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ORIGINAL PAPER

Using Pivotal Response Treatment to Improve Language Functions of Autistic Children in Special Schools: A Randomized Controlled Trial

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Abstract

Language difficulties exert profound negative effects on the cognitive and social development of autistic children. Pivotal Response Treatment (PRT) is a promising intervention for improving social communication in autistic children, but there is a lack of a comprehensive examination of language functions. This study aimed to investigate the effectiveness of PRT in promoting the primary language functions (requesting, labeling, repeating, responding) defined by (Skinner, B. F. (1957). Verbal behavior. Martino Publishing.) theory of verbal behavior in autistic children. Thirty autistic children were randomly divided into the PRT group (M_{age} = 6.20, SD_{age} = 1.21) and control group (M_{age} = 6.07, SD_{age} = 1.49). The PRT group were provided with an 8-week training of the PRT motivation component in addition to treatment as usual (TAU) in their schools, whereas the control group only received TAU. Parents of the PRT group were also trained to practice the PRT motivation procedures at home. The PRT group demonstrated greater improvements in all four measured language functions compared to the control group. The improvement in language functions in the PRT group was generalized and maintained at the follow-up assessment. In addition, the PRT intervention enhanced untargeted social and communicative functioning, cognition, motor skills, imitation, and adaptive behaviors in the autistic children. In conclusion, language intervention using the motivation component of PRT is effective in promoting language functions as well as widespread untargeted cognitive and social functions in autistic children.

Keywords Autism spectrum disorder · Pivotal response treatment · Motivation procedure · Language functions

Autism spectrum disorder (ASD) is characterized by social communication impairments along with restricted, repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). One of the most notable features of autistic children is deficits in language (Kwok et al., 2015; Marini et al., 2020; Reindal et al., 2021), including delayed language development (Marrus et al., 2018), impaired verbal imitation (Chen et al., 2022; Wang et al., 2021), and atypical response to speech (Chen et al., 2019; Ramezani et al., 2019). Language-related deficits in autistic children have been found to exert enormous impact on cognitive and social development (Franchini et al., 2018; Tang et al., 2022; Weismer et al., 2018), such as the acquisition of social skills (Levinson et al., 2020). Indeed, atypical language performance has been shown to be a major concern of parents of autistic children (Issarraras et al., 2019; Richards et al., 2016). Therefore, it is critical for effective therapies to be developed that can help to facilitate the development of language skills in autistic children.

Among a wide range of interventions that have attempted to improve language in autistic children, Pivotal Response Treatment (PRT) has emerged as a promising approach (Fossum et al., 2018; Koegel et al., 2019; Mohammadzaheri et al., 2014, 2021; Verschuur et al., 2014). PRT is a naturalistic developmental behavioral intervention based on the principles of applied behavior analysis (ABA) (Koegel et al., 1987). At its core, PRT proposes that targeting pivotal areas of a child's development, such as motivation and

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self-initiation, will lead to widespread improvements in behavior, communication, and social interactions (Koegel & Koegel, 2006, 2016). During PRT, learning opportunities are imbedded in child-led, semi-structured interactions between the child and administrators, who may be the therapists or parents (Koegel & Koegel, 2019). Compared to other strictly structured ABA approaches, such as discrete-trial training (DTT) (Lovaas et al., 1974), PRT is less time-consuming and less costly and has been shown to result in improved maintenance and generalization of the intervention outcomes (Koegel & Koegel, 2019).

Motivation is regarded as the fundamental component of PRT, with the rationale being that a child is more likely to learn when they are motivated (Koegel & Koegel, 2019; Koegel et al., 2001). To improve motivation during training sessions in PRT, evidence-based procedures have been developed (Dunlap, 1984; Dyer et al., 1990; Koegel, et al., 1998a, 1998b; Moes, 1998). Several studies using these PRT motivational procedures have found improvements in verbal initiations (Koegel et al., ; Popovic et al., 2020) and utterance length (Mohammadzaheri et al., 2014). Moreover, the improvements in the targeted linguistic skills in autistic children were found to generalize to new and unfamiliar settings (Koegel et al.,) as well as to other untargeted pragmatic skills (Mohammadzaheri et al., 2014, 2021).

Although PRT has demonstrated promising effects on language and communication in autistic children, a recent review by Forbes et al. (2020) found that most existing PRT intervention studies did not provide sufficient description or distinguishment of the targeted language outcomes. Common outcome measures have included broad communication skills (Baker-Ericzén et al., 2007; Fossum et al., 2018; Stock et al., 2013) or social facilitation and engagement (Feldman & Matos, 2013; Kim et al., 2017). The unclear and inconsistent measurement of language complicates the comparison and applicability of findings across previous studies. To resolve this issue, it is important to examine the effect of PRT using a widely used and accepted language framework.

A classic language framework has been developed by Skinner (1957), referred to as the theory of verbal behavior. According to Skinner (1957), language is similar to other operant behavior, acquired and maintained by its antecedent and consequences. Rather than emphasizing the mechanics of language (e.g., morphology, syntax, semantics), Skinner (1957) focused on the functions of language (e.g., requesting, labeling, repeating, and responding). As Skinner's verbal behavior framework directly links the targeted communicative skills with observable context, it has been broadly applied to guide language therapies and research in ASD (Forbes et al., 2020; Johnson et al., 2017; Sundberg & Michael, 2001). It remains unclear, however, whether PRT can be applied to improve the language functions proposed by Skinner (1957).

The current study aimed to examine the effectiveness of PRT on well-defined language functions based on Skinner's (1957) theory of verbal behavior in autistic children. In this study, an 8-week PRT motivation intervention targeting verbal requesting, labeling, repeating, and responding was implemented in autistic children in autism-specialized schools. It was hypothesized that the PRT intervention relative to regular treatment would result in greater improvement in the targeted language functions and other untargeted cognitive and behavioral functions.

