Research Note

Effects of a Cycling Dual Task on Emotional Word Choice in Parkinson's Disease

Audrey A. Hazamy,^a Sara A. Horne,^b Michael S. Okun,^{c,d}
Chris J. Hass,^{d,e} and Lori J. P. Altmann^{b,d}

Purpose: Individuals with Parkinson's disease (PD) demonstrate language- and emotion-related impairments; however, emotional language production has received little attention within the literature despite the fact that deficits could significantly impact one's daily interactions with loved ones and others. Multitasking (i.e., dual tasking), specifically while completing language tasks, is a common everyday occurrence and typically impacts performance on 1 or both tasks. This study compared emotional word use during discourse production in individuals with PD and healthy older adults (HOAs) under single- and dual-task conditions.

Method: Participants completed a discourse task while sitting in a quiet room and while stationary cycling. Discourse output was analyzed along several emotional and intellectual language dimensions obtained from the Linguistic

Inquiry and Word Count program (Pennebaker, Booth, & Francis, 2007).

Results: Groups did not differ on any outcome measure in the single-task condition. However, HOAs produced a higher percentage of words associated with affective processes and positive emotion while completing the dual-task condition, whereas the PD group exhibited a decrease in production of these words. Compared to the single-task condition, during cycling, individuals with PD also produced a lower percentage of inhibition-related words.

Conclusions: These results suggest that cycling, like other types of exercise, improves mood as manifested in discourse word choice in HOAs; however, it may lead to reduced use of emotional words in individuals with PD. Expressing emotion may also be more difficult in those with PD than in HOAs and, therefore, easily disrupted in distracting circumstances.

Depletion of dopaminergic neurons in the substantia nigra pars compacta contributes to the cardinal motor impairments of Parkinson's disease (PD) including tremor, rigidity, and bradykinesia. However, dopamine depletion can have far-reaching effects beyond motor deficits. The axons from the substantia nigra pars

compacta, ventral tegmental area, and hypothalamus form the mesocortical, mesolimbic, nigrostriatal, and tuberoinfundibular pathways, which mediate several nonmotor symptoms of PD including changes to cognition (Chaudhuri & Schapira, 2009) and emotion (Péron, Dondaine, Le Jeune, Grandjean, & Vérin, 2012). Other neural circuits also degenerate in PD, a process that contributes to both motor and nonmotor deficits in this disease.

There is long-standing evidence that persons with PD demonstrate difficulties in the processing and production of nonlinguistic emotional cues (for a systematic review, see Péron et al., 2012). For instance, researchers document impairments in categorizing (Dara, Monetta, & Pell, 2008; Pell & Leonard, 2003), rating (Pell & Leonard, 2003), and producing emotional prosody (Borod et al., 1990) in individuals with PD. Deficits have also been noted to extend to the recognition (Borod et al., 1990; Dujardin et al., 2004) and production (Smith, Smith, & Ellgring, 1996) of emotional faces and even to reduced psychophysiological reactivity in response to aversive emotional pictures (Bowers et al.,

^aDepartment of Speech Communication Arts and Sciences, Brooklyn College, NY

^bDepartment of Speech, Language, and Hearing Sciences, University of Florida, Gainesville

^cDepartment of Neurology, University of Florida, Gainesville

^dFixel Center for Neurological Diseases, Movement Disorders and Neurorestoration Program, University of Florida, Gainesville

^eDepartment of Applied Physiology and Kinesiology, University of Florida, Gainesville

Correspondence to Audrey A. Hazamy:
audrey.hazamy68@brooklyn.cuny.edu

Editor-in-Chief: Sean Redmond
Editor: Carl Coelho

Received October 25, 2018

Revision received February 7, 2019

Accepted February 25, 2019

https://doi.org/10.1044/2019_JSLHR-L-18-0428

Disclosure: The authors have declared that no competing interests existed at the time of publication.

2006). However, explorations into whether emotional deficits impact language remain relatively sparse.

There is growing evidence of non emotional-based language impairments in PD that impact word, sentence, and discourse levels of processing (Murray, 2008). For example, research demonstrates that persons with PD have difficulty with comprehension of grammatically complex sentences and processing of information that is ambiguous or inferential in nature (Murray, 2008). From an expression standpoint, numerous deficits are noted, particularly during high-level (i.e., sentence and discourse) language tasks (for a review, see Altmann & Troche, 2011). For instance, Murray (2000) documents the production of smaller proportions of grammatical and informative utterances in persons with PD compared to controls during picture description tasks. Deficits in fluency (e.g., pauses, false starts; Illes, Metter, Hanson, & Iritani, 1988; Troche & Altmann, 2012) and information completeness (Troche & Altmann, 2012) during various language production tasks are also of note. Additionally, there are also reports of possible syntactic deficits in production; however, these findings are mixed (Altmann & Troche, 2011). Importantly, studies also document that cognitive changes (e.g., working memory and executive functions) may exacerbate the aforementioned impairments in language production in persons with PD (e.g., Altmann & Troche, 2011).

