CHAPTER 3

PARKINSON’S DISEASE AND RECOGNITION OF PROSODY: A SYSTEMATIC REVIEW

3.1. INTRODUCTION

Up to 90% of PwPD eventually develop HD in the course of the disease (Ho et al., 1999b; Tjaden, 2008). HD affects a number of aspects in speech production of PwPD, and prosodic deficits are a common manifestation (Darley et al., 1969b). In general, prosodic disturbances that are seen most frequently in acquired disorders such as dysarthria are caused by disorders such as stroke or PD (Darley et al., 1969b; Peppé, 2009). Moreover, management and intervention with regards to such atypical prosody may be difficult for speech and language therapists (Peppé, 2009). Such common presence of prosodic disturbances alongside the neurological disorders and evidence that patterns of affected prosody differ among dysarthria types (Darley et al., 1969a,b) have lead several studies to suggest that prosodic disturbances in speech may be used as a marker of neurological disorders (Ma et al., 2010b; Brabenec et al., 2017).

Although there is no widely and universally accepted gold standard for speech changes associated with dysarthria, the modern classification of dysarthria rests largely on two articles published five decades ago (Darley et al., 1969a,b). These articles identified five types of dysarthria associated with distinctive clusters of deviant perceptual speech dimensions, and described these dimensions in terms of dysarthria ratings. According to Darley et al. (1969b), out of the ten deviant dimensions ranked the highest for HD, six are associated with prosody: monopitch (restricted pitch variability), reduced stress, monoloudness (reduced loudness variability), inappropriate silences, short rushes of speech, and variable speech rate\(^1\). Moreover, among the 13 most commonly occurring deviant speech dimensions in HD, eight represent prosodic phenomena: in addition to the above-mentioned six, two other dimensions consist of increased rate in segments (progressively increasing rate within separate segments of connected speech), and an increase in rate overall (Darley et al., 1969b). These dimensions tend to be more severely impaired in HD than in any other type of dysarthria (Duffy, 2013).

\(^{1}\)Dimension of imprecise consonants is sometimes considered as a component of prosodic deviancy in hypokinetic dysarthria (Darley et al., 1969b; Duffy, 2013)
Research demonstrates that despite differences across languages, prosody production deficits in PwPD are present independently of the spoken language and prosody is always among the most affected speech characteristics, which suggests the universality of the prosodic aspect of HD (Pinto et al., 2017). For example, prosody issues on the acoustic level have been reported for Czech (Rusz et al., 2011; Orozco-Arroyave et al., 2016), Cantonese (Ma et al., 2010b,a), Spanish (Orozco-Arroyave et al., 2016), German (Skodda and Schlegel, 2008; Skodda et al., 2011b; Orozco-Arroyave et al., 2016), French (Basirat et al., 2018), English (Darley et al., 1969b; Plowman-Prine et al., 2009), and Japanese speakers (Tanaka et al., 2011). Therefore, since speech prosody impairment may have crucial consequences for the intelligibility of speech, and for communication abilities of dysarthric speakers (Bunton et al., 2001; Anand and Stepp, 2015; Pinto et al., 2017), investigation of prosody deficits both from speakers’ and listeners’ sides is necessary to get insights into the nature of communication difficulties that PwPD face.

AIMS OF THE REVIEW

The present review aims to systematically map the evidence regarding the effect of PD on the perception and recognition of linguistic prosody, and to explore the listeners’ role in the assessment of linguistic prosody of PwPD. Previous research points to a bias in the auditory-perceptual assessments of HD that considers HD as “one motor sign among others”, rather than “an indicator of communication efficiency” (Pinto et al., 2017, p. 163). Besides, efficient communication depends on both listening and speaking. Therefore, this review takes a relatively broad focus by analyzing research evidence relevant to the two aspects of speech perception and recognition and PD: the perception and recognition of typical prosody by people with PD, and the perception and recognition of prosody affected by HD on the part of listeners with different degrees of familiarity with PD. The underlying methodological question for this study is how PD-related issues of linguistic prosody perception and recognition are conceptualized, measured and reported in the literature. There is abundant evidence that prosody produced by PD speakers is consistently different on the acoustic level from prosody in unaffected speech (Pinto et al., 2017; Brabenec et al., 2017). Also, there are studies demonstrating that listeners are sensitive to changes in prosody that appear in the speech of PwPD (De Letter et al., 2007; Anand and Stepp, 2015). In addition, previous research has shown that training and experience allow people to recognize and to better focus on specific patterns (Burk et al., 2006; Driscoll et al., 2009), suggesting the potential advantage of listener experience for the assessment of HD prosody. Moreover, there is evidence that emotional prosody perception is affected in the speech of PwPD (Gray and Tickle-Degnen, 2010; Kwan and Whitehill, 2011; Péron et al., 2012). However, studies on the perception and recognition of linguistic prosody in PD are relatively scarce. Therefore, both the effect of PD-related changes in linguistic prosody on neurologically healthy listeners’ perception and recognition of HD speech, and the effect of PD on the way PwPD perceive and recognize the unaffected linguistic prosody are yet to be investigated thoroughly.

Furthermore, there is evidence that the existence of a link between speech perception and production has implications for speakers with HD. Basirat et al. (2018) suggested that auditory perceptual deficits impact the motor representations of speech, leading to speech production impairments. Their study demonstrated that people with PD whose speech production is affected tends to coincide with changes in their speech perception (Basirat
et al., 2018). This chapter is structured as follows. Section 3.2 provides a description of this chapter’s approach to systematic review including search strategies and inclusion of the studies. Section 3.3 reviews the selected studies with regards to three research questions: 1) Which prosodic cues taken as indicative of PD appear across studies in the literature? (section 3.3.1), 2) Do individuals with PD show deficits in perception and recognition of typical prosody associated with healthy speech? (section 3.3.1); 3) Does listeners’ degree of familiarity with PD affect their perception and recognition of atypical prosodic cues of speakers with PD? (section 3.3.2). Section 3.4 summarizes and discusses the findings and is followed by the concluding remarks (section 3.5).

