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Teaching young nonverbal children with autism useful speech:

A pilot study of the Denver Model and PROMPT interventions

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Abstract

This single subject design study examined two models of speech-language intervention: Denver Model (which merges behavioral, developmental, and relationship-oriented intervention), and PROMPT (a neuro-developmental approach for speech production disorders). Ten young, nonverbal children with autism were matched in pairs and randomized to treatment. They received 12 one-hour weekly sessions of therapy and daily one-hour home intervention delivered by parents. Fidelity criteria were maintained throughout. Eight of the 10 children used 5 or more novel, functional words spontaneously and spoke multiple times per hour by the conclusion of treatment. There were no differences in acquired language skills by intervention group. Initial characteristics of the best responders were mild to moderate symptoms of autism, better motor imitation skills, and emerging joint attention skills.

Introduction

Autism is a complex neurodevelopmental disorder that severely compromises functioning in multiple developmental domains, including social relatedness and reciprocity, nonverbal and verbal communication, and cognitive and adaptive functioning. Language proficiency is one of the two most important variables in predicting outcomes in autism (the other being IQ) (Venter, Lord, & Schopler, 1992). Because the language deficit is so disabling, and the acquisition of language so important for outcomes, autism interventions have focused much attention on helping children with autism acquire language.

Treating Language Deficits in Autism

Two general approaches for developing communicative speech in young children with autism have been available to the field for many years. These approaches typically apply learning theory principles to development of speech, using one of two main methods.

The first method, commonly known as “discrete trial teaching”, uses a didactic, adult-directed instruction delivered from a pre-set curriculum often taught in massed trials. First described by Wolf, Risley, and Mees (1964), this approach has been most thoroughly described and manualized by Lovaas and his associates (Lovaas, 1981; Lovaas, 2002). In this approach, children are taught to attend to adults and respond to simple instructions (receptive language training); to imitate manual, oral motor, and vocal behavior; and then to imitate speech. Association learning is then used to teach increasingly sophisticated expressive language skills. Motivation in this approach is provided through the use of various external rewards. Many published studies have supported the efficacy of this approach, as recently reviewed by Goldstein (2002).

The second approach involves a more naturalistic use of learning theory principles. In this approach, first described in a landmark paper by Hart and Risley (1968) the intervention begins with a

child-initiated behavior in a natural interactive context. The adult, using modeling and shaping techniques, follows the child's initiation with a prompt or model of more sophisticated verbal behavior and consequates the child's production by providing the child-requested object or activity, thus providing a "natural" reinforcer. This type of teaching approach is variously referred to as natural language teaching, incidental teaching, or pivotal response training (Koegel, Koegel, & Carter, 1999) and is also compatible with a developmental orientation to language development (Prizant & Wetherby, 1998). It varies considerably from adult-directed, or discrete-trial teaching in many ways, including the extent of adult directedness, the individualization of the learning opportunity, the reliance on natural reinforcers, the role of the child as initiator of the interaction, and the emphasis on generalization and expansion of skills across settings, activities, and people. This approach has also been found to be effective in a number of independent replications, as recently reviewed by Goldstein (2002) and Koegel (2000).

Both of these approaches require intensive interventions, practiced many times daily, over significant periods of time, to lead to speech acquisition in young nonverbal children with autism. Children with best outcomes in either approach have typically learned to produce speech in the first year of treatment, often receiving 25-40 hours of intervention per week in carefully structured settings and home treatments (McEachin, Smith, & Lovaas, 1993; McGee, Morrier, & Daly, 1999).

While the behavioral approaches to teaching speech to children with autism have demonstrated efficacy, they are built on a behavioral model of language development that has been replaced over the past twenty years by the developmental-pragmatics understanding of language development, first introduced by the writings of Bruner (1975), Bates (1976) and others in the late 1970's and early 1980's. The language impairment in autism is currently understood as a **developmental** disorder, stemming from several potential mechanisms, including impaired development of earlier, prelinguistic

communicative mechanisms, as defined by a long line of studies beginning with work by Wetherby and Prutting (1984) and Mundy, Sigman, Ungerer, and Sherman (1986) and supported by a number of researchers and theorists (Carpenter & Tomasello, 2000; Stone, Ousley, Yoder, Hogan, & Hepburn, 1997; Wetherby, Prizant, & Schuler, 2000 among many others). Lack of social engagement, joint attention, imitative ability, and presence of cognitive impairments are assumed to play pivotal roles in poor language acquisition, and developmentally oriented treatments focus on increasing social engagement, imitation skills, means-end concepts, and understanding of language in order to develop spoken language.

Thus, developmental approaches to language treatment have considerable theoretical strength, and main characteristics of a developmental approach are well described by Prizant and colleagues (Prizant, Wetherby, & Rydell, 2000). The Denver Model (described in Rogers et al, 2000) is a **developmental** approach to early autism treatment that delivers a specified developmental curriculum (individualized for each child based on current abilities) using a combination of empirically supported **teaching techniques** (massed trial and naturalistic behavioral teaching and affective dyadic exchanges) to attain specific developmental outcomes. The Denver Model involves a curriculum and method of teaching based on both attention to teaching techniques and attention to the interpersonal relationship, fostered in very specific ways. The Denver Model can be delivered in a variety of formats: preschool group instruction in either inclusive or special classes, individual therapy sessions, and intensive 1:1 intervention. These formats are often combined.

Outcomes of children receiving the Denver model (Rogers & DiLalla, 1991; Rogers et al., 1986; Rogers & Lewis, 1989; Rogers et al., 1987) described significant accelerations in developmental rates of children diagnosed with autism or PDD-NOS, ages 3 to 5 in several developmental areas, including cognition, language, and social development, including acquisition of useful speech in previously

nonverbal children. These studies, using pre-post data, suggested that the Denver Model has the capacity to affect development in many areas. Furthermore, four independent replications of the model were carried out in rural Colorado school districts (Rogers et al, 1987). Group data from the replication sites demonstrated the same child change effects from the model that the original studies found.

For the purposes of the present study, delivery of one aspect of the Denver Model, the communication curriculum, occurred through a combination of once weekly 50-minute therapy sessions and daily home review by the parent. This method of delivery was used because it is a typical delivery method of speech and language therapists working in schools, clinics, and birth to three early intervention programs. Brief periods of naturalistic social-affective teaching interactions ("sensory social routines") alternated with brief periods of didactic teaching during the therapy hour to tap the strengths of each kind of teaching approach.

The content of the treatment focused on language acquisition and included four separate teaching strands that begin in the first treatment session:

(1) Using naturalistic teaching strategies and highly motivating social games and object activities to develop the foundations of nonverbal communication through a high frequency of social interactions, turn taking, and elicitation and shaping of natural gestures ('talking bodies") into intentional conventional gestures to serve a variety of communicative functions, especially requesting, initiation and maintenance of social games, greetings, protest, requests for help, and;

(2) Teaching imitation of actions on objects, body movements, oral-facial movements, and speech sounds using both massed trial and naturalistic behavioral strategies, in both adult directed and child initiated interactions, including drills, object play, songs and finger plays and object and social requests;

(3) Teaching receptive understanding through naturalistic behavioral teaching of simple instructions (sit down, stand up, come here, look to name), and use of very simple, repetitive language to name social and sensory activities, songs, and objects;

(4) Teaching object associations by teaching children to match similar objects, pictures, and pictures to objects (Lovaas, 1981).

(5) Increasing verbal approximations of target words in object play and social routines using naturalistic behavioral teaching approaches including modeling, and shaping increasingly more accurate approximations with intrinsic reinforcement strategies.

Treatment begins with an assessment using the **Denver Model Curriculum** (Rogers et al, unpublished manuscript). Treatment objectives are written to teach the set of developmental skills just beyond the child's current performance level. Teaching programs are developed for each of the teaching settings and implemented in the treatment. Progress data are gathered and reviewed weekly with adjustments made in the teaching programs to assure progress. The child's curriculum is packaged in a notebook that contains goals and objectives, instructional plans and activities, and data (both quantitative and qualitative).

