Title

Cognitive Aging Effects on Language Use in Real-Life Contexts:
A Naturalistic Observation Stu

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 41(0)

Authors

Luoa, Minxia
Schneider, Gerold
Martin, Mike
et al.

Publication Date

2019

Peer reviewed

Cognitive Aging Effects on Language Use in Real-Life Contexts: A Naturalistic Observation Study

Minxia Luo[a,b], (m.luo@psychologie.uzh.ch)
Gerold Schneider[c,d] (gschneid@cl.uzh.ch)
Mike Martin[a,b] (m.martin@psychologie.uzh.ch)
Burcu Demiray[a,b] (b.demiray@psychologie.uzh.ch)

[a] Department of Psychology, University of Zurich
[b] University Research Priority Program "Dynamics of Healthy Aging", University of Zurich
[c] English Department, University of Zurich
[d] Institute of Computational Linguistics, University of Zurich

Abstract

This study examined age effects on real-life language use and within-person variations in language use across social contexts. We used the Electronically Activated Recorder (i.e., a portable audio recorder that periodically records sound snippets) to collect over 31,300 snippets (30 seconds long) from 61 young and 48 healthy older adults in Switzerland across four days. We examined vocabulary richness and grammatical complexity across the social contexts of (a) activities (i.e., socializing, working); and (b) conversation types (i.e., small talk, substantive conversation). Multilevel models showed that vocabulary richness and grammatical complexity increased during socializing and substantive conversations, but decreased in small talk. Moreover, young adults produced shorter clauses at work than not at work. Furthermore, compared with young adults, older adults used richer vocabulary and more complex grammatical structures at work; and used richer vocabulary in small talk. In contrast, young adults used richer vocabulary than older adults during non-socializing and non-working occasions, such as watching TV and exercising. Results are discussed in the context of cognitive aging research with a novel emphasis on context.

Keywords: vocabulary richness; grammatical complexity; social context; cognitive behavior; electronically activated recorder (EAR); naturalistic observation method

Introduction

Real-life language use is mostly embedded in social interactions and conversations (e.g., Clark, 1996). While effects of social context on language use have been widely acknowledged in sociolinguistics, linguistic ethnography, and social psychology (e.g., Finkbeiner, Meibauer, & Schumacher, 2012), they have been underrepresented in cognitive aging research (e.g., Horton, Spieler, & Shriberg, 2010). Rooted in laboratory experiments, cognitive aging research assumed that cognitive change with aging was the primary determinant of variations in language use (Burke & Shafto, 2008). However, unlike in the laboratory, where the upper limits of one's abilities are tested (Baltes, Dittmann-Kohli, & Dixon, 1984), in real life, contexts should also play a role in influencing behaviors (Lewin, 1951). Although some cognitive aging studies have controlled for the effects of social context in their examination of age and real-life language use, they have not treated social context as an essential determinant in their theoretical frameworks (Meylan & Gahl, 2014; Moscoso del Prado Martín, 2016). Furthermore, past studies, focusing on comparisons of different speakers in different contexts (i.e., between-person differences), were limited in inferring how the same individuals varied their language across contexts (i.e., within-person variations; Hamaker, 2012). Moreover, many real-life speech samples in the literature have been collected via telephone conversations between strangers, which may not be representative of naturally occurring language use. In sum, only one recent study has combined cognitive aging effects with within-person variations across social contexts in the investigation of language use in real life (Luo, Robbins, Martin, & Demiray, under review).

The current study used a naturalistic observation method to collect speech samples in real life and examined age effects in language use across different social contexts. Using the Electronically Activated Recorder (EAR; Mehl, Pennebaker, Crow, Dabbs, & Price, 2001), a digital recorder which periodically and unobtrusively captures ambient sounds in natural environments, we assessed language use and social contexts by examining speakers' moment-to-moment conversations. Vocabulary richness and grammatical complexity are related to cognitive changes with age (e.g., Horton, et al., 2010). We examined vocabulary richness and grammatical complexity across two types of social contexts that have been shown relevant to language use: (a) activities (i.e., socializing, working); and (b) conversation types (i.e., small talk, substantive conversations; Levinson, 1992). Our goals were to examine (1) whether individuals changed their language across real-life social contexts; and (2) whether age effects on language use differed across social contexts. Thus, this study is the first to examine cognitive aging effects on real-life language use in relation to within-person variations across different activities and conversation types.

