Language planning and pauses in story retell: evidence from aging and Parkinson's disease

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Key words: Parkinson's disease, language planning, language formulation, pause production, healthy aging, story retell

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ABSTRACT

We examined if and how pauses during connected speech reflect cognitive processes underlying language formulation in typical aging and Parkinson's disease (PD), beyond respiratory and motor-speech mechanisms. The frequency of silent pauses was measured (a) in relation to different linguistic (independent clausal, subordinate clausal, phrasal, and atypical) boundaries and (b) proficiency measures of language production in young adults, older adults, and individuals with PD. At the group level, aging, but not PD, resulted in increased pausing at atypical linguistic locations. However, in both aging and PD, individuals' reduced production of syntactically complex sentences was associated with more frequent pausing at various typical prosodic (clausal or phrasal) boundaries. Frequency of pauses was not associated with individual performance in grammaticality of sentences and lexical-semantic production. Overall, the present study demonstrated that production of pauses during connected speech reflects cognitive processes underlying language production beyond respiratory-physiological processes of communication. Assessing production of pauses in connected speech may augment, but does not replace, assessment of language production in clinical practice.

Keywords: Parkinson's disease; language planning; language formulation; pause production; healthy aging; story retell

Highlights

- Older adults produced pauses at atypical locations more frequently than young adults in extemporaneous speech.
- Individuals with PD showed similar distributions of silent pauses across linguistic boundaries as healthy older adults.
- In both aging and PD, frequent pauses in connected speech may reflect deficits in syntactic production.
- Pauses reflect cognitive processes of language formulation in aging and PD, beyond respiratory-motor control.

Introduction

One goal of a speaker is to produce relatively fluent and accurate utterances to convey a message. Although a speaker may have a general idea of what to say in utterances, the formulation of sentence structures and retrieval of lexical items proceed in an incremental, piecemeal manner, requiring intricate and timely coordination of planning what to say and the production of what is prepared. Thus, one central question in the study of language production has been how speakers allocate processing resources to efficiently coordinate planning and speaking. Experimental studies with young, healthy speakers revealed that the human language production system adapts to different scopes of planning to optimize the use of processing resources (Ferreira & Swets, 2002; Lee, Yoshida, & Thompson, 2015; Wagner, Jescheniak, & Schriefers, 2010). Speakers may plan utterances in smaller chunks (e.g., a single phrase) to minimally tax the pre-speech memory buffer (de Smedt, 1990; Gleitman, January, Nappa, & Trueswell, 2007; Griffin & Spieler, 2006; Kempen & Hoenkemp, 1987; Lee et al., 2015; Schriefers, Teruel, & Meinshausen, 1998). They may also plan utterances in larger chunks (e.g., a clausal boundary) to prevent unexpected difficulties during speech at the expense of increased demands on memory buffer (Ferreira, 2000; Ford, 1982; Ford & Holmes, 1978; Garret, 1988; Lindsley, 1975; Meyer, 1996). However, little is known about if and how individual differences in 'processing resources' affect the ways that speakers coordinate between planning and speaking. The present study focuses on the impact of aging and Parkinson's disease (PD) on production of pauses during a story retell task.

Converging evidence from healthy speakers suggests that pauses may reflect cognitive mechanisms underlying language production beyond the physiological mechanics of respiratory and motor speech control (e.g., Ford, 1982; Ford & Holms, 1978; Hammen & Yorkston, 1996; Huber, Darling, Francis, & Zhang, 2012; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991; Shah, Baum, and Dwivedi, 2006; Wang, Kent, Duffy, & Thomas, 2005). The locations of pauses often coincide with syntactic boundaries, although the two are not identical (Ferreira, 1993; Ford, 1982; Gee & Grosjean, 1983; Hammen & Yorkston, 1996; Huber et al., 2012). For example, healthy young adults tend to pause most frequently prior to production of a sentence (or an independent clause). However, they also pause at other syntactic locations such as subordinate clausal (e.g., *Mary preferred to take a taxi*; *He believes that Mary got there by a taxi*) and phrasal boundaries (e.g., *He went to the store in the morning*). Pauses at other locations such as within a phrase or word would be considered 'atypical' and occur less frequently than the pauses at the 'syntactic' locations. In addition, the ways that speakers produce pauses can be modulated by cognitive-linguistic demands of the linguistic material or task. For example, speakers produce increased pauses prior to producing words that are semantically or contextually less predictable or those with low frequency (Beattie & Butterworth, 1979; Horton, Spieler, & Shriberg, 2010; Goldman-Eisler, 1968; Griffin & Bock, 1998; Jescheniak & Levelt, 1994; see also Mack, Chandler, Meltzer-Asscher, Rogalski, Weintraub, Mesulam, & Thompson, 2015 for evidence in primary progressive aphasia). Also, Wang et al. (2010) found that 24-60 year-old healthy adults produced increased atypical pauses in an extemporaneous language production task compared to an oral reading of written passage.

