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Brief Report: A Mobile Application to Treat Prosodic Deficits in Autism Spectrum Disorder and Other Communication Impairments: A Pilot Study

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Abstract

This study examined the acceptability of a mobile application, *SpeechPrompts,* designed to treat prosodic disorders in children with ASD and other communication impairments. Ten speech-language pathologists (SLPs) in public schools and 40 of their students, 5–19 years with prosody deficits participated. Students received treatment with the software over eight weeks. Pre- and post-treatment speech samples and student engagement data were collected. Feedback on the utility of the software was also obtained. SLPs implemented the software with their students in an authentic education setting. Student engagement ratings indicated students' attention to the software was maintained during treatment. Although more testing is

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Keywords (separated by '-')	Autism - Technology - Intervention - Prosody - Speech
Footnote Information	

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BRIEF REPORT

Brief Report: A Mobile Application to Treat Prosodic Deficits in Autism Spectrum Disorder and Other Communication Impairments: A Pilot Study

Elizabeth Schoen Simmons[1] · **Rhea Paul**[2] · **Frederick Shic**[1]

Abstract This study examined the acceptability of a mobile application, *SpeechPrompts,* designed to treat prosodic disorders in children with ASD and other communication impairments. Ten speech-language pathologists (SLPs) in public schools and 40 of their students, 5–19 years with prosody deficits participated. Students received treatment with the software over eight weeks. Pre- and post-treatment speech samples and student engagement data were collected. Feedback on the utility of the software was also obtained. SLPs implemented the software with their students in an authentic education setting. Student engagement ratings indicated students' attention to the software was maintained during treatment. Although more testing is warranted, post-treatment prosody ratings suggest that *SpeechPrompts* has potential to be a useful tool in the treatment of prosodic disorders.

Keywords Autism · Technology · Intervention · Prosody · Speech

Introduction

For the majority of individuals with autism spectrum disorder (ASD) who acquire spoken language, expressive prosody—the rhythm, stress, and intonation of speech—is among the most noticeable and chronic impairments (Baltaxe and Simmons 1985; DeMyer et al. 1973; Kanner 1971; Lyons et al. 2014; Rutter and Lockyer 1967; Shriberg et al. 2001). Prosodic deficits have been shown to impact how listeners perceive the social and communicative competence of high-functioning individuals with ASD (Paul et al. 2005) and those with intellectual disability (Shriberg and Widder 1990). Deficits in these suprasegmental features of speech also impede social interaction and limit participation in vocational, recreational and learning activities (Lewis et al. 2004; Wilson and Warton 2006). Prosodic deficits are also observed in children with other communication disorders, as well as those with ASD (Catterall et al. 2006; Marshall et al. 2009; Stojanovik et al. 2007; Wells and Peppé 2003).

A limited number of intervention strategies to treat these deficits exist, with the majority of these lacking empirical support. Diehl and Paul (2009) and Peppé (2009) reviewed current prosodic intervention literature and reported that methodological issues (e.g., small sample sizes) made it difficult to interpret and generalize the findings.

The proliferation of mobile technology, including tablets and smartphones, provides speech-language pathologists (SLPs) with another medium to deliver intervention. A recent survey of approximately 300 school-based SLPs (Fernandes 2011) reported that a majority owned either a tablet or smartphone and used their personal device during intervention sessions with students. Emerging research suggests higher levels of student engagement during sessions that use technology than those using traditional materials (American Speech-Language Hearing Association 2011).

A small body of literature suggests that mobile technology is a valuable tool in the treatment of communication deficits and behavioral issues commonly observed in students with ASD and other communication disorders.

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Increased frequency of peer initiations and response to peer bids were observed after iPod training in a group of adolescents with autism using an iPod Touch loaded with an augmentative and alternative communication (AAC) application (Carpenter 2012). In a single subject study, the use of an iPad was shown to decrease levels of challenging behavior while increasing academic engagement in two students with autism spectrum disorder (Neely et al. 2013). While the literature suggests using technology can improve engagement, there is a dearth of research regarding the utility of technology for improving specific communication skills, such as prosody, in these populations.