Cognitive Aging Effects in Language Use

The differences in language use between young and older adults have been associated with cognitive changes with age. For example, the observations of older adults using richer vocabulary than young adults have been explained as due to lifelong vocabulary accumulation in old age (e.g., Horton, et al., 2010). Moreover, the findings of older adults producing simpler grammatical structures than young adults have been interpreted as due to decreasing working memory in old age (e.g., Cheung & Kemper, 1992). Majority of these findings came from laboratory tasks, which asked participants to describe a novel picture, an important person, or a historical event (e.g., Cheung & Kemper, 1992). These studies assumes that cognition was the primary determinant of vocabulary richness and grammatical complexity and that participants' speech reflected their cognitive abilities in a controlled and consistent environment.

In theory, behavior is conceptualized as the interactions between personal characteristics and different supporting or impeding contexts (e.g., WHO, 2015; Verhaeghen, Martin, & Sędek, 2012). That is, in real life, where the environment is more diverse than in the laboratory, contextual effects should be taken into account. In order to improve the generalizability of their findings, some researchers examined speech outside of the laboratory, such as in telephone conversations (e.g., Horton, et al., 2010). These studies examined age effects on language use and controlled for contextual factors (e.g., talking with different conversional partners; Meylan & Gahl, 2014; Moscoso del Prado Martín, 2016). However, these studies examined between-person differences, instead of within-person variations across contexts (Hamaker, 2012). Additionally, the telephone conversations between strangers may not represent naturally occurring conversations.

In sum, some studies have identified effects of social context on language use, but they have not considered social context as an essential determinant of language use in their theoretical frameworks. Additionally, past studies have not examined contextual effects on vocabulary richness and grammatical complexity in naturally occurring language use with a within-person research design. Amid the growing interest in examining age effects on language use in real life, it is necessary to understand contextual effects on language use with data that properly capture within-person variations in language use in naturally occurring conversations.

Contextual Effects in Language Use

Social context is an important construct in the theoretical frameworks of language use in social psychology, sociolinguistics and linguistic ethnography (e.g., Clark, 1996; Finkbeiner, et al., 2012). There are substantial variations in language use across different social contexts, such as types of activities (i.e., socializing, working; Levinson, 1992). For example, speakers use more swearing words in leisure activities than at work (Cameron, 1969). Speakers refer to themselves more often in socializing and entertaining activities than while working (Mehl & Pennebaker, 2003). Furthermore, types of conversations (e.g., small talk, substantive conversation) also have effects on language use. Conversation topics and discourse markers (e.g., "anyway" and "you know") are different in small talk versus formal conversations, and the differences influence the degree of trust among speakers (Bickmore & Cassell, 2001). In addition, how speakers engage in small talk and substantive conversations is associated with their well-being (Mehl, Vazire, Holleran, & Clark, 2010).

Past studies have shown that the contexts of activity types and conversation types have effects on language use. However, majority of these studies have explained effects of social context from the perspective of social role and social identity and have not linked their findings to cognitive effects (e.g., Mehl & Pennebaker, 2003). In fact, cognitive-biological and socio-cultural determinants of language use are intertwined and inseparable (e.g., Gerstenberg, & Voeste, 2015). Furthermore, variations in language use across social contexts are likely to differ between young and older adults (e.g., Adams, Smith, Pasupathi, & Vitolo, 2002).

In sum, research that identifies effects of contexts on language use has highlighted the importance of understanding variations in language use across contexts. Thus, it is important to consider cognitive and contextual effects in the examination of real-life language use.

The Current Study

This study used the EAR to periodically and unobtrusively capture ambient sounds and speech in real life. The intensive and repeated sampling approach of the EAR captures multiple observations from each participant and, thus, allows us to analyze within-person variations in language use across social contexts. We treated social contexts and age as two important concepts in our theoretical model and inspected their joint effects on real-life language use.

The first goal of our study was to examine contextual effects on real-life language use. We focused on vocabulary richness and grammatical complexity that are associated with cognitive aging. We examined the contexts that have been found to have effects on language use: (a) activities (i.e., socializing, working); and (b) conversation types (i.e., small talk, substantive conversation). If activities and conversation types had effects on language use, we considered it in line with our assertion that contextual factors should be examined in the understanding of real-life language use. However, as there was a lack of evidence on how these social contexts would influence vocabulary richness and grammatical complexity, we refrained from forming hypotheses about the directionality of contextual effects. The second goal of our study was to explore whether age effects on real-life language use varied across different social contexts. If age effects on language use differed across different contexts, we considered it offered support for our anticipation that age effects on language use would be influenced by contexts.