Motor Dysfunction in Children with ASD

In the past few years a specific mechanism impairing speech development in autism has been suggested: oral motor dysfunction (Adams, 1998; Page & Boucher, 1998). The question of motor dysfunction in autism has a long history. As a result of her studies of imitation in autism, DeMyer and colleagues (1972) suggested that dyspraxia may be part of the syndrome, severely affecting communication, adaptive behavior, and learning through limiting imitation of other people, causing a severe level of disability (DeMyer, Hingtgen, & Jackson, 1981). While the question of motor dysfunction has been raised sporadically in the autism literature (Damasio & Maurer, 1978; Ohta, 1987)

since DeMyer's original observations, little attention was paid to the motor question until the past decade. Recently, two sets of literatures have provoked new interest in a possible underlying motor disorder in autism. One literature that stimulated this thinking is the (largely discredited) literature on facilitated communication, which suggested that people with autism had intact inner communication abilities that could not be expressed due to motor output problems (Perry, Bryson, & Bebko, 1998).

The second literature involved a number of recently published empirical studies demonstrating motor dysfunction in autism (see reviews by Rogers & Bennetto, 2000 and Anzalone & Williamson, 2000) , including studies of dyspraxia-related manual and oral-motor movements (Rogers et al., 1996; Hughes, 1996; Page & Boucher, 1998; Seal & Bonvillian, 1997; Adams, 1998; Bennetto, 1999; Roy, Elliott, Dewey, & Square-Storer, 1990). In a descriptive study, Page and colleagues (1998) reported that 79% of a large group of children with autism performed very poorly on tests of oral-motor functioning and suggested that poor oral and manual development contributed to impaired speech and signing in the group. In a small comparative study, Adams (1998) demonstrated autism-specific difficulties with oral-motor control of the motor speech mechanisms for four children with autism compared to age-matched controls, difficulties similar to those seen in children with oral-motor apraxia. Finally, two groups of researchers: Stone and colleagues (1997) and Rogers, Hepburn, and Stackhouse (2003) found that young children with autism were more impaired in the ability to imitate single oral-motor movements than developmentally matched clinical controls. In the Stone study, oral motor imitation predicted to speech development in the children with autism one to two years later.

Over the past twenty years, a novel clinical therapy approach: PROMPT **(Prompts for Restructuring Oral Muscular Phonetic Targets)** has been developed as a treatment for speech production disorders in both children and adults based in accepted neuromotor principles of speech production (Chumpelik (Hayden) 1984). As PROMPT has evolved, it has developed a

defined Philosophy, Approach, System and Technique for analyzing and organizing treatment. (Chumpelik, 1984). Central to the PROMPT Philosophy is that touch is a primary sensory modality that can be used to: 1) develop, rebalance or re-establish speech motor control, 2) provide a foundation for integrating sensory modalities (audition and vision) in developing concepts and expressive language and, 3) enhance social- emotional interaction and trust between clinician and client.

Several papers have been published on the efficacy of PROMPT. Chumpelik (Hayden) & Sherman (1980) described the progress of an 8-year old, non-speaking child with autism and cognitive impairment who gained 30 functional words over a four-month period. Other published single subject studies on the method described children and adults with nonautism disorders including apraxia of speech, Broca's aphasia, and developmental dyspraxia (Chumpelik (Hayden) & Sherman, 1982; Square-Storer & Hayden, 1987; Square-Storer & Hayden, 1989). Square and colleagues (2000) treated 6 males (ages 4; 2 to 4; 6 years) with unintelligible speech (who had made minimal progress in traditional therapy) in twice weekly 90-minute group sessions for 15 weeks. Assessment with the Systematic Analysis of Language Transcripts, SALT (Miller & Chapman, 1993) revealed perceptually improved speech even on untrained words, and significant improvement on overall behavior, social interactions, and language skills.

There are nine core elements that are considered essential in typical PROMPT sessions. They are:

1) The use of tactile-kinesthetic information as a critical modality for recognizing, developing, re-balancing and integrating cognitive, linguistic and motor behavior.

2) Determining a Communication Focus or an aspect of development in which to embed and focus communication intervention.

3) Developing goals and embedding objectives that embody the Communication Focus while working on motor/language, cognitive, and social function.

4) Analyzing the global and speech motor sub-systems to determine three priority areas that need immediate development or rebalancing and create an initial, functional lexicon (core vocabulary).

5) Deciding on the purpose of prompting and what types of prompts should be used to support and develop motor control for speech and language and/ or interaction and cognitive development.

6) Concrete understanding of how chosen goals and objectives will directly affect motor resourcing and therefore, materials, activity choices.

7) Insuring that a high degree of motor-sound practice (using prompts for accuracy of production) and generalization of these into novel syllables and words within naturalistic activities are used within each session.

8) The inclusion of reciprocal interaction or choice making, in all activities, in almost every turn.

9) Presentation of the same or similar activities over time to provide a structure in which increased motor-language complexity and cognitive learning of events and sequences may be practiced.

Using PROMPT in Early ASD

When used with young children with autism, the PROMPT therapist first structures the treatment hour so that the child must attend to toy-based activities and produce an intentional sound to request.

The child's utterance is then supported through integrated auditory and tactile cues. The adult uses both vocal modeling and actual manual manipulation of the child's jaw, lips, and other speech mechanisms while the child vocalizes to elicit speech approximation of a target word. Physical cues are gradually faded into visual cues, so that the child responds to a hand movement rather than a touch, and then further faded. In Phase 1, open vowels are first shaped into a consonant vowel syllable. As an example, if the child "requests" a ball through reaching for it and any vocalization¸ the therapist says "Ball, you want ball", while manipulating the child's lips to produce the initial syllable /ba/or prompting in the entire sequence /bal/, and gives the child the ball in order to play with it. They play for a very brief period and then the situation is repeated so that the child has much opportunity to practice.

In phase 2, syllables are shaped into words and short phrases, and then in Phase 3 the prompts are faded and the complexity of all aspects of speech and language are increased. The chosen activities are those that are 1) motivating to the child 2) within the child's' mental age, 3) consider the motor resourcing or competing motor task requirements, 4) those that enable initial lexicon choices and 5) support functional interaction and independent speech across settings (Hayden, 1999). Repetition of these similar patterns over different activities allows the child to build success, practice repeatedly and expand motor, language and cognitive aspects over time.

The Denver Model

Salient Features and Differences Between the Two Models

The Denver and PROMPT Models share some similar features as well as differences in their intervention programs. Both are developmental, target shared attention and interaction, use naturalistic communicative exchanges, work towards positive affective communicative behavior, work to match appropriate level activities to the child's developmental level, and initially provide a high degree of adult

structure. These are commonalities with other high quality language intervention approaches. Differences between the two models include the way in which the evaluation and information gained in the evaluation is organized and how the goals and treatment objectives (including sensory, motor, cognitive, linguistic, social and emotional) are chosen and integrated, the way the motor system is organized towards tasks (both in fine motor and speech sub-systems), the use of imitation versus provision of tactual-kinesthetic input, the way tasks are taught, and how and when they are expanded or changed.

The Present Study

The nature of the barrier to speech development for some young children with autism is not known. If the social and imitative aspects of autism prevent speech, then treatment should focus on these targets. If oral motor impairments are preventing development of speech, then this should be the focus of treatment. The purpose of the present pilot study was to develop the methodologies and preliminary tests of two different models for developing speech in nonverbal preschoolers with autism: the Denver Model and PROMPT. While both these treatments have been previously published, both approaches needed additional empirical support. We also wished to gather data about possible variables moderating response to each treatment to generate hypotheses for further research. Furthermore, we wished to examine whether a typical language therapy delivery paradigm involving one hour per week of speech and language therapy and daily parent review at home could be sufficient to improve speech outcomes in this group of children.