The present study's primary aim was to assess the acceptability of an application, *SpeechPrompts,* for mobile devices in the treatment of prosodic disorders in school-age children with ASD and those with other communication impairments. A secondary aim was to provide preliminary evaluation of the potential utility of this application for improving prosody skills in students with prosodic deficits.

Table 1 SLPs' clinical experiences

	$N = 10$ (%)
Current employment setting*	
Preschool	30
Elementary school	80
Middle school	40
High school	20
Years in current position	
0–5 years	20
6–10 years	40
11–15 years	20
16–20 years	0
≥21 years	20
Experience with tablets (e.g., iPads)	
Minimal experience	20
Some experience	20
Significant experience	60

* Percentage >100 as a subset of SLPs work in more than one setting

Methods

Participants

Speech-Language Pathologists

Inclusion criteria for SLPs included: (1) licensure by the department of public health in the State of Connecticut (2) certification by the American-Speech-Language-Hearing Association and (3) caseloads including students who had prosodic difficulties. Ten (10) SLPs were enrolled in this pilot study. Each was asked to complete an online survey to collect information about work setting, familiarity with tablet devices and any training already received on assistive technology (see Table 1).

Student Participants

Each SLP recruited four students from her caseload who met the following inclusion criteria: (1) enrollment in speech and language intervention as part of special education services, (2) speech containing full sentences, and (3) exhibiting prosodic difficulties secondary to ASD or other communication disorder. A total of 40 students, aged 5 through 19 years, met study criteria and were enrolled for participation. Approximately 67.5 % of the students had a school-based classification of ASD on their individualized education plan (IEP); the remainder were classified with other impairments (e.g., speech and language impairment, intellectual disability, multiple disabilities, traumatic brain injury). Diagnostic information was not available at an individual level for all students due to the study's IRB format; therefore, a subset analysis for 12 students with ASD who had linkable diagnostic and study data is provided in the appendices for greater specificity of information for students with ASD. A wide distribution in the ages of students was included to determine whether both younger and older students would be engaged with the software. A majority of the students (72.5 %) were assessed as having impairments in two or more prosodic domains as rated by their SLP. See Table 2.

Procedures

Software

SpeechPrompts was developed for iOS devices (e.g., iPad); its main function was to provide a visual representation of the prosodic features of speech. It contained two primary features. The *VoiceMatch* feature allowed the SLP to record a short target phrase, then view a waveform visualization of the phrase. The student would then attempt to produce a waveform matching the target by adjusting his/her speaking rate and/or stress (see Fig. 1). The second feature, *VoiceChart,* provided real-time feedback on speaking volume by displaying visual cues to monitor and adjust the volume of speech. Slider controls were used by the SLP to adjust the target speaking thresholds during instruction. This feature had customizable visuals for younger and older participants (i.e., teddy bears and written words, respectively) (see Fig. 2).

The software was designed with usage-tracking embedded within the application. This tool automatically

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Table 2 Student participant characteristics

	$N = 40$
Gender	
Male	31
Female	9
Mean age in years (*SD*)	9.63 (3.70)
Grade level	
Elementary (PreK–4th)	22
Middle school (5th–8th)	13
High school (9th–12th)	5
Diagnosis based on IEP[a]	
ASD	27
Speech and language impairment	7
Intellectual disability	3
Traumatic brain injury	1
Multiple disabilities	1
Other health impairment	1
Number of students with prosodic impairments, by domain, as rated by SLP[b]	
Rate/rhythm	27
Stress	29
Volume	28

[a] Individualized education plan

[b] A subset of students were rated as having impairments in more than one prosodic domain