Methods

Participants

Participants were enrolled between May and July 2020 from two special schools and two rehabilitation centers in Ningbo, Zhejiang province, China. These institutions provided similar schooling and training services for children with ASD. Thirty-five subjects aged between 4 and 8 years were initially recruited. Participants were included only if they (1) had received a clinical diagnosis of ASD based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (American Psychiatric Association, 2013), (2) had no other genetic disorders or severe physical or psychiatric disorders, especially hearing impairment, and (3) had never received any PRT intervention. Five children were excluded as two children could not ensure completing the intervention and three parents were unable to complete the PRT parent training.

Thirty children were randomly assigned to the PRT group and control group in a 1:1 ratio using a computer-generated algorithm. The PRT and control groups were not significantly different in age, sex, or receptive vocabulary knowledge (Table 1). Based on the standardized Peabody Picture

Table 1 Demographic characteristics of participants

Variables	PRT ($n=15$)	Control ($n=15$)	Group comparison
Age, *M (SD), range*	6 (1), 5–9	6 (1), 4–8	$t(58)=0.48$, $p=.79$
Gender			
Male, *n* (%)	12 (80)	10 (67)	$\chi^2(1)=0.68$, $p=.41$
Female, *n* (%)	3 (20)	5 (33)	
PPVT-R, *M (SD)*	6 (5)	5 (5)	$t(28)=0.77$, $p=.62$

Age was measured in years. The raw score of the Peabody Picture Vocabulary Test Revised Edition (PPVT-R) was used to compare receptive vocabulary between the two groups

PRT Pivotal Response Training

Vocabulary Test Revised Edition (PPVT-R) scores, all participants had an intellectual disability (i.e., IQ ≤ 50).

Therapists

Twenty qualified therapists were enrolled, with 10 in the PRT group and 10 in the control group. All enrolled therapists (1) had an educational background in special education, (2) had worked in special education for at least 5 years and were currently working in this sector, and (3) had received systematic ABA training. Therapists in the PRT group had obtained the PRT Level I Certificate and had conducted PRT for at least 2 years. Therapists in the control group had not received any PRT training.

Scorers

Four scorers were selected to assess the language abilities, cognition, and behavior of the participants. The selected scorers (1) had an educational background in special education, (2) had worked in special education for at least 10 years and were currently working in this sector, and (3) had qualifications for scoring the Chinese Psychoeducational Profile—Third Edition (CPEP-3) and the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP) and had at least 5 years of experience scoring the two measures. The scorers were blind to the group of the participants. The four scorers conducted pre-tests of language functions in two autistic children using the CPEP-3 and VB-MAPP and achieved a reliable interobserver agreement (all Kendall's $W > 0.90$, $p < 0.001$).

Materials

Peabody Picture Vocabulary Test Revised Edition (PPVT-R)

The Chinese version of the Peabody Picture Vocabulary Test Revised Edition (PPVT-R) was used to measure receptive vocabulary (raw score) and intelligence quotient (standardized score) (Dunn & Dunn, 1981; Sang & Miao, 1990). In the test, the child listens to a word uttered by the interviewer and then selects one of four pictures that best reflects the meaning of the word. One hundred and twenty items were included in the current test. The PPVT-R has been shown to be moderately correlated with performance in a Chinese language course for school-age children ($r = 0.54$; Sang & Miao, 1990) and has been shown to have high-to-very-high test–retest reliability ($r = 0.82$–0.92; Tillinghast et al., 1983).

Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP)

The Chinese version of the Verbal Behavior Milestones Assessment and Placement Program (Huang & Li, 2017) was used to assess language functions based on Skinner's (1957) Theory of Verbal Behavior. The VB-MAPP has been shown to have moderate-to-high content validity (Padilla & Akers, 2021).

Social Communication Questionnaire (SCQ)

The Chinese version of the Social Communication Questionnaire (Gau et al., 2011; Rutter et al., 2003) was used to evaluate communication skills and social functioning. The SCQ contains 40 questions (yes = 1, no = 0) that is completed by the principal caregiver of the autistic individual, with higher scores indicating higher severity of autistic symptoms. The SCQ has demonstrated adequate test–retest reliability (intraclass correlation coefficient = 0.77–0.78) and moderate concurrent validity with the Autism Diagnostic Interview-Revised ($r = 0.49$–0.63; Gau et al., 2011).

Chinese Psychoeducational Profile—Third Edition (CPEP-3)

The performance test of the Chinese version of Psychoeducational Profile—Third Edition (CPEP-3; Schopler et al., 2005; Shek & Yu, 2014) was used to assess cognition, motor skills, and adaptive behaviors. The CPEP-3 is suitable for autistic and non-autistic children between 2 and 7.5 years old. The CPEP-3 has been reported to have high-to-very-high internal consistency (Cronbach's alpha > 0.70) and test–retest reliability ($r > 0.70$; Yu et al., 2019).

Intervention Procedures

After initial screening and informed consent, 30 children with ASD were randomly divided into the PRT group and the control group (Fig. 1). All participants received an 8-week one-on-one language intervention at the respective special school or training center in which they were enrolled. Based on Skinner's framework (1957), four primary types of verbal behaviors -mand, tact, echoic, and listener responding- were targeted. A mand refers to requesting an object or event from others. A tact refers to labelling or naming objects and events. An echoic refers to repeating what is heard. Listener responding occurs when the listener responds to the verbal request of another person in the form of an action. There were three 35-min intervention sessions each week. The control group received treatment as usual (TAU), while the PRT group received the motivational components of PRT in addition to TAU. During the intervention phase, parents of the PRT group were provided with a one-hour online PRT learning session relating to the theory and techniques of PRT. The parents in the PRT group were asked to administer a 30-min PRT motivational procedure with their autistic child at home each day until the conclusion of the study.