Both respiratory-physiological and cognitive-linguistic changes occur in typical aging. However, little research is available on how aging influences production of pauses during language production. Older adults show reduced recoil pressure/chest wall compliance, decreased muscle mass, reduced vital capacity, increased reserve volume, and decreased lung volume excursion (Hoit & Hixon, 1987; Huber, 2008; Huber & Stathopoulos, 2015; Lalley, 2013). These respiratory physiological changes may cause older individuals to pause more frequently to compensate for respiratory differences (Huber et al., 2012). It is also well-known that older adults experience a reduction in cognitive processes such as working memory and inhibitory control, resulting in difficulty producing and comprehending complex sentences (Kemper, 1987; Kemper, Kynette, Rash, O'Brien, & Sprott, 1989; Caplan & Waters, 1999) and deficits in lexical retrieval (Burke & Shafto, 2004; LeGrane & Spieler, 2006; Nicholas, Obler, Albert, & Goodgrass, 1985). These cognitive changes in older adults may lead to use of different processing strategies during a complex linguistic task from that of younger adults (Stine, Cheung, & Henderson, 1995; Stine-Morrow, Soederberg Miller, & Hertzog, 2006; see also Horton et al., 2010). Stine and colleagues, for example, found that older adults process information in smaller chunks than young adults, using a self-paced, word-by-word moving window paradigm during silent reading of texts. Young adults spent extra reading time at major syntactic (sentential and clausal) boundaries, suggesting that they integrated information at larger syntactic units. Older adults were less likely to spend extra reading time at major syntactic boundaries than their young counterparts. Instead, they spent extra reading time at phrasal boundaries more frequently than young adults. The older adults' tendency to use smaller processing units was attributed to their reduced cognitive resources such as working memory. Hence, it is possible that healthy older adults pause more frequently at smaller linguistic units during language production compared to young adults.

With regard to PD, pauses have mostly been studied in relation to declines in respiratory-motor control for speech production. Changes to lung volume at speech initiation and termination have been reported in individuals with PD, resulting in shorter utterances per breath and greater work of breathing to support speech (Bunton, 2005; Huber & Darling, 2011; Huber & Stathopoulos, 2015; Sadagopan & Huber, 2007; Solomon & Hixon, 1993). Decreased coordination between speaking and breathing contributes to reduced speech intelligibility in PD (Hammen & Yorkston, 1996). Declines in higher-level cognitive skills such as working memory and inhibitory control are common in individuals with PD from a relatively early stage of the disease (Troche & Altmann, 2012 for review). Although the findings are not always consistent, deficits in language production have also been reported in PD, including reduced syntactic complexity, increased grammatical errors, reduced information content, and inefficiency in lexical retrieval and selection (Caplan & Waters, 1999; Copland, 2003; Dick et al., 2018; Grossman, Carvell, Gollomp, Stern, Reivich, Morrison, Alavi, & Hurtig, 1993; Lee, 2017; Longworth, Keenan, Barker, Marslen-Wilson, & Tyler, 200; Murray, 2000; Troche & Altmann, 2012).

Very few studies, however, have examined production of pauses in relation to language formulation in PD. Bunton (2005), examining the participants' lung volume use in spontaneous connected speech, found that individuals with PD paused at syntactic boundaries less frequently (50-71% of the time) than healthy older adults (75-87% of the time). However, no statistical analyses were performed in Bunton (2005). More relevant to the current study, Huber and colleagues (2012) investigated the effects of typical aging and PD on the relationship between breath pauses and syntax during oral reading of a written passage. Proportions of pauses were analyzed at three linguistic locations in young, older, and PD participants, including the major syntactic (sentential), the minor syntactic (subordinate clausal and phrasal), and the atypical linguistic boundaries. Older adults paused more frequently at minor syntactic boundaries and less frequently at major syntactic boundaries compared to young adults. These age-related differences in pause patterns were viewed as a result of respiratory rather than cognitive changes because older adults still predominately paused at typical syntactic boundaries. On the other hand, individuals with PD produced more pauses at atypical boundaries than did older adults, suggesting that changes in breath-pausing patterns in PD may indeed result from a combination of changes in respiratory physiology and cognition. Huber et al. (2012), however, used an oral reading task, which does not involve spontaneous language formulation. Thus, it needs to be examined whether the observed effects of aging and PD on the production of pauses still hold in an extemporaneous language production task.

Another question of interest is what specific language formulation difficulties are reflected in the pauses produced by older adults and participants with PD. In clinical practice, it is often presumed that increased pauses are indicative of some sort of reduced efficiency in language formulation including lexical-semantic or syntactic formulation deficits. However, most existing studies are devoted to the dichotomic division of ‘normal’ vs. ‘abnormal’ patterns of pause production between neurologically impaired and unimpaired individuals, failing to demonstrate if there are indeed a systematic relation between frequency of pauses and specific language formulation difficulties (Bunton, 2005; Huber, et al., 2012; Shah et al., 2006; Wang et al., 2005). We know of only one study by Mack and colleagues (2015) where pause rates were examined as an effect of different types of lexical retrieval deficits in primary progressive aphasia (PPA). They found that individuals with the logopenic PPA, whose object naming tends to be more impaired than action naming, produced more frequent pauses before nouns than verbs, whereas those with agrammatic and semantic variants of PPA produced similar pause rates between nouns and verbs. Although Mack et al. focused on aphasia (not PD or aging) and the processes of lexical retrieval, their findings still imply that it may be feasible to use pauses as a means to assess the degree and nature of an individual’s difficulties in language production.

