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Music in the treatment of childhood speech sound disorders: Evaluating prosody in Dutch-speaking children

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Abstract

Purpose: Music is frequently used in the treatment of childhood speech sound disorders (SSD). The prosodic overlap between speech and music is explored to improve both segmental accuracy and prosody in children with SSD. In a pilot study, evaluation of speech-music therapy for aphasia showed improved speech production at the level of segmental accuracy and intelligibility. However, measures of fluency used in that study were inadequate for evaluating prosody.
Method: Two new methods for the evaluation of prosody were developed. The first method was a scale for perceptual judgement of prosody in spontaneous speech through a focus on naturalness. This scale was evaluated and validated in a group of children with and without SSD. The second method was a task for the realisation of lexical stress in non-words.
Results: Preliminary results of the evaluation of the prosody judgement scale indicate that the scale discriminates between children with and without SSD.
Conclusion: The evaluation of prosody in treatment studies of children with SSD was not possible with existing measures. A newly developed prosody judgement scale is suitable for the assessment of prosody in spontaneous speech. Evaluation of the developed lexical stress task is ongoing. Preliminary results will be ready for presentation.

Index Terms: prosody, treatment evaluation, childhood motor speech disorders

1. Introduction

Inappropriate or atypical prosody is one of the key features of childhood apraxia of speech (CAS), a subtype of speech sound disorders (SSD) [1], [2]. Dysprosody has a negative impact on intelligibility in CAS [3], [4], which negatively affects functional communication and social participation [5]. However, few treatment options are available for children with CAS that focus on or include prosody [4]. Additionally, assessment of prosody is hindered by a lack of instruments for Dutch-speaking children.

1.1. Prosody in speech sound disorders

Prosody encompasses various aspects of speech, both relating to the speaker, such as voice quality and loudness, and relating to the linguistic structure of an utterance, such as lexical and phrasal stress, intonation and pauses [6]. While voice quality can be impaired in speech sound disorders such as dysarthria, assessment and treatment of prosody in CAS mostly focus on the linguistic aspects of prosody [1], [6]. CAS is characterized by three core features, one of which is inappropriate prosody, including the realization of lexical stress [2]. For English, the inappropriate realization of lexical stress is found in the presence of equal stress at word level. Inappropriate realization of phrasal stress is found in segregation of words and syllables [7]. Additional features of inappropriate prosody in CAS include variations in speech rate, reduced range of variation in pitch and reduced range of variation in loudness [2], [7]. In this study we focus on the linguistic aspects of prosody.

1.2. Treatment of prosody

Studies on the treatment of prosody in CAS are limited and mostly focus on the realization of lexical stress [4], [8], [9]. Most studies include treatment methods that are based on or include principles of motor learning and focus on the overall effect of this treatment, with prosody as one of the features that is assessed [8], [9], [10], [11], [12]. Studies on Dynamic Temporal and Tactile Cueing (DTTC; [9]) show positive results on an overall rating of production accuracy that includes prosody [11], [12], [13]. Studies on the effect of Rapid Syllable Transition Treatment (ReST; [8]) show positive results on measures of lexical stress [4], [14]. While these results hold promise for the treatment of the realization of lexical stress, an issue came up in the study by McCabe et al. [4]. Children in their study showed progress on either lexical stress production or segmental accuracy, but remained unable to synchronously produce both correct stress patterns and correct segments. This is a known challenge in the treatment of developmental speech disorders [15].
In contrast to the previously described articulatory-kinematic type approaches, rate/rhythm control type approaches use musical features to support suprasegmental aspects of speech production, such as fluency and speech rate [16], [17], [18], [19]. Melodic Intonation Therapy (MIT; [16]) is a rate/rhythm control type approach that is used in the treatment of CAS [17], [20]. A systematic review of studies on the effect of MIT and other treatments with musical elements in the treatment of childhood SSD revealed that most studies report positive effects, but the methodological quality of these studies was insufficient and effect on prosody was not specifically evaluated [21].