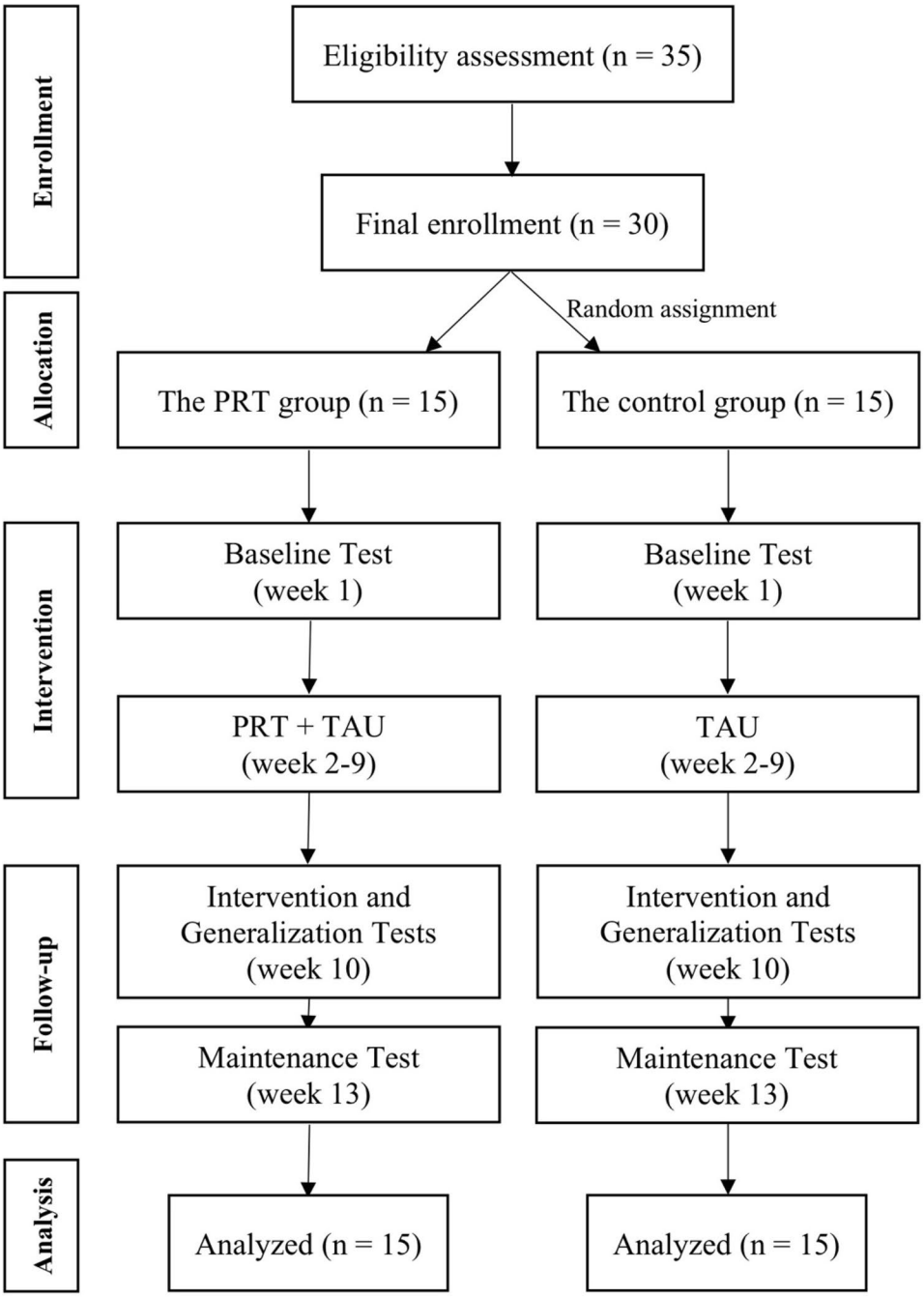

Fig. 1 CONSORT Flowchart of Study Procedure. *PRT* Pivotal Response Treatment; *TAU* treatment as usual

Pivotal Response Treatment (PRT)

The PRT intervention was based on published guides of PRT motivational procedures (Koegel, R. L., & Koegel, 2012; Stahmer et al., 2011). The targeted language functions (i.e., mand, tact, echoic, and listener responding) were the same for all autistic children, but the intervention plan was individualized based on the child's interest and language abilities (for examples, see Table 2). Therapists selected stimulus items according to the child's preference. Parents and therapists signed a consent form to ensure that the selected stimulus items were only used them during the intervention sessions. Items and activities that were easily achieved were prioritized. The reinforcement was directly related to the targeted behaviors. For example, the therapist reinforced the spontaneous request "open the door" from a child by opening the door rather than by giving edibles. In addition to the directly related reinforcer, the therapist would reinforce the desired behaviors through generalized praise, such as "Great job!". The child was reinforced for meaningful attempts to achieve the targeted behaviors, even if they were not able to achieve the targeted behaviors. The