The purpose of the present study was two-fold. The first aim was to examine if there are aging- and PD-related changes in pause production during an extemporaneous language production task, i.e., Cinderella story retell. We analyzed frequency of silent pauses at typical syntactic (independent clausal, subordinate clausal, phrasal) as well as atypical locations in speech samples of younger adults, older adults, and participants with PD (Ford & Holms, 1982; Huber et al., 2012; see also Ford, 1979). We included a group of young adults to compare with older adults in order to obtain more precise information on the effect of aging on pause production. We predicted that if age-related changes in pause production are associated with language formulation difficulties in addition to physiological mechanics, older adults would show increased pauses at atypical locations, compared to young adults. However, if pauses in older adults reflect only respiratory changes, older adults may show differences only at syntactic boundaries, but not at atypical locations, as shown in the older adults of Huber et al. (2012). For individuals with PD, we expected that they would continue to show increased pauses at atypical boundaries compared to older adults, with the group difference being greater than in Huber et al.'s study.

The second aim was to test if frequencies of syntactic and atypical pauses show correlations with individual variability in a set of clinical measures of language production and if so, what specific measure(s) show reliable correlations with pauses. To index individual proficiency in language production, we used four measures that are commonly used in clinical and research settings: proportion of grammatical sentences, clause density (number of embedded clauses/sentence), Noun: Verb ratio, and percent correct information units (% CIUs). It was reasoned that identifying the presence and nature of the correlations will inform clinical practice as it relates to assessment of pauses in the context of language production.

Methods

Participants. A total of 49 participants were tested: 15 young adults (YA), 18 older adults (OA) and 16 individuals with PD. The YA group was included to compare with the OA group to test for the effect of aging. The participants had to produce at least 10 silent pauses in their Cinderella story in order to be included for data analyses. This excluded one older adult and one participant with PD from data analyses because they produced 4 and 5 silent pauses, respectively. Participants' demographic data are presented in

Table 1. Older adults had more years of education than young adults (*t* (30) = 2.91, *p* < .01). Individuals with PD and older adults were matched for age (*t* (30) = .347, *p* = .731) and education (*t* (30) = .001, *p* = .999). None of the participants had a history of neurological or psychological conditions that could affect speech and language other than PD. The average amount of time since diagnosis of PD was 7.2 years (SD = 3.7), and all participants with PD were tested while they were taking PD-related medications (see Table 2 for specific medications). All participants were monolingual native speakers of American English and passed a pure-tone hearing screening at 500, 1000, and 2000Hz at 40 dB in at least one ear. No participants reported visual deficits. This study was approved through Purdue University's Institutional Review Board, and informed consent was obtained from all participants.

The Cognitive-Linguistic Quick Test (CLQT, Helm-Estabrooks, 2001) was used to screen the cognitive skills of all participants (see Table 1). All healthy young and older adults had to score normal Clinical Severity Rating (CRS) of 3.8 or higher for age norms in order to be included in the study. Participants with PD had to score no less than mild CRS scores on the CLQT to ensure that none presented signs of dementia. Subdomain scores of the CLQT were compared between the groups using a set of one-way ANOVA's. Group effects were found for Attention (*F* (2, 46) = 7.98, *p* = .001), Executive Functions (*F* (2, 46) = 16.04, *p* < .001), and Visuospatial Skills (*F* (2, 46) = 10.83, *p* < .001), but not for the domains of Memory (*F* (2, 46) = .87, *p* = .423) or Language (*F* (2, 46) =2.80, *p* = .071). Older adults showed significantly lower scores on these three domains, compared to young adults (Attention: *t* (30) = -3.466; Executive functions: *t* (30) = -4.053; Visuospatial skills: *t* (30) = -4.177, *p*'s <. 01). The PD group did not statistically differ from older adults in any domain (Attention: *t* (30) = -1.018; Executive functions: *t* (30) = -1.762; Visuospatial skills: *t* (30) = -.856, *p*'s >.05).

A set of additional speech-language tests were administered for older adults and participants with PD, as shown in Table 2. The participants' ability to repeat words and sentences with increasing length and complexity was examined using the Repetition subsection of the Western Aphasia Battery-Revised (WAB-R, Kertesz, 2006). Participants with PD showed greater impairment in repetition than healthy older adults (*t* (30) = -2.26, *p* = .031), in line with the results from Troche & Altmann (2012). Action naming was examined

Table 1. Each participant group's demographic data and performance on the Cognitive-Linguistic Quick Test (with means and standard deviations).

Variables	YA (n=15)	OA (n=17)	PD (n=15)
Age	21 (2.2)	68 (2.7)	69 (6.2)
Education (years)	14 (1.5)	17 (2.7)	17 (2.8)
Gender	9F, 6M	9 F, 8 M	7 F, 8 M
Cognitive-Linguistic Quick Test			
Attention (max 215)	207.3 (5.5)	194.7 (12.3)	189.9 (16.7)
Memory (max 185)	173.8 (11.1)	169.5 (9.6)	168.6 (14.2)
Executive function (max 40)	35.9 (2.5)	31.0 (3.9)	28.5 (4.4)
Language (max 37)	34.7 (2.1)	34.3 (2.1)	32.9 (2.5)
Visuospatial (max 105)	100.5 (3.4)	90.7 (8.2)	88.1 (10.0)
Clinical Severity Rating (max 4)	4.0 (0.1)	4.0 (0.1)	3.9 (0.2)

using the Verb Naming Test of the Northwestern Assessment of Verbs and Sentences (NAVS, Thompson, 2011). Participants with PD showed significantly reduced retrieval of single verbs from action-related pictures, compared to the healthy older adults (t (30) = -2.92, p = .007) in line with previous studies showing impaired verb retrieval in PD (Péran et al., 2003; Piatt et al., 1999).

