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Relationship between Perception and Production of Intonation of French in Parkinson's Disease

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Abstract

Parkinson's disease (PD) causes impairments in both perception and production of speech. The link between perception and production disorders in PD is, however, not well known. In this study, we examined whether there is a relationship between perception and production of intonation in French in PD individuals. Fifteen PDs and fifteen age-matched controls discriminated questions and statements in auditory-only, visual-only and audiovisual modalities. They were also asked to produce these utterances while their voice was recorded. Participants had to process intonation cues to discriminate between yes-no questions and statements in the perception task and to mark these utterances in the production task. Our results showed that PDs marked their questions and statements less than controls: the F0 rise at the end of the questions was smaller in PDs and contrary to controls, no F0 fall was observed at the end of the statements produced by PDs. Importantly, PDs who were more impaired in marking questions and statements were poorer at discriminating between these utterances in the perception task. These findings suggest that dysprosody in PD weaken the performance of PD individuals in processing prosody cues during speech perception.

Index Terms: prosody production, prosody perception, Parkinson's disease, sensorimotor interaction, French intonation

1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder [1] and causes significant impairments of speech production. Prosody is one of the aspects which is strongly impaired in PD: parkinsonian speech is characterized by less variable fundamental frequency (F0) and intensity, and longer pause times (for a review, see [2]). Dysprosody has a strong impact on communicative abilities of PDs as listeners have difficulties to detect the intention of PD individuals when it is conveyed by prosody cues. For example, contrastive stress or yes-no questions produced by PDs are less accurately recognized by listeners [3]. In addition to prosody production impairment, it has also been suggested that PDs may suffer from prosody perception [4], but the amount of deficiency differs greatly between patients, probably because of specific brain lesions [5].

Although disorders in both perception and production of speech have been reported in PD, the link between these deficits is not well understood. It is well known that perception and production systems of speech are closely interrelated (e.g. [6, 7, 8]), and this throughout the lifespan. For example, if the movement of a relevant articulator (e.g. tongue tip) is constrained when 6-month-old infants listen to speech sounds, their ability to discriminate phonemes that involve this articulator decreases [9]. In adults, motor learning influences the way speech sounds are perceived: disturbances to jaw movements while repeating words (motor learning period) modify the way adults classify vowels after the motor learning period [10]. Speech perception is thus influenced by modifications in speech production system. Based on these findings about the influence of production system on the speech perception, we hypothesize that speech production impairments in PD would impact the speech perception of PD individuals. If this is true, speech perception disorder observed in PD could be understood as a consequence of the impairment of the speech production system.

It has also been suggested that speech perception deficit in PD individuals may also impact their speech production [11]. For example, the external auditory feedback (i.e. feedback from one's own voice during speech production) is less monitored by PDs than controls [12]. This impairment, in long term, may affect speech motor representations and thus worsen speech production [13]. These findings suggest that the disorders in speech perception and production in PD are interrelated even if the precise nature of this relation remains to be clarified.

The goal of the current study is to examine the relationship between prosody perception and prosody production in PD. We focused on the intonation difference between yes-no questions and statements in French of France. As intonation cues are conveyed by both auditory and visual speech [14], we also examined the ability of PDs in visual speech processing. Based on the above-mentioned literature, we expected that there would be a positive correlation between the performance of PDs in perception and production of prosody.

2. Materials and methods

2.1. Participants

Fifteen individuals with idiopathic PD in their "on" state of medication (4 females) and fifteen one-to-one age-matched controls (11 females) participated in this study. All participants were native French speakers of France. Their mean age was 67 years (SD = 9). They did not have hearing problems by self-report and all had normal or corrected-to-normal vision. The mean disease duration of PD individuals[1] was 11 years (SD = 5). The PD individuals have not had deep brain stimulation surgery. The study was conducted in accordance with the Helsinki Declaration and the ethical guidelines of the Department of Speech and Language Therapy of University of Lille. Before testing, all participants were informed about the study

[1]This data was not available for one of the PD individual.

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by a written document and signed a consent statement.

2.2. Materials and stimuli

Twelve French sentences were selected from [15]. A male native French speaker of France produced each sentence twice, once as a statement and once as a yes-no question (e.g. "il parle Français." vs. "il parle Français ?"). Thus, no morphosyntactic cue was available to distinguish between questions and statements. The speaker was recorded audiovisually by a camera in front of him. The head, neck, and shoulders of the speaker were visible in the videos. The videos were edited using Adobe Premier Pro. The sound level was adjusted to 70 dB using Praat [16].

2.3. Experimental design and procedure

During the experiment, the participants performed a prosody perception task followed by a prosody production task. All stimuli were presented using OpenSesame [17].