Table 2 Examples of language interventions in the PRT group

Targeted skills	Examples
Mand	
Task 1: Verbally initiate four requests with language prompts	The therapist demonstrated soap bubbles and other items to the child. When the child stared at the bubbles, the therapist asked, "What do you want?" The child answered, "bubbles". Bubbles were then given to the child
Task 2: Spontaneously verbally initiate five items in 1 hour	Without any prompts from the therapist, the child said "slide". The child would then be allowed to ride a slide
Task 3: Verbally initiate eight requests with or without language prompts	The child said "push", and the therapist would then push the swing. The therapist might ask, "What do you want?" as a prompt for the request from the child
Tact	
Task 1: Name the reinforcing stimuli through imitation, with 90% agreement	The therapist and child read the names of everyday items on picture cards. Once the child repeated the names with or after the therapist pronounced the names, the therapist would then pass the picture cards to them and say, "You are right!"
Task 2: Independently name four items in one hour	The child independently named items in a book, such as a watermelon, a door, etc. The therapist might provide a prompt, such as, "What is this?" If the child named the item correctly, the therapist would praise and repeat their answers (e.g., "You are right! This is a watermelon.")
Task 3: Spontaneously name ten items	Without any prompts from the therapist, the child named 10 items based on their interest during play. If the child named the items correctly, the therapist would pass the items to the child
Task 4: Name 25 items when others ask, "what is this?"	The therapist pointed to a picture card and asked, "What is it?" The child named the item in the picture correctly. If the child named the item correctly, the therapist would pass the cards to the child. Once the child has consistently named the items correctly, the therapist would say, "You are right!" without passing the cards
Task 5: Independently name five actions	When the therapist instructed the child to do some exercise with music, the child independently named an action. Once the child named the action, the therapist would do the action with the child
Echoic	
Task 1: Repeat nouns with 90% agreement	The therapist played a game of cutting fruits with the child and encouraged the child to imitate pronouncing the word "apple", "banana", "knife", etc. If the child pronounced the words correctly, the therapist would then pass the named toys to the child
Task 2: Repeat phrases (noun + verb) with 90% agreement	In the fruit cutting game, the therapist said, "cutting a watermelon" and prompted the child to repeat. If the child repeated the phrase, the therapist would show cutting watermelon or cut the watermelon with the child
Task 3: Repeat short sentences	Based on the child's interest, the therapist chose a suitable music video. Whilst watching the music video, the therapist said some short sentences based on the rhythm of the music and prompted the child to repeat. If the child repeated, the therapist would then demonstrate the named actions
Listener responding	
Task 1: Respond to their name five times	When the therapist called the child's name, the child looked at the therapist. Once the child looked at the therapist, the therapist would hug the child
Task 2: Complete six gross motor movements according to other's verbal instructions	During exercise time, the child could complete a gross motor movement following the verbal instruction of the therapist. The movement need not be perfect. If the child showed the correct movement, the therapist would play the movement-related games with the child
Task 3: Identify 20 items from pairs of four following others' verbal instructions	The therapist provided four items to the child during play. The child could identify the item based on the verbal instruction of the therapist. If the child correctly identified the items, the therapist would then pass the items to the child

The task difficulty increased with the task number. The commencing and concluding tasks were tailored to each child's verbal and learning abilities

reinforcement was provided immediately when an attempt or behavior occurred. When a task had been learned, a more difficult task was introduced (for examples, see Table 2). The ratio of the learned to new tasks was 7:1.

To enhance the fidelity of intervention implementation, all therapists participated in an online meeting halfway through and at the conclusion of the intervention phase. The meetings were to discuss the children's behaviors and the issues of intervention and to adjust the intervention plan based on the PRT theory. For the parent-interventions, parents were asked to share a video of their intervention in turns in the weekly online parent-learning session. Then the therapists provided suggestions to ensure that parents' intervention were in line with the PRT motivational procedure.

Treatment as Usual (TAU)

TAU targeted the same language functions as the PRT intervention, but the TAU sessions were led only by the therapists and not the parents. The choice of stimuli, the criteria for the target response, and the type of reinforcement were pre-defined and fixed. During TAU, the reinforcement was not directly related to the targeted behaviors. For example, a child was rewarded with edibles when they initiated a request to open the door. Children were only rewarded when they completed a targeted behavior, and the provision of the reinforcement might be delayed.

Data Collection

Assessments using the VB-MAPP, SCQ, and CPEP-3 were conducted prior to the language intervention (i.e., baseline test) and in the week following the completion of the intervention (i.e., intervention test). In the same week after the intervention test, to examine the generalization of language functions, children were tested with new stimuli and therapists in new environments using the generalization components of VB-MAPP. To assess the maintenance of language functions, a maintenance test was conducted three weeks following the completion of the intervention using the same VB-MAPP as the baseline and intervention tests. An 8-week intervention with a 3-week follow up test was chosen to fit into a school term to avoid missing data and confounding factors during school holidays.

Data Analyses

The data were analyzed using SPSS 21.0. To examine whether different language functions facilitated each other, Pearson's correlation analyses were conducted to examine the relation between the measurements of different language functions (i.e., mand, tact, echoic, and listener responding) of all participants. To determine whether the PRT intervention improved the language abilities and whether the effect was maintained following the conclusion of the intervention, repeated measures analysis of variance (ANOVA) was performed on the score of each language skill, with the treatment group (PRT versus control) and phase (baseline, intervention, generalization, maintenance) as the main factors. To explore whether the PRT intervention improved other social and cognitive functions, repeated ANOVA was performed on the SCQ score and CPEP-3 scores (i.e., cognition, fine motor, gross motor, imitation, and adaptive behaviors), with the treatment group (PRT versus control) and phase (baseline versus intervention) as the main factors. Partial eta square of 0.01, 0.06, and 0.14 were considered to represent small, medium, and large effect sizes, respectively.

Table 3 Pearson's correlations between language functions

	Mand	Tact	Echoic	Listener responding
Mand	–			
Tact	.85*	–		
Echoic	.70*	.66*	–	
Listener Responding	.68*	.66*	.69*	–

Language functions were measured using the Chinese version of the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP)

*$p < .05$

Results

Although two participants in the PRT group received lower language and CPEP-3 scores compared to other participants in the same group, their scores did not significantly affect the comparison between the PRT and control groups. Therefore, no data were excluded.