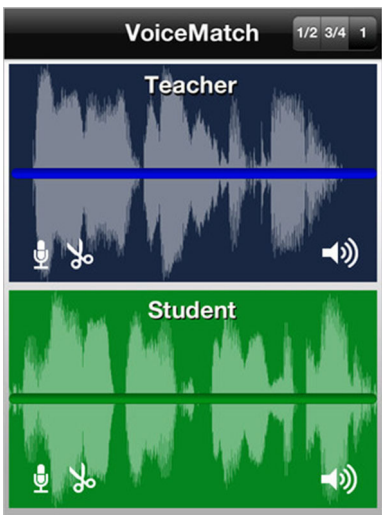

Fig. 1 Screenshot of waveforms generated by *VoiceMatch* feature. The *top* waveform is a sentence produced by the SLP while the bottom waveform is the student's production of the same target sentence. The small microphone, scissors and speaker icons control recording, editing and volume functionality within the app

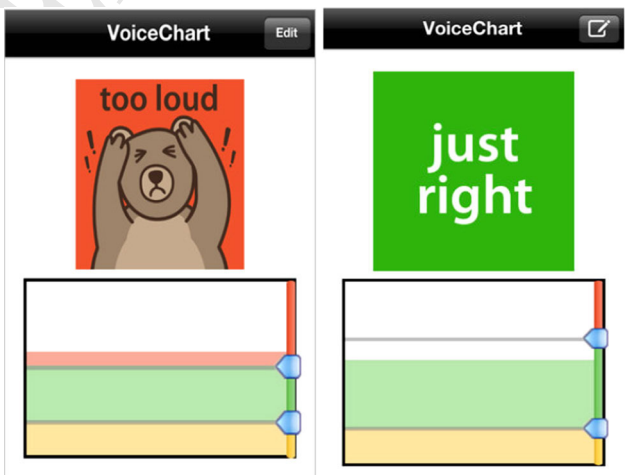

Fig. 2 Screenshot of *VoiceChart* with customizable visual supports and volume thresholds. The *top* half of the window provides the visual feedback. On the*left* is a teddy bear for younger students and on the *right* written words for older students. The *bottom* half of the window allows the SLP to move the sliders to set an appropriate speaking volume level

compiled usage statistics for each SLP including duration of treatment sessions, frequency of application use, and ranges of features accessed during each session. The application was designed in collaboration with the authors and a small software company. The authors received no financial compensation from the company.

Speech Samples

Five-minute speech samples were collected by each SLP, pre- and post-treatment, from student participants; these samples were audio recorded for later coding. A topic prompt, *tell me about your family and everyone who lives with you*, was

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provided. The SLP rated each sample on the following prosodic features (a) rate, (b) stress in words, (c) stress in sentences and (d) intensity. Each SLP also provided a global intonation summary rating for each sample. A scale of 0 (typical prosody), 1 (mildly atypical prosody), or 2 (clearly atypical prosody) was used for these ratings.

Speech Sample Reliability

A randomly selected 20 % of speech samples were re-coded by a second coder blind to whether the sample was collected pre-treatment or post-treatment. Inter-rater reliability was established using Cohen's Kappa coefficient. Inter-rater agreement of 0.68 was obtained across the prosodic parameters of global intonation, rate, and stress, indicating substantial agreement (Viera and Garrett 2005). Inter-rater reliability could not be established for intensity as sample collection did not include calibration for baseline intensity.

SLP Training

Each SLP received an iPad 2 (iOS 6.0) preloaded with *SpeechPrompts*. A 20-min training tutorial was delivered by the research coordinator, which covered the use of the main features, enabled the SLP to navigate through the application and to answer any questions that arose during the tutorial session. The coordinator was available for the duration of the study to provide technical assistance as needed.

Intervention

The *SpeechPrompts* software was presented to the students as part of their speech and language services that took place in their local school. The SLPs were instructed to use the application with four selected students at least once each week for 8 weeks.