Method

Participants

Our sample included over 31,300 sound files collected from 48 healthy older adults (62-83 years, M = 70.5, SD = 4.7; 22 men, 26 women) and 61 young adults (19-31 years, M = 23.0, SD = 3.10; 24 men, 37 women). Participants were recruited via the participant pool of our department, via flyers in university buildings and advertisements in a local newspaper, and through snowball sampling used by a research assistant. All participants were local residents and spoke Swiss German.

Older participants were healthy with no record of neurological or psychiatric illness and lived independently. Their years of education ranged from seven to 25 (M = 10.55, SD = 3.02). Five of them were working part-time or full-time. They were compensated with 50 Swiss Francs. Young participants were mostly university students, whose years of education ranged between three and 17 years (M = 12.35, SD = 2.41). Eight of them had a part-time or full-time job. They could choose between 50 Swiss Francs and research credits for compensation.

Procedure

The study included an introduction session, a four-day EAR observation period, and a feedback session. In the introduction session, participants were given instructions on the study. They were asked to sign an informed consent form and to complete questionnaires including demographic and psychological measures. Next, participants received an iPhone with the EAR application installed. Participants were informed that the EAR would randomly record 30 seconds of ambient sounds. They were told that they would not notice when the EAR was recording, so that they could continue their normal lives. They were informed that they would have the opportunity to review and delete any sound files at the end of the study, before anyone listened to them.

After the introduction session, participants carried the EAR with them for four consecutive days. Additionally, they kept a diary every evening about their hour-by-hour activities of that day. Finally, participants met with the researchers again for a feedback session, in which they returned the phone and completed further questionnaires. They evaluated their experience with carrying the phone. They were given a password-protected CD containing all of their sound files to review. All procedures were approved by the local ethics committee.

EAR We provided each participant with an iPhone 4S, where the EAR application was installed (version 2.3.0). We programmed the EAR to record 30-second sound files at random times throughout the day. It was set to record 72 sound files per day (a total of 288 sound files per participant). We set a blackout period between midnight and 6 AM, when the EAR was inactive. We turned on the “Airplane mode” of the iPhone and locked it with a screen-lock password. Thus, participants could not access the EAR settings or use the phone for other purposes. We set a reminder in the phone calendar to automatically beep every evening at 9 PM to remind the participants to charge the iPhone overnight.

Linguistic Measures

All utterances of the participants captured by the EAR were transcribed. A research assistant created the transcripts, which were then checked and corrected by a second research assistant. Swiss-German dialect was translated word-by-word into standard written German and then transcribed. The utterances of interlocutors or bystanders were not transcribed due to ethical reasons.

We used the the TreeTagger (Schmid, 1999) via the R package of “koRpus” version 0.10-2 (Michalke, 2018) to process the transcripts. First, we identified each word according to its grammatical class (e.g., a noun, a verb), a process called *part-of-speech tagging*. We also turned each word to its lemma form, a process called *lemmatization*. For example, we turned *isst* (“eats”), *aß* (“ate”), and *gegessen* (“eaten”) to the lemma form of *essen* (“eat”). Subsequently, we calculated the following two linguistic measures.

Vocabulary Richness: Entropy. Vocabulary richness was calculated with Shannon entropy measure, representing the diversity of words (e.g., Moscoso del Prado Martín, 2016). We calculated the frequency of occurrence of each word based on its lemma form and part-of-speech tag. Afterwards, we calculated the Shannon entropy of each sound file using the frequency. We used the R package of “entropy” (version 1.2.1; Hausser & Strimmer, 2018) to calculate Shannon entropy and corrected the results with Chao-Shen estimator, according to Moscoso del Prado Martín (2016). Higher scores of entropy indicate higher usage of unique words.

Grammatical Complexity: Clause Length. Clause length is the word count in a clause, representing the complexity of grammatical structures (e.g., Horton, et al., 2010). We used the German Pro3Gres parser (Sennrich, Schneider, Volk, Warin, 2009) to identify the following patterns as clauses: (a) a root element, i.e. the top element of a sentence, typically the inflected verb; (b) a relative clause (which is attached with the label rel to the NP it modifies); (c) a subordinated adjunct clause (label neb); (d) a subordinated complement clause (label objc or subjc); and (e) coordination at clause level (kon); (f) a fragmented or complete sentence (label s; Foth, 2005). Finally, we calculated word count per clause in each sound file.

EAR Coding

Every sound file has been manually coded for the participant’s momentary (a) activity (i.e., socializing, working); and (2) conversation types (i.e., small talk, substantive conversations). More specifically, *socializing* refers to when the participant is doing something to socialize or entertain with others. *Working* refers to doing paid work. *Small talk* refers to any conversation that is completely non-instrumental, with no (or very trivial) information being exchanged. Finally, *substantive conversation* is any conversation that serves the purpose of exchanging information and ideas about a topic, e.g., news, politics.

