such as false starts were not included in the word count. This was done to obtain a conservative measure of propositional density as a semantic measure, rather than a measure highly dependent on the number of dysfluencies in the language samples.

The final coding was performed by a trained linguist (ŠM) who was blind to group membership of the participants. To assess inter-rater agreement, another coder coded all the spoken samples based on childhood memories, i. e. 25 % of all the PD data analyzed in the present paper. Pearson's correlation coefficient between propositional density scores based on the two codings was $r=0.92$; i.e. comparable with other studies (Kemper & Sumner, 2001: correlation 0.91).

RESULTS

Descriptive statistics on all measures are reported in Table 1 separately for the two groups (HC and MCI). Generally, measures of episodic memory and verbal fluency showed lower performance in the MCI group.

INSERT TABLE 1 HERE

Propositional density in spoken samples across groups. The first set of hypotheses was addressed by comparing the mean PD across groups using the paired-samples t-test, with results reported in Table 2. Paired-samples test was used because each participant with MCI was individually matched with a healthy control participant. Significant difference between groups was found for PD in spoken samples with the childhood topic, ($t(19)=2.47$, $p=0.02$). For the spoken samples describing recent events, the difference between PD scores was not statistically significant ($t(19)=1.04$, $p=0.31$) but was in the expected direction, i. e. with lower PD for the participants with MCI.

Propositional density in written samples across groups. No differences were observed (both p's>0.6), the written samples showed almost identical values of PD in both groups.

INSERT TABLE 2 HERE

Relations between PD and neuropsychological measures. The second major set of analyses examined the relation between PD on one hand and some neuropsychological tests and education on the other hand. Verbal fluency measures were the primary candidates given the existing research, especially Kemper et al. (2001). In addition to that, backward digit span was included as a measure of working memory, and education as a potentially relevant demographic variable.

The relation between PD values and neuropsychological tests was first examined using linear regression models with group membership and neuropsychological tests as predictors. The effect of group membership was not significant in any of these models, so group was dropped as a predictor from the subsequent analyses. This reduced the analyses to simple regression which is equivalent to correlation. The results are reported in Table 3. Significance of the individual correlations was calculated using the Holm-Bonferroni correction for each set of correlations with one dependent variable.

Significant relation was found between PD in spoken samples based on remote memories (childhood) and measures of verbal fluency and education in years. No other correlations between the remaining PD measures and the neuropsychological variables were significant. For PD in spoken samples on recent past, the uncorrected correlations with phonemic verbal fluency were marginally significant but did not approach significance after correction.

INSERT TABLE 3 HERE

For written samples, no relations with any other measure were found. This suggests that PD in written samples is not sensitive to the cognitive status of the participants. This could be because PD in written language is unrelated to PD taken from spoken productions. However, as Table 4 shows, there were moderate correlations between some PD measures in spoken and written language, suggesting that PD in spoken and written language reflect similar factors. The lack of relations between written PD and cognitive measures is thus likely due to the limitations in our procedure for written language elicitation that resulted in low reliability.

INSERT TABLE 4 HERE

DISCUSSION

The primary goal of the study was to develop a propositional density metrics for Czech and use it to compare language productions in older people with and without aMCI. We have developed a manual scoring system (Štěpánková & Smolík, 2013) with high inter-rater reliability, and used it successfully with results that are consistent with other findings in the field, such as the relation between PD and verbal fluency. Comparisons of persons with aMCI and healthy controls suggested that there are some differences in PD between these groups but these differences are only present in some types of language productions. In particular, PD was lower in participants with aMCI only in spoken language productions with childhood topics, but not with recent topics. No relations to aMCI were found for written language. Similar pattern was found for relations between PD and neuropsychological measures: only PD in spoken productions about childhood showed significant relations with psychometric tests.

The present study demonstrates that it is possible to adopt the propositional density metrics to a highly inflected language and obtain valid measures. The scoring system based on parts of speech proved to be useful. There are few precedents of using the analysis of language productions in older people speaking Slavic languages. Gubarchuk and Kemper (1997) encountered the problem of morphological errors, i.e. omitted obligatory inflections, case markers and verb conjugations in Russian speakers, which made it difficult to code their production adequately. This was not a problem in the current study because not even highly colloquial Czech allows such omissions of morphological markers.

