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Improvements in micro level indices of social communication following Pivotal Response Treatment (PRT)

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A R T I C L E I N F O

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A B S T R A C T

Background: Pivotal Response Treatment (PRT) is an evidence-based treatment for individuals with ASD that targets social communication skills, most notably social motivation. The aim of the current study was to map microanalytic changes in social communication during dyadic child-therapist interactions following a 16-week trial of PRT. We proposed that a microanalytic approach would allow us to meticulously outline the dynamics of the "building blocks" of children's discourse, stressing certain aspect that might go unnoticed in global methods of coding. We hypothesized that PRT would improve measures of linguistic social communication in children.
Method: We utilized continuous microanalysis of behavior to explore changes in social communication during PRT sessions in 20 high-functioning children with ASD (ages 4–7 years). For each child, two videotaped PRT sessions – at the beginning and end of these 16 weeks – were coded for vocalizations and verbalizations. This allowed us to compare the amount, fluency, adequacy and reciprocity of social communication between child and therapist at the early versus final stages of PRT.
Results: Compared to baseline, at endpoint, children increased their overall use of vocalizations as well as the congruency of their responses to those of the therapist. The amount of non-congruent responses also dropped significantly. Additionally, children improved in measures of conversational fluency and use of self-referential pronouns.
Conclusions: These results provide a mapping of microanalytic changes in social and linguistic communication that occur during PRT and point to children's improvement in social communication behavior leading to greater social reciprocity and conversational synchrony following treatment.

1. Introduction

The social motivation theory of Autism Spectrum Disorder (ASD) (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012) explains the core social deficit in ASD as a case of diminished social expertise. A moderated social interest deprives the developing child of social inputs and opportunities for social learning and social reciprocity, leading to deficits in social communication and social cognition (Chevallier et al., 2012). This early disruption leads to canalization in brain development, such that the typically developing (TD) connections between brain areas responsible for social information processing are greatly altered. For example, Dubey, Ropar, and de Hamilton (2015) have shown that TD adults prefer social stimuli over non-social stimuli, but this preference is weaker

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in TD adults with higher levels of autistic traits. They also showed that compared to TD individuals, adults with ASD had a reduced preference for direct gaze from faces. Dawson et al. (2004) have shown that social orienting, joint attention and attention to another's distress were compromised in children with ASD compared to TD children. It has been hypothesized that decreased neural activations in social "wanting" brain regions may have a crucial role in mediating social engagement, and thus a dysfunction in this capacity can explain some of the ASD phenotype related to disruptions in social communication (Kohls, Chevallier, Troiani, & Schultz, 2012). Implications for treatment following this framework mean refining reward-based intervention programs to specifically target social "wanting" skills, namely social motivation.

1.1. Pivotal Response Treatment (PRT)

Pivotal Response Treatment (PRT) is an evidence-based treatment for individuals with ASD, derived from the principles of applied behavioral analysis (ABA). This approach targets pivotal areas of social communication development. It is hypothesized that changes in these areas can lead to widespread changes in behavior (Koegel & Koegel, 2012; Koegel, Koegel, & McNerney, 2001; Kohls et al., 2012).

In line with the social motivation theory (Chevallier et al., 2012), the core target of PRT in ASD is the motivation to engage in social communication, which is linked to both an underlying neurological basis and to many individual behaviors that are affected as children develop. Targeting social motivation in intervention may eventually partially compensate for the altered neural development that leads to decreased social interest (Koegel & Koegel, 2012; Koegel et al., 2001).

As such, a primary focus of PRT is increasing children's motivation to respond in social settings so that they will be able to self-initiate social, linguistic, and academic interactions (Koegel et al., 2001). This improvement is related to specific changes to neural function in regions supporting social perception and social motivation (Ventola et al., 2015). Due to the efficacy of the treatment, accurate behavioral mapping of the patient-therapist processes and interactions is needed. This would further the understanding of the active ingredient inherent in PRT.