All coding categories were dichotomous, indicating the presence (1) or absence (0) of the targeted item within a sound file. Trained coders coded these categories by listening to the pitch of the participants’ voice, ambient sounds, and conversation topics in each sound file, and by referring to the adjacent sound files. The coders also verified their coding with the participants' diaries. Note that the coders were not aware that vocabulary richness and grammatical complexity would be analyzed. Thus, the coders coded for activity and conversation types without referring to these linguistic measures. Social contexts were coded by only one research assistant, because the reliability of the coding of these contextual variables is found to be high in past EAR studies (e.g., Mehl, & Pennebaker, 2003; Mehl, et al., 2001).

Results

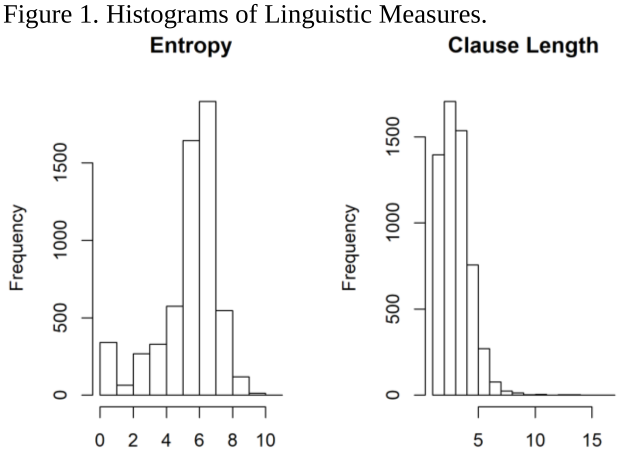
Preliminary Analyses

We collected over 31,300 sound files. For privacy reasons, 15 participants deleted 133 sound files, ranging from 1 to 40 sound files per person. From the remaining sound files, 6,542 included participant speech, ranging from 2 to 158 per participant (*M* = 60.02, *SD* = 32.09). That is, participants were talking, on average, in 21% of the sound files.

Young and older participants reported that the EAR did not affect their daily activities or way of speaking, in line with past EAR studies (e.g., Mehl, et al., 2001). Additionally, the proportion of the sound files in which the participants mentioned the EAR was low (only 0.8% of all sound files that included speech).

Out of the 6,542 sound files, 778 were deleted, as the participants' speech was unclear or included another language than German. This resulted in a final sample of 5,764 sound files. There were over 140,000 spoken words. The average score of entropy was 5.36 (*SD* = 1.9, Range: 0.00-10.24), and the average length of clauses was 3.09 words (*SD* = 1.39, Range: 1-17). The word count in sound files ranged from 1 to 123 words (*M* = 24.34, *SD* = 21.36). Figure 1 shows the histograms of entropy and clause length.

Figure 1. Histograms of Linguistic Measures.



Averaging across participants, in young adults, 7% of sound files (*SD* = 6%, Range: 0-23%) have been coded as including socializing, 2% (*SD* = 5%, Range: 0-19%) included working, 1% (*SD* = 1%, Range: 0-5%) included small talk, and 12% (*SD* = 7%, Range: 0-33%) included substantive conversation. In older adults, 6% of sound files (*SD* = 6%, Range: 0-18%) included socializing, 1% (*SD* = 4%, Range: 0-27%) included working, 2% (*SD* = 1%, Range: 0-7%) included small talk, and 12% (*SD* = 9%, Range: 0-38%) included substantive conversation.

Analytical Approach

The sound files (level 1) are nested within individuals (level 2). We analyzed these hierarchical data with multilevel models, which simultaneously examine between-persons and within-person variances (Bolger & Laurenceau, 2013). We estimated separate models for the two linguistic measures and for the different social contexts. In each model, we first estimated effects of age group and social context, and then added Age Group × Social Context interactions. More specifically, the full model is specified as follows:

Level 1: $Language_{ti} = \beta_{0i} + \beta_{1i}(Context_{ti} - Context_{i}) + e_{ti}$

Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01}(AgeGroup_{i}) + U_{0i}$

$\beta_{1i} = \gamma_{10} + \gamma_{11}(AgeGroup_{i}) + U_{1i}$

where *i* indexes individuals and *t* indexes sound files. At level 1, $Language_{ti}$ represents the linguistic variable. β_{0i} is the random intercept, and β_{1i} represents within-person effects of contexts. The contextual variables were coded such that a non-event served as the reference group (i.e., socializing versus non-socializing, working versus non-working, small talk versus non-small talk, substantive conversation versus non-substantive conversation). This contrast scheme was used in line with the dichotomous nature of the contextual variables (coded as 0 vs. 1). e_{ti} represents the unexplained within-person context-to-context differences in language use. At level 2, β_{0i} represents the intercept of each age group and is modelled in detail through the level-1 model. β_{1i} is the slope of each age group. γ_{00} represents the grand mean of outcomes over all of the participants. γ_{10} represents the grand mean of slopes over all of the participants. γ_{01} and γ_{11} represented effects of age group, where young adults were the reference group. U_{0i} represents the random intercepts of individuals. U_{1i} represents the random slopes of individuals.