The results conflict with our original expectation that oral expository statements about recent events would show differences in PD between cognitively impaired and healthy individuals. We expected this because remote memories, which were subject to long-term consolidation, tend to be preserved better than recent memories (Meeter & Murre, 2004), even in people with aMCI (Leyhe et al., 2009). Better memory recall should result in less effort during language production, which might mask the deficit in people with mild cognitive impairment. However, the results showed a different pattern. There was a non-significant tendency towards producing more material in the childhood stories, but the advantage for remote, consolidated memories was not reflected in the propositional content of language productions. The most likely reason is that PD is not strongly related to memory measures but rather to measures of verbal fluency (Kemper et al., 2001; Snowdon et al., 1996), which was confirmed also in the current study. Better memory for remote events does not automatically mean semantically rich linguistic description of these events, even though it may result in longer elicited stories.

The present findings are in conflict with those reported by Farias et al. (2012), who found no differences in PD between MCI patients and controls, using oral language samples based on childhood memories. One possible reason could be that Farias et al. tested MCI patients who had a milder deficit in verbal fluency and working memory measures than patients reported here, even though it is difficult to make a direct comparison. Farias et al. reported the domain score of executive function that included working memory and verbal fluency, with the z-score difference of 0.5 between MCI and control participants. In the present study, the group difference on verbal fluency measures was between 0.54 and 1.39 z-score units, and 0.74 z-score units for backward digit span. While both our participants and those reported by Farias et al. had the core deficit in episodic memory, our participants appear to have weaker performance also in verbal fluency and working memory tasks (85% were diagnosed with multi-domain aMCI). Since PD is primarily related to verbal fluency, it is then not surprising that our participants show some effects not found in Farias et al. The differences between the studies are thus likely due to different characteristics of the MCI groups including persons with different subtypes of MCI. This is also in line with some discrepancies between the present study and our preliminary results reported elsewhere (Štěpánková et al., 2014). Unlike the present results, the preliminary analyses indicated a difference between MCI and cognitively healthy participants in oral samples based on recent memories. However, the present findings should be viewed as a more reliable comparison between people with and without aMCI. Our preliminary sample included a larger number of participants (N=65) but the groups were less closely matched than the present sample and included more heterogeneous MCI sample (61% aMCImd, vs. 85% in the present study). The discrepancies between the present study and previous research suggest that the MCI subtype and the corresponding cognitive profile is important when studying the effects of MCI in language.

Unlike spoken language samples, the written samples showed no group differences and no relations with cognitive tests. This seems surprising because a number of findings suggested that PD from written language productions is related to cognition in older age, both predictively and concurrently (Engelman et al., 2010; Iacono et al., 2009; Mitzner & Kemper, 2003). We suspect that this is due to the way we elicited the written language samples. Because participants wrote their stories in their homes, the format gave them enough time to overcome the effects of decreasing verbal fluency that could have resulted in decreased PD in spoken samples. Participants had a chance to plan the story production and edit their text. In addition, the topics of the written stories were the same as for the spoken samples, and thus rehearsed before writing. Our null findings thus point out that the method of written language sample elicitation, particularly the time available for planning, may mask the differences in written PD between people with and without aMCI. Future research should focus on the conditions under which written samples provide reliable estimates or predictors of cognitive status.

The present study extends the range of studies that found some relations between propositional density and cognitive impairments in old age. While such studies exist, it is important to note that the nature of PD as a measure still poses open questions. Clearly, the measure is not very practical as a diagnostic measure: collecting, transcribing, and analyzing the language samples is rather time-consuming, and the variability of the measure depends on many random factors, thus limiting its reliability. If automatic procedures for its analysis are available, it could provide some information about patients in addition to standard neuropsychological tools, but the present use is primarily in research. As such, it provides a way to observe the effects of cognitive changes in spontaneous behavior. This is a valuable check on the ecological validity of the clinical categories such as dementia or mild cognitive impairment. In addition, the possible differences between different types of cognitive impairment, such as the amnestic and non-amnestic or dysexecutive types of MCI, may be examined via their effects on propositional density, which may clarify the real-life correlates of these classifications.