Despite growing support for both language- and emotion-based deficits in this population, few studies have examined the possible impact of the disease on emotional language, and those that do provide contradictory results. Borg et al. (2012) identify deficits in emotional language processing during an explicit emotional word categorization task simultaneous with intact implicit emotional language processing in a lexical decision task. Similarly, Hillier, Beversdorf, Raymer, Williamson, and Heilman (2007) report that persons with PD have blunted ratings of emotional words. Specifically, they report that ratings of emotional words are more neutral in persons with PD than those of control subjects for words expressing both positive and negative emotions. However, Kan, Kawamura, Hasegawa, Mochizuki, and Nakamura (2002) observe no deficits in persons with PD in the categorization of emotional sentences. Thus, deficits in emotional language processing, if they exist in PD, may be task dependent. Interestingly, one study that examined emotional language production asserts that, compared to controls, individuals with PD produce more words when describing emotional, highly arousing negative events (Crucian et al., 2001). The authors interpret these results as a possible facilitation effect, such that the emotional nature of the stimuli promotes verbal emotional expression in this population. However, that same result may ensue if participants with PD have difficulty accessing emotional words and concepts, and, consequently, produce more circumlocutions when discussing emotional topics.

A crucial element of maintaining social relationships is the ability to effectively communicate one's emotional wants, needs, and ideas and to understand those of others. Emotional communication may take place via multiple

channels (e.g., prosody, facial, linguistic); however, as discussed prior, persons with PD have documented non-linguistic emotional processing and production impairments. Language production could potentially be useful in compensating for these deficits if emotional language use is intact. Thus, understanding whether, and to what extent, emotional language production is also impacted in PD is imperative to appreciating how emotional deficits may affect the quality of a patient's daily interactions.

The Current Study

Performing simultaneous tasks, "dual tasking," is a common occurrence in everyday life (e.g., walking and talking), and researchers often utilize dual-task paradigms to explore multitasking abilities. Dual tasking often leads to decrements in performance in one or both tasks compared to baseline (e.g., Verhaeghen, Steitz, Sliwinski, & Cerella, 2003), and persons with PD typically demonstrate greater susceptibility to these effects than healthy older adults (HOAs; e.g., O'Shea, Morris, & Ianssek, 2002). However, research within the acute exercise literature reports enhancement of performance in some cognitive abilities (e.g. working memory, information processing) in healthy adults specifically during concurrent cycling (e.g., Audiffren, Tomporowski, & Zagrodnik, 2008; Lambourne & Tomporowski, 2010; Tomporowski, 2003). Furthermore, we have recently reported dual-task benefits on cycling performance during a range of cognitive tasks in both HOAs and persons with PD, whereas cognitive performance during cycling either improves or remains stable (Altmann et al., 2015, 2016; Hazamy et al., 2017). In Hazamy et al. (2017), we report facilitation effects in select tasks assessing the cognitive domains of processing speed, controlled processing, working memory, and executive functions during a cycling dual-task compared to single-task performance. We noted this dual-task facilitation in response times in visual tasks across cognitive domains and improved verbal recall during an executive function task. Importantly, these effects were noted in both groups, despite the PD group demonstrating impairment in some tasks compared to controls, and in the absence of a significant decrement in cycling speed compared to baseline. The differential effects of various motor tasks on secondary task completion may be attributed to differences in task demands. For instance, it has been suggested that lower amounts of attentional resources are needed during cycling compared to other motor tasks such as walking (Lambourne & Tomporowski, 2010).

Language allows a person to reliably and effectively externalize their inner thoughts and feelings. Studies note that language use, across a number of dimensions, may differ as a function of variables such as age, gender, and even health (e.g., Mulac, Bradac, & Gibbons, 2001; Pennebaker, Mehl, & Niederhoffer, 2003). Using discourse data collected during a recent project (Altmann et al., 2016), the current study investigates language use, specifically affective and intellectual words, during discourse production in persons

with PD and HOAs under single-task conditions and during a concurrent motor task (i.e., cycling).

The current study addresses three hypotheses.

1. Individuals with PD will utilize fewer emotional words during baseline, single-task discourse compared to HOAs. Given the extent of impairments in persons with PD in emotional, nonlinguistic domains (e.g., prosody, faces), deficits are also expected to impact emotional language.
2. Deficits apparent in the single-task condition will be minimized during cycling. This prediction is based on the aforementioned benefits specifically associated with dual-task cycling (Altmann et al., 2015; Hazamy et al., 2017; Lambourne & Tomporowski, 2010).
3. If cycling ameliorates some of the cognitive effects of PD, these changes will be reflected in their discourse during the dual task.

Method

Participants

Thirty-eight individuals with PD (31 men, 7 women) were recruited from the Center for Movement Disorders and Neurorestoration in Gainesville, Florida, and 21 HOAs (six men, 15 women) were recruited from the surrounding Gainesville community. Thirty patients with PD presented with asymmetric symptoms (15 right-dominant, 15 left-dominant), and seven showed symmetry in their presentation. One patient could not be classified due to missing data (Unified Parkinson's Disease Rating Scale; Goetz et al., 2008). As designed, groups differed in age such that persons with PD ($M = 65.45$, $SD = 9.95$) were younger than HOAs ($M = 72.74$, $SD = 9.33$), $F(1, 57) = 6.820$, $p = .012$, $\eta_p^2 = .107$. This was done to better match overall level of cognition, as individuals with PD generally have reduced cognitive abilities compared to age-matched peers (e.g., Aarsland, Andersen, Larsen, & Lolk, 2003; Dirnberger & Jahanshahi, 2013). Group data were collected concurrently, and groups were matched on education and overall cognition as assessed by the Dementia Rating Scale-2 (Jurica, Leitten, & Mattis, 2001). In addition, participants completed several measures of mood, including the Apathy Evaluation Scale (Marin, Biedrzycki, & Firinciogullari, 1991) and the Beck Depression Inventory-II (Beck, Steer, & Brown, 1996; see Table 1 for detailed participant descriptors).