Method

Participants

Ten children, ages 20 to 65 months, participated in this study. All participants were male; 80% were Caucasian, 10% African-American, and 10% Hispanic/Biracial. See Tables 1 and 2 for participant

descriptions. Participants were recruited from a tertiary university evaluation clinic that specializes in autism spectrum disorders, as well as through local parent groups (e.g., Autism Society of Colorado), other early intervention programs and the research database maintained by the Autism Research Group at the University of Colorado. Inclusion criteria were: (1) diagnosis of autism, (2) spontaneous use of less than 5 functional words **per day** according to parent report as well as clinician observation, (3) developmental quotient (mental age/chronological age * 100) of at least 30, and (3) an absence of a known co-morbid medical condition (such as tuberous sclerosis). Autism diagnosis was based upon meeting all of the following criteria: (1) past clinical diagnosis of autism, (2) current clinical diagnosis as determined by the psychologist on the research team (SJR, SLH), (3) exceeding autism cutoff on the Autism Diagnostic Observation Schedule – Module I (Lord, Rutter, DiLavore, & Risi, 1999) , (4) exceeding the autism cutoff on the Social Communication Questionnaire, and (5) meeting APA criteria for autism as specified in DSM-IV. Estimates of spontaneous use of functional speech were obtained through a brief interview with the parent, as well as by clinical observation during the developmental and diagnostic assessments, which usually occurred in two, 2-hour assessment sessions. Four additional children who were referred were not enrolled in the study due to: (a) not having autism (n=1), (b) speaking in more than 5 words per day (n=2), and (3) presenting with a developmental quotient of less than 30 (n=1). These families were referred to clinical services in the community.

Information concerning other treatments the children were receiving was collected by parent interviews every third therapy session and is summarized in Table 2. Intervention participation did not change across the 12-week study period for any of the children. One of the children was not enrolled in any other interventions or school programs. Nine children received individual speech/language therapy. Of these, 6 were enrolled in 30 minutes to 1 hour of speech therapy per week through their public schools and had been receiving these services for an average of 13 months prior to inclusion in this

project. Three children were enrolled in 2-3 hours per week of speech therapy for an average duration of 15 months.

Nine children were enrolled in some type of preschool program. Of these, 3 had been served for 12-30 hours per week for over 2 years prior to participating in the study, and 6 participated in preschool programs for 4 -12 hours per week, for an average of 9 months prior to joining the study. Finally, one child participated in a 30-hour per week home- and center-based intervention program for 9 months prior to enrolling in the study.

Design

A single subject design (A-B-A) was implemented in this study across the 10 participants. The advantage of such a design allows for the establishment of an extended baseline level of performance for each child against which to compare treatment results, so each child acts as his or her own control. This is considered an acceptable design for examining treatment effects and an alternate choice to group designs involving a no treatment control group (Barlow & Hersen, 1984). Each child participated in a pre-treatment and post-treatment assessment battery that included diagnostic, developmental, and speech-language assessments (see Measures). In addition, examination of treatment effectiveness included behavioral coding of functional use of speech in 10-minute samples from each speech therapy session as well as speech probes conducted in an unstructured play assessment in three phases of the project (baseline, intervention, maintenance). The number of functional words used by the child per session were charted and evaluated by visual inspection, as described by Barlow and Hersen (1984). This method of analysis allows for examination of individual differences in response to treatment, and does not require the withholding of treatment for any of the participants.

Procedure

When families volunteered, each eligible child was administered pre-treatment assessments and several baseline assessments of functional use of speech during unstructured play with an adult. After completion of the pre-treatment assessment, the child was randomly assigned to a treatment and a therapist for 12 weekly 1-hour sessions using a computer-generated random numbers table. If families missed one or more sessions, additional sessions were added to complete the 12-session schedule.

During treatment, assessment of generalization of speech occurred at monthly intervals (described below). Information concerning other interventions was also gathered at monthly intervals. At the conclusion of treatment, post-treatment assessment occurred on the standardized measures and a report was provided to families. Three months after the end of treatment, one more behavioral assessment of speech during unstructured play was carried out to examine maintenance of gains in treatment.

This research was conducted at the University of Colorado Autism and Developmental Disabilities Research Laboratory in Denver, Colorado. Baseline, intervention, post-intervention, and maintenance evaluation sessions occurred in a two-room suite with a one-way observation mirror and digital videotaping capabilities. All sessions were videotaped. Parents observed all therapy sessions and participated in all Denver Model sessions.

Measures

Pre-treatment

All participants were given standardized assessments of cognitive and language functioning, adaptive behavior, and autism symptoms pre- and post- treatment. In addition, parents were interviewed about the child's autism symptoms, adaptive behaviors and use of words and gestures. Diagnostic and developmental batteries were administered either by a clinical psychologist with extensive experience in

autism, or by a graduate student under her supervision. Assessments were not conducted by children's therapists, and assessors had no direct knowledge of the speech the child was acquiring in treatment. The following measures were included:

Autism Diagnostic Observation Scale (ADOS; Lord et al., 2000). All lab personnel were trained to 85% reliability on the full range of scores so that, in addition to generating the traditional cutoff scores, we could also generate severity scores. All assessments were videotaped and reliability was assessed for 60% of ADOS administrations. Weighted kappas on item-agreement ranged from .72 - .96. Administrators of the ADOS were aware that the child was in the treatment study, but were blind to which treatment the child was receiving. An additional 40% of the ADOS administrations were coded by a trained observer who was unaware that the child was enrolled in a treatment study. Weighted kappas for blind observers ranged from .78 -.92.

The Social Communication Questionnaire (SCQ; Berument, Rutter, Lord, Pickles, & Bailey, 1999) is a parent questionnaire developed from the most sensitive items of the Autism Diagnostic Interview (Lord, Rutter, & Le Couteur, 1994) . The SCQ has excellent concurrent validity when compared to the ADI-R. The SCQ takes approximately 20 minutes to complete.

Mullen Scales of Early Learning (Mullen, 1995). This is a standardized, normed developmental assessment for children aged birth through 68 months. Twenty per cent of the assessments were scored by two raters for reliability checks. Reliability on subscales was calculated using weighted kappas and ranged from .82 to .92. The raw scores from the expressive and receptive language subscales were used to assess change related to experimental treatment.

Vineland Adaptive Behavior Scales – Interview Edition (Sparrow, Balla, & Cicchetti, 1984) was used to gather parent report of child communication abilities in the home and community.

MacArthur Communicative Development Inventory (CDI; Fenson et al., 1993) is a parent report measure of the child's use of spontaneous, functional speech throughout the day. The CDI provides a list of target words and the parent endorses which words were spoken by the child in the preceding week.

Previous intervention history. Detailed information was collected about all the different types of treatment a child has received, including the type of treatment, the ratio of children to adults, and the hours involved. The form was completed through an interview with the parent during the pre-test assessment, and then was re-examined with the parent every third session of the child's treatment in this project.

Background information. Demographic and medical history forms, background information on several variables (e.g., maternal education, SES, ethnicity, medical history) was collected via parent report.

Baseline speech probes. Children participated in 3 baseline speech probes to establish a stable baseline rate of speech prior to beginning the intervention. During this 15-minute play-based procedure, the child was presented with a novel toy set every five minutes by an examiner and was encouraged to play and interact with the toys and the adult. The examiner was a research assistant (not a therapist) who is instructed to be a responsive play partner, but not an initiator of play activities. The examiner followed the child's lead, made statements concerning what the child is currently doing (i.e., "You're beating on the drum") and verbally responded to the child's communications. During each 5-minute period, the examiner provided one press for a request (e.g., by holding up two toys and waiting for the child to indicate a choice either verbally or nonverbally), and one press for response to joint attention (e.g., "Daniel – look!"). The adult behavior was standardized and procedural fidelity examined via a fidelity checklist, completed every 3rd administration, and exceeded 85%. The child's functional use of

speech during this unstructured play activity with an adult was coded from videotape in 5-minute intervals. Coding involved frequency counts of the following variables: (1) number of words and/or approximations produced by the child; and (2) number of phrases produced by the child, as described in the section above. Two coders rated behaviors on more than 40% of tapes and inter-rater reliability examined using weighted kappas on categories of communication in generalization probes were as follows: spontaneous words: .82-.88; spontaneous phrases: .92-.96, imitated words: .88-.92; imitated phrases: .82-.88; communicative function: .64-.68. Reliability was also not established for use of eye gaze or gesture, primarily due to problems with camera angles; therefore, nonverbal communicative behaviors were not coded. The identical coding procedures and definitions were used to assess speech during therapy sessions, maintenance probes, and follow-up probes.