1.2. Behavioral microanalysis

A microanalytic approach to understanding interactive behavior grants a granular understanding of social interaction behaviors. Microanalysis of behavior has been defined as "operating like a 'social microscope'," identifying 'subterranean', rapid communications, which are often not quite perceptible in real time" (Beebe & Steele, 2013). Micro-level analysis allows for observing and mapping the dynamics of the "building blocks" of children's discourse, stressing certain aspect that could go unnoticed in more global methods of coding (Hamo, Blum-Kulka, & Hacohen, 2004). A central feature of microanalytic analysis of behavior is that of "interaction synchrony" (Feldman, 2007), defined as the temporal coordination of micro-level relational behaviors into patterned configurations that become internalized and, over time and repeated experience, shape development. Interactional Synchrony is anchored in the most fundamental human attachment bonds, provides the basis for later development of symbol use, attachment, self-regulation, and empathy (Feldman, 2007; Gordon & Feldman, 2008), and has an extensively characterized biological foundation (Gordon & Feldman, 2015). Most studies investigating the efficacy of PRT in the behavioral domain have used self-report measures or more global analysis methods that assess an overall impression of the child. For example, a recent study (Duifhuis et al., 2017) reported that PRT, versus treatment as usual, improves children's total score on the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, Risi, & Gotham, 2008) as well as their general problem behavior as assessed by the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000). One of the advantages of microanalytic measures is that they mitigate global impression, thus differentiating between behavioral categories and "pinpointing" the changes that occur. Additionally, there is literature confirming that the chances of finding changes in outcome measures that relate to social function in treatments for ASD increase if the measurement level is more proximal to the construct being targeted in treatment and when these measurements are done in contexts similar to those presented in treatment (Yoder et al., 2013). We therefore hoped that the microanalytic approach to quantifying social engagement within PRT treatments, which address social communication deficits directly would yield significant results. A recent examination of a parent-mediated version of PRT in 15–21 month old infant with ASD via microanalytic changes showed an improvement in verbal communication as a consequence of the intervention alongside reductions in symptoms of autism (Bradshaw, Koegel, & Koegel, 2017). In a case-study in three young children with ASD (Vernon et al., 2012) that also used continuous micro-analysis of behavior in children and their parents, it was found that the use of parent-delivered social intervention PRT strategies led to increases in children's use of eye contact, directed positive affect, and verbal initiations, as well as improvements in parent-child synchronous social engagement. We wish to build upon and extend these initial results from a similar fine-grained approach to behavioral analysis. In the current study we will thus use a microanalysis approach to reach a fine-grained window to more automatic implicit changes in social communication following treatment.

1.3. Linguistic correlates of difficulties in social communication in ASD

Individuals with ASD have significantly impaired language and communication skills (American Psychiatric Association, 2013; Lord et al., 2008). The rate of spontaneous initiation of communication in ASD is relatively low, and speech acts in free play or in open-ended situations tend to be less frequent and less varied (Tager-Flusberg, Paul, & Lord, 2005). In children with ASD language is used to a lesser amount to explain or describe events in a conversational context (Ziatas, Durkin, & Pratt, 2003). Speech acts that are usually under-used are the ones that put an emphasis on social rather than regulatory use of language (Warren et al., 2010; Wetherby, 1986). Eales (1993) reported on difficulties in pragmatic aspects of speech relating to the ability to accurately represent intentions in adults with ASD. Similarly, individuals with ASD had more difficulty than controls in responding to topics introduced by others, and in maintaining a reciprocal conversation (Paul, Orlovski, Marcinko, & Volkmar, 2008). Reciprocity during conversation was also found to be reduced in ASD a study that assessed speech acts in youth alongside findings showing reduced ability to manage topics and information during conversations (Paul et al., 2008). Finally, children with ASD have also been found to wait longer to respond in conversation compared to TD children (Heeman, Lunsford, Selfridge, Black, & Van Santen, 2010). Taken together, these results point to diminished speech, reduced social communication as well as difficulties in social responsiveness and engagement in ASD that is apparent in linguistic components during conversations. In the current study, we thus utilized microanalysis of behavior to explore changes in linguistic aspects of social communication following PRT sessions in children with ASD. We analyzed these microbehaviors in both interacting partners (therapist and child) so that we could achieve a more crystallized understanding of the dynamic exchange that occurs during PRT that may support improvement in the child.

1.4. Aims and hypotheses

In the current study, we aimed to evaluate child outcomes in microanalytic behaviors following a trial of PRT. Additionally, we explored the relationship between the therapist's behaviors and the child’s micro-level behavior change.

Specifically, we expected that the children would evidence stronger reciprocal social communication skills following treatment. We hypothesized: 1. Children would use more “on-topic” remarks (i.e., comments that are congruent with the therapist’s comments within a conversation). 2. Children’s conversational timing would improve (i.e., (a) decreased latency to respond and (b) fewer interruptions). 3. Children would use more first- and second- person pronouns, as a metric of reciprocal social engagement. 4. We also hypothesized that there would be an increase in the amount of vocalization made by children, indicating increased communicative engagement by the child following PRT.