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Another rate/rhythm control type approach is Speech-Music Therapy for Aphasia, which was originally developed for adults with aphasia and/or apraxia of speech (SMTA; [18]). Hurkmans et al. [22] showed in a proof-of-principle study that SMTA had a positive effect on fluency and intelligibility in adults with apraxia op speech. SMTA is recently introduced in the treatment of CAS [19]. This method combines speech therapy and music therapy and is provided simultaneously by both therapists. In this treatment, target items are chosen to be both functionally relevant and fitting for the speech targets and communication goals of the individual child. The music therapist composes unique melodies that support the natural prosody of the chosen target item. During practice, musical support is phased out in a protocol that starts with singing, followed by rhythmic chanting, and speaking. During the speaking phase, the support that is given by the speech therapist is phased out, starting with simultaneous speaking, followed by imitation, and ending with response to a question [19]. SMTA was evaluated in a single-subject design study with a five-year-old boy with CAS. Results of this study showed that intelligibility improved, as well as segmental accuracy. Fluency was assessed as a measure of prosodic ability, but this measure was found to insufficiently reflect prosodic ability [19].

Prosody in speech is realised through the modification of the features pitch, duration and intensity [6], which are similar to the musical parameters of melody, rhythm and dynamics [23]. This similarity holds promise for the treatment of prosody in CAS with SMTA, potentially providing a way to support children in synchronous production of correct stress patterns and segments. This requires adequate evaluation of prosodic ability in studies on the effect of SMTA.

1.3. Evaluation of prosody

The evaluation of prosody in CAS focusses on the realization of lexical stress, which can be measured perceptually, acoustically or kinematically. Acoustic and kinematic measures are mainly used in research, while perceptual measures are used in both research and clinical practice. However, most measures are not validated and lack norm or reference data [6].

For Dutch, there is one validated instrument that includes an assessment of prosody. The Dutch Dysarthria Assessment-Children includes perceptual judgement of melodic accent, dynamic accent and temporal accent in spontaneous speech, imitation and reading on a four-point scale [24]. The assessment of prosody in this instrument is used with additional measures to diagnose dysarthria in children. This instrument and the judgement of prosody therein were not validated for the evaluation of prosody in children with CAS.

Dysprosody in CAS is not only found in inappropriate realization of lexical stress, but also in segregation of words and syllables, variations in speech rate and reduced range of variation in pitch and loudness [2], [7]. These aspects of dysprosody in spontaneous speech have a negative effect on intelligibility, functional communication and social participation [3], [4], [5]. Evaluation of these prosodic features provides insights in speech production at the ICF-levels of activities and participation [25]. In treatment evaluation these measures could also provide insight in potential generalization of treatment effects.

There are no instruments available to assess prosody in Dutch-speaking children with CAS. To evaluate treatment effects of SMTA, which has the potential to impact prosody, valid measures are needed to assess prosody in both spontaneous speech and realization of lexical stress. Therefore, the aim of the current study was to develop measures of prosody for Dutch-speaking children with CAS that assess prosodic features in spontaneous speech and realization of lexical stress in a controlled task.

2. Method

In this study we developed two methods for the evaluation of prosody in treatment studies. The first is a scale to judge prosody in spontaneous speech. The second task evaluates the realization of lexical stress in a non-word repetition task to assess a child's ability to produce prosodic features in a controlled task. Both tasks are described below. Evaluation and validation of both tasks is ongoing. Preliminary results for the rating of prosody in spontaneous speech are presented in this paper.

2.1. Prosody in spontaneous speech rating

The scale for rating prosody in spontaneous speech is constructed in resemblance to the Intelligibility Rating by Dobinson [26], [27]. It takes both quality of prosody and listeners comfort in consideration. Three indicators of prosodic appropriateness are combined to judge the naturalness of the speech sample. These indicators are intonation, fluency and rate. The scale is divided in five levels based on the severity of atypical realization of intonation, fluency and rate. The first four levels are additionally subdivided based on the comfort level for the listener. The overall scale comprising nine levels is shown in Figure 1.

Naturalness	Comfort of listening	Score
Tempo, fluency AND intonation of speech were natural	Very pleasant Pleasant	9 8
Tempo, fluency OR intonation of speech was slightly unnatural	Pleasant Slightly unpleasant	7 6
Tempo, fluency OR intonation of speech was unnatural	Moderately unpleasant Unpleasant	5 4
Tempo, fluency AND intonation of speech were unnatural	Unpleasant Very unpleasant	3 2
Tempo, fluency AND intonation of speech were very unnatural	Highly unpleasant	1

Figure 1: *Naturalness rating scale.*

The prosody rating scale was evaluated in a validation study. Research questions for this study were:

(1) Does the prosody in spontaneous speech rating scale discriminate between children with and without SSD?

(2) Does knowledge of the age of the child in the sample influence scoring?

(3) Do experienced and non-experienced raters score differently?