We decomposed each dummy-coded contextual variable into between-persons variance and within-person variance (Bolger & Laurenceau, 2013). More specifically, we firstly calculated the average score of context of each participant ($Context_{i}$). Afterwards, we deducted the score of context in each sound file from the mean score of context of each participant ($Context_{ti}$ - $Context_{i}$; i.e., within-person contextual effect). The within-person contextual variables were our contextual predictors. Finally, we controlled for sex and education in each model.

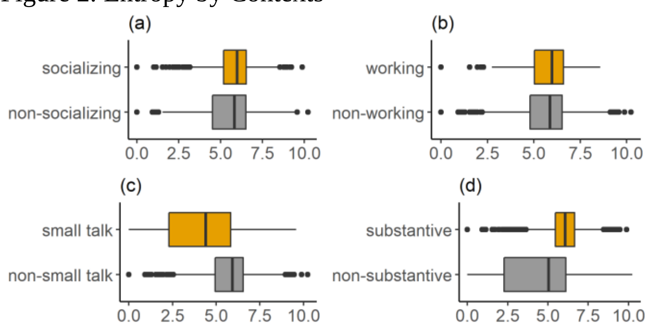
We used the R package "lme4" (version 1.1-17) in R (version 3.5.2) to estimate the models and the 95% confidence intervals (CI). We estimated the models with full information maximum likelihood estimation method, which treated incomplete data as missing at random and adjusted for unbalanced data (Singer & Willett, 2003). We additionally calculated p-values with R package "lmerTest" (version 3.0-1) and considered $p < .05$ as significant.

Major Analyses

Our first research goal was to examine contextual effects on language use. Thus, we estimated models with effects of age group and social context. We, then, added Age Group × Social Context interaction to the model for the second research goal: exploring whether age effects on language use were influenced by different social contexts. Due to their non-significant effects, we dropped sex and education from our final models. Additionally, we dropped the random slope effects from the models of socialization, working, and small talk in vocabulary richness, because the random intercept and slope models did not fit better than the random intercept models.

Vocabulary Richness: Entropy In the model of socialization, as shown in Figure 2 (a), participants used richer vocabulary while socializing than non-socializing (*M* = 0.32, *p* = <.001, 95% CI [0.20, 0.44]).[1] As shown in Figure 3 (a), young adults used richer vocabulary than older adults during non-socializing (*M* = -0.23, *p* =.014, 95% CI [-0.41, -0.05]). However, there was no age group difference during socializing (*M* = 0.17, *p* = .155, 95% CI [-0.07, 0.41]).

Figure 2. Entropy by Contexts

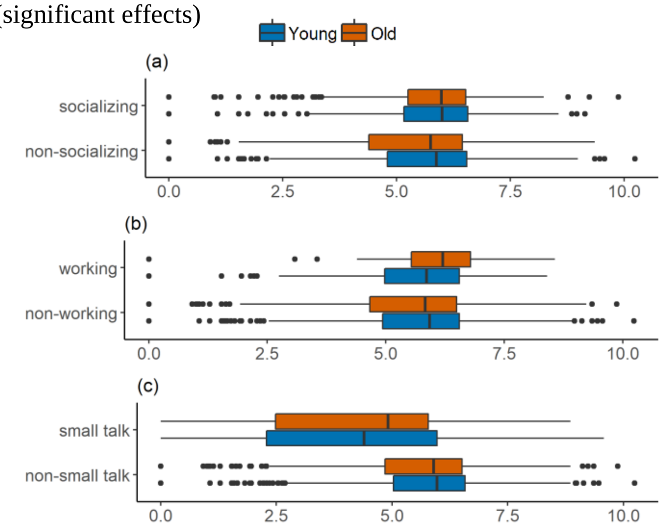


In the model of working, as displayed in Figure 2 (b), there was no significant difference in vocabulary richness between working and non-working occasions (*M* = 0.17, *p* = .291, 95% CI [-0.14, 0.47]). As presented in Figure 3 (b), young adults used richer vocabulary than older adults in non-working occasions (*M* = -0.21, *p* = .026, 95% CI [-0.38, -0.03]). In contrast, older adults used richer vocabulary than young adults at work (*M* = 0.96, *p* = .030, 95% CI [0.09, 1.82]).