Student Engagement Questionnaire

Each SLP completed a rating scale to assess the student's engagement while using the software following each treatment session. For each student, SLPs rated (1) enjoyment of the software, (2) attention while using the application, (3) consistent attempts to produce responses and (4) off-task behavior. Numerical ratings ranged from 1 (Strongly Agree/Highly Engaged) through 5 (Strongly Disagree/Not engaged).

Post-Study Questionnaire

Each SLP completed a questionnaire containing Likert-scale ratings and open-ended questions regarding experiences with the software at study conclusion.

Results

Software Utilization

The mean number of sessions, or how many times the SLPs used the software, across student participants ranged from 1 to 12 sessions with a mean of 4.7 sessions ($SD = 2.79$) although they had been asked to use the software at least one time a week for 8 weeks (see Discussion). Session length ranged from five to 90 min with a mean of 21.25 min ($SD = 11.82$ min). Feature usage from the data-tracking component of the software revealed that *VoiceMatch* and *VoiceChart* features were used 52.9 and 47.1 % of time spent with the software, respectively.

To ascertain whether clinical experience was related to software utilization (i.e., frequency and duration of intervention sessions), bivariate Pearson's correlations were computed between the SLPs' number of years in their current position and both the total number of intervention sessions conducted as well as total number of treatment minutes completed. Since the number of treatment minutes was highly correlated with number of treatment sessions ($r = .81$, $p = .005$), only treatment minutes was used in this analysis. There was no significant relationship between number of SLPs' years in current position and total number of treatment minutes received by student participants ($r = .259$, $p = .470$).

Student Engagement

A total of 188 student engagement questionnaires were collected. The number of students with mean scores ≤ 3 across sessions in each engagement category, indicating high levels of engagement, were tallied to derive proportions. These proportions suggest that the students enjoyed the *SpeechPrompts* sessions (92.5 %; 37/40 students; $M = 1.66$, $SD = 0.67$), maintained attention during the sessions (87.5 %; 35/40 students; $M = 1.74$, $SD = 0.80$), provided consistent responses to stimuli (87.5 %; 35/40 students; $M = 1.78$, $SD = 0.80$) and did not produce maladaptive behaviors (85.0 %; 34/40 students, $M = 1.79$, $SD = 0.93$) during the sessions. Ratings were stable on the questionnaires from the first to final sessions (see Fig. 3).

SLP Feedback

Post-study surveys completed by all participating SLPs revealed that the majority (≥ 80 %) found the software (1) enjoyable, (2) easy to use (3) functional and (4) resulted in positive changes to students' prosody. All of the SLPs ($N = 10$; 100 %) reported feeling comfortable recommending the software to colleagues.

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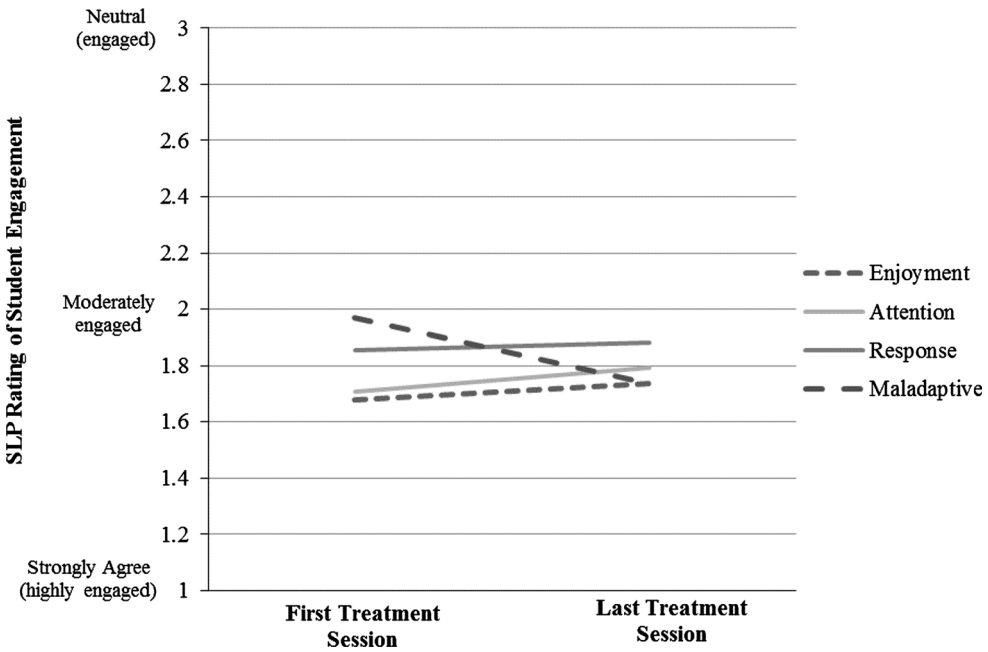