**3.2. METHODS: SEARCH STRATEGY AND SELECTION CRITERIA**

**APPROACH TO SYSTEMATIC REVIEW**

The current review follows, where possible, the well-established methods for conducting and reporting systematic literature reviews suggested by the PRISMA statement (Moher et al., 2009). Out of the 27 items on the PRISMA checklist (http://www.prisma-statement.org/documents/PRISMA%202009%20checklist.pdf), this review follows 18 in the title, introduction, methods, results, discussion and funding sections of the checklist. Given the aim to systematically investigate how PD-related issues of linguistic prosody perception and recognition are conceptualized, measured and reported in the literature across a very diverse set of studies, the focus of the review is on deviant speech dimensions, rather than on detailed results. Thus, this chapter does not report on certain items in the method and result sections, namely the risk of bias within or across studies (#12, 15, 19, 22), summary measures (#13), additional analyses (#16, 23), or syntheses of results (#14, 21).

**IDENTIFYING RELEVANT STUDIES**

The Web Of Science (WoS) database was used to search for studies that have investigated the effect of PD on the perception and recognition of linguistic prosody in PwPD, and in neurologically healthy listeners. To generate a list of relevant studies, a search was performed within the WoS Core Collection, which enables searches for papers published since 1945 within the sciences, social sciences, arts, and humanities. It provides access to the Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, and Emerging Sources Citation Index.

**STUDY SELECTION**

For a study to be included in the list, a number of criteria needed to be met: (1) articles must be written in English; (2) at least one of the participant groups under analysis must be diagnosed with PD; and (3) articles must concern the topic of linguistic (non-emotional) prosody perception. Studies dealing with emotional prosody were not included in this review for two reasons. First, relatively recent reviews on the topic already exist, which have been carried out by three independent teams (Gray and Tickle-Degnen, 2010; Kwan and Whitehill, 2011; Péron et al., 2012). Second, the assessment of emotions is particularly prone to subjectivity, since there is a lack of sufficiently rigorous criteria by which emotional prosody can be elicited or analyzed (for details on the deficit of emotional prosody processing in PwPD, and several theories accounting for such deficits, see Kwan...
and Whitehill (2011), Gray and Tickle-Degnen (2010) and Péron et al. (2012)). Review papers that came up in the search were not included in this systematic review, although they were used to identify other relevant studies, increasing the scope of the review.

The search was conducted from the WoS inception date, 1945, to April 2021 with a broad set of search terms to include as many studies as possible. The key terms “Parkinson’s” or “dysarthria” were used in a regular expression form (“*parkinson*” and “*dysarthr*”). Additionally, other terms that referred to the level where problems occur were used, specifically “prosody”, “perception”, “intonation”, “pitch”, “intelligibility” or “communication”. The formula used for the search was

\[
fs = (*parkinson* or dysarthr*) \text{ and } fs = (*prosod* or intonation* or pitch or percept* or intelligib* or communic*)
\]

The search engine identified the terms either in the title, the keywords, and/or the abstract. The use of the terms “Parkinson’s” or “dysarthria” in all search attempts facilitated a very inclusive approach, while the other set of terms ensured that studies using different terms for prosodic dysfunctions would not be missed. An additional search was performed with the term “recognition”, which was refined by the combined terms “speech” and “recognition”:

\[
fs = (*parkinson* or dysarthr*) \text{ and } fs = (*prosod* or intonation* or pitch or percept* or intelligib* or communic* or recogni*) \text{ and } fs = (recogni*) \text{ and } fs = (speech).
\]

The searches resulted in 6215 records, many of which did not address the topics of speech perception and prosody, and were dedicated to other aspects such as medication, surgery, or physiology. The search was then narrowed down to 3328 records by means of applying linguistic, neurological, and psychological WoS categories. Articles were initially screened by applying the eligibility criteria to their title and abstract. The inclusion of a study was subsequently validated by reviewing the full article. A PRISMA-based (Moher et al., 2009) flow diagram mapping out the number of records identified, included and excluded, and the reasons for exclusions is presented in Figure 3.1.

### 3.3. Results

**Characteristics of the included studies**

The above-described searches and the review process yielded a list of 24 publications concerned with either the perception/recognition of speech by listeners with PD, or with the perception/recognition of speech produced by speakers with PD (see Appendices C.1 and C.2 for the complete list of the included studies). The body of research covered an international base of studies including the United States (n=7), Belgium (n=4), Canada (n=2), China / Germany (n=2), Netherlands (n=2), the United Kingdom (n=2), France (n=2), USA / New Zealand / Taiwan (n=1), China (n=1), and Belgium / Cuba (n=1). The studies were from a total of 11 journals and one peer-reviewed conference proceeding, and were written by 79 different authors. Of these 24 studies, six were published between 1984 and 2000, seven were published between 2001 and 2010, and 11 were published after 2010. The research designs of all studies were experimental group designs. Eleven of these are mixed methods designs focusing on the production and perception of speech, two are pretest-posttest studies, and eleven are devoted to the perception of different speech aspects. Since the search considers a broad range of perception and recognition of prosodic aspects
3.3. Results

Records identified through database searching (n = 6215)

Additional records identified through other sources (n = 10)

Records after duplicates removed and after search refined through WoS categories (n = 3328)

Records screened (n = 3328)

Records excluded (n = 3267)

Full-text articles assessed for eligibility (n = 61)

Full-text articles excluded, with reasons (n = 37)

Reasons:
Not relevant (n = 26)
About other dysarthria types (n = 7)
About emotional prosody (n = 2)
Not in English (n = 2)

Studies included in qualitative synthesis (n = 24)

Figure 3.1 | PRISMA Flow Diagram explaining the records inclusion.
of speech in relation to PD, this chapter includes diverse studies with various research foci: prosody identification and discrimination, the evaluation of communication efficiency through assessments of prosody, and the perceptual assessment of effects of medical or intonation treatment on prosody in PD.