Effects of PRT on Language Functions

Based on Pearson's correlation analyses, the four language functions (i.e., mand, tact, echoic, and listener responding) were correlated with each other (all $rs > 0.6$, $ps < 0.01$; see Table 3).

Based on repeated measures ANOVAs, PRT demonstrated consistent improvements in all four language measures (see Fig. 2). The ANOVAs showed a large main effect of group (all $ps < 0.05$, $\eta^2 > 0.2$) and phase (all $ps < 0.001$, $\eta^2 > 0.4$) and a large interaction effect between group and phase (all $ps < 0.001$, $\eta^2 > 0.2$) (see Table 4). According to simple effects analyses, the PRT group scored significantly higher on all language measures in the intervention,

generalization, and maintenance phases compared to the baseline phase (all $ps < 0.001$) and showed no significant change in scores in the generalization and maintenance phases compared to the intervention phase (both $ps > 0.05$; see Fig. 2 and Supplementary Table 1).

In contrast, although the control group showed improvements in tact, echoic, and listener responding in the intervention phase compared to the baseline phase (all $ps < 0.05$), no improvement was found in mand. A significant decrease was found in all four language measures in the maintenance phase compared to the intervention phase (all $ps < 0.001$; see Fig. 2 and Supplementary Table 1).

When comparing the groups in each phase, the PRT group demonstrated similar language scores to the control group at the baseline phase ($ps > 0.05$) but scored significantly higher with large effect sizes in the intervention, generalization, and maintenance phases (all $ps > 0.05$, $\eta^2 > 0.19$; see Fig. 2 and Supplementary Table 2).

Effects of PRT on Other Cognitive and Behavioral Measurements

A series of repeated measures ANOVAs were conducted to assess the effects of PRT on other aspects of cognition and behaviors (see Fig. 3 and Table 5). The PRT group showed greater reduction in social and communicative difficulties, evidenced by a greater decrease in SCQ scores between the intervention and baseline phases compared to the control group (i.e., significant Group × Phase interaction; for results of the ANOVAs, see Table 5; for results of the simple effects analyses, see Supplementary Table 3 & 4). In addition, the PRT intervention also improved cognition, fine motor skills, gross motor skills, imitation, and adaptive behaviors significantly more than the usual treatment, evidenced by greater increases in all the CPEP-3 measures between the invention and baseline phases compared to the control group (i.e., significant Group × Phase; see Table 5 and Supplementary Table 3 & 4).

Discussion

The current study investigated the effects of Pivotal Response Treatment (PRT) on language functions in autistic children according to Skinner's (1957) theory of verbal behavior. Following an 8-week intervention of a PRT motivation module conducted in autism special schools, autistic children demonstrated greater improvements in

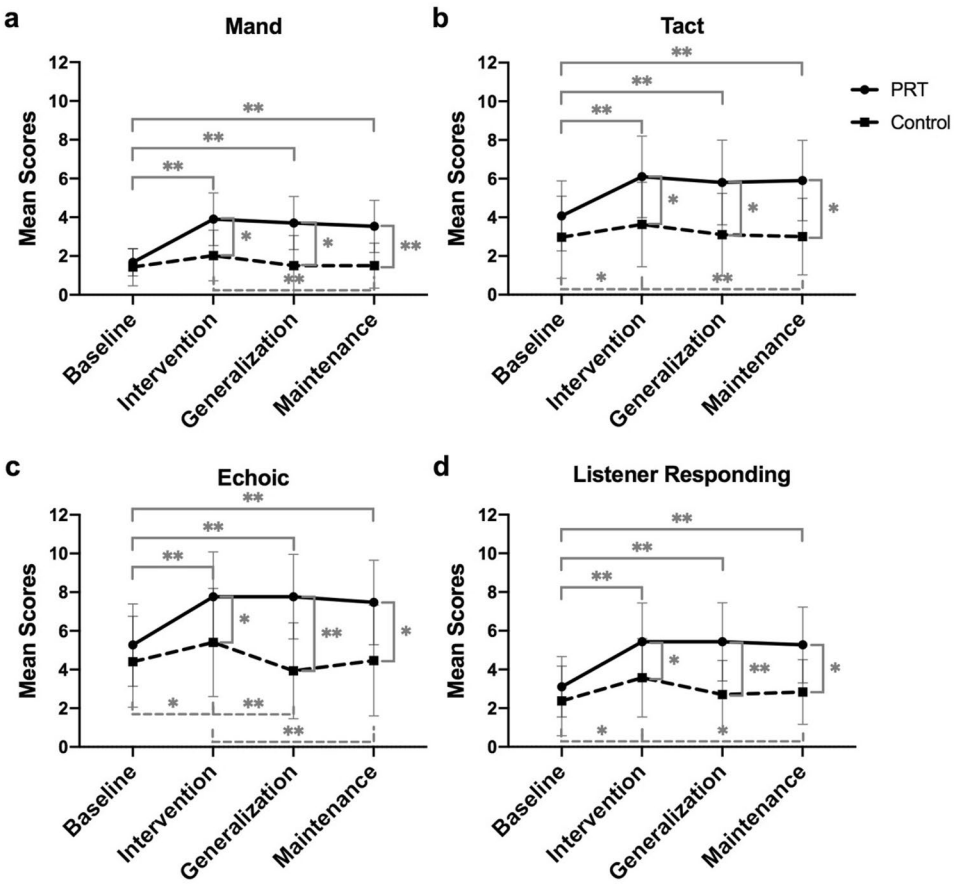

Fig. 2 Effects of PRT and Regular Training on Language Functions in Autistic Children. *Note.* The PRT group showed significant, generalizable, and sustainable improvements in **a** mand, **b** tact, **c** echoic, and **d** listener responding, compared to the control group. The horizontal solid brackets indicate the significant results between different phases in the PRT group. The horizontal dotted brackets indicate the significant results between different phases in the control group. The vertical solid brackets indicate the significant findings between group in each phrase. Language functions were measured using the Chinese version of the VB-MAPP. The intervention and generalization assessments occurred in Week 10. The maintenance assessment occurred in Week 13. *PRT* Pivotal response training