Fig. 3 Mean student engagement ratings from the first session to the last session are plotted over time. SLPs rated student's engagement from 1 (highly engaged) to 5 (not engaged). No student received a rating of 4 or 5. Low, stable ratings across sessions illustrate high engagement throughout the duration of treatment. Diminishing maladaptive behaviors during the course of treatment are also illustrated here

Speech Sample Ratings

Pre- and post-treatment prosody ratings were assigned to speech samples obtained from 32 of the 40 student participants. Speech samples were not collected from the remaining 8 students due to absenteeism, clinician error and equipment malfunction. A mean pre-treatment prosody rating was calculated across the four main prosodic categories: rate, stress in words, stress in sentences and intensity. Students' mean prosody rating ranged from 0.25 to 2.00 with an average mean rating of 1.08 ($SD = 0.44$) across these constructs. Paired *t*-tests were used to compare pre- and post-treatment prosody ratings for the four broad prosodic categories and the summary category. A lower mean score, indicating improved prosodic performance, was observed in each domain (Stress in Words, $p = .012$, $d = 0.48$; Stress in Sentences, $p = .001$; $d = 0.77$; Intensity, $p = .001$, $d = 0.77$; Global Intonation, $p = .001$, $d = 0.71$) with the exception of *Rate* ($p = .100$). Figure 4 illustrates the prosody ratings for each prosodic category. No relationship was observed between change in the Global Intonation prosody rating from pre-treatment to post-treatment and number of treatment minutes received ($r = .16$; $p = .394$), potentially reflecting heterogeneity of learning in the sample.

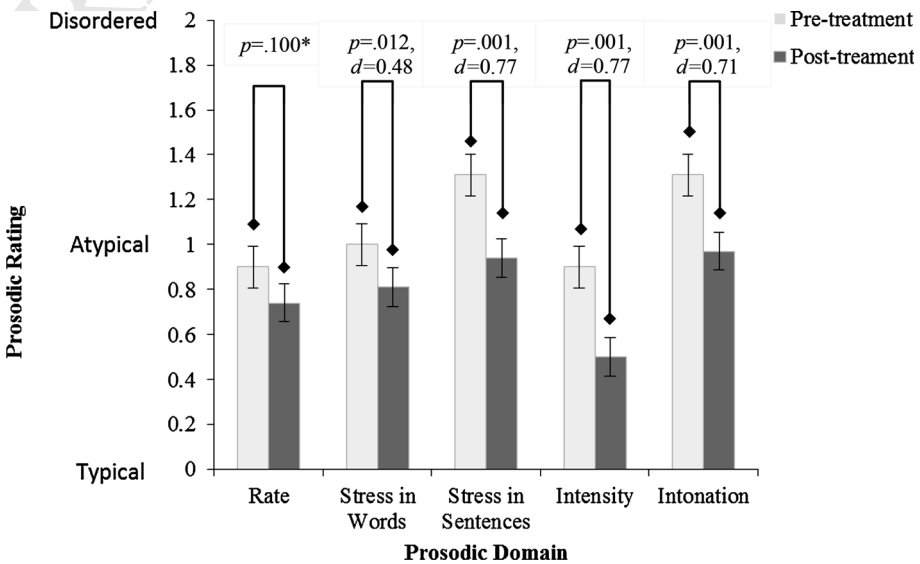

Fig. 4 Pre- and post-prosody ratings derived from speech samples coded by SLPs. *Error bars* represent ±1 SE. *ns *p* value