2. Method

2.1. Participants

The sample included 20 (14 boys, 6 girls) child-therapist dyads. Children ages range 4–7 years (*Mean age at beginning of treatment*: 5.82y, *SD* = 1.01). All children were diagnosed with using “gold-standard” diagnostic procedures. 17 children were diagnosed with ASD and 3 children were diagnosed with PDD-NOS. Children were diagnosed by a highly-experienced licensed clinical psychologist at the Yale Child Study Center, where PRT sessions took place. Diagnostic clinical impressions were also informed by the Autism Diagnostic Observation Schedule (ADOS: Lord et al., 2008) and the Autism Diagnostic Interview-Revised (ADI-R: Rutter, LeCouteur, & Lord, 2003). All children met criteria for a classification of either autism spectrum or autism on the ADOS and autism on the ADI-R, and final diagnosis was made based on expert clinical judgment. All children received either Module 2 or 3 of the ADOS (17 children received Module 3, and 3 children received Module 2) so that all children had phrase speech to fluent speech. Table 1 depicts characterization information for children included in this study.

2.2. Procedure

Children participated in a PRT program which was carried out by Bachelors/Masters-level clinicians. The lead clinician was a licensed PhD-level clinical psychologist who was trained on PRT by faculty from the research institution where PRT was developed (University of California Santa Barbara: UCSB). The Bachelors/Masters-level clinicians had several years of experience working with children with ASD.

The treatment included individual work with the child as well as parent training and took place in both the clinic and home settings for 7 h weekly for 16 weeks.

Parents provided informed consent to have their children participate in this study. The study was approved by the Yale University ethical committee.

All treatment sessions were videotaped using a Samsung HMX-F90, which records frames at 60 frames per second. The videos each depicted a 7-min sample of a PRT session. The video samples were taken at random points during the treatment sessions. For this study, two sessions were sampled: the first session (pre-treatment) and the final session (post-treatment). The sessions were play-

Table 1
Characterization of the study’s sample.

	Age at baseline evaluation (mo)	Vineland ABC* baseline	Vineland ABC* endpoint	SRS Total Raw Score baseline	SRS Total Raw Score endpoint	ADOS Total Score baseline	ADOS Total Score endpoint
Avg. Score	70.05	83.53	82.42	73.35	67.25	15.20	11.75
SD	12.22	7.63	23.46	12.1	10.66	5.93	4.958
Range	54–88	70–99	70–115	51–90	47–84	5–25	2–19

* Standard Score Mean 100, s.d. 15.

based and used materials such as craft supplies, balls, blocks, and 'play-doh', etc. The clinician repeatedly provided skill-learning opportunities for the child according to PRT components.

Specific treatment goals for the children participating in the study included responding to others' social bids, initiating social bids, and increasing reciprocity within the context of a conversation.

2.3. Fidelity of implementation

The lead clinician was trained in PRT by faculty from the University of California Santa Barbara (UCSB), the research institution where PRT was developed. The lead clinician sent two separate videotaped sessions (of different children) to the trainer to ensure maintenance of treatment fidelity. Both videos met the standard fidelity criteria. To ensure that the bachelors-level clinicians were correctly implementing PRT during their sessions, they met with the lead clinician (licensed clinical psychologist) for two hours per week. During these meetings, clinicians discussed the children's progress, current presentation, and specific activities for the treatment sessions that would be motivating and foster skill development. Additionally, the lead clinician observed sessions live and via videotape at least once weekly for each participant.

Formal fidelity of implementation was assessed for two randomly coded treatment sessions for each subject. Two randomly selected five-minute segments per session were used for this fidelity assessment. The standard fidelity assessment published by the developers of the approach was used, and per convention, fidelity was defined as demonstrating the treatment components (child choice, child attending, clear opportunity, contingent reinforcement, natural reinforcement, reinforcement of attempts, and interspersal of maintenance/acquisition tasks) in 80% of opportunities (Koegel & Koegel, 2012; Koegel, Koegel, & Carter, 1998; Koegel, Kuriakose, Singh, & Koegel, 2012). The scoring was dichotomous; if the therapist demonstrated the component, a checkmark was used, and if not, a minus was used. All therapists maintained the defined treatment fidelity across the duration of the study.

2.4. Measures

Autism Diagnostic Interview- Revised (Rutter et al., 2003). The ADI-R is a comprehensive diagnostic parent-report interview that focuses on language/communication, reciprocal social interactions and restricted, repetitive and stereotyped behaviors and interests. The ADI-R was administered to the parents for subject characterization.

Autism Diagnostic Observation Schedule (Lord et al., 2008). The ADOS is a semi-structured diagnostic assessment that allows clinicians to observe and assess social, communication and repetitive behaviors associated with ASD. The ADOS was administered by expert clinicians with no other involvement in the current study. The ADOS was used for subject characterization.

The Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). The SRS is well validated and extensively used parent-report questionnaire that measures the severity of social impairment in ASD, from nonexistent to severe. SRS was administered twice in the current study, before and after PRT.

Vineland Adaptive Behavior Scales- Second Edition (VABS-II; Sparrow, 2011). An extensively used and well-validated measure of adaptive behavior from birth to childhood was administered twice before and after PRT.