2.3.1. Prosody perception task

In the perception task, participants received an auditory-only (A), an audiovisual (AV) and a video-only (V) block. In each block, ten pairs of sentences, i.e. ten questions and ten statements, were presented to participants through headphones (in A and AV modalities) and on the computer screen (in AV and V modalities). Two other pairs were repeated twice in order to remove any response bias. These pairs were not included in data analyses. The order of the stimuli presented in each block was random. During the experiment, participants were asked to classify each sentence as "question" or as "statement" by pressing F or J keys. The keys were counterbalanced across participants. Before the experimental blocks, all participants received a training block (one question-statement pair) in the auditory-only, audiovisual and visual-only modalities. This was done to familiarize them with the experimental procedure. The order of the experimental blocks was counterbalanced across participants.

2.3.2. Prosody production task

In the production task, participants were asked to produce all the sentences used in the prosody discrimination task, once as "question" (question block) and once as "statement" (statement block). Due to the fatigability of PDs, no distractor was included. In each trial, one of the sentences was selected in a randomized order. The selected sentence was written on the computer screen in front of the participants. All productions were recorded on the computer using a headset microphone. The participants received a training block (one question-statement paire) before the experimental blocks. The order of the experimental blocks was counterbalanced across participants.

2.4. Data Analyses

2.4.1. Prosody perception task

The number of correct and false responses was calculated for each speech modality (A, AV and V) and each type of sentences (question and statement). The ability of participants to discriminate between questions and statements was measured using d-prime as suggested in the signal detection theory [18]. D-prime is the difference between the z-score of the hit rate and the z-score of the false alarm rate. A greater d-prime in this experiment represents a better ability to discriminate between questions and statements based on prosody. A repeated-measures Analysis of variance (ANOVA) was performed using Group (PD/control) as a between-subject factor and Modality (A/AV/V) as a within subject factor. Student's *t* tests were used for post hoc comparisons.

2.4.2. Prosody production task

For each produced sentence, the mean F0 of the first and the last vowel was extracted using Praat [16]. This was done as yes-no questions and statements are typically marked in French by respectively a F0 rise and a F0 fall at the end of the utterance [19, 20]. Vowels were automatically detected using the Praat script Prosogram [21] when possible, or were subjectively selected using the signal and the second formant as cues. Measurements were made using semitones, a scale that helps reducing gender differences [22]. Thus, four measures per participant and per question-statement pair were obtained: initial F0 and final F0 for the question and initial F0 and final F0 for the statement. Mean F0 was then averaged across questions and statements per participant. A repeated-measures ANOVA was performed using Group (PD/control) as a between-subject factor and Type (question/statement) and Position (initial/final vowel) as within subject factors. Student's *t* tests were used for post hoc comparisons.

2.4.3. Relationship between perception and production tasks

Our main goal was to test whether there is a relationship between the performance of PDs in prosody perception and prosody production tasks. In the perception task, we used d-primes which represent the ability of participants to distinguish different prosodies. For prosody production, we focused on the F0 changes throughout utterance production. We measured the performance of each participant by calculating the difference between the F0 rise throughout their questions and the F0 fall throughout their statements (i.e., [final F0 – initial F0] in questions – [final F0 – initial F0] in statements). This represents to what extent participants marked questions and statements. For the sake of brevity, this value is called ΔF0. We tested the correlation between d-primes and ΔF0s (i.e. perception-production correlation) using Pearson correlation coefficient.

3. Results

3.1. Prosody perception task

Figure 1 shows the averaged d-primes in auditory-only, audiovisual and visual-only modalities for PDs and controls. The ANOVA yielded a significant effect of Modality ($F(2,56) = 18.92, p < 0.001$): The d-primes in the visual-only modality was smaller than the d-primes in the auditory-only modality ($t(29) = 5.19, p < 0.001$) and the d-primes in the audiovisual modality ($t(29) = 4.45, p < 0.001$). There was no difference between the auditory-only modality and the audiovisual modality ($t(29) = 0.19, p = 0.85$). The main effect of Group and the Group x Modality interaction were not significant (respectively, $F(1,28) = 1.06, p = 0.31$ and $F(2,56) = 0.20, p = 0.82$).