Limitations

The most important limitation of the present study is that the type of MCI in the affected participants was not strictly controlled. All patients suffered from amnestic MCI, with memory problems being their main weakness. However, the exact profile of their cognitive impairment varied. Most participants with aMCI could be classified as multiple-domain (as opposed to single-domain) amnestic MCI according to Petersen (2004), with multiple cognitive functions affected. However, the future studies should examine more closely which domains are impaired, and which impairments show relations with propositional density. Of particular importance are the findings reported by Libon et al. (2010) which suggest the existence of distinct subgroups in MCI, amnesic and dysexecutive. The dysexecutive group is marked by impairments in verbal fluency tasks. Because propositional density is related to verbal fluency (Kemper & Sumner, 2001), it is thus possible that only patients with the dysexecutive MCI type, who have verbal fluency deficits, show decreased PD values. This needs to be addressed directly.

The method for collecting written samples was seriously limited by having participants write on rehearsed topics and with unlimited opportunity to plan, revise, and edit. The results from written samples thus should not be viewed as evidence that PD in written language is spared in MCI, but rather as a suggestion that the elicitation procedures for written samples need to be carefully designed if PD is the variable of interest. In particular, participants should have limited opportunity to plan and edit their written productions.

Further limitation of the present study is the relatively small sample size, both in terms of the number of participants as well as language sample length. Increasing the sample size would increase the likelihood of observing a significant group effect. Also the fact that we excluded false starts and fragments may contribute to the modest effects observed here; at the same time, this procedure ensured that our estimates of PD in spoken samples are conservative. In the present results, the limited sample size might be the reason why there was no significant difference between groups in spoken samples eith childhood topics, even though the absolute difference was in the expected direction. On the other hand, larger samples could find a significant difference between groups even if the difference were too small for being practically important

Finally, it could be viewed as a limitation that the study had to rely on manual coding of propositional density. It is not really a weakness of the study as this was standard in studies of PD until the automatic part-of-speech tagging became routinely available in 2000's. However, the experience from the project suggests that it is fairly difficult to learn the coding system and use it reliably. It would thus be desirable to have access to automatic analyses in Czech. Besides increasing the consistency and reliability of the coding, it would also result in more efficient processing of the language samples.

Conclusions

The present study confirmed that propositional density in spoken Czech is related to the cognitive status of the speakers, but only for language productions based on remote memories. This relation was identified in matched group comparisons of participants with aMCI and cognitively healthy controls, and also in correlations between PD and phonemic and category verbal fluency measures, as well as education. Written language samples showed no relation between PD and any neuropsychological or demographic variables.

Participants with aMCI had lower propositional density than matched participants with no cognitive impairment. This confirms that MCI affects normal language production, and thus influences everyday communicative activities. At the same time, the effect is not robust across language productions with different topics, which suggests that the decline of PD is relatively mild. .

The lack of relations between PD in written language and other measures of cognition may be due to the way the written language samples were collected, which allowed the participants to compensate any possible cognitive limitations. Further research should examine under which condition written language samples reflect or predict the cognitive status.

REFERENCES

Bezdicek, O., Stepankova, H., Moták, L., Axelrod, B. N., Woodard, J. L., Preiss, M., … Poreh, A. (2014). Czech version of Rey Auditory Verbal Learning test: Normative data. *Aging, Neuropsychology, and Cognition*, *21*(6), 693–721. doi:10.1080/13825585.2013.865699

Brown, C., Snodgrass, T., Kemper, S. J., Herman, R., & Covington, M. A. (2008). Automatic measurement of propositional idea density from part-of-speech tagging. *Behavior Research Methods*, *40*(2), 540–545. doi:10.3758/BRM.40.2.540

Brown, R. (1973). *A First Language: The Early Stages*. Harvard University Press.

Burke, D. M., & Shafto, M. A. (2004). Aging and Language Production. *Current Directions in Psychological Science*, *13*(1), 21–24. doi:10.1111/j.0963-7214.2004.01301006.x

Engelman, M., Agree, E. M., Meoni, L. A., & Klag, M. J. (2010). Propositional Density and Cognitive Function in Later Life: Findings From the Precursors Study. *The Journals of Gerontology*

Series B: Psychological Sciences and Social Sciences, *65B*, 706–711. doi:10.1093/geronb/gbq064

Farias, S. T., Chand, V., Bonnici, L., Baynes, K., Harvey, D., Mungas, D., … Reed, B. (2012). Idea density measured in late life predicts subsequent cognitive trajectories: implications for the measurement of cognitive reserve. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *67*(6), 677–686. doi:10.1093/geronb/gbr162

Folstein, M. F., Folstein, S. E., McHugh, P. R., & Fanjiang, G. (2001). *Mini-Mental State Examination user´s guide*. Odessa, FL: Psychological Assessment resources.