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ASD Specific Findings

The same analyses were completed for a subset of 12 participants, for whom diagnosis and treatment data could be linked, are reported in the appendices. The mean number of intervention sessions across these participants ranged from 2 to 10 sessions with a mean of 5.83 sessions ($SD = 2.41$). Session length ranged from 10 to 30 min with a mean session lasting 25.99 min ($SD = 6.25$).

Discussion

The primary aim of this study was to evaluate the feasibility and acceptability of *SpeechPrompts,* a mobile application that provides a visual representation of the suprasegmentals of the speech signal to treat prosodic deficits. Although not designed to meet the standards of a randomized controlled trial, this study meets criteria for an adequate intervention research report based on the guidelines defined by Reichow et al. (2008), with quality indicators (including description of both participant and interventionist, operational and replicable descriptions of dependent measures, a clear link between the research question and data analysis, and use of appropriate units of measurement) well documented within this report.

Results of this pilot study suggest that SLPs were able to use the application in an authentic educational setting with students who exhibit prosodic impairments. SLPs from our study reported a high level of familiarity with tablets, as other reports on the use of mobile technology among clinicians suggest (Fernandes 2011). Even those SLPs who reported little experience were able to utilize the application with their students.

Although prosodic impairments are observed in multiple clinical populations (Staum 1987; Wells and Peppé 2003; Catterall et al. 2006), the majority of students who participated in this study had a diagnosis of ASD. The experience of children with other clinical diagnoses in our sample, however, suggested that this application might be useful for a range of disorders, not solely ASD. Measures of student engagement reported by the SLPs suggest that the application captures student attention, is enjoyable and elicits consistent responses in a diverse group of students. Stable student engagement ratings suggest that students continued to attend to the software and provided responses throughout treatment, not only during the first session, suggesting the results were unlikely due to a "novelty" effect alone. Moreover, maladaptive behaviors were reported to diminish over the course of treatment.

Lastly, data collected from SLPs about their responses to the software at the end of the study indicated that they liked the software, thought it was functional and enjoyable for their students and that they felt comfortable recommending the application to colleagues.

A secondary aim of this research was to assess the efficacy of the software when implemented by licensed clinicians in authentic settings. Although preliminary in nature, results suggest that *SpeechPrompts,* even in low doses, can be useful in the treatment of prosodic impairment in students with communication disorders, as evidenced by changes in prosodic functioning documented in this sample.

Although asked to use SpeechPrompts at least once a week for 8 weeks, most SLPs used it less than this, perhaps because of conflicting demands from other IEP goals. The relatively positive changes seen in prosodic ratings of speech, even at this low dose of intervention, suggest that use of SpeechPrompts has a potential for efficacy, although caution is warranted in interpreting the results, since SLPs were not blind to treatment status. Nonetheless, the question of adequate dosage remains an unanswered question for this intervention, as it does for many speech-language interventions, and further research is needed to resolve it.

Additionally, it may be possible to use the application to address prosodic production while working on other language goals. For example, the *VoiceChart* feature could be used while practicing conversational skills. *VoiceMatch* feature could be used while teaching specific language targets. Again, more research is needed to determine whether working on multiple goals simultaneously is an effective strategy.