Behavioral Microanalysis Coding. Child-clinician interactions were micro-coded on a computerized software (The Observer XT12 by Noldus, Waggenigen, The Netherlands) that allows for continuous behavioral coding (up to a resolution of 0.01-s frames if needed) for several categories of verbal and non-verbal behavior. Each category included a set of mutually exclusive codes. Each code was entered offline by a trained human coder as they looked at the videotaped recording via the Observer – when a behavior occurred the coder coded its beginning. For several codes, only the existence of a behavior was entered (without its duration) and for other codes, the coder entered a shift in said behavior when it stopped and was replaced by a beginning of a different behavior, which indicated its ending. These codes include the existence of a behavior as well as its duration. The following categories were used in the microanalysis coding scheme:

Codes that include duration – *Vocalizations*: Subjects' vocal output (verbal or non-verbal) was coded with affective valence – Positive, Negative, or Neutral. Positive vocalization was defined as laughter, or any verbalization/vocalization made in enthusiasm or while smiling. Negative vocalization was defined as a vocalization made while being upset, frowning, yelling etc. All other vocalizations were considered neutral. This type of vocalization affective code is extensively used in the microcoding scheme applied in the current study and is in line with prior work on microcoding interactive behavior (for recent examples see Gordon et al., 2017; Levy, Goldstein, & Feldman, 2017; Saxbe et al., 2017). Since we did not have a specific hypothesis regarding the affective aspects of vocalizations, we later collapsed all these to a single component named "Total Vocalizations" which was the sum of RpM of positive, neutral and negative vocalizations. This component denotes the frequency of any type of vocalization or verbalization uttered by the child. *Response Type:* Subjects' verbal output (response) was coded with reference to counterpart's last verbal output – On-Topic (the content of response is explicitly reactive to the content or context of the preceding utterance. This includes comments like "yeah" or "OK" if they follow this "congruency" rule), Off-Topic (the content is arbitrary or referring to a context not directly preceding the response; Codes that do not include duration – *Pronouns:* First-Person ("I", "Me"), "We", Second-Person ("You"), Third-Person ("He", "She", "They"), First Name (of child, therapist, or third-party). *Therapist's Prompt*: In PRT, prompts refer to supports aimed to elicit a child's behavior (e.g., modeling appropriate language; re-phrasing the question/statement). Each time the therapists prompted, this was indicated in the coding. Coding was conducted by a graduate student trained for this purpose. An interrater reliability for codes that include duration was established for 10% of the videotaped interactions. Reliability was computed as following: 100 – Percent of Disagreement (Disagreement was calculated as the number of misaligned codes between two raters divided by all codes in a specific category). For the "Vocalization" variable 86.5% reliability was achieved and for the "Response Type" variable 86.1% reliability was achieved. Video coders were not blind to the stage of the treatment session (before or after) as the content of verbalization inherent to the interaction is unblinding and made it relatively impossible to shield from the coders.

2.5. Analytic plan

To test each of our hypotheses we planned to perform repeated measures GLMs where appropriate. Prior to each analysis, we performed a Kolomogorov-Smirnoff test of normality for each dependent variable at each time-point of the study. We report these normality tests prior to each analysis in the results section. When normal distributions were not confirmed, we performed additional non-parametric tests, specifically related-samples Wilcoxon signed ranks tests, that allow to assess differences between related pre- and post-measures.

3. Results

3.1. Conversational flow

3.1.1. Congruency of response—on-topic versus off-topic child responses

To assess changes in conversational flow we conducted a 2 × 2 Repeated measures ANOVA where percentage of target verbal responses out of total child vocalizations was used as the measure, and time (first PRT session/final PRT session) and response type (on-topic/off-topic) were used as independent factors. One significant main effect and one significant interaction effect were found.

An overall effect for response type ($F(1,19) = 177.781, p < 0.001, \eta_p^2 = 0.903$), indicated that the percentage of on-topic responses ($M = 6.709, SE = 1.958$) was higher than the percentage of off-topic responses ($M = 22.58, SE = 1.632$).

A time*response type interaction effect ($F(1,19) = 10.503, p < 0.05, \eta_p^2 = 0.356$) followed by a simple effects examination with Bonferroni correction revealed that all differences in the interaction were significant. This means that children increased their on-topic responses from pre-treatment to post-treatment (*Mean Difference* $= 11.01, SE = 3.258, p < 0.05$) and decreased their off-topic responses from pre-treatment to post-treatment (*Mean Difference* $= 5.845, SE = 2.569, p < 0.05$). Fig. 1 portrays the interaction.

3.1.2. Lag sequential analysis of on-topic responses following therapists prompts

To determine if the therapist's use of PRT prompts specifically increased congruency of conversation in the child, we conducted a Lag Sequential Analysis.