Speech samples from the SPEECH study [28] were used and included two 20-second samples of spontaneous speech per child from 20 children without speech-and language disorders and 60 children with SSD. Ages ranged from 4;0 (years; months) to 6;10 for children without speech-and language

disorders and from 4;0 to 6;10 for children with SSD. Speech samples were collected in a conversation on familiar subjects, such as sports, hobbies, school and pets. Fragments were selected that included mostly the child speaking and that reflected the whole conversation. The speech samples were rated with the prosody in spontaneous speech rating scale by two groups of raters. The first group consisted of nine SLT's and students of neurolinguistics (8 female, 1 male). The second group consisted of nine individuals 8 female, 1 male) without any experience in speech-language pathology or linguistics. Ages of the assessors ranged from 21 to 54 years for the experienced group and from 20 to 57 years for the non-experienced group. All assessors had self-reported normal hearing and speech-language abilities. They gave informed consent for participation in the study.

An online questionnaire was used in which each rater scored samples of 20 children without speech disorders and 20 children with SSD. There were three versions of the questionnaire, all including the samples of the 20 children without SSD supplemented with the samples of 20 children with SSD. The raters scored two samples of each child and knew the age of the child for one of those samples.

Data from the online questionnaire were processed in Excel to be analyzed with SPSS, version 28.

The Wilcoxon Signed Ranks Test was used to assess whether the rating scale differentiates children with and without speech sound disorders. This test was also used to determine whether knowledge of the child's age lead to a different rating. The Mann-Whitney test was used to assess differences in scores between experienced and non-experienced raters.

2.2. Lexical stress task

The lexical stress task is a non-word repetition task. It includes twelve pairs of non-words in a CVCV structure in two stress conditions, iambic and trochaic. The first syllable consists of a /d/ with /ə/ in the iambic condition and /d/ with /e/ or /ɛ/ in the trochaic condition. The second syllable consists of /d/, /b/, /s/ or /f/ combined with /u/, /i/ or /a/. Minimal pairs with limited variation in consonants were chosen for the ability assess co-articulation with the same task. The list of items is shown in table 1. The items are embedded in a carrier phrase: 'It is /dəsa/ again'.

Table 1: *Items in the lexical stress task*

iambic	**trochaic**
dəˈbi	ˈdɛbi
dəˈba	ˈdɛba
dəˈbu	ˈdɛbu
dəˈdi	ˈdɛdi
dəˈda	ˈdɛda
dəˈdu	ˈdɛdu
dəˈsi	ˈdesi
dəˈsa	ˈdesa
dəˈsu	ˈdesu
dəˈfi	ˈdefi
dəˈfa	ˈdefa
dəˈfu	ˈdefu

The task is integrated in the existing Computer Articulation Instrument (CAI) [29] and administered with a computer or laptop. The child is guided to repeat each item five times. Recordings are made and saved in the program for analysis afterwards. Analysis consists of calculation of the Pairwise Variability Index (PVI) for duration, amplitude and F0 for the paired items.

This task is being validated in a group of typically developing three- to ten-years-old children. This age range will provide insight in the development of the realization of lexical stress in typical development. This data will serve as reference data for children with CAS that are included in the treatment study. Validated speech tasks, such as the CAI are administered alongside this new task to assess its validity.

3. Results

The evaluation and validation of both tasks are ongoing. Preliminary results of the evaluation of the prosody in spontaneous speech rating scale are presented here.

Scores for children with and without SSD are presented in figure 1. Analysis with the Wilcoxon Signed Ranks Test showed that scores for children with SSD were significantly lower than scores for children without SSD ($z = -3.724$, $p < 0.01$).

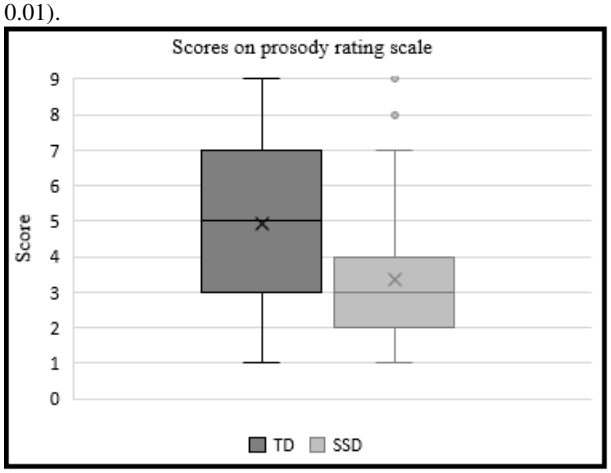

Figure 1: *Scores of children with and without SSD on the prosody rating scale. TD= typically developing, SSD = speech sound disorder*

Knowledge of the age of the children lead to different scores in both the children with SSD and children without SSD. Children with SSD received higher scores when the age was given ($z = -3.167$, $p = 0.002$), but children without SSD received lower scores when age was given ($z = -2.705$, $p = 0.007$). Analysis with the Mann-Whitney U test showed no significant differences in scores by experienced and non-experienced raters for both children with SSD ($U = 18.5$, $z = -1.948$, $p = 0.051$) and children without SSD ($U = 22.5$, $z = -1.590$, $p = 0.112$).