Figure 2 (c) shows that participants used richer vocabulary in non-small talk than in small talk (*M* = -1.31, *p* < .001, 95% CI [-1.51, -1.11]). Figure 3 (c) shows that there was no significant age group difference in non-small talk (*M* = -0.18, *p* = .050, 95% CI [-0.36, 0.00]). However, in small talk, older adults used richer vocabulary than young adults (*M* = 0.42, *p* = .041, 95% CI [0.02, 0.82]).

Figure 2 (d) shows that participants used richer vocabulary in substantive conversations than in non-substantive conversations (*M* = 1.57, *p* < .001, 95% CI [1.47, 1.67]). There was no significant age group difference in non-substantive conversations (*M* = -0.14, *p* = .376, 95% CI [-0.44, 0.17]) or in substantive conversations (*M* = 0.15, *p* = .348, 95% CI [-0.17, 0.47]).

Figure 3. Entropy Across Age Groups and Contexts (significant effects)



Grammatical Complexity: Clause Length In the model of socializing (Figure 4 [a]), participants uttered longer clauses while socializing than non-socializing (*M* = 0.18, *p* = <.001, 95% CI [0.09, 0.27]). There was no age group difference in non-socializing (*M* = -0.13, *p* = .086, 95% CI [-0.27, 0.02]) or socializing occasions (*M* = 0.11, *p* = .234, 95% CI [-0.07, 0.28]).

In the model of working (Figure 4 [b]), there was no significant difference in grammatical complexity between working and non-working occasions when examining both older and young adults (*M* = -0.18, *p* = .112, 95% CI [-0.41, 0.04]). However, young adults produced shorter clauses at work than not at work (*M* = -0.31, *p* = .013, 95% CI [-0.55, -0.07]). As shown in Figure 5, age group difference was non-significant in non-working occasions (*M* = -0.12, *p* = .101, 95% CI [-0.27, 0.02]), but was significant at work (*M* = 0.86, *p* = .008, 95% CI [0.23, 1.49]). That is, older adults used longer clauses than young adults at work.

Figure 4 (c) shows that participants produced shorter clauses during small talk than in non-small talk (*M* = -0.60, *p* < .001, 95% CI [-0.74, -0.45]). There was no age group difference in non-small talk (*M* = -0.10, *p* = .170, 95% CI [-0.24, 0.04]) or in small talk (*M* = 0.01, *p* = .954, 95% CI [-0.47, 0.50]).

As depicted in Figure 4 (d), participants produced longer clauses than in non-substantive conversations (*M* = 0.77, *p* < .001, 95% CI [0.70, 0.85]). There was no age group difference in non-substantive conversations (*M* = -0.05, *p*

[1] While our analyses focused on within-person variations in each participant, for simplicity, the figures show within-person variations across all participants.

= .607, 95% CI [-0.24, 0.14]) or in substantive conversations (M = 0.00, p = .966, 95% CI [-0.21, 0.20]).

Figure 4. Clause Length by Contexts

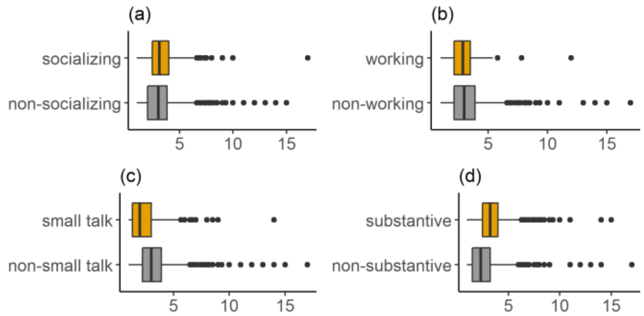
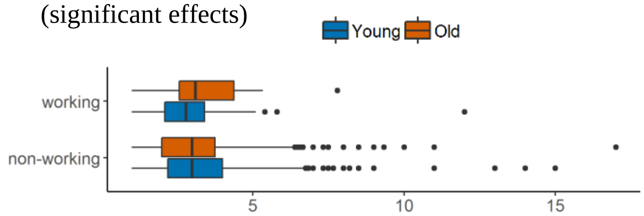


Figure 5. Clause Length Across Age Groups at Work (significant effects)



Discussion

Using a naturalistic observation method, we examined age group differences in language use across social contexts in real life. We found that for both young and older adults, vocabulary richness and grammatical complexity increased while socializing and during substantive conversations. These findings indicate that participants activated richer vocabulary and produced more complex grammar to communicate information in these social contexts. Moreover, for both young and older adults, vocabulary richness and grammatical complexity decreased during small talk. These findings suggest that small talk includes routine and probably repetitive information. Furthermore, young adults produced shorter clauses at work than not at work. Young adults may have been inexperienced at the workplace and thus grammatical complexity differed at work versus not.