3.2. Prosody production task

Figure 2 shows the mean F0 of initial and final vowels in the questions and statements for PDs and controls. Significant results of the ANOVA performed on F0s are reported in table 1. As expected from the literature, there was a significant

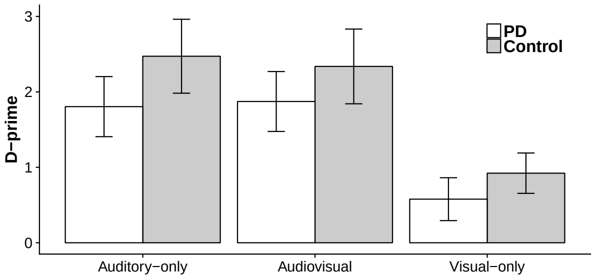
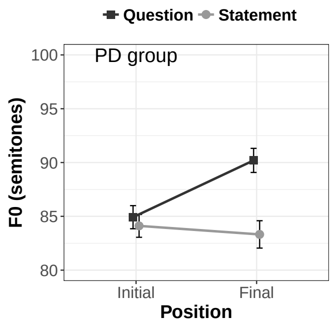


Figure 1: *Prosody discrimination Task. Mean D-prime in auditory-only, audiovisual and visual-only modalities for PDs and controls. Error bars indicate standard errors of the mean.*



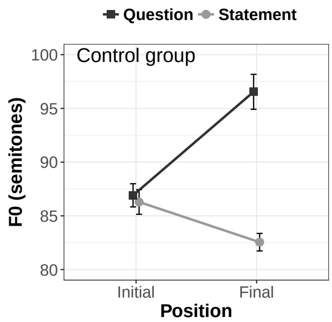


Figure 2: *Prosody production Task. Mean F0 of initial and final vowels for questions and statements for PDs (top) and controls (bottom). Error bars indicate standard errors of the mean.*

interaction between Position and Type. Importantly, PDs and controls performed differently in the production task as shown by significant Group × Type and Group × Position × Type interactions. Post hoc analyses showed that there was a F0 rise in the questions for both PDs and controls (respectively, $t(14) = 5.80, p < 0.001$ and $t(14) = 10.29, p < 0.001$). However, this rise was smaller for PDs compared to controls ($t(28) = 3.34, p < 0.01$). Moreover, there was a significant difference between PDs and controls in producing statements ($t(28) = -3.60, p < 0.01$): there was a F0 fall for controls ($t(14) = -6.41, p < 0.001$) but not for PDs ($t(14) = -1.38, p = 0.19$).

It is worthwhile to remind that there were more females in the control group than in the PD group (11 versus 4). To ensure that the difference between PDs and controls in the prosody production task was not due to the gender difference, we compared age-matched subsets of PDs and controls with exactly the same number of females and males in each group: we analyzed all

Table 1: *Significant results of ANOVA for the prosody production task.*

Effect	*F(1,28)*	*p*
Position	60.58	<0.001
Type	112.25	<0.001
Position × Type	127.15	<0.001
Group × Type	10.84	<0.01
Group × Type × Position	17.95	<0.001

Table 2: *Correlation between the performance of PDs and controls in the production and the perception tasks in auditory-only (A), audiovisual (AV) and visual-only (V) modalities.*

Group	Speech modality	Pearson's *r*	*t(13)*	*p*
PDs	A	0.68	3.33	< 0.01
PDs	AV	0.64	2.99	< 0.05
PDs	V	0.73	3.82	< 0.01
Controls	A	0.32	1.24	$= 0.24$
Controls	AV	0.14	0.53	$= 0.61$
Controls	V	-0.02	-0.07	$= 0.95$

possible age-matched subsets with four females and four males with PD and four females and four males without PD (thirty six subsets in total). We focused on ΔF0s (i.e., [final F0 – initial F0] for questions – [final F0 – initial F0] for statements, see Data Analyses). When all participants were included, the ΔF0 was 6.07 semitones for PDs and 13.37 semitones for controls (see Figure 2). The same trend has been observed when the age-matched subsets of 4 females and 4 males with PD and 4 females and 4 males without PD were analyzed: across subsets, the mean ΔF0 was 4.54 semitones for PDs and 11.99 semitones for controls. Student's *t* tests showed that the difference between PDs and controls was significant for all subsets (mean $t(14) = 3.60$, mean $p = 0.006$).

3.3. Relationship between perception and production of prosody

Figure 3 shows the performance of each participant in the perception (vertical axis) and production (horizontal axis) tasks. For the perception task, the d-primes in the auditory-only, audiovisual and visual-only modalities are shown. For the production task, ΔF0s are shown. The correlation between these measures for PDs and controls are presented in table 2. For PDs, the correlations were strong (A: 0.68, AV: 0.64, V: 0.73) and significant (see table 2). No significant correlations were observed for controls (A: 0.32, AV: 0.14, V: -0.02).

4. Discussion

Numerous studies report that both speech perception and speech production are impaired in PD. However, the link between these deficits is not well understood. Our goal was to investigate whether there is a relationship between perception and production of prosody in PD. We examined the ability of PDs and age-matched controls in a prosody perception task followed by a prosody production task. Our main findings are discussed below.