Therapy sessions and home intervention. Children received either Denver Model or PROMPT treatment, one hour per week, for 12 treatment hours, as described in the previous section. Each session was scheduled one week apart. If the parents or therapist had to cancel a session due to illness or vacation, the child was seen the following week. All 12 sessions were delivered for each child.

For children receiving Denver Model therapy, the parent was present and active in each treatment session. During a session, the therapist reviewed the child's notebook and the parent's data, asked the parent to demonstrate some of the treatment objectives, taught the child and parent at least one new skill in each of the four areas described above, and had the parent practice that new skill. Each parent was asked to spend 45 minutes each day carrying out certain of the child's treatment objectives in home or other settings. Each individual family determined how a child's current treatment objectives would be incorporated into family routines. The tasks for the parents were specified in the child's treatment notebook, where parents recorded all activities and the child's performance.

For PROMPT treatment, parents observed the entire treatment session via video, and at the end of each session the therapist provided a target for daily home interventions. Parents did not provide tactile cues for speech at home, but rather provided daily opportunities to practice new words or word approximations that the child has learned to produce spontaneously or through a verbal model only. Parents were asked to spend approximately 30 minutes per day carrying out the child's treatment objectives within an activity in home or other settings. In conjunction with the clinician, each individual family determined how the child's treatment objectives would be incorporated into family routines. The tasks for the parents were specified in the child's treatment notebook, where parents recorded all activities and the child's performance.

Speech samples acquired during treatment sessions. Every treatment session was videotaped. One 10-minute sample was randomly selected from each treatment session to be coded using a set of operational definitions developed by the research team. Time samples were chosen within an "active treatment" component of the session (i.e., samples were chosen from a random number table, randomly selected beginning anywhere between minute 5 and minute 40). If, during the randomly chosen sample, the child left the room (e.g., for a bathroom break), or the therapist focused on the parent and not the child, then additional child-therapist time was included in the sample following the break in treatment to have a full 10 minutes of therapist/child interaction.

Behaviors that were coded were: (1) number of novel words and/or approximations produced by the child; and (2) number of novel phrases produced by the child. For each word, approximation, or phrase, coders also determine the function of the communication (e.g., behavioral regulation, joint attention, social interaction – based upon Mundy et al., 1990), and whether the utterance was spontaneous or prompted. Behaviors were coded by three trained observers and reliability was assessed on over 40% of samples. Inter-rater reliability examined using weighted kappas on categories of

communication were as follows: spontaneous words: .86-.92; spontaneous phrases: .88-.92; imitated words: .86-.88; imitated phrases: .88-.94; communicative function: .62-.70.

Post-treatment. Participants completed the same diagnostic and developmental measures described above within three weeks of the last treatment session (one child was seen after 6 weeks due to parental scheduling mishaps). These assessments were conducted in 2-3 sessions by a clinical psychologist and a graduate student under her supervision.

Three-month follow-up. Three months after the post-test assessment, the family was invited to return for a speech probe/play assessment (identical to the procedures used in baseline and during intervention to assess the child's functional use of speech). Three families (30%) were unable to be scheduled for these visits and attempts to conduct this maintenance assessment are on going.

Fidelity of Treatment Implementation

Two speech language therapists with considerable experience treating young children with developmental disorders including autism (TH, RCS) were trained to fidelity on both models by the experts/developers of each treatment. Dr. Rogers developed a fidelity rating system involving Likert style ratings of features that must be present in a Denver Model therapy session and trained each therapist to a level of 85% or better on the measure. Ms. Hayden developed a similar instrument to assess PROMPT fidelity. Each of these treatment developers viewed and coded tapes of the therapists regularly, visited the site at least quarterly, and provided telephone supervision at least monthly. Treatment fidelity of each therapist was assessed and fidelity achieved at 85% or better on three consecutive pilot sessions before the experimental treatment began, and maintained at that level as determined by ratings of 25% of each therapist's sessions, for both treatments.

Results

Single-subject Design

Efficacy of treatment to promote use of functional speech. Eight of the 10 children in the project demonstrated functional, spontaneous use of 5 novel words or more by the completion of treatment. Figures 1 and 2 present each subject's data, including the frequencies of speech use at baseline, during each therapy session, at generalization probes during the treatment phase, and at post-treatment generalization points. As seen in these figures, 8 of the 10 children used speech routinely during therapy sessions and during generalization probes both during and after treatment. However, child use of functional speech during the play/generalization sessions was usually markedly less frequent as compared to their performance in treatment. See Probes detailed in Figures A and B. This may be due to several factors, including: (a) length of treatment (12 sessions) is insufficient to promote generalization and maintenance; (b) treatment models need to be modified to target generalization and maintenance; (c) method of assessment in the probes included too many novel aspects (new person, new toys, new activities); (d) children were not spontaneous enough in their language to initiate use in an unstructured context.

Collateral gains in social and communicative functioning. Each child participated in Module I of the ADOS at pre-treatment and post-treatment. Collateral gains in social and communicative behaviors were observed for some of the children in each intervention model and are displayed in Table 3. Significant gain was defined as follows: (1) child obtained a score of 2 or 3 on the ADOS at pre-treatment, and (2) child obtained a score of 0 at post-treatment. Gains in integration of verbal and nonverbal communication were observed in both models. More

children in the Denver Model group demonstrated particular gains in imitation and more children in the Prompt group demonstrated gains in functional play.

Generalization to home: Parent report of words used. Table 4 presents the pre- and post-treatment data of parent report of words used by the child during the past week, collected via the MacArthur CDI. Nine of 10 children were reported to use more words after treatment. One child (David) was reported to use fewer words at the end of treatment. This child was described by his mother as experiencing a regression in several aspects of behavior during the 4-month period in which he was participating in the intervention. His reported regression included fewer attempts to communication, increased aloofness, poor sleeping and eating, decrease in independence in toileting, and increased irritability. The family was referred to a pediatric neurologist who initiated assessment and treatment of a possible seizure disorder, with concerns about metabolic functioning as well. Assessment and treatment are on going and David's condition is reported to be improving slowly.

In the following section, a closer examination of three pairs of participants will be provided: (a) children evidencing the most gains in functional speech; (b) children who made no meaningful progress in functional speech; and (c) older children (age 5) who participated in the two models.

Children evidencing the most gains in functional speech. One child in each treatment group (Ethan and Jeffrey; note all names are fictitious) responded very well to the interventions. Post-treatment, both used spontaneous phrases regularly and used over 50 different words per session. Pre-treatment, both were two and had nonverbal developmental quotients above 60 (e.g., 62, and 94). Both demonstrated intentional nonverbal communication and functional and symbolic imitation, although joint attention behaviors were poor. Post-treatment, both demonstrated

increased communicative complexity (i.e., integrating eye gaze and gesture with vocalizations), as well as consistent joint attention (both responding and following). Neither had had much intervention, other than preschool group several hours per week. Their mothers had college degrees, as in the other participant families. Both children had multiple siblings and their mothers reported implementing the interventions less than one hour per day. Autism severity was mild to moderate for both pre-treatment, and mild for both post-treatment. Their age, cognitive abilities, imitation and intentional communication skills, and milder autism symptoms may have moderated their positive treatment response. These children may well have acquired functional speech without these treatments; however, the provision of these treatments may have catalyzed their language growth.