4. Discussion

In these studies we developed instruments to assess prosody in Dutch-speaking children with CAS. Valid assessment of prosody in this group is necessary in treatment evaluation and specifically in the study into the effect of SMTA. Our aim was to assess the realization of lexical stress in a controlled task and prosodic features intonation, fluency and rate in spontaneous speech. The assessment of the realization of lexical stress was chosen, because this prosodic skill is explicitly mentioned in the

diagnostic criteria for CAS [2] and is used in both diagnostic and treatment studies into CAS [4], [7]. The assessment of prosodic features in spontaneous speech was chosen to reflect generalization of potential treatment effects and to assess prosody at the level of activity and participation of the ICF [25]. While validation of the naturalness rating scale is ongoing, preliminary results show that this scale differentiates between children with and without SSD. These results support the known disruption of prosody in SSD and CAS specifically [2], [30].

Raters scored samples of both children with and without SSD differently when they knew the age of the child. However, scores changed in opposite directions with children without SSD scoring lower when their age was known and children with SSD scoring higher when their age was known. Further research is needed to find an explanation for these effects.

The age of the child is an important factor in the rating of prosody in spontaneous speech. In both groups of children, raters scored significantly different when they knew the age of the child, compared to when they were unaware of the child's age. It remains unclear which of both scores better reflects the child's abilities. Further research into potential developmental stages that may be distinguished with the prosody in spontaneous speech rating scale could provide more insight in the influence of age and speech development on scores on this scale.

There were no differences in scores between experienced and non-experienced raters. This result is similar to results in another study in which raters had to judge nasality in children with cleft palate [31]. Other studies showed that non-experienced listeners were more accurate in recognizing disordered speech than experienced listeners [32], [33]. However, these studies were conducted in adults with Parkinsons disease and judgements were on speech being disordered in general and not on specific features such as prosody or nasality. These differences in assessed features and speakers could explain the different results in these studies. Further research is needed to see what factors influence scoring by experienced and non-experienced raters.

The evaluation of the lexical stress task is ongoing. While this type of measure is widely used in diagnostic and treatment studies into CAS in English-speaking children [6], it is unclear whether this measure will yield similar results in Dutch-speaking children. A study into the development of lexical stress production in English speaking children showed that children produce the strong-weak pattern correct at the age of three, but that the production of the weak-strong pattern still differs from adultlike production at the age of seven [14]. Dutch and English are both stress-timed languages and the same patterns of strong-weak and weak-strong for lexical stress are present in Dutch. In both languages, the strong-weak pattern is the predominant pattern [34]. Based on these similarities, it is to be expected that Dutch-speaking children will have more problems with the correct realization of the weak-strong pattern, similar to the results found by Ballard et al. [14].

4.1 Limitations

This study has some limitations. First, the raters indicated that the rating scale was difficult to use. They found that combining the three indicators rate, fluency and intonation in one judgement was difficult. Separating these indicators could make a rating scale easier to use and would provide more specific information on the realization of prosodic features in the speech samples. This would lead to a longer questionnaire, which might pose other problems for raters, such as duration of scoring.

Second, the age range and distribution of the children in the study was insufficient to assess differences in scores between children of different ages. To gain insight into changing scores with age in both children with and without SSD, research in a broader age range is necessary.

Third, the actual experience of the experienced raters was not specified. Based on their educational background, some knowledge on SSD and prosody can be assumed, but the level of expertise in children with SSD and/or prosody may vary. This could influence differences between groups of experienced and non-experienced raters.

5. Conclusions

Two new instruments for the assessment of prosody in Dutch-speaking children with CAS were developed. These tasks can be used to evaluate treatment of children with CAS and will be used to evaluate the effect of SMTA in the treatment of CAS. Preliminary results of the evaluation of a prosody in spontaneous speech rating scale show that this scale distinguishes between children with and without speech sound disorder. Further research into this scale is necessary to gain insight into the development of prosodic ability with increasing age. The evaluation of a lexical stress task is ongoing.

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