The results are presented in two sections, which analyze the included literature from different perspectives. The first section addresses the first two research questions: “which prosodic perceptual cues taken as indicative of PD appear across studies in the literature?”, and “do PwPD show deficits in perception and recognition of typical prosody associated with healthy speech?”. The second section deals with the third research question – “does listeners’ degree of familiarity with PD affect their perception and recognition of atypical prosodic cues of speakers with PD?”, – where the focus is on the perception of listeners with different competence levels: untrained listeners, trained non-expert listeners (i.e. graduate students or research assistants), or expert listeners (i.e. neurologists or speech and language therapists/pathologists). The full list of studies on the perception and recognition of HD, and the main features of their designs are presented in the tables in Appendices C.1 and C.2.

3.3.1. PERCEPTION AND RECOGNITION OF LINGUISTIC PROSODY WITH REFERENCE TO DEVIANT DIMENSIONS

The classification system of dysarthria, as described by Darley et al. (1969b), has been widely used by clinicians and researchers, and was revised in 2009 by Plowman-Prine et al. (2009). The authors addressed the question of whether Levodopa medication, which is primarily used to manage PD symptoms, has an effect on HD speech. In addition, Plowman-Prine et al. (2009) replicated and validated the original perceptual evaluation of 35 abnormal speech and voice characteristics identified for dysarthria from Darley et al. (1969b). Their observations confirmed the findings of Darley et al. (1969b), showing that the prosody cluster of speech dimensions is the most deviant of the eight clusters of perceptual speech dimensions.

To pursue the first research question of this review, “which prosodic perceptual cues taken as indicative of PD appear across studies in the literature?”, this section analyzes the literature included to produce an overview of how the prosody-related dimensions discussed by Darley et al. (1969b) are perceived and recognized by listeners. The focus is on the way untrained and trained listeners perceive and recognize the linguistic prosody of speech affected by HD. Articles dealing with the perception and recognition of typical prosody by listeners with PD (see Appendix C.1) were included in the analysis in order to explore the perception and recognition of linguistic prosody by listeners with PD in terms of deviant dimensions, and to answer our second research question “do PwPD show deficits in perception and recognition of typical prosody associated with healthy speech?”. The list of the top-ranked prosody-related speech dimensions according to Darley et al. (1969b), and the studies focusing on them, is presented in Table 3.1.
Table 3.1 | List of the most affected speech dimensions related to prosody ranked according to Darley et al. (1969b), and references to the studies in which they appear.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Speech dimension</th>
<th>Studies</th>
<th>Main outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monopitch</td>
<td>Blonder et al. (1989); Caekebeke et al. (1991); Pell (1996); Lloyd (1999); Bunton et al. (2001); Ma et al. (2010a,b); Klopfenstein (2015); Martens et al. (2015, 2016); Whitehill et al. (2003); Pell et al. (2006); De Letter et al. (2007); Kuo et al. (2014); Anand and Stepp (2015); De Keyser et al. (2016); Basirat et al. (2018)</td>
<td>Monopitch is one of the most affected speech dimensions. It negatively influences both the intelligibility and naturalness of speech. Even when the speech of PwPD is rated as highly intelligible, monopitch negatively affects listeners’ perception of speech affected by HD.</td>
</tr>
<tr>
<td>2</td>
<td>Reduced stress</td>
<td>Scott et al. (1984); Darkins et al. (1988); Blonder et al. (1989); Pell (1996); Lloyd (1999); Martens et al. (2011, 2016)</td>
<td>The findings on the ability to convey stress and focus intonation in PwPD is controversial. The ability to comprehend both the lexical stress and the focus intonation appears to be unaffected in PwPD.</td>
</tr>
<tr>
<td>3</td>
<td>Monoloudness</td>
<td>Whitehill et al. (2003); De Letter et al. (2007); Ma et al. (2010a); Klopfenstein (2015)</td>
<td>A lack of loudness variability is perceptually prominent. The medication intake effect on the perceived intensity of speech showed increased variability of intensity.</td>
</tr>
<tr>
<td>5</td>
<td>Inappropriate silences</td>
<td>Whitehill et al. (2003)</td>
<td>The perception of speech is mildly affected due to inappropriate silences.</td>
</tr>
<tr>
<td>6</td>
<td>Short rushes</td>
<td>Whitehill et al. (2003)</td>
<td>The perception of speech of PwPD is moderately affected due to short rushes (“short phrases” in the paper by Whitehill et al. (2003) ). The evaluation of this dimension has the highest inter-listener reliability in the study.</td>
</tr>
<tr>
<td>10</td>
<td>Variable rate</td>
<td>Kuo et al. (2014); De Letter et al. (2007); Whitehill et al. (2003); De Keyser et al. (2016); Hsu et al. (2019)</td>
<td>Variable rate neither noticeably influences intelligibility, nor is it perceived as affected in either off or on medication states. When evaluating their own speech, PwPD describe their speech rate as similar to the control group.</td>
</tr>
</tbody>
</table>
Pitch

All prosodic deviant speech dimensions from Darley et al. (1969b) have been discussed with regards to HD perception and recognition, but only monopitch has received wide attention, being ranked the highest in the list of phenomena constituting HD (Darley et al., 1969b). Most studies concerned with speech listeners’ perspective on prosodic deficits associated with HD include experiments on the recognition of intonation contrasts, both by PwPD and by neurologically healthy controls. The experimental design used to evaluate the influence of monopitch usually involves intonation contrast discrimination tasks and intonation identification tasks. In the majority of experimental studies on sentence type discrimination where PwPD act as listeners, PD groups are found to be as accurate as the healthy control groups in discrimination of sentence types (Blonder et al., 1989; Caektebeke et al., 1991; Pell, 1996; Martens et al., 2016; Basirat et al., 2018). Studies by Scott et al. (1984) and Pell (1996) are an exception. Scott et al. (1984) found that their PD group had lower scores than the control group in a sentence type discrimination task. The study by Pell (1996) slightly differs in the design: authors tested sentence type discrimination by PD and control groups on two types of material — meaningful sentences and nonsense words. They found that the PD group had more difficulty with the pure prosody material than the control group. However, when tested on the identification of sentence prosody, PwPD performed less accurately compared to the control group (Pell, 1996), a finding also reported in a study by Lloyd (1999).