Children who did not develop functional speech. Two children (one in each model) did not develop functional speech (defined as using 5 or more functional words spontaneously on a daily basis) by the completion of treatment. Both presented with significant problems attending to an adult, tolerating demands, and participating in treatment routines. For Alex, who was only 20 months old and had never participated in any structured intervention before, the focus of the first 6 PROMPT sessions was on encouraging attention and engagement with adult-directed activities. In the beginning of treatment, Alex reacted with intense distress when new materials or activities were presented to him. Over time, these tantrums decreased in frequency, intensity, and duration. By the conclusion of treatment, at the age of 25 months, Alex was just beginning to engage actively in focused activities and had acquired two words in therapy, but made no meaningful gains in standardized test scores or parent report of use of speech. Alex appeared to need a longer course of treatment. In fact, 3 months after termination of treatment and continued weekly speech therapy in the community he is reportedly using 15 new, functional words.

Justin did not develop any speech during the treatment. Pre-treatment, Justin was 38 months old, had an overall developmental quotient of 34, language abilities clustering around 10 months, and severe autism symptoms. He demonstrated poor social responsiveness, limited requesting behavior, no initiation or response to joint attention, deficient imitation ability, and poor functional play. Justin's activity level varied substantially from session to session, as he was sometimes extremely lethargic and other times quite active and restless. The clinicians also observed some possible signs of seizures and referred the family to a pediatric neurologist for further evaluation. As with Alex, it was the clinician's impression that 12 sessions of treatment was not sufficient to promote functional improvements for Justin. No follow-up data are available for him.

Treatment of older children. At pre-treatment assessment, Dylan (PROMPT) and Freddie (Denver Model) were approximately 5 years old (65 and 57 months, respectively) and had been actively engaged in intervention for well over two years. Dylan had participated in thousands of hours in a naturalistic intervention approach, where he reportedly made significant gains in social and emotional responsivity, but no gains in functional speech. He also had received weekly speech therapy, occupational therapy and full-time preschool for the past two years. At intake, he vocalized rarely and was being taught to use an augmentative device that he did not use spontaneously. Pre-treatment, Dylan presented with many strengths: integration of eye gaze with gesture, initiation and response to joint attention, functional and symbolic imitation, and shared enjoyment. With the examiner and therapists, his social overtures were unusual and his responsiveness was inconsistent but was improved with his mother, to whom he directed many of his facial expressions and vocalizations. Dylan's functional play was very limited and he exhibited frequent running, pacing, jumping, and hand-flapping. His receptive language age was

approximately 32 months; expressive abilities were estimated at about 10 months. His scores on the visual-receptive domain (age equivalent of 48 months) and fine motor (age equivalent of 22 months) were quite disparate. On the Leiter International Performance Scale – Revised he obtained an age equivalent of 64 months and a nonverbal IQ estimate of 94.

Dylan made steady, gains in PROMPT therapy. During therapy, he consistently spoke more than 60 words per hour in 11 of 12 sessions. His mother reported an increase in vocabulary size to 145 words. Clinicians' impressions were that Dylan's gains were related to (a) his readiness for structured intervention; (b) the emphasis on building a solid oral motor foundation within the PROMPT approach; and (c) the active involvement of his mother in the daily provision of treatment exercises as well as the integration of the techniques into daily activities. It is important to note that Dylan demonstrated limited generalization of functional speech in the unstructured play probes. He made modest gains in his scores on standardized assessments over the period of 4 months (gain of 2 months in expressive abilities and 3 months in receptive abilities). Dylan continues to participate in community speech/language treatment and is reported to be gaining expressive skills.

The other 5-year old, Freddie, made moderate gains in functional speech used in therapy sessions and parent report of vocabulary size (CDI), and gained three months in expressive language ability over the 3-month treatment course. However, like Dylan, he used very few words in the generalization and maintenance probes. In the pre-treatment assessment sessions, Freddie presented as a child with mild symptoms of autism and demonstrated good social orienting, joint attention, and imitation abilities prior to treatment. These skills may have facilitated his ability to utilize the interventions. It was the impression of the clinicians that Freddie responded well to the relationship-based focus of the Denver Model. He continues to

participate in speech therapy through is school and is reported by his mother to be making continued gains.

Discussion

Lack of speech development is one of the most concerning symptoms that young children with autism present, given the association between early speech and better outcomes in autism. Only a few language treatment approaches have provided empirical support for their efficacy. The purpose of this project was to develop the methodologies and preliminary tests of two different models for developing speech in nonverbal preschoolers with autism. Both approaches had been previously described in the clinical literature, but neither had been directly tested on nonverbal children. The two models, PROMPT and Denver Model, shared some commonalities, including a developmental orientation to language development, but also had significant differences. PROMPT uses a naturalistic communicative framework based on joint activity routines with toys, and relies on therapists' use of manual facilitation of speech motor movements to assist the child to approximate speech sounds during communicative temptations in these routines. The language "module" of the Denver Model emphasizes a specific curriculum involving social- affective development, motor imitation, receptive language, development of nonverbal communicative behaviors, shaping speech from vocalizations, and object representations.

A single subject design was used in which each child served as his or her own control. The extended baseline period, and the children's histories of lack of speech development, provide a description of their lack of speech use before treatment. However, given that these were young children still in a developmental period in which language develops rapidly, a design that uses a no treatment control group would be needed to demonstrate that a similar group of

children would not make these kinds of gains in a few months without these particular treatments. For these reasons, and the small number of subjects, the results reported here should be considered preliminary and in need of replication and extension.

Of the ten children enrolled in this pilot study, eight developed vocabularies of at least multiple single words used routinely during therapy sessions and also demonstrated during generalization and follow up probes. Parents reported a larger vocabulary used at home during natural routines. Of these eight children who acquired some speech, four developed phrase speech, two of whom generated and used phrase speech spontaneously and in multiple situations. All ten children had been rigorously diagnosed with autism, both clinically and again by the research team prior to enrollment. All had markedly delayed development and used fewer than five word approximations per day before the treatment, according to maternal verbal report and verified in baseline measurements. Furthermore, the children received these treatments for one hour per week by a carefully trained speech and language pathologist and with daily review at home by the parent, for 12 treatment sessions. Parental response to both treatments was quite positive. Parents were pleased at the children's progress and followed through at some level at home, according to their own reports and to data that they kept.

It is important to recognize how limited the eight children's speech production was at the end of this treatment. They were still very language delayed and continued to meet all criteria for autism. They were however using speech intentionally, spontaneously, and meaningfully in therapy sessions and at home. Their beginning skills indicated a readiness to move further with continued language therapy, to which all were referred. What is responsible for the children's progress? For some children, the outcome is probably due to their young age and response to initiation of good treatment with daily home follow-through. These children may have developed

speech given any reasonable therapeutic approach. However, these effects were not due solely to the initiation of good treatment in previously untreated and very young children. Nine of the 10 had had previous treatment, and some children had had years of speech and language therapy prior to enrollment in this study. Furthermore, our baseline procedures demonstrated that whatever other treatments they were receiving were not affecting their use of speech prior to the onset of these experimental sessions.

Given that the children received only 12 hours of direct treatment, parent involvement likely played a significant role. Parents in the Denver Model were physically present in all sessions and participated while being coached by the therapist. Parents in both treatments observed every session, were coached in specifics to practice each week, were taught to keep data, and handed their data in to their therapists. Thus, the parents continued the treatment for many more hours each week. Positive results of parent-delivered treatment is a consistent finding in the autism literature (Howlin & Rutter, 1989; Harris, Wolchik & Weitz, 1981; Laski, Charlop& Schreibman, 1988; Charlop & Trasowech, 1991). Finally, both therapies involved interventions very carefully fitted to children's current level of understanding, and delivered in a fairly structured format that emphasized child intentional communication and child initiative. It may be that these similarities in the treatments resulted in the similar outcomes. Given the small number of subjects and the study design, direct comparison of the two treatments was not possible. It will require a much larger study, with a different design, to determine whether certain child characteristics moderate response to each of these treatments.