Lastly, a severity rating of the participants' speech production was conducted by three raters who had a Master's degree in speech-pathology with specialized experience in motor speech disorders, and were blind to the purpose of the study. For each of the PD and healthy older participants, a representative speech sample (20 secs in duration) was clipped from the audio recordings of their Cinderella story retell. The speech samples were presented to each rater via a headset in a randomized order. The rater was asked to judge the severity of the participants' speech impairments by marking on a 150-millimeter line, with one end being 'normal' and the other being 'very severe'. Raters listened to each sample once. The distance from the ‘normal’ end to the raters’ mark was measured in millimeters and converted to percentages (of the total line distance). The higher values indicate greater speech impairment. Participants with PD presented significantly greater speech impairment compared to healthy older adults (t (30) = 56.50, $p < .001$).

Materials & Procedures. A Cinderella story retell task was used to elicit extemporaneous narrative speech samples from the participants. Participants were given a wordless picture book depicting the story of Cinderella and asked to look through it. The book was then taken away and participants were instructed to tell the story of Cinderella. Praat was used to record the participants’ utterances (Boersma & Weenink, 2015). If needed, only general feedback was provided during the task such as “can you tell me more,” or “you’re doing fine.”

Data Analysis. All speech samples were transcribed verbatim and segmented into individual utterances based on linguistic and prosodic cues, following the Northwestern Narrative Language Analysis (NNLA; Thompson, 2013). Then, pause and linguistic analyses of each sample were conducted as described below.

For the analysis of pauses, silent pauses in the speech samples were identified using spectrogram and acoustic analyses in Praat (Boersma & Weenink, 2015). A pause was determined as any segment of non-speech of 150 milliseconds or longer. Once all the pauses were identified, the pauses were tallied based on their locations in utterances following previous studies (Ford, 1982; Ferreira, 1993; Huber et al., 2012): (a) independent clausal boundaries, (b) subordinate clausal boundaries, (c) phrasal boundaries, and (d) atypical boundaries.

Pauses at an independent clausal boundary occurred between sentences or between conjoined independent clauses (e.g., *Cinderella lived at home with a stepmother and stepsisters. [pause] They made her clean; Stepsisters hated Cinderella [pause] and they made her do all the work around the house*). An utterance was considered as a ‘sentence’ when at least a subject noun and a main verb was produced (e.g., *Cinderella cried*). Pauses at subordinate clausal boundaries occurred at finite (e.g., *Cinderella was upset [pause] that she couldn’t go to the ball*) or non-finite subordinate clauses (e.g., *The stepmother asked Cinderella [pause] to clean up the house*). Pauses at phrasal boundaries included a pause following a lexical

Table 2. Language testing results for older adults and participants with PD and PD-specific demographics

Group	Time since Diagnosis (years)	PD-related medications	WAB-R Repetition (10)	NAVS Verb Naming (%)	Speech Severity Rating (%)
Participants with PD					
PD1	2.7	Azilect, Pramipexole	10	82	3
PD2	3.3	Azilect	10	77	9
PD3	8.6	Carbidopa-Levadopa, Mirapex, Comtan	10	96	18
PD4	10	Mirapex	9.4	82	11
PD5	6	Carbidopa-Levadopa, Neupro	8.4	64	15
PD6	1.7	Pramipexole	10	100	13
PD7	11	Sinemet, Sinemet ER	10	91	27
PD8	4.5	Carbidopa-Levadopa, Ropinirole	9.8	96	21
PD9	11.7	Comtan, Sinemet, Mirapex	9.8	86	11
PD10	6	Ropinirole, Selegiline	9.2	77	18
PD11	7	Carbidopa-Levadopa, Trihexyphenidyl	9.8	91	9
PD12	8.5	Carbidopa-Levadopa, Ropinirole HCL	9.4	96	13
PD13	11	Carbidopa-Levadopa	10	96	27
PD14	1	Carbidopa-Levadopa	9.4	96	3
PD15	11	Sinemet, Mirapex, Amantadine	9.4	96	28
Mean			**9.6**	**88.4**	**15.1**
SD			**0.4**	**10.1**	**8.1**
Healthy Older Adults					
OA1	n/a	n/a	10	100	7
OA2	n/a	n/a	10	100	6
OA3	n/a	n/a	10	100	5
OA4	n/a	n/a	10	96	12
OA5	n/a	n/a	10	82	3