Although many studies claim that sentence type discrimination in PwPD is unaffected, Basirat et al. (2018) demonstrated that PD speakers who performed more poorly at marking utterances as questions and statements in their speech, also performed less accurately than the control group in the sentence type discrimination task. This suggests that deficits in the production of prosody might also affect speakers’ perception (Basirat et al., 2018). The findings of Basirat et al. (2018) are complemented by the outcomes of De Keyser et al. (2016), who show that while assessing their own speech, speakers with PD do not rate pitch or pitch variability differently than the control group.

Monopitch in speech produced by speakers with PD affects listeners’ perception and recognition of such speech and hinders understanding of the intended message (Pell et al., 2006; Ma et al., 2010b; Anand and Stepp, 2015). Monopitch also correlates with both intelligibility and naturalness of speech and their deterioration (Bunton et al., 2001; Anand and Stepp, 2015; Klopfenstein, 2015). In a study by Pell et al. (2006), listeners often misidentified questions produced by PwPD as statements, even though the speech of all PwPD was rated as highly intelligible. Bunton et al. (2001) analyzed the influence of monopitch on intelligibility. They performed experiments with resynthesized PD speech material, flattening the fundamental frequency ($f_0$) by different degrees. Their findings demonstrated that the reduction in the $f_0$ range is followed by a decrease in both transcription and scaling scores. These results are in agreement with other studies on the relationship between intelligibility and $f_0$ variability: as shown in Laures and Bunton (2003), flattened $f_0$ negatively affects sentence intelligibility in different background noise conditions. Moreover, it appears that any abnormal $f_0$ contour affects speech intelligibility (Miller et al., 2010). Regarding the perception of $f_0$ variability changes in PwPD, a study by De Letter et al. (2007) demonstrated a positive effect of Levodopa treatment on monopitch as assessed by neurologically healthy listeners.
3.3. RESULTS

Overall, these studies highlight that prosodic deviances are a critical source of potential communication failures for PwPD (McNamara and Durso, 2003; Pell et al., 2006). At the same time, a study by Bunton et al. (2001) offers an additional perspective on the communication efficiency of PwPD. The authors demonstrated that when the sentences produced by PwPD were modified to completely flatten the $f_0$, they were just as intelligible as the unmodified version of the sentences. This finding suggests that PwPD have adopted compensatory strategies related to prosody (Bunton et al., 2001).

STRESS PATTERNS IN SPEECH

In the context of PD, stress patterns in speech have been covered in the literature to a considerable degree. Conveying information related to lexical and contrastive stress information has been described as a definite area of weakness for speakers with HD (Pell et al., 2006). The literature search yielded five studies that assess recognition issues of lexical and contrastive stress in PwPD (Darkins et al., 1988; Blonder et al., 1989; Pell, 1996; Lloyd, 1999; Martens et al., 2016). According to Blonder et al. (1989) and Lloyd (1999), PwPD perform poorly in lexical discrimination tasks based on stress contrasts. Yet, the latter study by Lloyd (1999) hypothesized that the findings could have been influenced by the conceptual difficulties associated with the task itself. Even though these two studies point to difficulties with stress recognition in PwPD, three other studies reported that PwPD display no significant deficiency in lexical stress recognition compared to neurologically healthy controls (Darkins et al., 1988; Pell, 1996; Martens et al., 2016). A different perspective to stress recognition can be found in studies by Scott et al. (1984) and Martens et al. (2016), which examined the recognition and comprehension of contrastive stress through discrimination and identification tasks, and found no significant problems for PwPD (Scott et al., 1984; Martens et al., 2016).

Listeners’ assessment of stress in speech affected by HD is discussed in the studies of Pell et al. (2006) and Martens et al. (2011). Pell et al. (2006) analyzed the impact of PD on vocal-prosodic communication and demonstrated that neurologically healthy listeners perform less accurately at identifying both lexical and contrastive stress in speech affected by HD compared to the stress in speech of healthy control speakers. A study by Martens et al. (2011) focused on better understanding the communicative efficiency of contrastive stress production in HD. The authors analyzed how speech and language pathologists assess the contrastive stress produced by PwPD. Their findings demonstrate that in a reading task the communicative efficiency of PwPD is similar to that of the control group. However, the results of the task on imitating contrastive stress demonstrate that speakers in the control group outperform speakers with PD. Such findings are in partial contradiction with the results reported in Pell et al. (2006), which could be explained by differences in the study designs. In the study by Martens et al. (2011), the visual stimuli in the reading task could have served as extra help for PwPD.

VARIABILITY IN LOUDNESS

The listeners’ impressions of deviant dimension of monoloudness are discussed in four of the studies found in the literature search (Whitehill et al., 2003; De Letter et al., 2007; Ma et al., 2010a; Klopfenstein, 2015). The studies by Whitehill et al. (2003) and by Ma et al. (2010a) focus on the perception of Cantonese speech affected by HD and explore how diverse speech dimensions, including monoloudness, are evaluated by listeners.
The resulting assessments revealed that monoloudness is in the top three of evaluated speech dimensions for speech of Cantonese PwPD (Whitehill et al., 2003; Ma et al., 2010a). Another perspective on monoloudness in HD is presented in the study by Klopfenstein (2015) with focus on the naturalness of HD speech. Her findings demonstrate that the reduced intensity range is associated with lower ratings of naturalness of speech of PwPD, which suggests that monoloudness might not be as prominent for the listeners as the changes in intensity range. The study by De Letter et al. (2007) looks into to the changes in intensity variability and Levodopa medication, demonstrating that Levodopa leads to the improvement of the perceived intensity range as assessed by SLTs.