There are several weaknesses in this study that need to be considered and that may affect the validity and the generalizability of the findings. It was a very small study with a very short time span, and the subjects were generally middle class families. The children were somewhat

heterogeneous in that they ranged in age from 2-5 years, nonverbal MA's ranged from 18-36 months, and expressive language from 12-18 months. Compared to other studies, however, this is probably a fairly homogeneous group. We do not know if all families could make similar use of these treatments. There was a long training period to reach fidelity in both models, even for these very sophisticated university based and autism experienced speech and language therapists. Each treatment approach has significant requirements for assessment, treatment planning, and data collection. Many elements were involved in each treatment, including parental coaching, parent follow through at home, and several different aspects of each treatment; we do not know which of the many elements are crucial for the outcomes. The children had quite different characteristics, and we do not know what child characteristics led to success or failure in each approach. The maintenance and follow-up data are very limited. Parent implementation was monitored only via parent report. There was no no-treatment control group. Finally, some children were getting other treatments during this treatment study (see "Participants"), the majority of which included 1 hour per week of speech and occupational therapy delivered within a public school setting. For 7 of the 9 children engaged in other treatments, the average length of time involved in those interventions before enrolling in this project was 14 months. Therefore, for 78% of children receiving other treatments, other intervention experiences had not significantly impacted their language functioning in well over a year of participation. Two of the children initiated other treatments approximately 4 months before beginning the present project and it is very difficult to attribute outcomes to specific treatments in these cases. We cannot rule out the effect of other treatments on the children's progress. Thus, we cannot determine what of the treatments were responsible for the change in the children, and the two treatments need to be examined further in replication studies that examine whether these effects can be replicated. If

so, then the variables responsible for the change will need to be isolated. Next studies should carefully examine relationships between individual child characteristics and response to each specific treatment, as well as effectiveness if the interventions in more community-based delivery systems. The present study represents the first step of many involved in empirical examination of treatments and effects. .

Thus, this was a preliminary study using very small numbers of children and the results await replication. However, these results are similar to earlier published reports of both didactic and naturalistic behavioral treatment successes at teaching nonverbal children to speak (Koegel, O'Dell, & Koegel, 1987; Lovaas, Berberich, Perloff, & Schaeffer, 1966). If the present findings are replicated in larger, more rigorous studies, the implications are several. For one, both approaches focused on development of speech, not use of alternative communicative systems. It will be important to examine the use of alternative systems (signs, pictures, etc) and child characteristics to determine for which children AAC systems accelerate, decelerate, or do not affect the rate of speech acquisition. A second implication involves expectations of speech development in early autism. Current studies of young children with autism suggest that approximately 75% will develop speech during the preschool years (Lord, Risi, & Pickles, 2004) given typical community intervention approaches. This leaves 25% without useful speech. If a larger study can replicate the finding here that a number of these children can learn to speak during their preschool years given carefully delivered treatment, the bar is raised considerably in terms of what the field should expect from language interventions in early autism. If presence of useful speech by 5 continues to be a moderator of better outcomes, this kind of attention to speech development may improve outcomes across the board for children with autism.

In conclusion, speech is a crucial tool for learning, self-advocacy, social relationships, and participation in community. Effective treatment of autism (and any other disorder that limits speech use) requires that we identify or develop effective treatments for teaching speech to preverbal children who are at risk for not developing speech. In addition, it requires that speech and language therapists and others know about effective approaches, can learn to deliver effective approaches at appropriate levels of fidelity, and can be funded by public agencies to deliver such care. However, empirically testing treatments is a necessary first step, and this pilot project contributes towards that goal.

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Table 1

Participant Characteristics

Child	**Chronological Age (mos.)**	**MSEL Overall mental age (mos.)**	MSEL Overall developmental quotient (DQ) (ma/ca*100)	MSEL Nonverbal mental age (mos.)	MSEL Expressive language age (mos.)	MSEL Receptive language age (mos.)	ADOS Severity of Autism
DENVER MODEL							
Ethan	**29**	**18**	62	21	14	14	Moderate
Justin	**38**	**13**	34	18	10	10	Severe
Freddie	57	29	48	36	13	28	Mild
Max	39	18	46	24	12	15	Moderate
Ryan	40	19	48	25	13	13	Moderate
PROMPT MODEL							
Jeffrey	24	23	94	24	18	23	Mild
Michael	28	13	53	16	9	10	Severe
Alex	20	13	63	16	6	8	Moderate
Dylan	65	27	41	31	16	31	Mild
David	44	17	38	22	9	14	Moderate

Table 2

Family and environmental characteristics

Child	Maternal education	# hours in preschool programs[1]	# hours in speech therapy[1]	Total # hours of intervention experience[1]
DENVER MODEL				
Ethan	College	4 hrs/wk for 6 mon	30 min./wk for 3 mon	@ 110 hours
Justin	HS	10 hrs/wk for 8 mon	30 min/wk for 8 mon	@350 hours
Freddie	Master's	12 hrs/wk for 3 years	1 hr/wk for 3 years	@ 2000 hours
Max	College	12 hrs/wk for 1 year	30 min/wk for 1 year	@600 hours
Ryan	College	12 hrs/wk for 8 mon	1 hr/wk for 6 months	@410 hours
PROMPT MODEL				
Jeffrey	College	12 hrs/wk for 8 mon	None	@380 hours
Michael	HS	30 hrs/wk for 9 mon	3 hours/wk for 9 mon	@1200 hours
Alex	College	6 hrs/wk for 4 months	30 min/wk for 8 mon	@78 hours
Dylan	College	30 hrs/wk for 2 years	2 hours/wk for 2 years	@3400 hours
David	Master's	30 hrs/wk for 2 years	3 hours/wk for 1 year	@3200 hours

[1] Prior to and during inclusion in research study

Table 3

Collateral gains in early social-communicative behaviors [2]

DENVER MODEL	Ethan	Justin	Freddie	Max	Ryan
Pointing	+		+		+
Gestures				+	
Integration of gaze and other behaviors during social overtures		+	+		+
Requesting			+		
Giving					
Showing	+				
Initiation of joint attention	+				
Response to joint attention	+	+		+	
Imitation	+	+		+	+
Functional play	+				

[2] Plus sign ("+") denotes a change in ADOS rating from a 2 or a 3 at pre-treatment (impairment) to a 0 at post-treatment (not impaired); imitation is shown as an improvement if child did not have functional imitation at pre-treatment and demonstrated it at post-treatment within the ADOS imitation item

PROMPT MODEL	Jeffrey	Michael	Alex	Dylan	David
Pointing			+		
Gestures	+			+	+
Integration of gaze and other behaviors during social overtures		+	+	+	+
Requesting	+				
Giving	+	+	+		+
Showing	+				
Initiation of joint attention	+			+	
Response to joint attention		+			
Imitation				+	
Functional play	+		+	+	

Table 4

Parent report of speech and communication behaviors at home using the McArthur CDI pre- and post-treatment[3]

DENVER MODEL	# of words child understands and says before Treatment	# of words child understands and says after Treatment
Ethan	20	193
Justin	*0*	*4*
Freddie	3	19
Max	10	24
Ryan	*4*	*12*
PROMPT MODEL		
Jeffrey	20	190
Michael	0	3
Alex	0	2
Dylan	18[4]	145
David	40/	8