This analysis relies on output that was computed by the Noldus' Observer XT12 that calculates probability of a target behavior (in this case, the child's on-topic response) to be the first event or behavior that occurred following the beginning of the utterance by the therapist (defined in the Observer as "one state"). Variables were computed as the probability of a target behavior occurring, given the occurrence of a preceding criteria behavior. Therapist's prompts were examined as criteria to children's target behaviors.

Prior to using a GLM, we tested the DV for normality using the Kolomogorov-Smirnoff test, which yielded a non-significant test statistic for the post measure ($KS = 0.154(19)$, $p = 0.2$) and a significant test statistic for the pre-measure ($KS = 0.203(19)$, $p = 0.038$). Therefore, we conducted a paired-samples t-test ($t(18) = -3.734, p < 0.05$, Cohen's $d = 1.26$) which revealed that the probability for a child's on-topic response to follow a therapist's prompt at the final stages of PRT ($M = 0.169$, $SD = 0.06$) was significantly higher than the probability for this response to follow a therapist's prompt at the beginning of PRT (M = 0.079, SD = 0.082). We also conducted a non-parametric related samples Wilcoxon ranks test which confirmed that the median of differences between both time points was significantly different (p = 0.004).

3.1.3. Latency of vocalization (vocalization gap)

This measure was calculated as the mean duration of the time that passed from the end of a therapist's vocalization to the beginning of a consecutive child's vocalization. In other words, this measure represents the silence preceding a child's response. This measure was distributed normally only in the final stages of PRT (results of Kolomogrov-Smirnov tests of normality were significant:

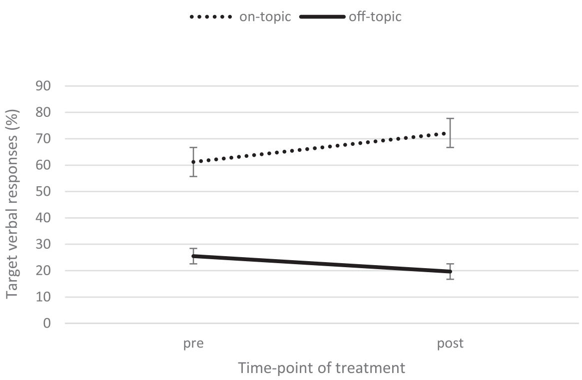

Fig. 1. Mean Percentage and SEs of On-topic and Off-topic target verbal responses during the early versus final sessions of PRT.

KS(20) = 0.233, *p* = 0.006). For the initial stages of PRT, this measure was not distributed normally (results of Kolomogrov-Smirnov tests of normality were significant statistic *KS(20)* = 0.155), *p* = 0.200, therefore we performed both a dependent samples parametric *t*-test and a non-parametric related-samples Wilcoxon signed ranks test to assess differences between pre- and post-latency. Both tests were significant and indicated a similar pattern. In the non-parametric test, the median of differences between both time points was significantly different (p = 0.002). Post-treatment latency was significantly shorter than pre-treatment latency. The parametric *t*-test ($t(19) = 3.249, p < 0.05$, Cohen's *d* = 0.96) confirmed that post-treatment latency ($M = 3.317, SE = 0.979$) was significantly shorter than pre-treatment latency ($M = 4.99, SE = 2.265$).

3.1.4. Interruptions in vocalizations (vocalization overlap)

This measure was calculated as the mean duration of the time that passed from the beginning of a child's vocalization to the end of a therapist's prior vocalization. In other words, this measure represents the extent of a child's interruption of a therapist's verbalization.

This measure was distributed normally only in the initial stages of PRT (results of Kolomogrov-Smirnov tests of normality were significant statistic *KS(20)* = 0.173), *p* = 0.12. For the later stages of PRT, this measure was not distributed normally (results of Kolomogrov-Smirnov tests of normality were significant statistic *KS(20)* = 0.215), *p* = 0.016, therefore we performed both a dependent samples parametric *t*-test and a non-parametric related-samples Wilcoxon signed ranks test to assess differences between pre- and post-latency. Both tests were significant and indicated a similar pattern. In the non-parametric test, the median of differences between both time points was significantly different (*p* = 0.037). A paired-samples *t*-test ($t(19) = 2.489, p < 0.05$, Cohen's *d* = 0.71) similarly revealed that vocal overlaps were significantly shorter post-treatment ($M = 0.421, SE = 0.115$) compared to pre-treatment ($M = 0.544, SE = 0.22$).