Inclusion criteria for participants with PD were as follows: (a) a clinical diagnosis of idiopathic PD according to the UK Brain Bank criteria, as confirmed by movement disorders neurologists, (b) a modified Hoehn and Yahr scale score between 1 and 3 in the "on" medication state (Hoehn & Yahr, 1967), and (c) a stable response to anti-parkinsonian and/or psychotropic medications. Exclusion criteria for the PD group included the following: (a) evidence of secondary or atypical parkinsonism, (b) presence of significant motor fluctuations, or (c) history of significant falls

as indicated by a score of > 1 in the fall item of the revised Unified Parkinson's Disease Rating Scale (Goetz et al., 2008).

Individuals from either group were excluded on the basis of the following: (a) presence of significant cognitive impairment (e.g., Mini-Mental State Examination score < 25 ; Folstein, Folstein, & McHugh, 1975) or major psychiatric disorder (e.g., major depression, generalized anxiety) that would cause difficulty in study participation, (b) taking moderate to high doses of beta-blockers with a resting heart rate below 60 beats per minute, (c) taking medications known to interfere with cognitive function, or (d) history of significant falls. Participants in the PD group were tested in the "on" medication state and were asked to take their medications 1 hr before each testing session. All participants had normal or corrected-to-normal vision. All participants signed an informed consent approved by the Institutional Review Board of the University of Florida.

Procedure

As part of a larger battery (Altmann et al., 2016), all participants completed a 3-min discourse task while sitting in a quiet room (single task) and while stationary cycling (dual task). Order of single and dual tasks was counter-balanced across participants. During single-task testing, the experiment was conducted using a Dell Latitude E6510 series laptop with a 15.6-in. widescreen display and a 1,280 $\times$ 800 resolution. The task was run using MediaLab software (Version 2006.2.40; Jarvis, 2006a) running DirectRT software (Version 2006.2.0.28; Jarvis, 2006b). During the dual task, instructions and prompts were projected from the laptop onto a backlit projection screen. Participants were tested in a quiet environment with minimal ambient noise. Participants wore a wireless headset microphone (Sennheiser Electronic GmbH & Co. KG) during both single- and dual-task sessions. Microphone sensitivity was calibrated for each participant individually prior to commencement of each testing session to ensure optimal voice recording. All responses were recorded by the computer for later transcription.

To obtain single-task cycling rates, participants were told to peddle at a comfortable pace for 2 min before beginning dual-task testing. During the dual-task session, participants performed the discourse task while simultaneously pedaling on a stationary bicycle located approximately 4 m from a projection screen. Participants were instructed to cycle at a comfortable, self-paced cadence during the task but not to cycle while the experimenter was explaining task instructions or during response preparation. After instructing participants to begin pedaling immediately before beginning their response, no additional instructions were provided regarding cycling. Heart rates were monitored at all times. The cycling task provided minimal resistance to cycling movement. Cycling rate was captured using a 10-camera motion capture system (Vicon Motion Capture System).

In each condition, participants responded to one of four prompts. Initial prompts were randomly assigned by subject and by which task condition (i.e., single or dual)

Table 1. Participant descriptive information.

Measure	PD (SD)	HOAs (SD)	<i>p</i>	Range
<i>N</i>	38	21		
Age	65.45 (9.95)	72.74 (9.33)	.01*	46–89
Education (years)	17.45 (3.97)	18.42 (2.01)	.495	10–28
DRS-2 (maximum: 145)	139.42 (4.84)	141.63 (1.77)	.098	120–145
BDI-II	5.63 (5.13)	3.58 (4.02)	.105	0–17
AES	8.95 (5.87)	8.32 (2.58)	.576	0–19
UPDRS ^a	34.04 (10.69)			15–53
H&Y ^b	2.14 (0.58)			1–3

Note. PD = individuals with Parkinson's disease; HOAs = healthy older adults; DRS-2 = Dementia Rating Scale–2; BDI-II = Beck Depression Inventory–II; AES = Apathy Evaluation Scale; UPDRS = Unified Parkinson's Disease Rating Scale; H&Y = Hoehn and Yahr scale. Asterisk indicates significance.

^aThe Movement Disorders Society revised UPDRS (Goetz et al., 2008) is a scale of PD severity based on nonmotor experiences of daily living, activities of daily living, motor performance, and motor complications due to pharmacological treatment. ^bH&Y (Hoehn & Yahr, 1967) is a clinical rating scale that defines categories of motor function in PD.

was first; subsequent discourse prompts followed in the same sequence for all participants. As this study was part of a larger study examining the effects of exercise on cognition in PD (Altmann et al., 2016), four different prompts were utilized to prevent repetition during subsequent posttesting. The discourse prompts are the following:

1. “Please tell me about a person who had an important impact on your life.”
2. “What do you think was the most important event of the last 100 years?”
3. “Please tell me about a vacation or event from your past that you remember well.”
4. “What do you think is the most important invention of the last 100 years?”