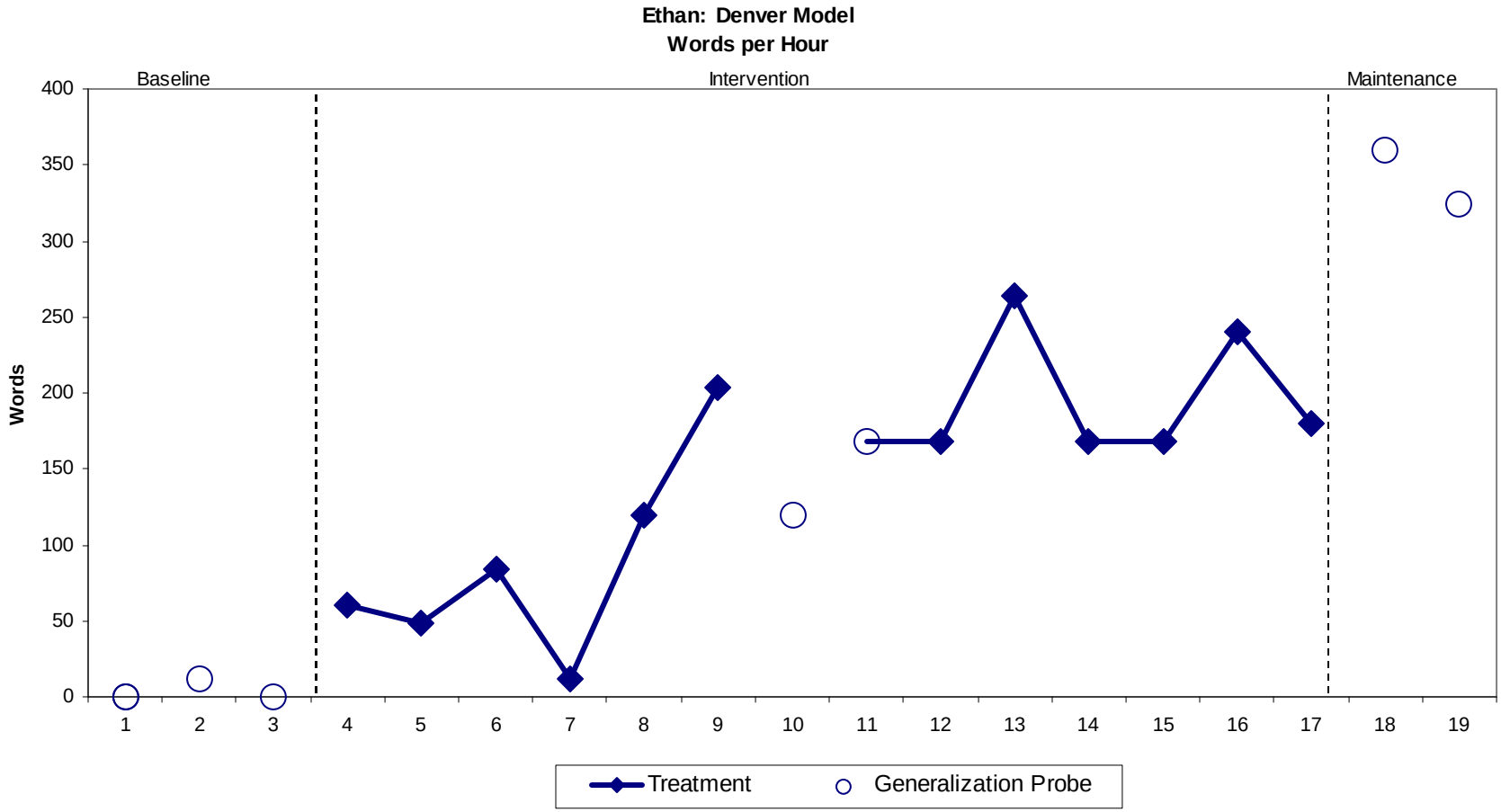
[3] Higher scores are indicative of better skills
[4] Parent noted that only she can understand his speech reliably