OA6	n/a	n/a	10	86	8
OA7	n/a	n/a	9.8	100	4
OA8	n/a	n/a	10	100	0
OA9	n/a	n/a	9.8	100	10
OA10	n/a	n/a	10	96	2
OA11	n/a	n/a	9.4	100	2
OA12	n/a	n/a	10	91	3
OA13	n/a	n/a	10	100	8
OA14	n/a	n/a	10	96	18
OA15	n/a	n/a	9.6	96	1
OA16	n/a	n/a	10	100	6
OA17	n/a	n/a	9.8	100	6
Mean			**9.9**	**96.6**	**5.9**
SD			**0.2**	**5.4**	**4.5**

subject noun phrase (NP) and prior to a predicate (*The prince [pause] danced with Cinderella)* and pauses occurring in a listing of three or more NP's that constitute a conjoined NP (e.g., *Fairy godmother gave Cinderella a beautiful dress [pause], a nice carriage, [pause] and a pair of shoes*). Pauses at phrasal boundaries also included a pause occurring before or after a prepositional or adverbial phrase that serves an adjunct in the sentence (e.g., *Cinderella goes to the ball [pause] in a beautiful gown*; *All of sudden [pause] the fairy godmother appears*). We excluded pauses following a pronominal subject NP (e.g., *She [pause] went to the ball*) from the phrasal boundaries and categorized them as occurring at 'atypical' boundaries. Because pronominal subjects are monosyllabic and unstressed, they form a prosodic phrase together with the predicate and speakers do not normally pause after a pronominal subject (Huber et al., 2012; Ferreira, 1993). Similarly, a phrase that is a complement to a head or semantically bound to a head as a 'colloquial' expression (e.g., *Cinderella goes to the ball; Cinderella got to dance with a prince*) was not considered as a typical phrasal boundary for pausing. The rest of the pauses were also considered as those occurring in the locations that are 'atypical' linguistic boundaries such as a pause occurring within a phrase (e.g., *Her [pause] foot fit in the slipper*) or a word (e.g., *step [pause] sisters*).

Pauses were measured by a group of trained student researchers including the third and fourth authors (JJ and JF). The third and fourth authors then tallied the pauses according to the four linguistic boundaries described above. Any discrepancy was resolved through discussions with the first author. To examine inter-measurer reliability for pause analysis, a set of 15 speech samples (30% of the total samples; 5 young adults, 5 older adults, and 5 participants with PD) were randomly selected for re-measurement of pauses. The inter-measurer comparisons revealed the mean 94% pause-by-pause agreement in the selected samples (Pearson $r = .997$, $p < .001$, 2-tailed).

For linguistic analysis, each utterance from each participant was linguistically analyzed to obtain four measures of interest: proportion of grammatically correct sentences, clausal density (mean number of embedded clauses/sentence), Noun:Verb ratio, and percent correct information units (% CIUs) (NNLA; Thompson, 2013; Nicholas & Brookshire, 1993). The proportion of grammatically correct sentences was calculated by dividing the total number grammatically accurate sentences by total number of sentences produced. The mean number of embedded clauses per sentence (clause density) was calculated for each participant by dividing the total number of embedded clauses (e.g., complement clauses, relative clauses, adjunct clauses, etc.) with the total number of sentences produced. For the Noun: Verb ratio, only lexical nouns and verbs were included. Copular and auxiliary verbs and pronouns were not included in the measure. A higher Noun:Verb ratio indicates greater production of nouns compared to verbs. As a measure of information content in connected speech production, % CIUs was computed for each participant by computing the proportion of accurate and relevant words out of the total number of words produced (Nicholas & Brookshire, 1993). In addition, we computed broader language measures including the mean length of utterances in words (MLU word) and the total number of sentences produced by each participant to ensure that the three groups produced comparable length and number of sentences in their Cinderella stories.

Linguistic analyses, including utterance transcription, segmentation, and language coding, were completed by the third and fourth authors, who were graduate students with training in the NNLA protocol. During the training phase, these authors established a minimum of 95% accuracy based on a set of Cinderella story practice samples provided in the NNLA manual (Thompson, 2013). No reliability measure was completed on the linguistic analyses. Rather, point-by-point differences between the two coders were resolved through the discussions with the first author for all samples.

Results

Measures of language production. A summary of language measures is provided in Table 3. The exploratory data analyses (Tukey, 1977) conducted for each group for each language measure revealed that there was only one outlier in the measure of clause density. This data point was replaced with the group mean for further statistical analyses. No outliers were noted on the remaining language measures and there were no missing data. Variances were equal across the three groups on all three measures except for the measure of clause density (Levene's test, $p < .05$). Therefore, the statistical results for the clause density were corrected using the Brown-Forsythe test for the unequal variances across the groups.

No significant group effects were found for MLU in words (F (2, 44) = 2.566, p = .089) or for total number of sentences produced (F (2, 44) = 3.031, p = .058), suggesting that the three groups produced similar length of utterances and numbers of sentences in their Cinderella stories. The analyses for the language measures of interest revealed that the three groups were not reliably different from each other in their production of grammatical sentences (F (2, 44) = 2.55, p = .096). The groups did not differ in the clausal density (F (2, 23.56) = .891, p = .424, adjusted for unequal variances using Brown-Forsythe test) or in the mean Noun: Verb ratios (F (2, 44) = .128, p = .880). Lastly, for % CIUs, the group effect did not reach significance, although participants with PD showed numerically reduced % CIUs (F (2, 44) = 3.006, p = .072).