Participants were given as much time as needed to think about their responses before speaking; however, once participants began speaking, all narratives were terminated at 3 min. Discourse responses were orthographically transcribed by five trained research assistants and mazed according to Systematic Analysis of Language Transcripts (Miller & Iglesias, 2012) protocols. Mazed words (e.g., filler words, grammatical errors) were excluded from the transcripts before submitting them to the Linguistic Inquiry and Word Count (LIWC) program (Version LIWC2007; Pennebaker, Booth, & Francis, 2007) for analysis. Interrater reliability for discourse transcription procedures was completed on 16% of the transcripts. Reliability for total number of mazed words and number of nonmazed words submitted to the LIWC was good (both Cronbach's α s > .92).

Computerized text analysis programs use word count and keyword indexing to analyze text. The LIWC program was developed to analyze various psychological and structural components present in verbal and written language samples. The default LIWC2007 dictionary is composed of 4,500 words and word stems. Eighty subdictionaries, or categories, represent groups of dictionary words that tap

a particular concept (e.g., positive emotion words). Words may be part of multiple categories; for instance, cried is part of five categories (i.e., sadness, negative emotion, overall affect, verb, and past tense verb). The application reads a submitted text file one word at a time. As each word is processed, if it is matched to a dictionary word, it will be ascribed to its associated category/categories. The output variables are expressed as a percentage of total words in a given passage (for more details on the LIWC application including a list of categories, see Tausczik & Pennebaker, 2010, and Pennebaker, Boyd, Jordan, & Blackburn, 2007). The program has been utilized in numerous studies across a variety of fields including studies that have analyzed linguistic complexity in the discourse of persons with PD (Holtgraves, McNamara, Cappaert, & Durso, 2010). Furthermore, research demonstrates that the program accurately identifies emotion in language use (Kahn, Tobin, Massey, & Anderson, 2007; Tausczik & Pennebaker, 2010), and program ratings of positive and negative emotional words during discourse have been reported to correspond with those of human raters (Alpers et al., 2005). Table 2 provides examples of the categories within the emotional and intellectual language dimensions of interest here.

Table 2. Linguistic Inquiry and Word Count language dimensions of interest and examples.

Category	Examples
Emotional language dimension	
Positive emotion	love, nice, sweet
Negative emotion	hurt, ugly, nasty
Affective processes	happy, cried, abandoned
Intellectual language dimension	
Perceptual processes	see, touch, listen
Causation	because, effect, hence
Inhibition	block, constrain, stop
Motion	walk, move, go

Data Analysis

All statistical testing was completed using repeated-measures analyses of covariance in which group was the between-subjects variable and task (i.e., single, dual) was the within-subject variable. As participants responded to a different question at each session, the question topic was covaried to account for possible differences in the prompts. Age was also entered as a covariate as the two groups differed in age. All statistical analyses were evaluated at $\alpha < .05$ and corrected for multiple comparisons via Bonferroni adjustment. Variables of interest within the emotional language dimension were evaluated at $p < .017$, and variables within the intellectual language dimension were evaluated at $p < .013$. Explorations of all significant group-related interactions were explored via planned pairwise comparisons. Reported effect sizes for partial eta squared (η_p^2) are benchmarked according to the following criteria: .01 as small, .06 as medium, and .14 as large (Cohen, 1969; Richardson, 2011).

Results

There was a main effect of group on cycling such that HOAs ($M = 55.38$, $SD = 15.31$) cycled faster than persons with PD ($M = 48.14$, $SD = 11.43$), $F(1, 52) = 10.073$, $p = .003$, $\eta_p^2 = .162$, but neither the task effect ($p = .432$) nor the interaction was significant ($p = .312$). There were no significant main or interaction effects of overall word count (all $F_s < 3.116$, all $p_s > .083$). Table 3 displays the group by dual-task means for word count as well as the emotional and intellectual domain variables (discussed separately below).

Emotional Language Dimensions

Analyses revealed a significant Group $\times$ Task interaction in affective words, $F(1, 54) = 6.647$, $p = .013$, $\eta_p^2 = .110$. Pairwise comparisons revealed that, during the dual task, HOAs ($M = 4.05$, $SD = 1.85$) produced a significantly higher percentage of affective words than people with PD

($M = 3.13$, $SD = 1.06$), $p = .013$, $\eta_p^2 = .109$; however, groups did not differ during the single task (HOAs: $M = 3.28$, $SD = 1.80$; PD: $M = 3.78$, $SD = 1.44$), $p = .320$, $\eta_p^2 = .018$. Regarding positive emotion words, again, group interacted with task, $F(1, 54) = 6.175$, $p = .016$, $\eta_p^2 = .103$. Planned pairwise comparisons revealed that HOAs ($M = 3.34$, $SD = 1.70$) produced a significantly higher percentage of positive emotion words in the dual task than people with PD ($M = 2.44$, $SD = 1.05$), $p = .013$, $\eta_p^2 = .108$. Groups did not significantly differ during the single task (HOAs: $M = 2.51$, $SD = 1.46$; PD: $M = 2.85$, $SD = 1.02$), $p = .516$, $\eta_p^2 = .008$. No other individual comparisons (i.e., group or task) or interactions were significant (all $F_s < 2.024$, all $p_s > .161$).