3.2. Verbalization content

3.2.1. Child pronouns

Prior to conducting the analysis we assessed normality in all of the dependent variables. Only rate per minute of "First Person" and "Second Person" utterances were distributed normally (Results of Kolomogorov-Smirnoff test of normality for "First Person" use in the initial stages of PRT: *KS(20)* = 0.147, *p* = 0.2 and in the final stages of PRT: *KS(20)* = 0.189, *p* = 0.06; "Second Person" use in the initial stages of PRT: *KS(20)* = 0.176, *p* = 0.106 and in the final stages of PRT: *KS(20)* = 0.159, *p* = 0.197). All other pronouns' measures were significantly non-normally distributed. Therefore, we conducted both parametric and non-parametric tests to affirm our results. First, a repeated-measures analysis of variance (ANOVA) was conducted, with time (pre/post) and pronouns (First Person/We/Second Person/Third Person/Name) as within-subject factors. Frequency (measures as mean rate per minute – RpM) of occurrence was used as the dependent measure. Two significant main effects and one significant interaction effect were found.

A main effect for frequency of pronoun occurrences ($F(4,76) = 56.085, p < 0.001, \eta_p^2 = 0.747$) was followed by post-hoc contrasts to reveal the following hierarchy between the occurrences of different pronouns: First Person ($M = 1.91, SE = 0.198$) > Second Person ($M = 0.889, SE = 0.121$) > We ($M = 0.306, SE = 0.063$) = Name ($M = 0.148, SE = 0.053$) = Third Person ($M = 0.034, SE = 0.011$). This finding could mean that most occurrences of pronouns were used to directly refer to one of the persons present in the sessions. Fig. 2 portrays the means of each pronoun frequencies in the initial and final stages of PRT. Table 2 displays the significant differences between the pronouns.

We conducted these post-hoc comparisons using non-parametric related samples tests as well in order to confirm our pattern of results. Related samples Wilcoxon signed ranks tests revealed that First person and Second person RpM was indeed more significant in the final stages of PRT (*p* = 0.019, *p* = 0.012 respectively). We and Third-Person were not significantly different across PRT sessions (*p* = 0.877, *p* = 0.1 respectively). Only in the non-parametric test, Name came out significantly more frequent in the final stages of PRT (*p* = 0.047). This trend can indeed be seen in Fig. 2, and yet the significance is very close to 0.05 so we will address this finding with caution.

A main effect for time ($F(1,19) = 8.527, p < 0.05, \eta_p^2 = 0.31$) indicated that average frequency of pronoun use was higher post-

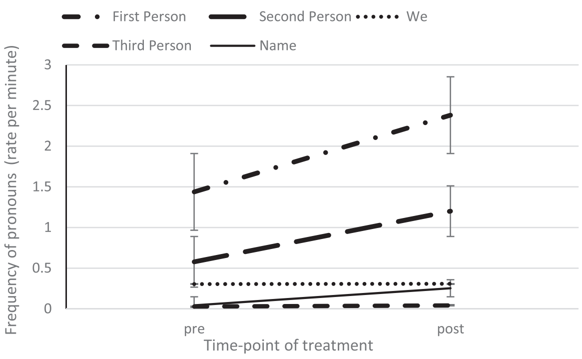

Fig. 2. Average Frequencies and SEs of types of pronoun produced by children during the early versus final sessions of PRT.

Table 2
Pairwise Comparisons for Frequency (rate per minute) of Pronouns.

(I) Pronoun	(J) Pronoun	Mean Difference (I-J)	SE
First Person	We	1.604*	0.208
	Second Person	1.020*	0.158
	Third Person	1.875*	0.197
	Name	1.762*	0.210
We	First Person	−1.604*	0.208
	Second Person	−0.583*	0.121
	Third Person	0.272*	0.064
	Name	0.158	0.076
Second Person	First Person	−1.020*	0.158
	We	0.583*	0.121
	Third Person	0.855*	0.123
	Name	0.741*	0.140
Third Person	First Person	−1.875*	0.197
	We	−0.272*	0.064
	Second Person	−0.855*	0.123
Name	Name	−0.114	0.050
	First Person	−1.762*	0.210
	We	−0.158	0.076
	Second Person	−0.741*	0.140
	Third Person	0.114	0.050

* $p \leq 0.05$.

treatment (*M = 0.837, SE = 0.101*) than pre-treatment (*M = 0.478, SE = 0.068*).

A pronoun*time interaction effect $F(4,76) = 4.064$, $p < 0.05$, $\eta_p^2 = 0.176$) followed by a simple effects examination with a Bonferroni correction revealed that the origin of the interaction is in the significant increase in First Person (*Mean Difference = 0.944, SE = 0.392, p < 0.05*) and in Second Person (*Mean Difference = 0.623, SE = 0.229, p < 0.05*) pronoun use from pre-treatment (*FP: M = 1.438, SE = 0.238; SP: M = 0.578, SE = 0.104*) to post-treatment (*FP: M = 2.382, SE = 0.314; SP: M = 1.201, SE = 0.211*), whereas there was no significant change for any of the other pronouns (Fig. 3).