In the prosody perception task, participants were asked to discriminate between questions and statements which were pro-

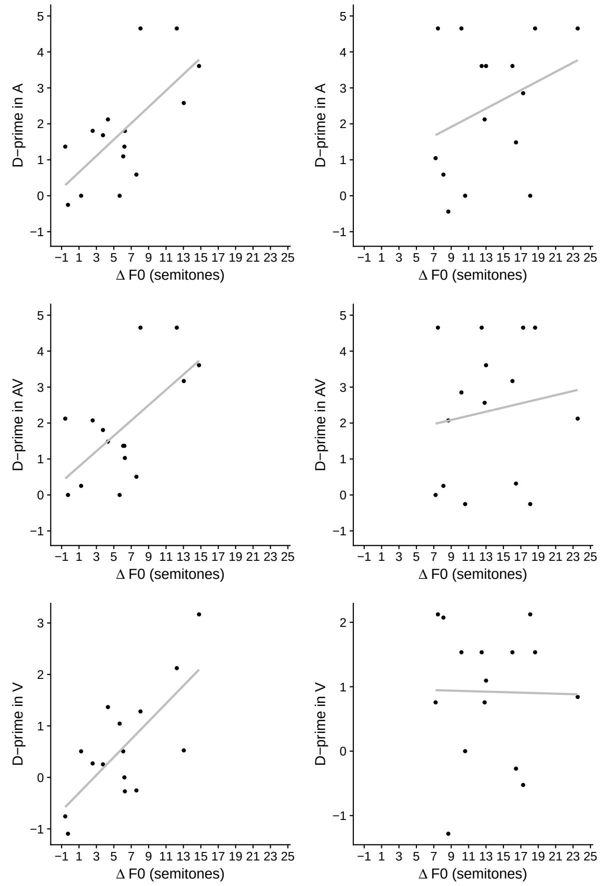


Figure 3: *Performance in the prosody production (horizontal axis) and prosody perception (vertical axis) tasks in the auditory-only (top), audiovisual (middle) and visual-only (bottom) modalities for PDs (left) and controls (right).*

duced by a typical speaker. As expected, prosody discrimination in auditory-only and audiovisual modalities was better compared to visual-only modality. The results showed that the performance of PDs did not significantly differ from that of controls. This was true for auditory-only, visual-only and audiovisual modalities. It has been suggested that only some PD individuals suffered from prosody perceptual deficits, probably because of specific brain lesions [5]. Although it is necessary to be cautious when interpreting a null result, our finding suggests that, in line with previous studies, PD does not systematically lead to abnormal perception of auditory and visual prosody cues.

In the prosody production task, we tested the performance of participants in marking questions and statements by respectively F0 rise and F0 fall at the end of these utterances. Our results revealed significant differences between PDs and controls. Although PDs marked questions by rising the F0, the F0 rise was smaller in PDs compared to controls. In statements, no F0 fall was observed for PDs contrary to controls. Our results are in line with previous studies showing that intonation production is impaired in PDs [23, 24]. Further research is required in order to establish if this absence of F0 fall in statements for the PD speakers is linked to an absence of Final Lowering [25], or if any other downtrend phenomenon such as declination [26], is involved. Moreover, it would be helpful to examine the influence of sentence length and structure, and production task (ex. reading versus narration) on this result.

The main goal of our study of was to examine whether there is a relationship between prosody production and prosody perception in PD. The results revealed a significant positive correlation between the performance of PDs in question-statement discrimination (d-prime) in the perception task and the amount of F0 difference between questions and statements (ΔF0) in the production task. This was true for the auditory-only, visual-only and audiovisual modalities. Although the relationship between speech perception and speech production in PD, especially in loudness processing [11, 27], has been discussed in the literature, the nature of this link remains debated. In fact, as discussed in the introduction, this link can been understood in two ways [9, 10, 11, 12, 13]: (1) Speech production disorders influence speech perception system and cause modifications in speech perception, (2) Auditory perceptual deficits impact speech motor representations and thus lead to speech production impairments. Our findings are consistent with the first mechanism. In fact, although PDs did not differ from controls in prosody discrimination, those who were poorer at marking questions and statements also showed poorer performance in prosody perception. This suggests that production impairments weakened their performance in discriminating between questions and statements. In other words, substantial disorders in prosody production impact mechanisms of auditory and visual prosody perception. This interpretation is consistent with the fact that prosody perception and prosody production were not correlated in controls as they did not suffer from any speech production disorder. To further investigate this issue, it would be helpful to carry out a longitudinal study in order to assess perception and production of prosody in PD starting from early stages of the disease.

5. Conclusion

In summary, we investigated the performance of PDs in the perception and production of intonation in French using questions and statements. We observed that PDs marked their questions and statements less than controls. Although PDs did not differ from controls in discriminating between questions and statements perceptually, those who were poorer at marking questions and statements showed poorer performance in the discrimination task. This suggests that deficits in prosody production in PD impact prosody perception mechanisms.

6. Acknowledgements

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