Table 4 Measures of language functions in the PRT and control groups in each phase

	PRT $M \pm SD$	Control	Statistics
Mand			
Baseline	1.67 ± 0.70	1.43 ± 0.96	Group: $F(1, 28) = 13.84$, $p = .001$, $\eta^2 = 0.33$
Intervention	3.90 ± 1.35	2.03 ± 1.30	Phase: $F(3, 84) = 36.12$, $p = < .001$, $\eta^2 = 0.56$
Generalization	3.70 ± 1.37	1.60 ± 1.55	Group × Phase: $F(3, 84) = 19.14$, $p = < .001$, $\eta^2 = 0.41$
Maintenance	3.53 ± 1.34	1.50 ± 1.16	
Tact			
Baseline	4.07 ± 1.81	2.97 ± 2.13	Group: $F(1, 28) = 9.62$, $p = .004$, $\eta^2 = 0.26$
Intervention	6.10 ± 2.11	3.63 ± 2.18	Phase: $F(3, 84) = 30.63$, $p = < .001$, $\eta^2 = 0.52$
Generalization	5.80 ± 2.19	3.10 ± 2.14	Group × Phase: $F(3, 84) = 15.56$, $p = < .001$, $\eta^2 = 0.36$
Maintenance	5.90 ± 2.08	3.00 ± 1.98	
Echoic			
Baseline	5.27 ± 2.13	4.40 ± 2.35	Group: $F(1, 28) = 8.36$, $p = .007$, $\eta^2 = 0.23$
Intervention	7.77 ± 2.31	5.40 ± 2.80	Phase: $F(3,84) = 59.40$, $p = < .001$, $\eta^2 = 0.68$
Generalization	7.77 ± 2.19	3.93 ± 2.48	Group × Phase: $F\ (3, 84) = 44.34$, $p = < .001$, $\eta^2 = 0.61$
Maintenance	7.47 ± 2.18	4.47 ± 2.86	
Listener responding			
Baseline	3.10 ± 1.56	2.37 ± 1.80	Group: $F(1, 28) = 9.78$, $p = .004$, $\eta^2 = 0.56$
Intervention	5.43 ± 2.00	3.57 ± 2.02	Phase: $F(3,84) = 24.03$, $p < .001$, $\eta^2 = 0.46$
Generalization	5.43 ± 2.02	2.70 ± 1.76	Group × Phase: $F(3,84) = 7.99$, $p = < .001$, $\eta^2 = 0.22$
Maintenance	5.27 ± 1.96	2.83 ± 1.67	

Language functions were measured using the Chinese version of the VB-MAPP. The intervention and generalization assessments occurred in Week 10. The maintenance assessment occurred in Week 13

PRT Pivotal response training

their language functions compared to autistic children who underwent treatment as usual (TAU). The improvement in language functions in the PRT group was generalized and maintained at the follow-up assessments. Moreover, the PRT intervention enhanced untargeted social and communicative functioning, cognition, fine motor skills, gross motor skills, imitation, and adaptive behaviors in autistic children. Taken together, the current study supports PRT as an effective intervention for facilitating language functions as well as general cognitive and social development in autistic children.

By incorporating Skinner's (1957) theory of verbal behavior, the current study provided new evidence supporting the effectiveness of PRT on improving language functions in autistic children. A recent systematic review showed that despite the promising evidence of PRT on facilitating language development in autistic children, the majority of existing studies lacked clear definitions of the forms and functions of the assessed language outcomes, hindering the comparison between research and clinical applications of PRT (Forbes et al., 2020). In the current study, autistic children scored significantly higher on mands (i.e., verbal requesting), tacts (i.e., labeling), echoics (i.e., repeating), and listener responding (i.e., responding to verbal requests) following the PRT intervention, and the improvements in the PRT group was significantly larger than the control group that received TAU. The therapeutic effects of PRT were generalized even when administrator and environment were altered and were maintained at the 3-week follow-up assessment. Given that previous PRT intervention studies on language have primarily focused on requesting and initiating questions (Koegel et al., 1998a, b; Mohammadzaheri et al., 2021; Popovic et al., 2020), the current study provides new evidence that PRT can exert a consistent, generalizable, and stable effect across a range of well-defined language functions in autistic children.