Fox, M. C., Berry, J. M., & Freeman, S. P. (2014). Are vocabulary tests measurement invariant between age groups? An item response analysis of three popular tests. *Psychology and Aging*, *29*(4), 925–938. doi:10.1037/a0038217

Ferguson, A., Spencer, E., Craig, H., & Colyvas, K. (2014). Propositional Idea Density in women’s written language over the lifespan: Computerized analysis. *Cortex*, *55*, 107–121. http://doi.org/10.1016/j.cortex.2013.05.012

Gubarchuk, I., & Kemper, S. (1997). Effects of aging on the production of Russian. *Discourse Processes*, *23*(1), 63–82. http://doi.org/10.1080/01638539709544982

Iacono, D., Markesbery, W. R., Gross, M., Pletnikova, O., Rudow, G., Zandi, P., & Troncoso, J. C. (2009). The Nun Study: Clinically silent AD, neuronal hypertrophy, and linguistic skills in early life. *Neurology*, *73*, 665–673. doi:10.1212/WNL.0b013e3181b01077

Kemper, S., Hoffman, L., Schmalzried, R., Herman, R. & Kieweg, D. (2011) Tracking Talking: Dual Task Costs of Planning and Producing Speech for Young versus Older Adults, *Aging, Neuropsychology, and Cognition: A Journal on Normal and Dysfunctional Development*, 18, 257-279, doi: 10.1080/13825585.2010.527317

Kemper, S., LaBarge, E., Ferraro, F. R., Cheung, H., Cheung, H., & Storandt, M. (1993). On the preservation of syntax in Alzheimer’s Disease. Evidence from written sentences. *Archives of Neurology*, *50*(1), 81–86.

Kemper, S., & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging*, *16*(2), 312–322.

Kemper, S., Thompson, M., & Marquis, J. (2001). Longitudinal change in language production: Effects of aging and dementia on grammatical complexity and propositional content. *Psychology and Aging*, *16*, 600–614. doi:10.1037//0882-7974.16.4.600

Kopeček, M., & Štěpánková, H. (2009). Test-retest minutové slovní produkce v kategorii zvířata a kratších variant u seniorů [Test-retest of one minute verbal fluency test in the category “animals” and shorter variants in seniors]. *Psychiatrie*, *13*(2-3), 61–65.

Lamar, M., Resnick, S. M., & Zonderman, A. B. (2003). Longitudinal changes in verbal memory in older adults: distinguishing the effects of age from repeat testing. *Neurology*, *60*(1), 82–86.

Laumann Long, L., & Shaw, R. J. (2000). Adult Age Differences In Vocabulary Acquisition. *Educational Gerontology*, *26*(7), 651–664. doi:10.1080/03601270050200644

Leyhe, T., Müller, S., Milian, M., Eschweiler, G. W., & Saur, R. (2009). Impairment of episodic and semantic autobiographical memory in patients with mild cognitive impairment and early Alzheimer’s disease. *Neuropsychologia*, *47*(12), 2464–2469. doi:10.1016/j.neuropsychologia.2009.04.018

Libon, D. J., Xie, S. X., Eppig, J., Wicas, G., Lamar, M., Lippa, C., … Wambach, D. M. (2010). The heterogeneity of mild cognitive impairment: A neuropsychological analysis. *Journal of the International Neuropsychological Society*, *16*(01), 84. doi:10.1017/S1355617709990993

Lindenberger, U., & Baltes, P. B. (1997). Intellectual functioning in old and very old age: Cross-sectional results from the Berlin Aging Study. *Psychology and Aging*, *12*(3), 410–432.