**Speech Rate**

Four out of the 24 studies that were included in the review explore listeners’ impressions of abnormal speech rate in HD (Kuo et al., 2014; De Letter et al., 2007; De Keyser et al., 2016; Hsu et al., 2019). The findings of Kuo et al. (2014) show that a faster speech rate is correlated with a decrease in intelligibility, even though the speakers in the study demonstrated variable speech rate changes. The authors investigated the effects of speakers’ faster and habitual speech rates on the intelligibility of their speech. The results demonstrate that monopitch, but not the speech rate, has a greater effect on intelligibility (Kuo et al., 2014). Another study that explores the assessment of speech rate in HD is by De Letter et al. (2007), with a focus on the effects of Levodopa on prosody comprehensibility in speech of PwPD. De Letter et al. (2007) examined changes in listeners’ assessments of variable rate in speech of PwPD. The authors reported no effect of Levodopa on listeners’ perceptual evaluation of the variable speech rate in HD (De Letter et al., 2007). On the other hand, with regards to the perception of their own speech rates, PwPD show no difference from the control group (De Keyser et al., 2016). Such findings suggest that the perception and recognition of speech rate may be less affected by the presence of PD, but rather more by a combination of speaking speed and the severity of the disease (Kuo et al., 2014). The recent study by Hsu et al. (2019) explored the effect of reduced speech rate on the scaled intelligibility of speech produced by Mandarin speakers with HD. Their findings demonstrate that when listeners assessed the speech of PwPD in the reduced rate condition, they rated “ease of understanding” slightly, but not significantly, higher.

**Inappropriate Silences and Short Rushes of Speech**

The remaining prosodic deviant speech dimensions listed in Table 3.1 – inappropriate silences and short rushes of speech – are briefly discussed in two studies focusing on the perception of Cantonese speech affected by HD (Whitehill et al., 2003; Ma et al., 2010a). These studies aim to create a “perceptual profile”, i.e. the list of prominently affected speech dimensions based on Darley et al. (1969b), for HD in speech of Cantonese PwPD. Despite differences in the lists of speech dimensions and in stimuli type, both studies demonstrate that short rushes of speech or inappropriate silences do not appear in the top ten most affected speech characteristics (Whitehill et al., 2003; Ma et al., 2010a). The authors reported that dimensions related to voice, reduced pitch, and loudness variation are the most severely affected as assessed by the listeners (Whitehill et al., 2003; Ma et al., 2010a).

To summarize, it appears that among the deviant speech dimensions discussed in the literature, it is monopitch and monoloudness, along with an overall decrease in loudness,
that are seen as the most prototypical dimensions that neurologically healthy listeners rate as the most prominent speech changes which occur with HD. Interestingly, De Keyser et al. (2016) demonstrated that when listener groups assess their own speech, these dimensions are not rated differently by listeners with PD as compared to the control group. This, however, does not imply that there is no difference in the perception of these speech dimensions between PD and control groups. There are two possible explanations to account for the presence of such discrepancy between PwPD’s self-assessment reported in De Keyser et al. (2016) and the previously discussed prosodic deficits as assessed by neurologically healthy listeners. First, it is possible that in the study by De Keyser et al. (2016), some participants could have experienced conceptualization difficulties when they were asked to assess the list of deviant speech dimensions. Second, it is plausible that PwPD may experience auditory perceptual deficits involved in prosody processing as suggested by De Keyser et al. (2016) and Basirat et al. (2018). On the other hand, a recent study by Basirat et al. (2020) concerned with the efficiency of PwPD in the word segmentation based on prosodic cues, reports no significant differences between PD and control groups. Therefore, given the findings in the existing literature, it is unlikely that PD systematically affects the processing of linguistic prosody in PwPD (Basirat et al., 2020). However, the scarcity of the research on this topic, and a few contradictory findings discovered in the early literature, warrant additional research.

3.3.2. Perception and recognition of atypical prosody associated with HD by neurologically healthy listeners

Since the publication of the two seminal articles by Darley et al. (1969a,b), their work has became the foundation for the current clinical methods of auditory-perceptual assessment and classification of dysarthria. Few studies have addressed the effect of listeners’ experience on such assessment, but the majority prefer to rely on the trained listeners’ opinions. The literature describes controversial findings regarding the role of listeners’ expertise and training (Dagenais et al., 1999; Bunton et al., 2007; Anand and Stepp, 2015; Smith et al., 2019; Carvalho et al., 2020). More recently, Smith et al. (2019) demonstrated that there is no significant difference between the intelligibility assessments of speech affected by HD when judged by untrained or trained listeners. However, another recent study focusing on intelligibility of PwPD shows that expertise matters, and healthcare professionals who have specialized PD-related training understand speech of PwPD better than SLTs, people familiar with HD, or untrained listeners (Carvalho et al., 2020). However, less is known about how listeners with different levels of expertise and training recognize linguistic prosody in HD speech. This section, therefore, focuses on the studies that have included untrained listeners, trained non-experts, and trained medical experts as assessors of speech produced by PwPD. A total of 14 studies that appeared in the literature search consider the perception or recognition of atypical linguistic prosody associated with HD by neurologically healthy listeners (see Appendix C.2). The majority of the studies involved graduate students or research assistants, who evaluated the naturalness, intelligibility or intended meaning of HD speech.
Untrained listeners’ perception and recognition

Only three studies in our collection concerned with the perception of linguistic prosody in speech affected by HD explored assessments of untrained listeners with no formal training in disordered speech or reported experience with speech and language disorders: Pell et al. (2006), Kuo et al. (2014) and Anand and Stepp (2015). The study by Pell et al. (2006) is solely focused on linguistic prosody and reports on the results of an experimental study concerning the impact of PD on prosodic aspects of vocal communication. Pell et al. (2006) showed that PwPD demonstrate an affected ability to convey question intonation as well as both lexical and contrastive stress distinctions. Their findings indicate that compared to the participants in the control group, PwPD are less successful at communicating intonation and stress distinctions, especially using contrastive stress intonation. Such impaired prosody may have serious and negative repercussions on communication efficiency.