The positive outcomes of PRT on language functions in the current study may have been due to several factors. One reason may be that autistic children were more engaged in the training in the PRT intervention compared to the traditional structured ABA intervention. During the PRT sessions, the stimulus items were chosen based on the children's interests and the training of desired behaviors was imbedded in the natural interactions between the child and the therapist. Due to the child-led semi-structured nature of the PRT intervention, autistic children may have been more likely to generate and maintain interest in the activities. The motivation to participate in the activities may then subsequently stimulate the use of different functions of language in autistic children (e.g., saying "bubbles" to request the therapist to

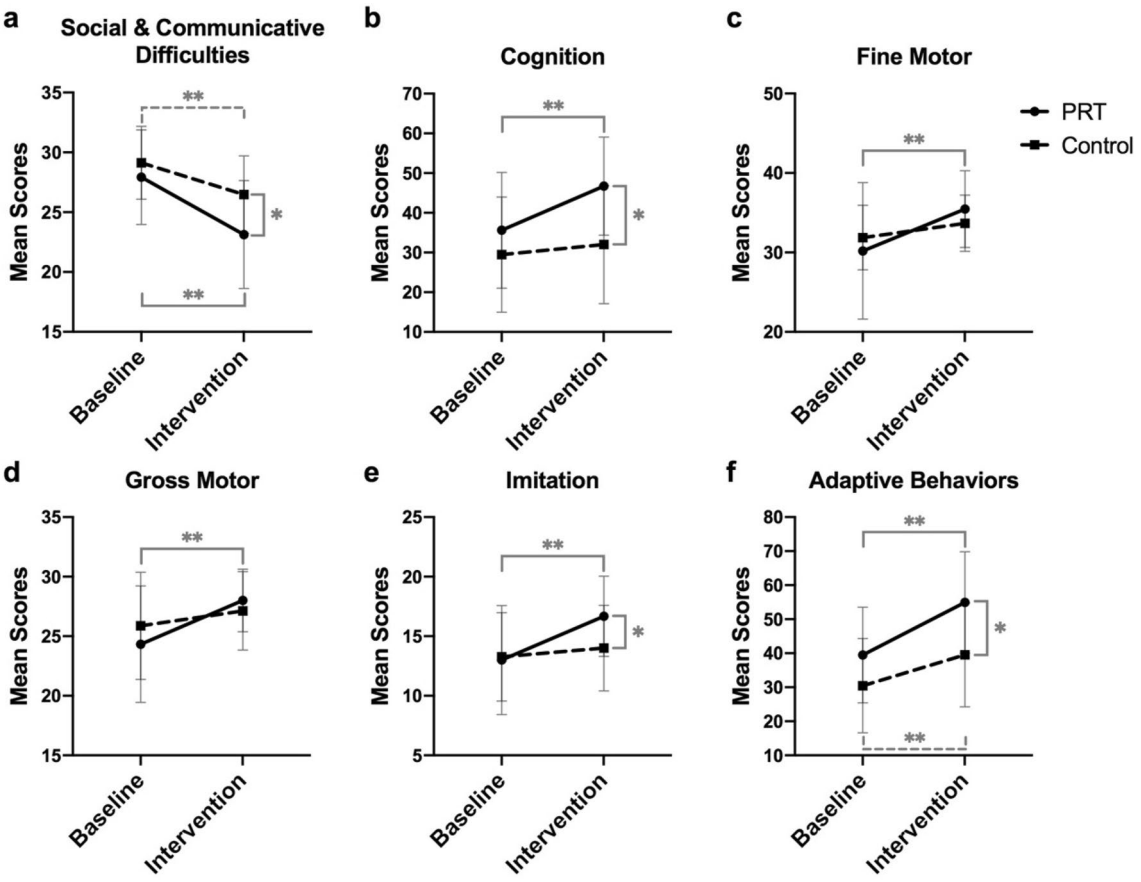

Fig. 3 Effects of PRT and Regular Training on Cognition and Behaviors in Autistic Children. *Note.* Autistic children showed consistent improvements in **a** social and communicative skills, **b** cognition, **c** fine motor, **d** gross motor, **e** imitation, and **f** adaptive behaviors, after the PRT versus regular intervention. The horizontal solid brackets indicate the significant results between different phases in the PRT group. The horizontal dotted brackets indicate the significant results between different phases in the control group. The vertical solid brackets indicate the significant findings between the groups in each phase. Social and communicative difficulties were measured using the Chinese version of the SCQ. Cognition, fine motor skills, gross motor skills, imitation, and adaptive behaviors were measured using the CPEP-3. The intervention assessment occurred in Week 10. *PRT* Pivotal Response Training

blow more bubbles and listening to the therapist's instruction when learning to dance). Indeed, our therapists noticed fewer disruptive and avoidance behaviors in the autistic children during the PRT sessions. Similar findings were also reported in previous research where the PRT intervention improved learning and decreased avoidance and escape behaviors in autistic children (Koegel et al., 1992; Mohammadzaheri et al., 2014, 2015).

The cooperation between therapists and parents is likely to contribute to the effectiveness of PRT on improving language outcomes. In the current study, although the PRT intervention was primarily administered by therapists in schools, parents of the children in the PRT group were trained to practice the PRT techniques at home for 12 weeks. This setting may have assisted in generalizing the PRT-induced language improvements to different natural contexts and in maintaining the achieved language functions after the completion of PRT in school. Consistent with these results, a previous study showed that a 12-week PRT parent intervention improved the frequency of utterances and adaptive communication skills in autistic children (Gengoux et al., 2015). Another study also found that the incorporating teacher- and parent-delivered PRT lead to an increase in socio-communicative skills and a reduction in behavioral and emotional problems (de Korte et al., 2021). These findings converge to suggest that the combination of therapist- and parent-delivered PRT should be considered in order to facilitate language and behavioral improvements in autistic children.