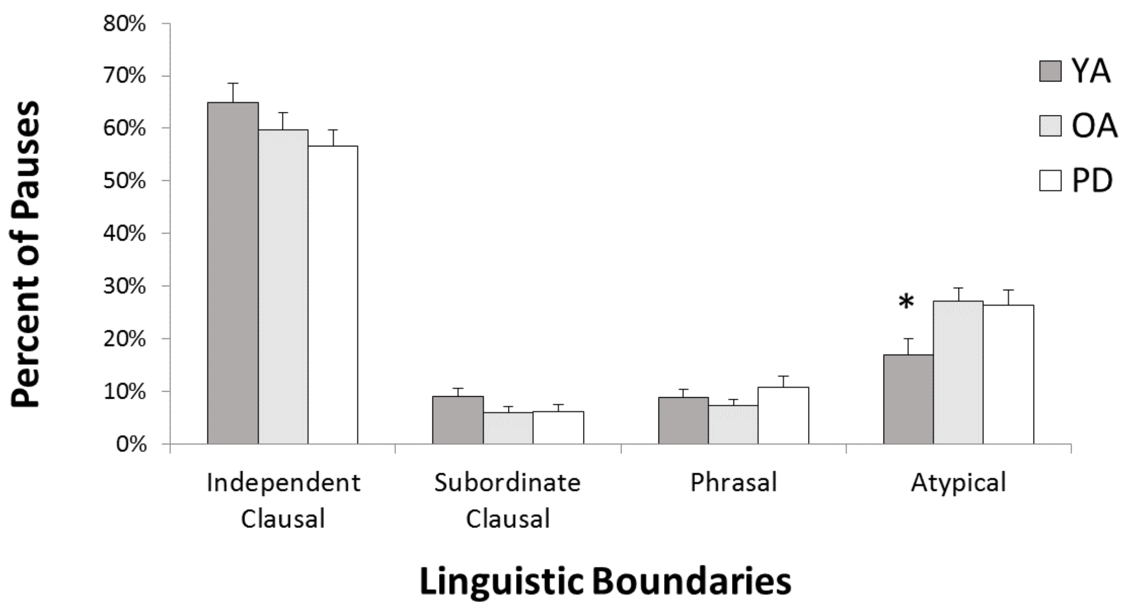
Table 3. Clinical measures of proficiency in language production for each group.

Language measures	Young	Older	PD
Mean Length of Utterance (MLU) in Words	12.39 (2.63)	10.84 (2.12)	10.69 (2.08)
Total Number of sentences	15.66 (8.14)	24.88 (14.14)	19.80 (7.68)
% grammatical sentences	91.15 (9.30)	93.55 (7.65)	86.38 (11.28)
Clause density	.67 (.42)	.55 (.13)	.64(.21)
Noun: Verb (N/V) ratio	1.15 (.28)	1.17 (.27)	1.12 (.20)
% Correct Information Units (CIUs)	82.69 % (7.50)	82.35% (7.49)	76.06 % (10.90)

Production of pauses at linguistic boundaries. The three participant groups produced comparable total numbers of pauses in their Cinderella stories (young: M (SD) = 26 (13); older: 36 (20); PD: 31 (12) pauses; F (2, 44) = 1.648, p = .204). To test group effects on the relative distribution of pauses across the different boundary types, we computed proportions of pauses at each linguistic boundary for each participant by dividing the number of pauses at a given linguistic boundary with a total number of pauses occurred in the sample (Bunton, 2005; Huber et al., 2012; Wang et al., 2010). Figure 1 shows mean proportions of pauses produced at each linguistic boundary for the participant groups. The exploratory data analyses (Tukey, 1977) revealed that there were no outliers. Variances were equal across the three groups on all pause types (Levene's tests, p 's >.05). One-way ANOVA was conducted for each linguistic boundary. When a group effect was significant, independent samples t-tests were conducted to compare young vs. older adults and older vs. PD adults, with the alpha level corrected for multiple comparisons (alpha = .025 (0.05/2)).

The ANOVA results showed no significant group effect for the pauses produced at the syntactic boundaries (independent clausal: F (2, 44) = 1.639, p =.206; subordinate clausal: F (2, 44) = 1.835, p = .172; phrasal: F (2, 44) = .737, p =.484). These results indicate neither typical aging nor PD impacted speakers' production of pauses at the syntactic locations during Cinderella story retell. However, there was a significant group effect for the pauses produced at atypical locations (F (2, 44) = 4.159, p = .022). Older adults produced significantly more frequent pauses at atypical locations than young adults (27% vs. 17 %; t (30) = 2.689, p = .012). However, the effect of PD was not reliable: PD participants did not differ from older adults in their production of pauses at atypical locations (26% vs. 27%, t (20) = -.299, p = .767).

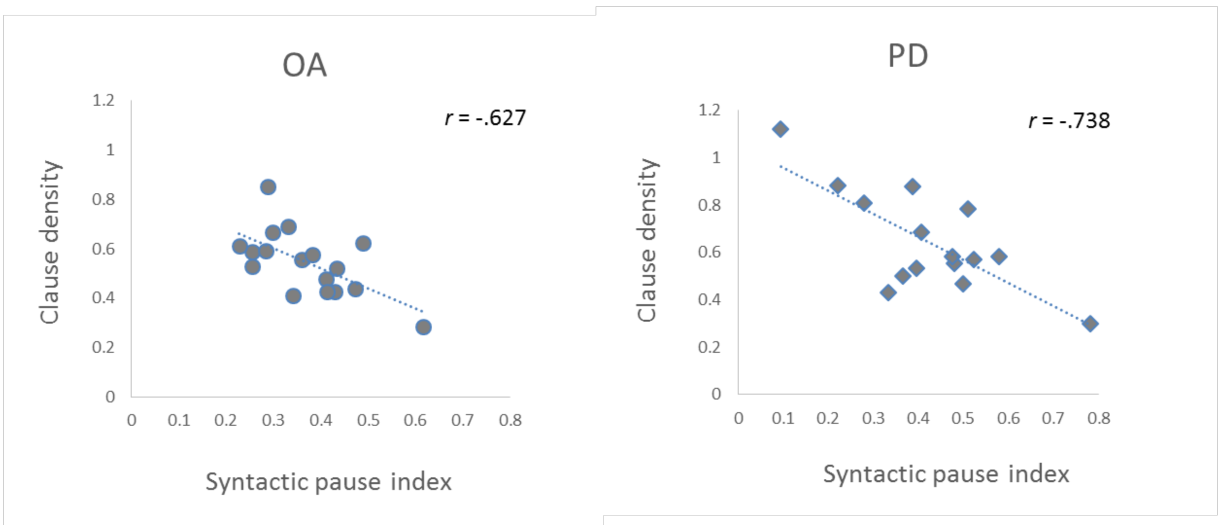
Figure 1. Mean percent of pauses (with standard errors) produced at different linguistic locations for each participant group (* p = .012; significant difference between YA and OA).