Lyons, K., Kemper, S., Labarge, E., Ferraro, F. R., Balota, D., & Storandt, M. (1994). Oral language and Alzheimer’s disease: A reduction in syntactic complexity. *Aging, Neuropsychology, and Cognition*, *1*(4), 271–281. doi:10.1080/13825589408256581

MacKay, D. G., & James, L. E. (2004). Sequencing, speech production, and selective effects of aging on phonological and morphological speech errors. *Psychology and Aging*, *19*(1), 93–107. doi:10.1037/0882-7974.19.1.93

MacWhinney, B. (2016). *The CHILDES Project: Tools for Analyzing Talk – Electronic Edition. Part 2: The CLAN Programs.* Retrieved from http://childes.psy.cmu.edu/manuals/clan.pdf

McDowd, J., Hoffman, L., Rozek, E., Lyons, K. E., Pahwa, R., Burns, J., & Kemper, S. (2011). Understanding verbal fluency in healthy aging, Alzheimer's disease, and Parkinson's disease. *Neuropsychology*, *25*(2), 210–225. doi:10.1037/a0021531

Medina, L. D., Rodriguez-Agudelo, Y., Geschwind, D. H., Gilbert, P. E., Liang, L.-J., Cummings, J. L., & Ringman, J. M. (2011). Propositional Density and Apolipoprotein E Genotype among Persons at Risk for Familial Alzheimer's Disease. *Dementia and Geriatric Cognitive Disorders*, *32*(3), 188–192. doi:10.1159/000333023

Meeter, M., & Murre, J. M. J. (2004). Consolidation of long-term memory: evidence and alternatives. *Psychological Bulletin*, *130*(6), 843–857. doi:10.1037/0033-2909.130.6.843

Nikolai, T., Štěpánková, H., Michalec, J., Bezdíček, O., Horáková, K., Marková, H., … Kopeček, M. (2015). Testy verbální fluence, česká normativní studie pro osoby vyššího věku [Verbal fluency tests. Czech normative study for older persons]. *Česká a slovenská neurologie a neurochirurgie*, *78/111*(3), 292–299.

Petersen, R. C. (2004). Mild cognitive impairment as a diagnostic entity. *Journal of Internal Medicine*, *256*(3), 183–194.

Petersen, R. C., & Morris, J. C. (2005). Mild cognitive impairment as a clinical entity and treatment target. *Archives of Neurology*, *62*(7), 1160–1163; discussion 1167.

Petersen, R. C., Smith, G. E., Waring, S. C., Ivnik, R. J., Tangalos, E. G., & Kokmen, E. (1999). Mild cognitive impairment: clinical characterization and outcome. *Archives of Neurology*, *56*(3), 303–308.

Rey, A. (1958). Memorisation d'une serie de 15 mots en 5 repetitions. In A. Rey (Ed.), *L'examen clinique en psychologie*. Paris: Presses Universitaires de France.

Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology, 5*. http://doi.org/10.3389/fpsyg.2014.00772

Snowdon, D. A., Kemper, S. J., Mortimer, J. A., Greiner, L. H., Wekstein, D. R., & Markesbery, W. R. (1996). Linguistic ability in early life and cognitive function and Alzheimer's disease in late life. Findings from the Nun Study. *JAMA: The Journal of the American Medical Association*, *275*(7), 528–532.

Spencer, E., Craig, H., Ferguson, A., & Colyvas, K. (2012). Language and ageing – exploring propositional density in written language – stability over time. *Clinical Linguistics & Phonetics*, *26*(9), 743–754. doi:10.3109/02699206.2012.673046

Štěpánková, H., Nikolai, T., Lukavský, J., Bezdíček, O., Vrajová, M., & Kopeček, M. (2015). Mini-Mental State Examination – česká normativní studie [Mini-Mental State Examination – Czech normative study]. *Česká a slovenská neurologie a neurochirurgie*, *78/111*(1), 57–63.

Štěpánková, H., & Smolík, F. (2013). Systém identifikace propozic. Manuál. Dostupné z http://www.pcp.lf3.cuni.cz/pcpout/dokumenty/System_identifikace_propozic_new.pdf

Štěpánková, H., Smolík, F., Vyhnálek, M., Nikolai, T., Horáková, K., & Niederlová, M. (2014). Propoziční hustota ve výpovědích seniorů [Propositional density in seniors' responses]. *Československá psychologie*, *58*(4), 317–325.

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*, *8*, 448–460.

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology: The Official Journal of the National Academy of Neuropsychologists*, *14*(2), 167–177.

Turner, A., & Greene, E. (1978). *The construction and use of a propositional text base* (No. Tech Report 87-02). University of Colorado: Institute of cognitive neuroscience.