Two other studies are concerned with the prosodic aspects contributing to speech intelligibility and naturalness of speech produced by PwPD and highlight the importance of suprasegmental modulations for speech intelligibility and naturalness (Kuo et al., 2014; Anand and Stepp, 2015). Kuo et al. (2014) focused on the effect of speech rate on dysarthric speech intelligibility. The authors analyzed both intelligibility and acoustic characteristics of speech of groups of PwPD in the normal and faster speech rate conditions. Kuo et al. (2014) demonstrated that when speech rate is conditioned, the acoustic contributions to intelligibility becomes complex, and it varies substantially between individual speakers. Moreover, it appears that monopitch contributions to lower intelligibility ratings by untrained listeners are larger than the contributions of the speech rate. The third study by Anand and Stepp (2015) explores the effects of monopitch on listeners’ impressions of speech naturalness and intelligibility. The results of the visual sorting and rating experiment demonstrated that while the correlation between monopitch and intelligibility was moderate, the correlation between monopitch and naturalness was high. The authors also observed that the changes in speech (e.g., speech naturalness) can occur before the decline in speech intelligibility with monopitch being a potential contributing factor (Anand and Stepp, 2015). Monopitch appears to have a greater effect on speech naturalness than on intelligibility and authors argued that prosodic characteristics should always be targeted when seeking to improve the naturalness of speech in the treatment of dysarthria in PD (Anand and Stepp, 2015).

Across the studies that explored the assessments of untrained listeners, the prominence of the monopitch characteristic of speech is clear. Monopitch affects how efficiently both focus and sentence type intonations are conveyed and leads to the reduced intelligibility and naturalness of speech. Overall, there seems to be evidence indicating that untrained listeners are sensitive towards prosodic deficits associated with HD. However, the scarcity of studies reporting on how untrained listener groups assess speech of PwPD prevents any definitive conclusions from being drawn, and highlights the need for further research.

Trained non-experts’ perception and recognition

Studies on the perception and recognition of dysarthric speech by trained non-experts usually include university students or research assistants. Such studies constitute the
majority of the research conducted on the linguistic prosody perception and recognition of linguistic prosody in speech of PwPD. This systematic review includes six studies in which students and research assistants acted as assessors of speech affected by HD (Blonder et al., 1989; Bunton et al., 2001; Whitehill et al., 2003; Ma et al., 2010b, a; Klopfenstein, 2015). Three out of these six studies focused on Cantonese speech affected by HD: two aimed to establish a “perceptual profile” of HD in Cantonese (Whitehill et al., 2003; Ma et al., 2010a), and one investigated the recognition of intonation contrasts produced by Cantonese speakers with HD (Ma et al., 2010b). The other studies explore the recognition of prosodic contrasts in PwPD (Blonder et al., 1989), the relationship between $f_0$ variability and speech intelligibility (Bunton et al., 2001), and correlations between a number of acoustic measurements of atypical prosody and speech naturalness (Klopfenstein, 2015). These studies explored listeners’ perception of dimensions of monopitch and monoloudness from different perspectives. The study by Bunton et al. (2001) demonstrates that monopitch correlates with speech intelligibility, studies by Blonder et al. (1989) and Ma et al. (2010b) show that monopitch affects speakers’ ability to convey question intonation, while studies by Whitehill et al. (2003) and Ma et al. (2010a) argue that monopitch is among the most prominent perceptual dimensions for Cantonese speech affected by HD. Regarding the dimension of monoloudness, the study by Klopfenstein (2015) reported on its correlation with speech naturalness, while studies by Whitehill et al. (2003) and Ma et al. (2010a) demonstrated that monoloudness is rated among the most prominent dimensions in the Cantonese speech affected by HD. Together, these studies indicate that monopitch and monoloudness appear to be the most affected and studied speech characteristics of HD as assessed by trained non-experts.

EXPERT LISTENERS’ PERCEPTION AND RECOGNITION

In total, the search results included five studies that involved the assessments of speech affected by HD by trained medical experts such as neurologists or speech and language therapists (SLTs). Four studies focused on the evaluation of changes appearing in the speech of PwPD. Thus, De Letter et al. (2007) and Plowman-Prine et al. (2009) explored the effectiveness of Levodopa treatment and Martens et al. (2011, 2015) focused on assessments of the communicative abilities of PwPD. The fifth study evaluated the possibility of whether trained expert listeners can recognize PD using only recorded voice data (Harris et al., 2016).

In the study by De Letter et al. (2007) the listeners evaluated speech of PwPD in “on” and “off” states of Levodopa medication. The assessments reveal no noticeable change in speech rate variability but a significant increase in variation in $f_0$, intensity and comprehensibility. Findings of De Letter et al. (2007) indicate that prosodic aspects of speech may be related to the intake of dopaminergic medication as assessed by trained expert listeners. Another study that recruited trained expert listeners to assess speech of PwPD confirms the results of Darley et al. (1969b), demonstrating that the prosody cluster is the most severely affected cluster in HD speech (Plowman-Prine et al., 2009). The authors reported that the dimensions of monoloudness, monopitch, and reduced stress are the most affected according to the evaluation of SLTs. However, in contrast with the findings from De Letter et al. (2007), no significant changes were present in the SLTs’ assessment of speech of PwPD in “on” and “off” medication states (Plowman-Prine et al., 2009).
Two studies by Martens et al. (2011, 2015) rely on the assessments by SLTs who had experience with dysarthric speech and explore the prosodic communication efficiency and effect of intonation treatment on intelligibility in PwPD. Martens et al. (2011) showed that a healthy control group performed systematically better than PwPD in the intonation imitation task. In another study, Martens et al. (2015) explored the changes in intonation contrasts in speech affected by HD in a pretest-posttest study on effects of intensive intonation speech therapy. Their results demonstrate that the sentence type identification rate improved significantly after speakers received treatment.

Another study concerned with prosody in speech of PwPD and the assessment of listeners of that speech provides a different perspective on the impressions of medical experts of prosodic deviancy in PwPD (Harris et al., 2016). Harris et al. (2016) have shown that trained expert listeners can reliably distinguish speakers with PD from the control speakers based solely on the recorded speech data: 82% of the assessors were able to correctly recognize voices of PwPD in a forced-choice task.

Therefore, despite the fact that studies relying on trained listeners’ assessments differed in the aims and focused on different intervention strategies, the evidence presented in this section suggests that trained expert listeners might be sensitive to monopitch and monoloudness. These are the same speech dimensions that both trained non-expert and untrained listeners are also sensitive to in speech affected by HD. However, as is the case with the studies relying on untrained listeners’ assessments, additional research is warranted to shed light on differences and similarities in the speech recognition strategies of the different listener groups.