Intellectual Language Dimensions

Analysis revealed a significant Group $\times$ Task interaction for inhibition-related words, $F(1, 54) = 7.361$, $p = .009$, $\eta_p^2 = .120$. Pairwise comparisons revealed that persons with PD produced a significantly lower percentage of inhibition-related words in the dual task ($M = 0.24$, $SD = 0.29$) than in the single task ($M = 0.44$, $SD = 0.42$), $p = .006$, $\eta_p^2 = .130$. While HOAs used a slightly higher percentage of words expressing inhibition in the dual task ($M = 0.37$, $SD = 0.36$) than the single task ($M = 0.25$, $SD = 0.31$), this effect was not significant, $p = .172$, $\eta_p^2 = .034$. No other analyses of the intellectual language dimension variables yielded significant results (all $F_s < 1.124$, all $p_s > .294$).

Discussion

This study examined emotional language production in persons with PD and HOAs during single- and dual-task conditions based on lexical analyses provided by the LIWC program (Pennebaker, Booth et al., 2007). Findings suggest that there may be altered cognitive and emotional states in both groups during the cycling dual task.

Table 3. Group by dual-task condition means and standard deviations.

Outcome measure	PD ($n = 38$)		HOA ($n = 21$)	
	Single	Dual	Single	Dual
Word count	389.05 (88.15)	373.21 (107.30)	401.24 (73.95)	416.95 (74.57)
Emotional language dimension				
Affective processes ^a	3.78 (1.44)	3.13 (1.06)	3.28 (1.80)	4.05 (1.85)
Positive emotion ^a	2.85 (1.02)	2.44 (1.05)	2.51 (1.46)	3.34 (1.70)
Negative emotion	0.89 (0.89)	0.68 (0.54)	0.58 (1.21)	0.69 (0.61)
Intellectual language dimension				
Perceptual processes	1.10 (0.88)	1.67 (1.22)	0.98 (0.72)	1.67 (1.26)
Causation	1.76 (1.19)	1.67 (1.36)	1.69 (0.97)	1.59 (1.27)
Inhibition ^a	0.44 (0.42)	0.24 (0.29)	0.25 (0.31)	0.37 (0.36)
Motion	2.27 (1.30)	3.08 (1.45)	2.06 (1.44)	2.55 (1.45)

Note. Language dimension variables are expressed as percentage of total words in a transcript. PD = individuals with Parkinson's disease; HOA = healthy older adult.

^aSignificant Group $\times$ Task interaction: $p < .017$ for emotional language dimension variables and $p < .0125$ for intellectual language dimension variables.

Emotional Language Dimensions

Inconsistent with our hypothesis, individuals with PD did not exhibit deficits in emotional language production during single-task discourse. In fact, there were no differences in any group comparisons in the single-task condition. Moreover, the prediction that individuals with PD would produce similar numbers of emotional words in the cycling dual task compared to HOAs was not realized. In fact, the cycling dual task had opposite effects on the two groups. HOAs produced a slightly higher percentage of words associated with affective processes and positive emotion while cycling; however, the PD group included a lower percentage of affective and positive emotion words during cycling. These findings are consistent with previous literature on the effects of exercise in HOAs, which has found that acute exercise is associated with improved mood in older adults (Hogan, Mata, & Carstensen, 2013). The current findings expand upon this and suggest that improved mood in HOAs through acute exercise may manifest itself in discourse word choice as well. In contrast, the PD group did not show these increases in affective and, particularly, positive emotion words in the dual task. There are at least two potential explanations for this phenomenon that are not mutually exclusive.

First, the drop in emotional language use by individuals with PD during the cycling dual task may be rooted in the disease process itself, coupled with arousal effects associated with dual tasking. According to Braak, Ghebremedhin, Rüb, Bratzke, and Del Tredici (2004), the limbic system, which comprises structures essential for the processing and production of emotion, begins to degenerate very early in the disease. This damage may be a source of emotional production deficits in people with PD, making it difficult for alternative, nonpharmacological methods of improving mood, such as exercise, to impact emotional expression in discourse. Importantly, deficits in emotional language production were not observed during the single task but emerged with the addition of the cycling dual task. This suggests that maintaining normal emotional language production may be more effortful for people with PD and, thus, may suffer when cognitive resources are divided. Discourse production, in general, places high demands on various aspects of cognition especially in older adults and those with PD (Altmann, 2016; Altmann & Troche, 2011). If accessing and using affective and, especially, positive affect words is slightly more difficult than accessing other words for people with PD, then the addition of the cycling dual task may have limited resources available for lexical activation, leading to faster access of more neutral words that also fit the intended message.

The theoretical basis for this reasoning, the arousal and attentional demands model of dual-task performance, is introduced in Altmann et al. (2015). The arousal and attentional demands model of dual-task performance posits that changes in attentional resources associated with cognitive and/or psychological arousal may differentially affect performance on one or both tasks depending on the relationship

between available resources and combined task demands. According to this model, performance on both tasks will be maintained if an increase in attentional resources, due to increased arousal, matches the demands of the combined dual tasks. Dual-task costs appear when additional exercise-related arousal does not provide enough resources to maintain performance levels in both tasks. In the current study, dual-task interactions may be evidenced by maintained cycling speed in persons with PD but decline in most word types, specifically significant declines in emotional word use during cycling. Indeed, participants with PD are only able to maintain performance commensurate with HOAs when resources are not divided. Therefore, the additional stress or demands of the dual task may overburden an already highly taxed language production system. This could lead to difficulties activating emotions associated with events and opinions discussed in the prompts or in timely access of emotional words in individuals with PD when dual-task demands outweigh additional resources associated with arousal.