3.3. Number of vocalizations

The rate per minute (RpM) of Total Vocalizations made by the child was analyzed as well. Kolomogrov-Smirnov tests of normality were significant for this measure only at the initial stages of PRT ($KS(20) = 0.22$, $p = 0.013$) and insignificant for the post measure ($KS(20) = 0.18$, $p = 0.065$). We therefore performed both a repeated measures *t*-test ($t(19) = -2.54$, $p = 0.02$, Cohen's $d = 0.64$) and a non-parametric related samples Wilcoxon signed ranks test ($p = 0.025$) to compare RpM of total vocalizations made by the child before and after PRT. Both analyses indicate a significant difference denoting that children made more vocalizations in the final stages of PRT ($M = 9.15$, $SE = 0.4$) compared to the initial stages ($M = 7.195$, $SE = 0.46$).

4. Discussion

The aim of the current study was to map the microanalytic changes in social communication during dyadic child-therapist interactions following a 16-week trial of PRT. Our data shows changes in communication in children who had received PRT, by several measures, strengthening the notion that PRT may be related to changes in the very basic building blocks of social

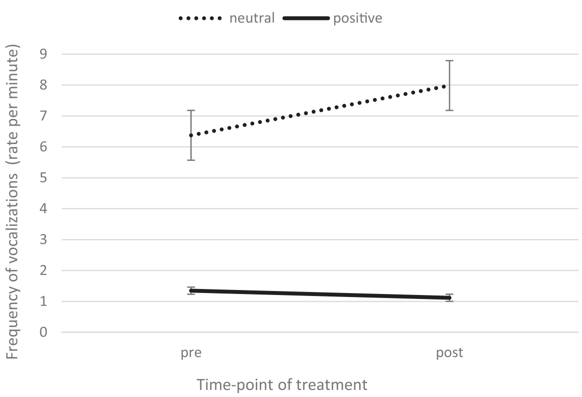

Fig. 3. Average frequency and SEs of neutral and positive vocalizations made by children during the early versus final sessions of PRT.

communication behavior.

In line with hypothesis 1, we found that children used more "on-topic" remarks (i.e., comments that are congruent with the therapist's comments within a conversation) following treatment. Children also reduced the amount of off-topic remarks following treatment. Response congruency with a prior utterance in conversation is considered a relatively straightforward measure for the presence of reciprocity in an interaction, and has been previously found to be distinctively lower in individuals with ASD (Paul et al., 2008). More "on-topic" responses and fewer "off-topic" responses observed in an interaction may serve as a measure for "back and forth" flow between the child and therapist. It is not surprising that an overall preference for "on-topic" responses was found in both the therapist and the child, because therapists are expected to strive to maintain a reciprocal interaction from day one, and to be responsive to the children. Nevertheless, the increase in this metric post-treatment is meaningful because it implies that treatment improved reciprocity in the child-therapist interactions. Given the nature of the social disability, the magnitude of change pre-post is also notable. As described below in future directions, as the study continues to expand and the sample increases, we will be able to relate the microanalytic results to scores from standardized assessments and will then be able to draw conclusions on the clinical meaningfulness of the change as well.

We also found, in line with hypothesis 2, that children's conversational timing improved following PRT (i.e., (a) decreased latency to respond and (b) fewer interruptions). The children presented a more fluid discourse in the interaction and evidenced, again, a greater sense of the inherent reciprocity. Our results are in line with data presented by Heeman et al. (2010) showing that children with ASD tend to wait longer to respond compared to TD children. This was attributed to a reduced awareness to turn-taking cues or to the social obligation to minimize silences between turns. Another possibility raised, is a diminished speed of processing that may lead to slower response times in ASD (Heeman et al., 2010). Other researchers have also reported on a diminished ability for turn taking or reciprocity in speech (Eales, 1993; Paul et al., 2008; Warren et al., 2010). The literature concerning Interactional Synchrony describes how its building blocks include both discrete behaviors and the contingencies and sequential properties (Feldman, 2007). In this sense, an increase in "on-topic" verbalizations and a decrease in "off-topic" remarks, together with an improved flow (reduced interruption and reduced amount of silences) can be considered an increase in Interactional Synchrony between therapist and child and a more adaptive social functioning following PRT.

Consistent with hypothesis 3, we found that children increased their use of first and second person pronouns throughout PRT, as a metric of reciprocal social engagement. Pronouns were found to be used more frequently at the end of treatment compared to the beginning of treatment. Additionally, pronoun use was differentiated by type, with a significant preference for "I" and "You" use over other pronouns. The use of pronouns may be a measure for incorporation of social elements into a conversation. Frequent use of "I" and "You" can imply a certain level of perspective taking and reciprocity in an interaction. Children with ASD often have a hard time in shifting their perspective (Lee, Hobson, & Chiat, 1994). For example, when a child is passive in a conversation they are referred to as "You", but when their turn comes to speak they should shift their perspective and refer to themselves as "I". Many children with ASD are challenged by this shift and continue referring to themselves as "You", or by using their first names, or do not refer to themselves at all (Lee et al., 1994). Therefore, the great increase in "I" use for children throughout the treatment is important, as it suggests that the treatment improved the shifting ability for the children, possibly allowing them to engage in perspective taking more easily.