Van der Linden, M., Hupet, M., Feyereisen, P., Schelstraete, M.-A., Bestgen, Y., Bruyer, R., … Seron, X. (1999). Cognitive Mediators of Age-Related Differences in Language Comprehension and Verbal Memory Performance. *Aging, Neuropsychology, and Cognition (Neuropsychology, Development and Cognition: Section B)*, *6*(1), 32–55. doi:10.1076/anec.6.1.32.791

Vousden, J. I., & Maylor, E. A. (2006). Speech errors across the lifespan. *Language and Cognitive Processes*, *21*(1-3), 48–77. doi:10.1080/01690960400001838

Wechsler, D. (1997). Wechsler Memory Scale - Third Edition. San Antonio, TX: The Psychological Corporation.

Table 1: Demographic information and cognitive scores

	HC (n = 20; 10 women) Mean (SD)	MCI (n = 20, 10 women) Mean (SD)	*p*	*d*
Age	72.05 (7.42)	72.05 (7.92)	---	---
min; max	60; 86	58; 90		
Years of education	14.35 (3.25)	13.45 (3.25)	---	---
min; max	10; 21	9; 18		
MMSE	28.85 (1.60)	26.20 (2.53)	<0.001	0.96
Verbal fluency – P (z)	0.48 (1.18)	-0.70 (1.05)	0.004	0.74
Verbal fluency – K (z)	-0.22 (0.98)	-0.76 (1.18)	0.054	0.50
Verbal fl. – animals (z)	0.58 (1.41)	-0.81 (1.62)	0.020	0.58
Digit span forward (z)	0.31 (1.15)	-0.01 (1.96)	0.705	0.09
Digit span backward (z)	0.49 (1.27)	-0.25 (0.94)	0.128	0.38
RAVLT (1-5) (z)	0.359 (0.75)	-1.192 (1.43)	<0.001	0.91
RAVLT - immediate (z)	0.33 (0.86)	-1.625 (1.27)	<0.001	1.22
RAVLT – delayed (z)	0.097 (0.86)	-1.993 (1.73)	<0.001	1.07

Note: HC = healthy control group; MCI = aMCI patient group; n = number; SD = standard deviation; MMSE = Mini-Mental State Examination; PD = propositional density; Digit span – correctly recalled items; RAVLT = Rey Auditory Verbal Learning Task; (1-5) = sum of trials 1 to 5; immediate - immediate recall after interference list recall; delayed = delayed recall after 30 min.

Table 2: Propositional densities (propositions/words*100) and language sample lengths in words.

	HC (n = 20; 10 women) Mean (SD) Min; max	MCI (n = 20, 10 women) Mean (SD) Min; max	*p*	*d*
PD, spoken, childhood	54.06 (4.81) 44.72; 63.84	50.52 (5.49) 42.74; 60.57	0.023	0.55
PD, spoken, recent	55.46 (5.64) 43.06; 64.23	53.76 (4.81) 43.97; 63.89	0.310	0.23
PD, written, childhood	60.62 (2.91) 56.84; 65.06	60.25 (3.72) 51.32; 65.41	0.721	0.08
PD, written, recent	62.31 (5.28) 51.89; 71.43	62.86 (3.78) 55.06; 69.70	0.683	0.09
Words, spoken, childhood	164.6 (48.1) 85; 253	140.6 (35.2) 88; 215	0.145	0.34
Words, spoken, recent	142 (28.9) 72; 192	124.85 (27.2) 79; 180	0.070	0.43
Words, written, childhood	130.3 (46.4) 51; 251	126.3 (36.1) 76; 201	0.754	0.07
Words, written, recent	125.6 (43.2) 50; 222	115.55 (45.8) 47; 197	0.454	0.17

Table 3. Correlations of PD and education and neuropsychological measures

	PD spoken - childhood	PD spoken - recent	PD written - childhood	PD written - recent
Education (yr)	0.40*	0.25	0.17	0.23
Digit span backward	-0.06	0.20	-0,03	0.08
Verbal fluency - P	0.42*	0.29	-0.07	0.10
Verbal fluency - K	0.41*	0.29	-0.09	0.02
Verbal fluency - animals	0.43*	0.19	0.03	0.00

Note: yr = year; PD = propositional density; * $p<0.05$ after Bonferonni-Holm correction.

Table 4: Correlations between PD from different language samples.

	PD spoken - recent	PD written - childhood	PD written - recent
PD spoken - childhood	0.39+	0.4+	0.32
PD spoken - recent		0.10	0.43*
PD written - childhood			0.13

Note: PD = propositional density. *p<0.05, +p<0.1.