Correlation between pauses and language measures. To enter into correlation analyses, we computed the two pause measures for each participant, the syntactic and atypical pause indices, and adjusted for individual variability in the total number of syntactic boundaries and utterances produced in their Cinderella stories. The *syntactic pause index* was computed by dividing the actual number of pauses produced by the total number of possible syntactic (independent clausal, subordinate clausal, and phrasal) boundaries in the Cinderella story of a given participant, where a pause could occur. We computed a single measure of syntactic pause index across the three different syntactic boundaries, because the three groups' pause patterns did not differ across the different syntactic boundary types (as shown above) and due to the lack of theoretical coherence to predict different correlation patterns for the boundary types. The *atypical pause index* was computed by dividing the total number of atypical pauses produced by the total number of utterances for each participant. Because atypical pauses can occur at any 'non-syntactic' location (e.g., within a word, within a phrase), it is difficult to determine the locations where a pause could occur. Thus, we adjusted this pause variable according to the number of utterances produced for each participant, instead of specific types of asyntactic locations. Each type of the pause indices was then correlated with the four clinical measures of language proficiency within each group, using 2-tailed Pearson correlations. The alpha level of 0.0125 (.05/4, Bonferroni) was adjusted for multiple correlations.

For young adults, neither syntactic nor atypical pause indices showed significant correlations with the measures of language proficiency (typical: $-.225 < r$'s $< .323$, p's $> .241$; atypical: $-.182 < r$'s $< .410$, p's $>.128$). For older adults, however, their syntactic pause index showed a significant negative correlation with the measure of clause density or the mean number of embedded clauses per sentence (Figure 2; $r = -.627$, $p = .007$). This indicates that the older adults who paused more frequently at syntactic boundaries in their Cinderella story tended to produce syntactically simpler sentences. The rest of the correlations were not statistically significant for both types of pause indices (syntactic pauses: $-.046 < r$'s $< .476$, p's $> .053$; atypical pauses: $.174 < r$'s $< .409$, p's $> .103$). Parallel findings were noted for participants with PD: their syntactic pauses were negatively correlated with clause density (Figure 2; $r = -.738$, $p = .002$). No other correlations were significant (syntactic pauses: -.078 < *r*’s < .577; *p*’s > .023; atypical pauses: -.219 < *r*’s < .395, *p*’s > .145).

Figure 2. Significant correlations between syntactic pause index and clause density in healthy older adults and participants with PD. No significant correlation was found for healthy young adults.



Discussion

This study examined the impact of aging and PD on how speakers coordinate pauses and language formulation in a Cinderella story retell task. The central question was whether or not pauses produced during connected speech are reflective of cognitive changes underlying language formulation in typical aging and PD. Frequency in production of pauses in young adults, older adults, and participants with PD was measured as an effect of different linguistic (independent clausal, subordinate clausal, phrasal, and atypical) locations to examine whether the groups differ in their ‘allocation’ of pauses. In addition, we examined if and how individuals’ frequency of syntactic and atypical pauses show reliable correlations with proficiency in measures of language production for the purpose of informing clinical practice.

With regard to the effect of aging, our older adults paused more frequently at atypical locations compared to young adults, in line with our prediction. However, the two groups did not differ in their pause production at the typical syntactic locations, including independent clausal, subordinate clausal, and phrasal boundaries. In Huber et al. (2012), the effect of aging was significant only in smaller syntactic (subordinate clausal and phrasal) boundaries, but not at major syntactic (independent clausal) or atypical boundaries. Based on their results, it was postulated that age-related changes in pause production during speech is respiratory in nature, not cognitive-linguistic. Our findings are in line with Huber et al. (2012) in that older adults tend to pause at smaller linguistic units more often than young adults. However, the smaller linguistic units in which they paused more frequently were atypical linguistic locations such as within a phrase (e.g., *Her [pause] feet was too big*). These results suggest that age-related effects on pause production, at least in part, reflect cognitive changes. However, the present study used an extemporaneous production task, rather than an oral reading task, and measured all silent pauses, not just breath pauses which differed from the design of Huber et al. Thus, it is possible that age-related changes in coordination between pauses and language formulation might have been revealed more clearly in the present study. This highlights the importance of considering task demands (Wang et al., 2005) and the types of pauses when studying the relationship between pauses and language formulation. The current results also reveal that increased production of pauses at atypical locations such as pauses within a phrase or word can be a part of normal aging; thus, they do not necessarily reflect pathological changes.