In addition to the targeted language functions, PRT demonstrated generalized effects to untargeted behaviors, including social communication, cognition, motor skills, imitation and adaptive behaviors in the autistic participants. This is consistent with the fundamental idea of PRT that increased motivation would elicit widespread improvements (Koegel & Koegel, 2019; Koegel et al.,

Table 5 Measures of cognition and behaviors in the PRT and control group in baseline and intervention phases

	PRT $M \pm SD$	Control	Statistics
Social & communicative difficulties			
Baseline	27.93 ± 3.95	29.13 ± 3.04	Group: $F(1, 28) = 2.85$, $p = .10$, $\eta^2 = 0.92$
Intervention	23.13 ± 4.51	26.47 ± 3.23	Phase: $F(1, 28) = 245.27$, $p < .001$, $\eta^2 = 0.90$
			Group × Phase: $F(1, 28) = 20.02$, $p < .001$, $\eta^2 = 0.42$
Cognition			
Baseline	35.60 ± 14.57	29.47 ± 14.48	Group: $F(1, 28) = 4.26$, $p = .048$, $\eta^2 = 0.13$
Intervention	46.73 ± 12.33	32.00 ± 14.86	Phase: $F(1, 28) = 49.19$, $p = < .001$, $\eta^2 = 0.64$
			Group × Phase: $F(1, 28) = 19.48$, $p = < .001$, $\eta^2 = 0.41$
Fine motor skills			
Baseline	30.20 ± 8.60	31.87 ± 4.07	Group: $F(1, 28) = 0.001$, $p = .97$, $\eta^2 = 0.00$
Intervention	35.47 ± 4.82	33.67 ± 3.54	Phase: $F(1, 28) = 31.46$, $p = < .001$, $\eta^2 = 0.53$
			Group × Phase: $F(1, 28) = 7.58$, $p = .01$, $\eta^2 = 0.21$
Gross motor skills			
Baseline	24.33 ± 4.89	25.87 ± 4.50	Group: $F(1, 28) = 0.6$, $p = .81$, $\eta^2 = 0.002$
Intervention	28.00 ± 2.62	27.13 ± 3.29	Phase: $F(1, 28) = 29.33$, $p = < .001$, $\eta^2 = 0.51$
			Group × Phase: $F(1, 28) = 6.94$, $p = .01$, $\eta^2 = 0.20$
Imitation			
Baseline	13.00 ± 4.58	13.27 ± 3.71	Group: $F(1, 28) = 0.81$, $p = .38$, $\eta^2 = 0.03$
Intervention	16.67 ± 3.37	14.00 ± 3.59	Phase: $F(1, 28) = 24.45$, $p = < .001$, $\eta^2 = 0.47$
			Group × Phase: $F(1, 28) = 10.87$, $p = .003$, $\eta^2 = 0.28$
Adaptive behaviors			
Baseline	39.47 ± 14.06	30.47 ± 13.87	Group: $F(1, 28) = 5.62$, $p = .03$, $\eta^2 = 0.17$
Intervention	54.93 ± 14.89	39.53 ± 15.24	Phase: $F(1, 28) = 90.89$, $p = < .001$, $\eta^2 = 0.76$
			Group × Phase: $F(1, 28) = 6.19$, $p = .02$, $\eta^2 = 0.42$

The intervention assessment occurred in Week 10. Social and communicative difficulties were measured using the Chinese version of the SCQ. Cognition, fine motor skills, gross motor skills, imitation, and adaptive behaviors were measured using the CPEP-3

PRT Pivotal response training

2001). Similarly, previous studies found that PRT intervention targeting initiating questions resulted in collateral gains in overall communicative skills (Mohammadzaheri et al., 2021), happiness and interest (Popovic et al., 2020). The current findings extend the existing literature by showing that incorporating the motivation component of PRT into a language intervention not only improves language and emotions but also benefits general cognitive and social development. It is possible that with increased motivation to practice language skills, autistic children create more play and interaction opportunities, leading to the learning of a variety of untargeted functions. Therefore, this study suggests that language functions should be considered an important intervention target in PRT intervention to facilitate general development in autistic children.

While the results of the current study are promising, several limitations should be noted. First, a 3-week follow-up assessment might not be sufficiently long to assess the long-term benefits of PRT. This timing was chosen to align the end of the testing with the end of the school term as school holidays might have introduced confounding factors and resulted in data loss. Previous studies have found that the therapeutic effects of PRT on communication were maintained 3 months following the conclusion of the intervention (Gengoux et al., 2015). To further understand the long-term benefits of PRT, multiple follow-up tests over a period of at least 3 months should be considered in future studies. Second, although the current study demonstrated the benefits of a combined therapist- and parent-delivered PRT intervention, it did not compare the effects of therapist- versus parent-administered PRT. To maximize the benefits of PRT, future investigation into the optimal parameters for intervention, such as frequency, intensity, duration, and administrator, is required. Third, although the current study recruited qualified and experienced therapists and hosted regular meetings to ensure fidelity of the treatment, more rigorous and consistent integrity checks should be conducted across the PRT and TAU groups.

Conclusions

In conclusion, the current study conducted the first experimental examination of the effects of PRT on language functions in autistic children in the context of Skinner's (1957) theory of verbal behavior. The results indicated that combining PRT motivational components with language intervention is helpful to facilitate the development of different language functions in autistic children. These functions included verbal requesting, labeling, repeating, and responding to the speech of others. The PRT-induced improvements in language functions were maintained when the testing environment changed and when the intervention concluded. In line with PRT theory, the PRT intervention also showed generalized effects on untargeted cognitive and social skills. While further research is needed to investigate the long-term effects of PRT on language development and the impact of the administrator (e.g., therapists versus parents), this naturalistic intervention appears to be a promising option for promoting language development in autistic children.

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Author contributions LW and CW developed the research questions. LW was responsible for data collection and analyzed the data with assistance from SL. LW, SL and CW were involved in interpreting the results. SL drafted the manuscript based on information provided by LW. All authors read, edited and approved the final manuscript.

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Declarations

Conflict of interest The authors declared no potential conflicts of interest with respect of the research, authorship, and/or publication of this article.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was reviewed and approved by the ethics committee of Nankai University.

Informed Consent Informed consent was obtained from the caregivers of all individual participants before they joined the current study.

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