Intellectual Language Dimensions

Consistent with our third prediction that cycling may ameliorate some of the cognitive effects of PD as reflected in word choice during discourse, individuals with PD produced a significantly lower percentage of inhibition-related words during the dual task than the single task. Interestingly, the reverse pattern was noted in HOAs, though it was not significant. At first glance, these results may seem beneficial for persons with PD; however, as the groups did not differ at baseline, these results become more difficult to interpret. They may reflect a dual-task blunting of executive inhibitory processes, as revealed in language use. Executive dysfunction characterized by deficits in inhibitory control, among other abilities, is seen early in PD (e.g., Dirnberger & Jahanshahi, 2013). Thus, although executive dysfunction reflected in discourse may not have been evident in individuals with PD during the single task, the additional demands of the dual task may have resulted in disinhibited thought processes, resulting in the production of a lower percentage of words associated with inhibition. However, as particularly small percentages of inhibition-related words were elicited overall (i.e., < 0.5% across groups and tasks), these results in particular require further exploration.

Limitations

Several limitations are of note. The duration of time between the initial presentation of the discourse prompt and the signaling by the participant that they were ready to begin the task was not formally tracked. Although, anecdotally, experimenters report that the time rarely exceeded 30 s, it is possible that differences in discourse planning time may have influenced results and should be considered in future studies. Second, unequal group size and the older age of the HOA group may have masked additional findings. Third, there was considerable variability in the prompts used to elicit discourse with one tapping declarative

memory of historical events, one tapping world knowledge, and two focusing on autobiographical memory. Although the prompt variable was covaried, this may have significantly impacted the results. Furthermore, language is contextually dependent, and researchers note that linguistic markers of psychological processes can vary by communication context (e.g., Mehl, Robbins, & Holleran, 2012). The narrative elicitation prompts utilized here did not specifically target the emotional or intellectual domains of interest. Future studies should thus choose more homogeneous prompts that are more contextually appropriate. Additionally, production of emotions during language use may vary between males and females (e.g., Mulac et al., 2001). The proportion of males and females varied considerably between groups in the current study, making this analysis untenable. Future studies examining emotional processing deficits in PD may find this a fruitful line of research. Finally, cycling as a dual task has elicited differential results on motor speed and cognition than typical dual tasks using walking, for example; thus, it is possible that the results elicited from a cycling dual task are specific to cycling and may be very different in more commonly utilized dual tasks (Altmann et al., 2015; Lambourne & Tomporowski, 2010).

Conclusion

The results of this study suggest that exercise, specifically cycling, may have divergent effects on emotional expression in the discourse of individuals with PD and HOAs. There were reductions in the percentage of words signifying positive emotions and overall emotional processes in the group with PD, but only in the dual task. At the same time, the production of these words in HOAs increased in the dual task, though not significantly. Therefore, individuals with PD may experience difficulty expressing affect in discourse during exercise and perhaps in other dual-task situations. In addition to documented impairments in non-linguistic emotion expression, difficulty in expressing emotion linguistically, particularly when resources are divided, may thus adversely impact the quality of daily interactions with loved ones and others. Additionally, the group with PD produced a lower percentage of words associated with inhibition during the dual task, suggesting that participation in a cycling dual task possibly resulted in reduced inhibitory thought processes. In summary, these findings suggest that cycling exercise may have differential effects on linguistic expression in HOAs and individuals with PD.

Acknowledgments

This research note was supported by Grant R21AG0033284-1A2 from the National Institute on Aging at the National Institutes of Health, awarded to Lori Altmann and Chris Hass. We would like to thank the members of the Language over the Lifespan lab, the Applied Neuromechanics lab, and the Center for Neurorestoration and Movement Disorders at the University of Florida for their help and support with this project. This project was also supported by the National Parkinson Foundation Center of Excellence located at the University of Florida.