These findings are particularly interesting in light of a very frequently described characteristic of ASD (Seung, 2007): personal pronoun reversal (PPR), i. e. the inverse use of "I" and "You". It is assumed that PPR is not caused by a general linguistic impairment, and there are several, presumably non-sufficient theories seeking to account for it. In his critical review, Brehme (2014) posits that the social-environmental context is not taken enough into account in theories of PPR. Some of these are Kanner's (1943) view of PPR as echolalia, a cognitive perspective explaining PPR by impaired understanding of discourse roles (e.g. Tager-Flusberg, 1994) or impaired self-other action memory (Dunphy-Lelii & Wellman, 2012). Within PRT, therapists presented children with an opportunity to practice the correct use of personal pronouns and deliberately taught and modeled correct pronoun usage and perspective-taking skills.

The finding of increased use of "I" is also noteworthy in light of a previous study which found that individuals with ASD have difficulties in the self-referential cognitive domain (Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007). In that study, using multiple measures to investigate self-referential cognition, an interesting finding had to do with relationships between self-referential cognition and mentalizing: ASD individuals who were more self-focused were better at mentalizing, and reported having fewer autistic traits. Conversely, for TD controls being more self-focused predicted less mentalizing ability. Considering this, the current findings are even more encouraging, as there was a significant increase of the use of a self-referential measure.

With regards to hypothesis 4, we found that there was an increase in the amount of vocalization made by children following treatment. This finding raises the possibility that children's discourse improves over the course of PRT, as previous data has shown that children with ASD produce less verbalizations compared to TD children (Warren et al., 2010). Increased frequency of vocalizations is consistent with children's enhanced communicative or linguistic social skills. The children's increase in vocalizations may indicate that more time was spent on adaptive, social communication, as opposed to silence or non-communicative acts. Nevertheless, we cannot be sure of this interpretation as increased vocalizations on their own do not always denote increased communicative value. For instance, Bishop, Hartley, and Weir (1994) found that children with language impairment, including children with ASD, can be mistakenly considered as more talkative than they are. This is because while children produce a relatively high number of verbalizations, most of those are initiations rather than responses, and thus lower the communicative value of utterances. For this reason, future directions may include analyzing the communicative value or quality of affective verbalizations and not only their existence.

4.1. Limitations and future directions

First, in the current study, we report pre- post- data in a single treated group, with no comparison group. Given the lack of a control group, changes occurring from baseline to post-treatment cannot be confidently attributed to treatment, as other explanations, such as maturation, cannot be ruled out. Future studies should incorporate this data with similar data from a comparison group. Another major limitation of the study was related to the physical features of the recordings, preventing the coding of some of the more classical components of microanalysis such as gaze, arousal and facial affect. Future studies should design the therapeutic setup in a way that would allow coding these elements, thus providing a platform for a much richer microanalytic view of treatment outcomes, in domains such as joint attention and bio-behavioral synchrony. An additional direction for future research should be investigating therapist characteristics, namely which characteristics together with micro-behaviors in therapists elicit better outcomes in children. This could contribute greatly to fine-tuning treatment protocols. Additionally, the small number of participants in the current study, despite the rich dataset yielded by microanalysis and the within-subject design, underpower the study and for that reason, interpretation of our results should consider this limitation. The small sample size did not allow us to further test individual differences in children and how those may interact with PRT to modulate changes or how the microanalytic measures may correlate with changes detected via standardized outcome measures for PRT. In the current study, such analyses would be underpowered. As a future direction and as we continue to increase our sample size, we will correlate the microanalytic data with results from standardized clinical assessments. This will allow us to compare the results from microanalysis of behavior in session with more global measures of functioning and information from a variety of sources/settings. We will then also be able to speak more definitively about clinical meaningfulness, as well as generalizability and stability of the results. Finally, all data was collected during PRT sessions as well as over a representative, yet limited period. Our dependent measures can be considered very proximal (Yoder et al., 2013) to PRT and so we cannot speak to the generalizability and stability of the findings from this data. Finally, we should note here as a limitation that coders were not blind to the timing of the sessions coded, as mentioned in the methods section. Nevertheless, this is one of very few examinations of changes in microbehaviors denoting social and linguistic communication during PRT and our results point to improvement in social reciprocity and conversational synchrony following treatment further validating the contribution of PRT.

Conflict of interest

We declare no conflict of interest.

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