3.4. DISCUSSION

This chapter focuses on the deficits in linguistic prosody perception and recognition related to HD. It considers how PwPD assess both their own speech and speech unaffected by HD. It also discusses how listeners with different expertise and training assess speech produced by PwPD. With regards to the research questions, the aim of the review was three-fold: to explore which prosodic perceptual cues taken as indicative of PD appear across studies in the literature, to investigate if PwPD show deficits in perception and recognition of typical prosody associated with healthy speech, and to gain insight into the effects of the degree of familiarity with PD of the listeners on their perception and recognition of atypical prosodic cues of PwPD.

Regarding the first research question, the chapter provided a comprehensive overview of prosodic deviant dimensions from Darley et al. (1969b) together with an overview of how the literature explores listeners’ perception and recognition of linguistic prosody in the speech of PwPD. Although all deviant dimensions related to prosody are discussed in the literature, those ranked higher in the classification by Darley et al. (1969b) received greater attention. Combined evidence from the reviewed studies suggests that these highest ranked dimensions, i.e., monopitch and monoloudness, have the greatest influence on the perception and recognition of speech affected by HD. Overall, monopitch and monoloudness are seen as the most prototypical source of prosodic speech problems for PwPD (Pell, 1996; Lloyd, 1999; Bunton et al., 2001; Whitehill et al., 2003; Pell et al., 2006; De Letter et al., 2007; Ma et al., 2010a; Klopfenstein, 2015; Kuo et al., 2014; Martens et al.,
The evidence on listeners’ impressions of monopitch demonstrates that monopitch greatly affects both intelligibility and naturalness of HD speech (Bunton et al., 2001; Anand and Stepp, 2015; Klopfenstein, 2015), and negatively influences listeners’ perception and recognition of speech affected by HD, both in tonal and non-tonal languages (Pell et al., 2006; Ma et al., 2010b). The dimension of monoloudness was found to correlate with the lack of speech naturalness (Klopfenstein, 2015), and was found to be a prominent characteristic of the Cantonese HD “perceptual profile” (Whitehill et al., 2003; Ma et al., 2010a). In view of the findings summarized above, monopitch and monoloudness seem to act as a primary prosodic source of potential failures in communication for PwPD, possibly leading to people with PD developing compensatory strategies for pitch in order to overcome this communication obstacle (Bunton et al., 2001).

The deviant dimension of reduced stress is relatively well-described in the literature on HD. Studies have demonstrated that both lexical and contrastive stress are affected in HD speech, but the success of listeners’ identification of the intended prosody may depend on the speech material that PwPD are asked to produce (Martens et al., 2011). Other prosodic dimensions have not been thoroughly studied. This could result from a lower ranking of these characteristics in Darley et al. (1969b), or from the fact that for listeners these other dimensions are simply less prominent in speech affected by HD. Therefore, the effects of the prosodic deviant dimensions of inappropriate silences, short rushes of speech, and variable speech rate on the perception and recognition of speech affected by HD remain less clear. Interestingly, the compromised ability of PwPD to convey stress and rising intonation is echoed by the findings on other types of dysarthria caused by neurological disorders such as multiple sclerosis (Kuo et al., 2014), or other movement disorders such as cerebral palsy (Patel and Campellone, 2009). This suggests that prosodic difficulties in dysarthria might not entirely be the consequence of any specific motor disorder.

As for the second research question, this chapter examined whether the literature may shed light on whether the perception and recognition of linguistic prosody is affected in listeners with PD. To that end, the relevant studies were analyzed with respect to the deviant dimensions. Although there is a clear link between deficits in the ability to process emotional prosody and the ability to convey emotions to listeners (Péron et al., 2012; Kwan and Whitehill, 2011; Gray and Tickle-Degnen, 2010), linguistic prosody perception and recognition by PwPD are not clearly connected. Overall, the majority of the reviewed studies dealing with prosody perception and recognition by listeners with PD has reported that the prosody discrimination abilities of PwPD are comparable to those of neurologically healthy listeners (Blonder et al., 1989; Caektekeke et al., 1991; Pell, 1996; Martens et al., 2016; Basirat et al., 2018). Nonetheless, two studies report that linguistic prosody identification abilities are affected in listeners with PD (Pell, 1996; Lloyd, 1999). Interestingly, six out of the nine studies dealing with the perception and recognition of prosodic cues by listeners with PD have also been concerned with production of those cues by the same group of people. Furthermore, all six studies indicate that listeners with PD had impaired prosody production (Scott et al., 1984; Blonder et al., 1989; Darkins et al., 1988; Caektekeke et al., 1991; De Keyser et al., 2016; Basirat et al., 2018), thus highlighting another gap in the studies on linguistic prosody perception and PD. Therefore, despite the paucity of research dedicated to the link between the perception and production of
prosody in people with PD, the existing evidence suggests that impairments in prosody production might correlate with less effective, but otherwise unaffected, linguistic prosody processing abilities in PwPD (Basirat et al., 2018, 2020). The findings from the studies by Martens et al. (2016) and Basirat et al. (2018, 2020) clearly indicate that the linguistic prosody processing in PwPD might be less affected than their perception and recognition of emotional prosody.

The need for additional research into the topic of perception and recognition of linguistic prosody by PwPD is highlighted by the fact that inconsistencies present in the findings could be accounted for by the diverse inclusion criteria employed by the studies. The reviewed studies used different thresholds for Minimal Mental State Examination (MMSE) scores: Martens et al. (2016) set the MMSE threshold score for inclusion at 27, in Lloyd (1999) the MMSE cut-off score was 23, whereas for Scott et al. (1984) it was 24, and for Darkins et al. (1988) it was 25. Another possible explanation for the inconsistencies is the dependence of prosody perception and recognition on the age of listeners, – an important observation made by Martens et al. (2016), who have shown that age is a relevant factor, especially when it comes to speech therapy. The same effect was also reported in Raithel and Hielscher-Fastabend (2004), who showed that young listeners demonstrate better results in prosody recognition than the older listeners. Moreover, there are other factors that have not been addressed in the literature in relation to the perception and recognition of linguistic prosody in speakers with dysarthria, such as depression or degrees of dysarthria severity.