References

- Aarsland, D., Andersen, K., Larsen, J. P., & Lolk, A. (2003). Prevalence and characteristics of dementia in parkinson disease: An 8-year prospective study. *Archives of Neurology*, 60(3), 387–392. <https://doi.org/10.1001/archneur.60.3.387>
- Alpers, G. W., Winzelberg, A. J., Classen, C., Roberts, H., Dev, P., Koopman, C., & Barr Taylor, C. (2005). Evaluation of computerized text analysis in an internet breast cancer support group. *Computers in Human Behavior*, 21(2), 361–376. <https://doi.org/10.1016/j.chb.2004.02.008>
- Altmann, L. J. P. (2016). Language, discourse production and communication. In N. A. Pachana (Ed.), *Encyclopedia of geropsychology*. Singapore: Springer. Retrieved from https://doi.org/10.1007/978-981-287-080-3_222-1
- Altmann, L. J. P., Stegemöller, E., Hazamy, A. A., Wilson, J. P., Bowers, D., Okun, M. S., & Hass, C. J. (2016). Aerobic exercise improves mood, cognition, and language function in Parkinson's disease: Results of a controlled study. *Journal of the International Neuropsychological Society*, 22(9), 878–889. <https://doi.org/10.1017/S135561771600076X>
- Altmann, L. J. P., Stegemöller, E., Hazamy, A. A., Wilson, J. P., Okun, M. S., McFarland, N. R., . . . Hass, C. J. (2015). Unexpected dual task benefits on cycling in Parkinson disease and healthy adults: A neuro-behavioral model. *PLOS ONE*, 10(5), e0125470. <https://doi.org/10.1371/journal.pone.0125470>
- Altmann, L. J. P., & Troche, M. S. (2011). High-level language production in Parkinson's disease: A review. *Parkinson's Disease*, 2011, Article ID 238956. <https://doi.org/10.4061/2011/238956>
- Audiffren, M., Tomporowski, P. D., & Zagrodnik, J. (2008). Acute aerobic exercise and information processing: Energizing motor processes during a choice reaction time task. *Acta Psychologica*, 129(3), 410–419. <https://doi.org/10.1016/j.actpsy.2008.09.006>
- Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: The Psychological Corporation.
- Borg, C., Bedoin, N., Bogey, S., Michael, G. A., Poujois, A., Laurent, B., & Thomas-Antérion, C. (2012). Implicit and explicit emotional processing in Parkinson's disease. *Journal of Clinical and Experimental Neuropsychology*, 34(3), 289–296. <https://doi.org/10.1080/13803395.2011.639296>
- Borod, J. C., Welkowitz, J., Alpert, M., Brozgold, A. Z., Martin, C., Peselow, E., & Diller, L. (1990). Parameters of emotional processing in neuropsychiatric disorders: Conceptual issues and a battery of tests. *Journal of Communication Disorders*, 23(4–5), 247–271.
- Bowers, D., Miller, K., Mikos, A., Kirsch-Darrow, L., Springer, U., Fernandez, H., & Okun, M. (2006). Startling facts about emotion in Parkinson's disease: Blunted reactivity to aversive stimuli. *Brain*, 129(12), 3356–3365. <https://doi.org/10.1093/brain/awl301>
- Braak, H., Ghebremedhin, E., Rüb, U., Bratzke, H., & Del Tredici, K. (2004). Stages in the development of Parkinson's disease-related pathology. *Cell and Tissue Research Journal*, 318(1), 121–134. <https://doi.org/10.1007/s00441-004-0956-9>
- Chaudhuri, K. R., & Schapira, A. H. (2009). Non-motor symptoms of Parkinson's disease: Dopaminergic pathophysiology and treatment. *The Lancet Neurology*, 8(5), 464–474. [https://doi.org/10.1016/S1474-4422\(09\)70068-7](https://doi.org/10.1016/S1474-4422(09)70068-7)
- Cohen, J. (1969). *Statistical power analysis for the behavioural sciences*. New York, NY: Academic Press.
- Crucian, G. P., Huang, L., Barrett, A. M., Schwartz, R. L., Cibula, J. E., Anderson, J. M., . . . Heilman, K. M. (2001). Emotional conversations in Parkinson's disease. *Neurology*, 56(2), 159–165. <https://doi.org/10.1212/WNL.56.2.159>