Additionally, older adults used richer vocabulary and more complex grammatical structures than young adults at work; they also uttered richer vocabulary in small talk. Older adults may be more inclined to use formal language than young adults in professional settings or in small talks, e.g., greeting the others. In contrast, we found that young adults used richer vocabulary than older adults during non-socializing and non-working occasions, such as doing housework, watching TV, exercising, or commuting in a bus.

Although vocabulary richness and grammatical complexity have been shown to be associated with cognitive abilities in past cognitive aging studies (e.g., Cheung & Kemper, 1992), our findings indicate that age effects can vary depending on the contexts in real life. In other words, unlike in laboratory studies that are designed to test the upper limits of cognitive abilities (Baltes, et al., 1984), in real life, variations in language use are likely to be associated with not only age, but also social contexts.

In cognitive aging and gerontology research, behavior is conceptualized as determined by the interactions between personal characteristics and contexts (e.g., WHO, 2015; Verhaeghen, et al., 2012). Our findings offer evidence for the effects of context on vocabulary richness and grammatical complexity, in addition to age. This perspective is particularly useful when there is a growing interest in collecting “big data” and understanding cognitive behaviors in real life (e.g., Demiray, Mischler, & Martin, 2017; Demiray, Mehl & Martin, 2018; Luo, et al. under review).

Limitations and Future Work

Despite the novel approach that we contributed to the literature, this study has limitations. First, the small number of observations for working and small talk could have influenced statistical estimations. Although multilevel models adjusted for unbalanced data, it is still worthy to prolong the data collection period in future research to obtain more observations. Second, even though the models’ fit seemed passable (i.e., the residuals of the models’ estimation looked normal), the distributions of the linguistic measures were not bell-shape normal. Limited by the capacity of the lme4 package, we treated these variables as normal distributions. Future studies could use other estimation approaches, e.g., Bayesian method to estimate the linguistic measures. Third, we observed that language use varied across different social contexts and offered speculative explanation for different contextual effects. Future studies should try to incorporate momentary self-reports from participants to understand the subjective perceptions of participants during language use across different contexts. Fourth, this study included only young and old age groups. Future studies should include middle-aged adults to understand language use across the whole adult lifespan.

Conclusion

We contributed to the literature by using a novel approach to unobtrusively collect thousands of sound files in natural environments and by examining age effects on language use with a focus on context. We found that (1) social contexts had effects on language use; and (2) age effects on language use varied across social contexts. Our findings showed that both personal (i.e., age) and contextual factors (i.e., social contexts) are important determinants in the understanding of real-life language use. We offer a new perspective for understanding age effects on real-life language use, or more generally real-life behavior, in the context of cognitive changes with age.

Acknowledgments

This research was supported in part by Hedwig Widmer Stiftung awarded to Minxia Luo, and Velux Stiftung (Grant 917) awarded to Mike Martin. The authors declared no conflict of interest.

References

Adams, C., Smith, M. C., Pasupathi, M., & Vitolo, L. (2002). Social context effects on story recall in older and younger women: Does the listener make a difference? *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *57*(1), 28-40.

Baltes, P. B., Dittmann-Kohli, F., & Dixon, R. A. (1984). New perspectives on the development of intelligence in adulthood: Toward a dual-process conception and a model of selective optimization with compensation. In Baltes, P. B. & Brim, O. G. Jr. (Eds.), *Life-span development and behavior* (Vol. 6, pp. 33-76). Orlando, Florida: Academic Press, Inc.

Bickmore, T., & Cassell, J. (2001, March). Relational agents: a model and implementation of building user trust. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 396-403). ACM.

Bolger, N., & Laurenceau, J. P. (2013). *Intensive longitudinal methods*. New York, NY: The Guilford Press.

Burke, D. M., & Shafto, M. A. (2008). Language and aging. In Craik, F. I. M. & Salthouse, T. A. (Eds.), *The handbook of aging and cognition* (3th ed.) (pp. 373-443). New York, NY: Psychology Press.