Notably, increased pauses at atypical linguistic boundaries in our older adults were observed in the absence of age-related reduction on the measures of language production. Older adults showed similar performance to young adults on grammaticality, clause density, lexical retrieval, and information content in their Cinderella stories (see Table 3). One speculation is that older adults may have allocated processing resources differently from their younger counterparts in response to age-related limitations in cognitive-linguistic processes (Horton et al., 2010; Stine et al., 1995; Stine-Morrow et al., 2006). Specifically, our older adults might have compromised the naturalness of pause production while devoting larger amounts of resources to maximizing linguistic complexity and content of their message within the constraints of reduced processing resources. As a result, they might have been forced to pause at syntactically inappropriate locations more frequently.

Interestingly, the participants with PD did not differ from their age- and education-matched healthy older adults in terms of distribution of silent pauses across linguistic boundaries. Different from our prediction, they did not produce more atypical pauses compared to older adults and the ways that they allocated location and frequency of pausing was quite similar to those seen in healthy older adults. Although they showed worse performance on some language production measures (lower % CIUs, fewer grammatical sentences) compared to older adults, the group differences did not reach statistical significance. This lack of PD-induced changes on the distribution of pauses is at odds with previous studies, in which their participants with PD produced more breath pauses at atypical linguistic boundaries (Huber et al., 2012) or a trend of reduced pausing at syntactic boundaries (Bunton, 2005). Participants in the current study may have been more mildly affected than those in earlier studies such that the cognitive or respiratory changes in our participants with PD were not substantial enough to be detected in the Cinderella story retell task. This null result could also be because we focused on only one disfluency measure: silent pauses. Other forms of disfluencies such as filled pauses or mazes might be more sensitive measures of the disease in the context of extemporaneous language production (see Alvar, Lee, & Huber, in press for evidence of abnormal production of filled pauses in mild PD, for example). Further research is needed to more clearly delineate the influence of these factors on pause production.

With regard to our second aim, the correlation results revealed that increased frequency of pauses in typical aging and PD are associated with reduced efficiency in language production, specifically reduced syntactic complexity of sentences. Both older adults and participants with PD showed a negative correlation between the clause density and syntactic pause index, indicating that those who produced fewer embedded clauses in the sentence tended to pause more frequently at various syntactic (clausal or phrasal) boundaries. The strength of the correlation was slightly larger for the participants with PD ($r = -.738$, $p = .002$) compared to older adults ($r = -.627$, $p = .007$; also see Figure 2). This pattern of correlation was not significant in young adults, indicating that the results in older adults and participants with PD are most likely due to their cognitive-linguistic changes, rather than the experimental design. The negative correlations between increased syntactic pauses and clause density in our older adults and participants with PD might have been driven by the participants' pausing more frequently at sentential boundaries due to their increased production of simpler and shorter independent clauses. They could also be attributed to the participants' pausing more frequently at phrasal boundaries because of increased production of adjunct phrases or a listing of multiple phrases in the sentence. More data are needed to determine what contributed to individuals' relative use of these strategies. Additionally, none of the groups showed significant correlations between pauses and the rest of the language measures (% grammatical sentences, Noun:Verb ratio, and % CIUs). This further suggests that frequency of pauses at typical prosodic boundaries may only be reflective of syntactic complexity of speech, but they are not reliably associated with cognitive processes supporting local grammatical computations (e.g., production of verb inflection) and lexical-semantic content of their utterances.

Collectively, the current findings suggest that observation of distribution and frequency of pauses in connected speech can be used to augment, but not to replace, language assessment in geriatric populations. Atypical pauses increase with aging; thus, increased pauses at atypical prosodic boundaries in neurologically impaired individuals may not always reflect pathological changes and may be, in part, due to aging. At the individual level, increased frequency of pausing at typical prosodic boundaries may be indicative of their reduced proficiency in language formulation processes, specifically difficulty constructing syntactically complex sentences. However, given that only one of the four clinical measures of language production showed a reliable correlation with frequency of the pauses, it is important to administer a detailed language assessment to diagnose the specific nature of language formulation difficulties in clinical practice.

Limitations of the present study include that we did not control for the participants' familiarity with the Cinderella story, thus, we cannot completely rule out the possibility that different degrees of story familiarity might have influenced the results. It is also possible that since our measures of language production were quite broad, they might have not been sensitive enough to detect PD-specific changes on the relation between pauses and language formulation. This study should be replicated with more severe cases of PD and different measures of language production and disfluencies.

In conclusion, the present study conducted a systematic investigation of the impact of aging and PD on the relation between pauses and language formulation in a Cinderella story retell task with the goal of providing implications on how differences in speakers' cognitive resources interact with language planning processes. Aging resulted in increased pausing at atypical linguistic locations. In both aging and PD, individuals' reduced proficiency in production of syntactically complex sentences was associated with increased pauses at various typical prosodic boundaries. Frequency of pauses was not associated with individual performance in grammaticality and lexical-semantic production. Overall, the present study has revealed that production of pauses during connected speech reflects cognitive processes underlying language production beyond respiratory-physiological processes in aging and PD. Assessing production of pauses in connected speech may augment, but does not replace, assessment of language production in clinical practice.

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