The third research question of this chapter addressed the issue of how listeners with different degrees of expertise and training perceive and recognize prosodic cues in HD speech. It appears that neurologically healthy listeners, regardless of their level of experience with dysarthria, consistently report linguistic prosody of PwPD to be affected, especially in the domain of monopitch and monoloudness. Moreover, monopitch appears to be a very important reference cue for all groups of listeners: for untrained listeners (Pell et al., 2006; Kuo et al., 2014), for trained non-experts (Bunton et al., 2001; Whitehill et al., 2003; Ma et al., 2010a,b; Klopfenstein, 2015), and for trained expert listeners (Martens et al., 2011). Similarly, in a recent study by Smith et al. (2019), in which trained and untrained listeners provided assessments of intelligibility ratings of HD speech, the authors concluded that there is no significant difference between the assessments carried out by the two groups of listeners. The opposite results, however, were reported by Carvalho et al. (2020), who demonstrated that trained listeners have the advantage of better understanding the speech of PwPD compared to untrained listeners. Such findings suggest that all neurologically healthy listeners could be sensitive to prosodic irregularities in speech affected by HD, however, the role of expertise and training is yet to be explore in detail.

It is difficult to make generalizations from such a limited number of studies regarding the role of training and expertise for listeners’ perception and recognition of atypical prosody associated with HD. Moreover, the existing literature involves a wide variety of study designs and methodologies, which hinders direct comparisons across studies – an issue compounded by the variety of stimuli used. Direct comparison of studies is further complicated by the wide variety of subjects and listeners examined within studies and an imbalance in the numbers of male and female participants with PD in some experiments. Moreover, some studies included in this review also lack control speakers.
As previous research has demonstrated, such details are important: for example, speakers’ gender-related differences are reported in the study on rhythm in HD speech (Skodda and Schlegel, 2008). All this highlights the importance of adequate sample sizes and the necessity of an age- and gender-matched control group.

Much research remains to be done to achieve a clear understanding of the scope of linguistic prosody perception and recognition problems caused by PD. Overall, there is a paucity of studies that systematically assess the prosody-related deviant dimensions as well as listeners’ impressions of linguistic prosody produced by PwPD. Although the presence of certain speech characteristics might affect the regular flow of discourse, the dimensions of inappropriate silences, short rushes of speech, or variable speech rate have hardly received any attention with regards to listeners’ perception and recognition of dysarthric speech and prosody. Such research gaps should be addressed from both the listeners’ perspective and from the diagnostic perspective, since it is unclear to what extent deviant dimensions other than monopitch and monoloudness influence the perception and recognition of speech affected by HD. On the other hand, additional research is also required to gain insights into the relationship between production of linguistic prosody by PwPD and their perception and recognition of linguistic prosody associated with healthy speech. The hypothesis of unaffected linguistic prosody processing in listeners with PD is therefore in need of further investigation. Furthermore, such future studies should take into account factors other than the disease itself that might influence the outcome: cognitive problems, depression, or varying degrees of dysarthria severity. Yet another topic in need of additional research concerns the accuracy of listeners in recognizing prosodic deficits and speech change in general in the speech of PwPD (Harris et al., 2016).

3.5. Conclusions

This review analyzed the literature on the perception and recognition of linguistic prosody in relation to PD. Overall, the findings reported in the existing literature indicate that the commonly used prosody-related deviant dimensions from Darley et al. (1969b) are somewhat perceptually impressionistic. Two out of the top three highest ranked dimensions – monopitch and monoloudness — have been reported throughout the literature to have the greatest influence on the listeners’ impressions of speech affected by HD. The effect of other dimensions, however, remains less clear. At the same time, although the studies reviewed in this chapter utilize a barely comparable variety of stimuli and are focused on diverse tasks and goals, monopitch and monoloudness keep emerging as the most prototypical prosodic deviant dimensions in speech of PwPD. Therefore, both monopitch and monoloudness are likely to lie at the heart of the communication problems of speakers with PD which is also reflected by the existing speech treatments of HD (Ramig et al., 2001).

Findings on the perception and recognition of linguistic prosody by listeners with PD prove to be somewhat contentious due to the scarcity of the studies. However, the existing evidence suggests that linguistic prosody perception might be unaffected in listeners with PD (Martens et al., 2016; Basirat et al., 2018, 2020). At the same time, results reported by Basirat et al. (2018) demonstrate that the problems of PwPD in conveying meaning through prosodic characteristics correlate with their less efficient discrimination
of intonation contrasts. Therefore, such controversial findings call for further exploration of relationships between production and perception and recognition of linguistic prosody in PwPD.

The role of listeners’ expertise and training on prosody perception and recognition also remains unclear. There is currently no evidence that the amount of experience with HD significantly influences listeners’ evaluations of linguistic prosody in speech of PwPD. According to the studies included in the review, there are similar patterns in the perception and recognition of dysarthric prosody by different groups of listeners: the presence of monopitch is the feature which listeners, both trained and untrained, heavily rely on in their assessment of speech affected by HD. Nonetheless, there are no studies that have compared the untrained and trained expert listeners’ ability to assess the atypical prosody in speech of PwPD or to reliably recognize PD from recorded speech data alone. Moreover, the results of Skodda and Schlegel (2008) and Martens et al. (2016) highlight the need for additional research that would target the effects of listeners’ training and expertise. Such future research should be conducted with a balanced experiment design accounting also for participants’ age and gender. Furthermore, clinicians working with HD could benefit from a better understanding of the linguistic prosody deviances from which PwPD suffer, as well as the relationship between the production and recognition of linguistic prosody in these individuals. Also, including linguistic prosody tasks into the standard treatment of dysarthria in PD which specifically target prosodic deficits related to monopitch and monoloudness may enhance speech naturalness, intelligibility and the communication efficiency of PwPD and subsequently improve their quality of life.