Cameron, P. (1969). Frequency and kinds of words in various social settings, or what the hell's going on?. *Pacific Sociological Review*, *12*(2), 101-104.

Cheung, H., & Kemper, S. (1992). Competing complexity metrics and adults' production of complex sentences. *Applied Psycholinguistics*, *13*(1), 53-76.

Clark, H. H. (1996). *Using language*. New York, NY: Cambridge University Press.

Demiray, B., Mehl, M. R., & Martin, M. (2018). Conversational Time Travel: Evidence of a Retrospective Bias in Real Life Conversations. *Frontiers in Psychology*, *9*. Article 2160.

Demiray, B., Mischler, M., & Martin, M. (2017). Reminiscence in everyday conversations: a naturalistic observation study of older adults. *The Journals of Gerontology: Series B, 00*(00), 1–11.

Finkbeiner, R., Meibauer, J., & Schumacher, P. B. (Eds.). (2012). *What is a context?: linguistic approaches and challenges* (Vol. 196). John Benjamins Publishing.

Foth, K.A. (2005). *Eine umfassende Contraint-Dependenz-Grammatik des Deutschen*. University of Hamburg.

Gerstenberg, A., & Voeste, A. (Eds.). (2015). *Language development: The lifespan perspective* (Vol. 37). Amsterdam: John Benjamins Publishing Company.

Hamaker, E. L. (2012). Why researchers should think “within-person”: A paradigmatic rationale. In Mehl, M. R. & Conner, T.S. (Eds.), *Handbook of research methods for studying daily life* (pp. 43-61). New York, NY: The Guilford Press.

Hausser, J., & Strimmer, K. (2018). Estimation of Entropy, Mutual Information and Related Quantities. R package version 1.2.1. https://cran.r-project.org/web/packages/entropy/entropy.pdf.

Horton, W. S., Spieler, D. H., & Shriberg, E. (2010). A corpus analysis of patterns of age-related change in conversational speech. *Psychology and Aging*, *25*(3), 708-713.

Levinson, S. C. (1992). Activity types and language. In *Talk at work: Interaction in institutional settings* (pp. 66-100). Cambridge University Press.

Lewin, K. (1951). *Field theory in social science*. New York, NY: Harper & Brothers.

Luo, M., Demiray, B., Robbins, M. L., & Martin, M. (under review) *Real-life Language Use Across Different Interlocutors: A Naturalistic Observation Study of Adults Varying in Age*.

Mehl, M. R., Pennebaker, J. W., Crow, D. M., Dabbs, J., & Price, J. H. (2001). The Electronically Activated Recorder (EAR): A device for sampling naturalistic daily activities and conversations. *Behavior Research Methods*, *33*(4), 517-523.

Mehl, M. R., & Pennebaker, J. W. (2003). The sounds of social life: A psychometric analysis of students' daily social environments and natural conversations. *Journal of Personality and Social Psychology*, *84*(4), 857-870.

Mehl, M. R., Vazire, S., Holleran, S. E., & Clark, C. S. (2010). Eavesdropping on happiness: Well-being is related to having less small talk and more substantive conversations. *Psychological science*, *21*(4), 539-541.

Meylan, S., & Gahl, S. (2014, January). The divergent lexicon: Lexical overlap decreases with age in a large corpus of conversational speech. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 36, No. 36).

Michalke, M. (2018, March). *“Entschuldigen Sie, dass ich Ihnen einen komplizierten Artikel schreibe, für einen lesbaren habe ich keine Zeit” -- Textanalyse mit den R-Paketen koRpus & tm.plugin.koRpus*. Paper at the Tagung experimentell arbeitender Psychologen (TeaP), Marburg.

Moscoso del Prado Martín, F. (2016). Vocabulary, grammar, sex, and aging. *Cognitive Science*, *41*(4), 950-975.

Schmid, H. (1999). Improvements in part-of-speech tagging with an application to German. In *Natural language processing using very large corpora* (pp. 13-25). Springer, Dordrecht.

Sennrich, R., Schneider, G., Volk, M., & Warin, M. (2009). "A New Hybrid Dependency Parser for German". *From Form to Meaning: Processing Texts Automatically*. *Proceedings of the Biennial GSCL Conference 2009*, 115-124.

Singer, J. D., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence*. Oxford university press.

Verhaeghen, P., Martin, M., & Sędek, G. (2012). Reconnecting cognition in the lab and cognition in real life: The role of compensatory social and motivational factors in explaining how cognition ages in the wild. *Aging, Neuropsychology, and Cognition*, *19*(1-2), 1-12.

World Health Organization. (2015). *World report on ageing and health*. Geneva: WHO Press.