Our primary goal was to assess acceptability; therefore, no intervention control group was included, limiting our ability to measure the efficacy of the *SpeechPrompts* treatment. Still, improvements from pre- to post-treatment were observed, suggesting a more controlled trial is warranted. Subsequent iterations of our work will address this omission as well as the need for (1) secondary, blind clinical observation ratings obtained independently of the treating clinician to control for bias; (2) a measure of treatment fidelity to ensure SLPs are using the software appropriately; (3) more nuanced statistical analyses addressing how individual characteristics (e.g. IQ or treatment dosages) impact outcome measures; (4) in-depth examination of the relationship between changes in prosody and treatment dosages; and (5) new application capabilities for addressing other prosodic domains such as pitch and for providing more in-depth visualizations of speech.

Although further research is needed to rigorously evaluate the efficacy of the application, preliminary results suggest that *SpeechPrompts* provides SLPs with an additional tool in their repertoire to address mild to moderate prosodic difficulties commonly observed in children with ASD and with other communication impairments, for which there are currently few validated treatment approaches. This research adds to the sparse literature regarding the treatment of prosody deficits (Peppé 2009) in school age students with ASD and other communication disorders.

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Appendixes

See Tables 3, 4.

See Fig. 5.

Table 3 ASD subset characteristics

	$n = 12$
Gender	
Male	11 (91.67 %)
Female	1 (8.33 %)
Mean age in years (SD)	8.25 (3.25)
Age range	6–12 years

Table 4 ASD subset prosody ratings

$n = 12$	Mean pre-treatment rating (*SD*)	Mean post-treatment rating (*SD*)	*p*	*d*
Rate	0.50 (0.67)	0.33 (0.49)	.116	–
Stress in words	0.50 (0.52)	0.42 (0.51)	.339	–
Stress in sentences	1.33 (0.49)	0.92 (0.51)	.017	0.80
Intensity	0.75 (0.87)	0.33 (0.65)	.017	0.90
Global intonation	1.17 (0.58)	0.75 (0.62)	.017	0.81

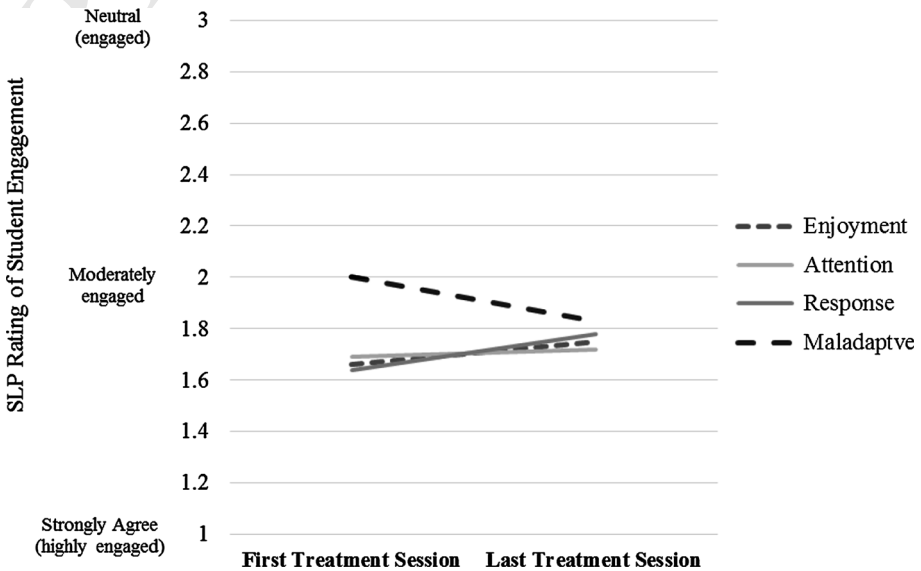

Fig. 5 Mean student engagement ratings from the first session to the last session are plotted over time for subset of 15 students with ASD. SLPs rated student's engagement from 1 (highly engaged) to 5 (not engaged). No student received a rating of 4 or 5. Low, stable ratings across sessions illustrate high engagement throughout the duration of treatment

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