- Dara, C., Monetta, L., & Pell, M. D. (2008). Vocal emotion processing in Parkinson's disease: Reduced sensitivity to negative emotions. *Brain Research*, 1188, 100–111. <https://doi.org/10.1016/j.brainres.2007.10.034>
- Dirnberger, G., & Jahanshahi, M. (2013). Executive dysfunction in Parkinson's disease: A review. *Journal of Neuropsychology*, 7(2), 193–224. <https://doi.org/10.1111/jnp.12028>
- Dujardin, K., Blairy, S., Defebvre, L., Duhem, S., Noël, Y., Hess, U., & Destée, A. (2004). Deficits in decoding emotional facial expressions in Parkinson's disease. *Neuropsychologia*, 42(2), 239–250. [https://doi.org/10.1016/S0028-3932\(03\)00154-4](https://doi.org/10.1016/S0028-3932(03)00154-4)
- Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-Mental State: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, 12(3), 189–198. [https://doi.org/10.1016/0022-3956\(75\)90026-6](https://doi.org/10.1016/0022-3956(75)90026-6)
- Goetz, C. G., Tilley, B. C., Shaftman, S. R., Stebbins, G. T., Fahn, S., Martinez-Martin, P., . . . LaPelle, N. (2008). Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results. *Movement Disorders*, 23(15), 2129–2170. <https://doi.org/10.1002/mds.22340>
- Hazamy, A. A., Altmann, L. J. P., Stegemöller, E., Bowers, D., Lee, H. K., Wilson, J., . . . Hass, C. J. (2017). Improved cognition while cycling in Parkinson's disease patients and healthy adults. *Brain and Cognition*, 113, 23–31. <https://doi.org/10.1016/j.bandc.2017.01.002>
- Hillier, A., Beversdorf, D. Q., Raymer, A. M., Williamson, D. J. G., & Heilman, K. M. (2007). Abnormal emotional word ratings in Parkinson's disease. *Neurocase*, 13(2), 81–85. <https://doi.org/10.1080/13554790701300500>
- Hoehn, M. M., & Yahr, M. D. (1967). Parkinsonism: Onset, progression and mortality. *Neurology*, 17(5), 427–442.
- Hogan, C. L., Mata, J., & Carstensen, L. L. (2013). Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychology and Aging*, 28(2), 587–594. <https://doi.org/10.1037%2Fa0032634>
- Holtgraves, T., McNamara, P., Cappaert, K., & Durso, R. (2010). Linguistic correlates of asymmetric motor symptom severity in Parkinson's disease. *Brain and Cognition*, 72(2), 189–196. <https://doi.org/10.1016/j.bandc.2009.08.004>
- Illes, J., Metter, E. J., Hanson, W. R., & Iritani, S. (1988). Language production in Parkinson's disease: Acoustic and linguistic considerations. *Brain and Language*, 33(1), 146–160.
- Jarvis, B. G. (2006a). DirectRT (Version 2006.2.028). New York, NY: Empirisoft.
- Jarvis, B. G. (2006b). MediaLab (Version 2006.2.40). New York, NY: Empirisoft.
- Jurica, S. J., Leitten, C. L., & Mattis, S. (2001). *Dementia rating scale: Professional manual*. Odessa, FL: Psychological Assessment Resources.
- Kahn, J. H., Tobin, R. M., Massey, A. E., & Anderson, J. A. (2007). Measuring emotional expression with the Linguistic Inquiry and Word Count. *American Journal of Psychology*, 120, 263–286.
- Kan, Y., Kawamura, M., Hasegawa, Y., Mochizuki, S., & Nakamura, K. (2002). Recognition of emotion from facial, prosodic and written verbal stimuli in Parkinson's disease. *Cortex*, 38(4), 623–630. [https://doi.org/10.1016/S0010-9452\(08\)70026-1](https://doi.org/10.1016/S0010-9452(08)70026-1)
- Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research*, 1341, 12–24. <https://doi.org/10.1016/j.brainres.2010.03.091>
- Marin, R. S., Biedrzycki, R. C., & Firinciogullari, S. (1991). Reliability and validity of the Apathy Evaluation Scale. *Psychiatry Research*, 38(2), 143–162.
- Mehl, M. R., Robbins, M. L., & Holleran, S. E. (2012). How taking a word for a word can be problematic: Context-dependent linguistic markers of extraversion and neuroticism. *Journal of Methods and Measurement in the Social Sciences*, 3(2), 30–50.
- Miller, J., & Iglesias, A. (2012). Systematic Analysis of Language Transcripts (Research Version 2012) [Computer software]. Middleton, WI: SALT Software.
- Mulac, A., Bradac, J. J., & Gibbons, P. (2001). Empirical support for the gender-as-culture hypothesis: An intercultural analysis of male/female language differences. *Human Communication Research*, 27(1), 121–152. <https://doi.org/10.1111/j.1468-2958.2001.tb00778.x>
- Murray, L. L. (2000). Spoken language production in Huntington's and Parkinson's diseases. *Journal of Speech, Language, and Hearing Research*, 43(6), 1350–1366. <https://doi.org/10.1044/jslhr.4306.1350>
- Murray, L. L. (2008). Language and Parkinson's disease. *Annual Review of Applied Linguistics*, 28, 113–127. <https://doi.org/10.1017/S0267190508080100>
- O'Shea, S., Morris, M. E., & Ianssek, R. (2002). Dual task interference during gait in people with Parkinson disease: Effects of motor versus cognitive secondary tasks. *Physical Therapy*, 82(9), 888–897. <https://doi.org/10.1093/ptj/82.9.888>
- Pennebaker, J. W., Booth, R. J., & Francis, M. E. (2007). *Linguistic Inquiry and Word Count: LIWC2007*. Austin, TX: Pennebaker Conglomerates.
- Pennebaker, J. W., Boyd, R. L., Jordan, K., & Blackburn, K. (2007). *The development and psychometric properties of LIWC2007*. Austin, TX: Pennebaker Conglomerates.
- Pennebaker, J. W., Mehl, M. R., & Niederhoffer, K. G. (2003). Psychological aspects of natural language use: Our words, our selves. *Annual Review of Psychology*, 54, 547–577. <https://doi.org/10.1146/annurev.psych.54.101601.145041>
- Pell, M. D., & Leonard, C. L. (2003). Processing emotional tone from speech in Parkinson's disease: A role for the basal ganglia. *Cognitive, Affective, & Behavioral Neuroscience*, 3(4), 275–288.
- Péron, J., Dondaine, T., Le Jeune, F., Grandjean, D., & Vérin, M. (2012). Emotional processing in Parkinson's disease: A systematic review. *Movement Disorders*, 27(2), 186–199. <https://doi.org/10.1002/mds.24025>
- Richardson, J. T. E. (2011). Eta squared and partial eta squared as measures of effect size in educational research. *Educational Research Review*, 6(2), 135–147. <https://doi.org/10.1016/j.edurev.2010.12.001>
- Smith, M. C., Smith, M. K., & Ellgring, H. (1996). Spontaneous and posed facial expression in Parkinson's disease. *Journal of the International Neuropsychological Society*, 2(5), 383–391. <https://doi.org/10.1017/S1355617700001454>
- Tausczik, Y. R., & Pennebaker, J. W. (2010). The psychological meaning of words: LIWC and computerized text analysis methods. *Journal of Language and Social Psychology*, 29(1), 24–54. <https://doi.org/10.1177/0261927X09351676>
- Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica*, 112(3), 297–324. [https://doi.org/10.1016/S0001-6918\(02\)00134-8](https://doi.org/10.1016/S0001-6918(02)00134-8)
- Troche, M. S., & Altmann, L. J. P. (2012). Sentence production in Parkinson disease: Effects of conceptual and task complexity. *Applied Psycholinguistics*, 33(2), 225–251. <https://doi.org/10.1017/S0142716411000336>
- Verhaeghen, P., Steitz, D. W., Sliwinski, M. J., & Cerella, J. (2003). Aging and dual-task performance: A meta-analysis. *Psychology and Aging*, 18(3), 443–460. <https://doi.org/10.1037/0882-7974.18.3.443>