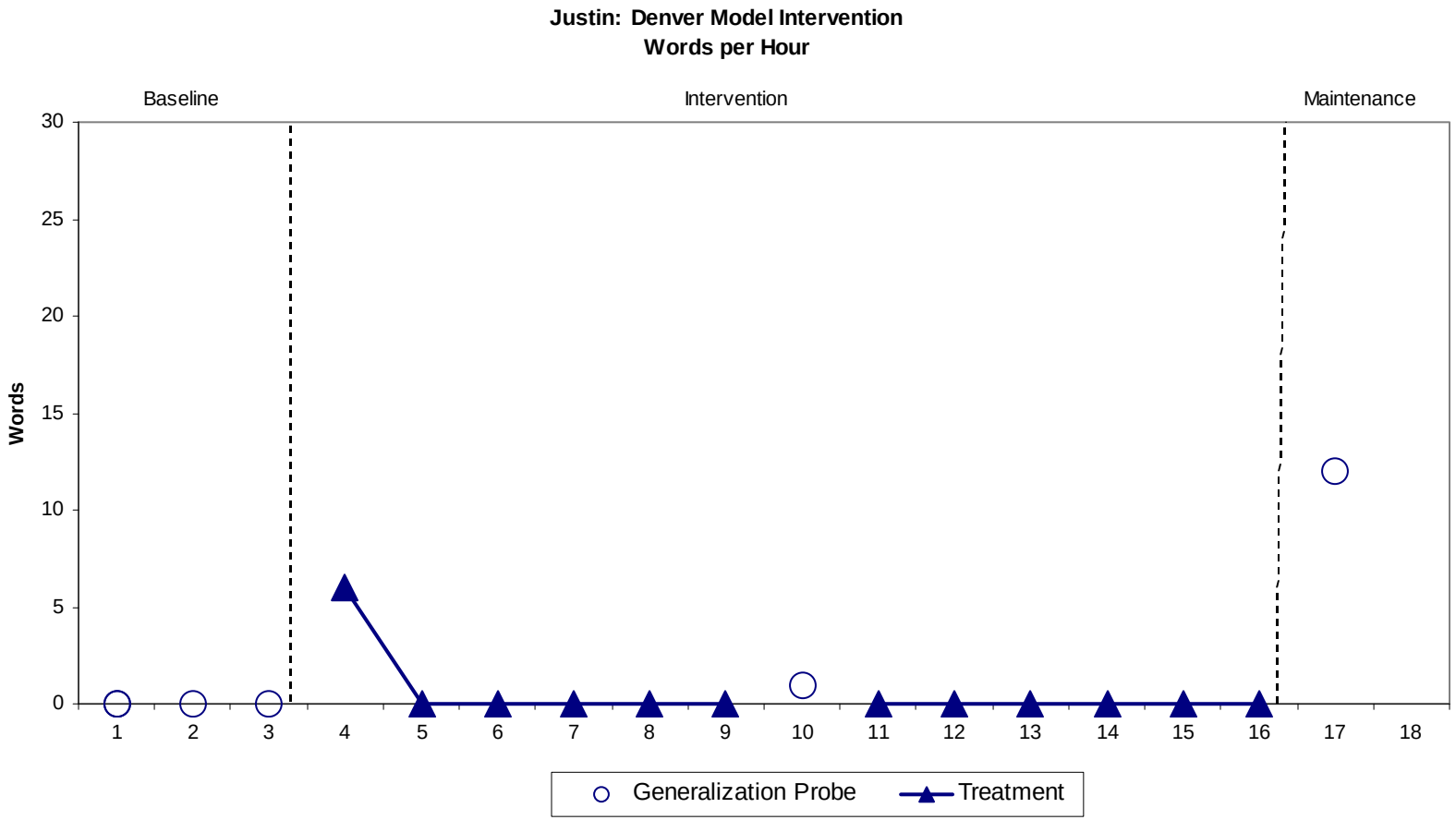
Table 5

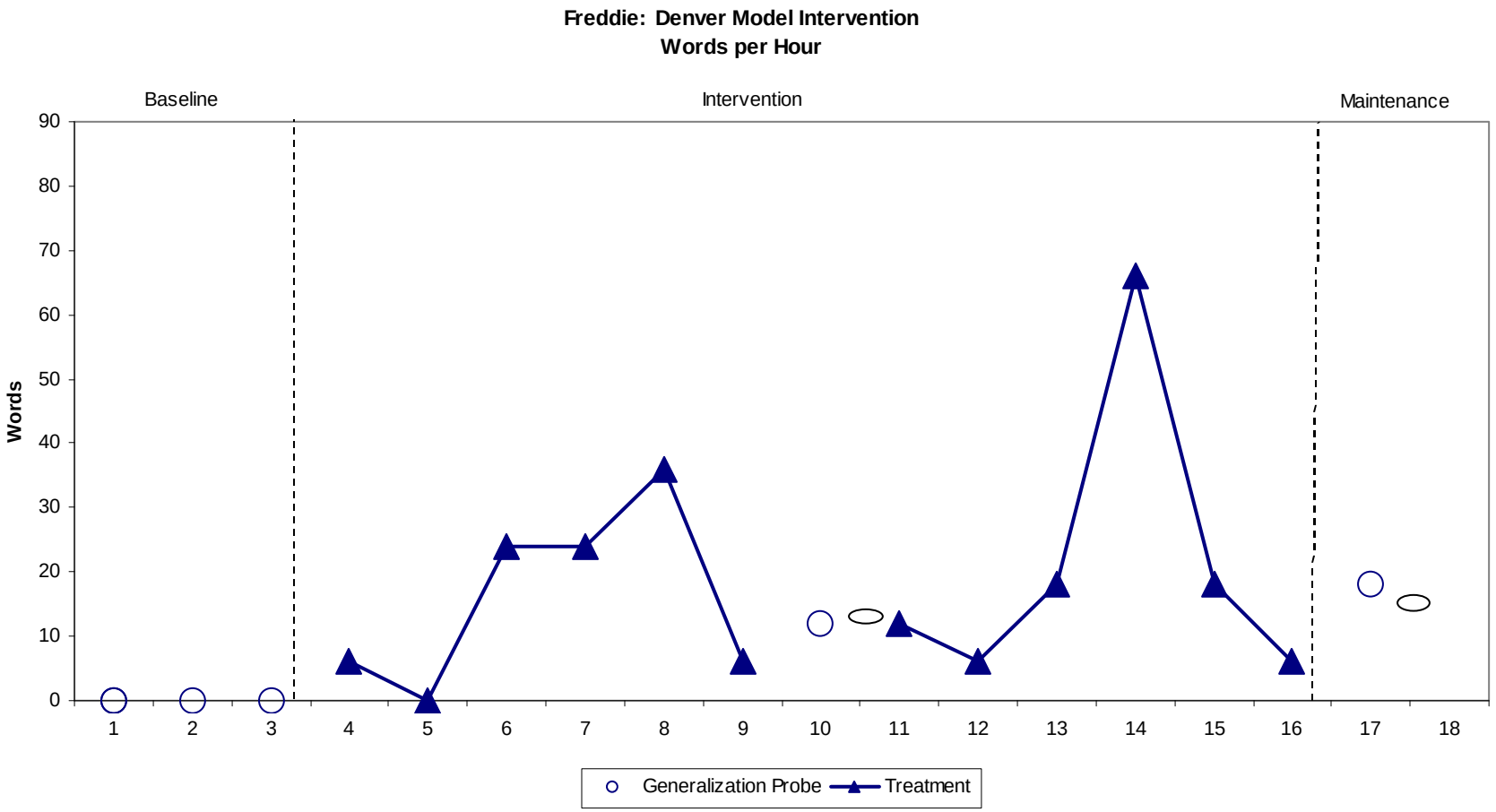
Pre-and post-treatment results of standardized measures of speech and language.

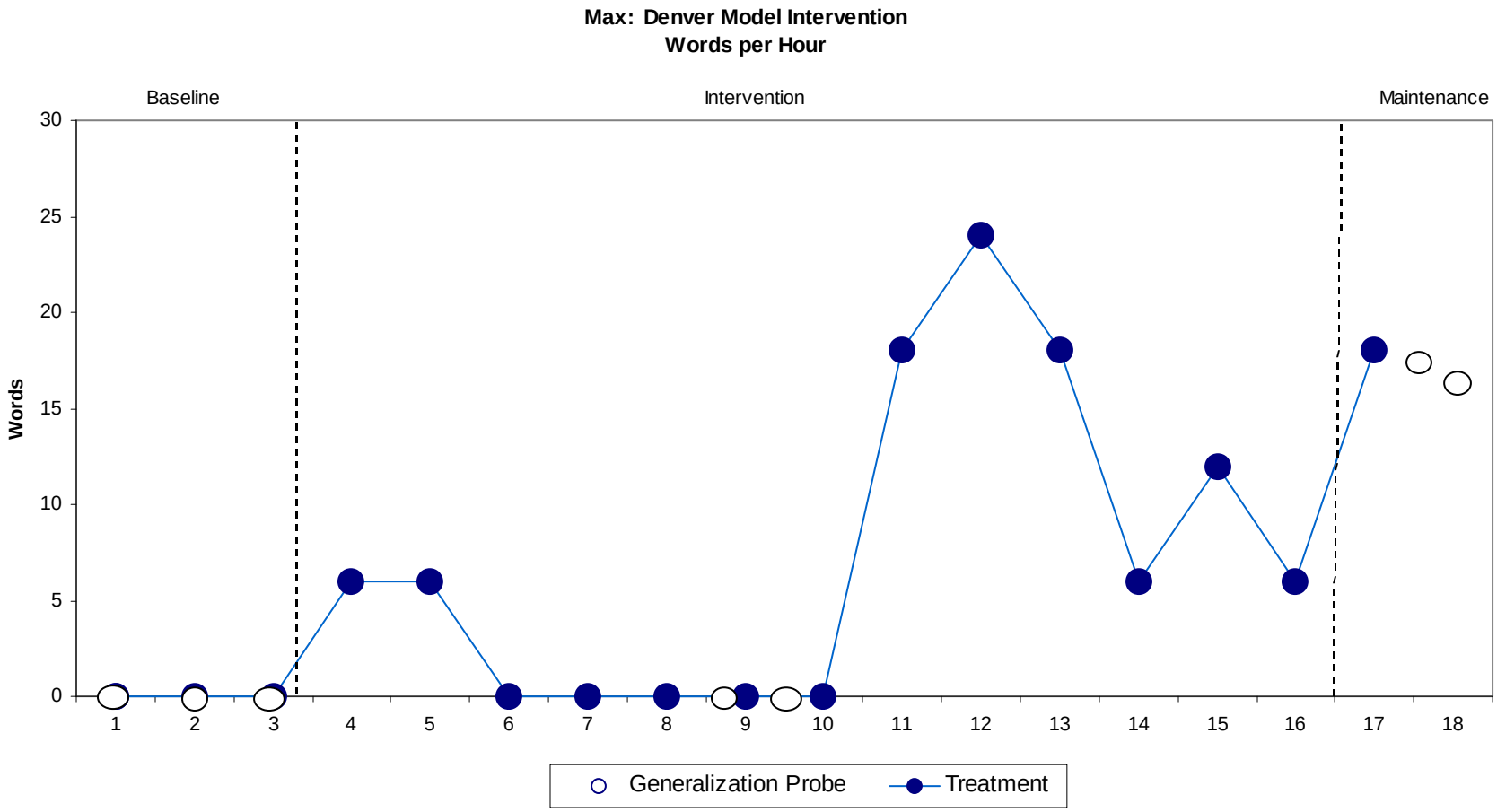
Child	Pre-tx MSEL Expressive Raw Score (age equiv.)	Post-tx MSEL Expressive Raw Score (age equiv.)	Gain in raw score points	Pre-tx MSEL Receptive Raw Score (age equiv.)	Post-tx MSEL Receptive Raw Score (age equiv.)	Gain in raw score points
Denver Model						
Ethan	15 (14 mos.)	25 (25 mos.)	10	15 (14 mos.)	23 (23 mos.)	9
Justin	11 (10 mos.)	11 (9 mos.)	0	10 (10 mos.)	12 (11 mos.)	2
Freddie	13 (13 mos.)	16 (16 mos.)	3	27 (28 mos.)	28 (30 mos.)	1
Max	12 (12 mos.)	15 (15 mos.)	3	16 (15 mos.)	16 (15 mos.)	1
Ryan	13 (13 mos.)	14 (14 mos.)	1	14 (13 mos.)	14 (13 mos.)	0
Prompt Model						
Jeffrey	18 (18 mos.)	31 (35 mos.)	13	23 (23 mos.)	29 (31 mos.)	6
Michael	10 (9 mos.)	11 (10 mos.)	1	10 (10 mos.)	12 (11 mos.)	2
Alex	7 (8 mos.)	9 (8 mos.)	2	8 (10 mos.)	13 (11 mos.)	5
Dylan	16 (16 mos.)	18 (18 mos.)	2	29 (31 mos.)	32 (36 mos.)	3
David	14 (14 mos.)	16 (16 mos.)	2	11 (9 mos.)	14 (13 mos.)	3

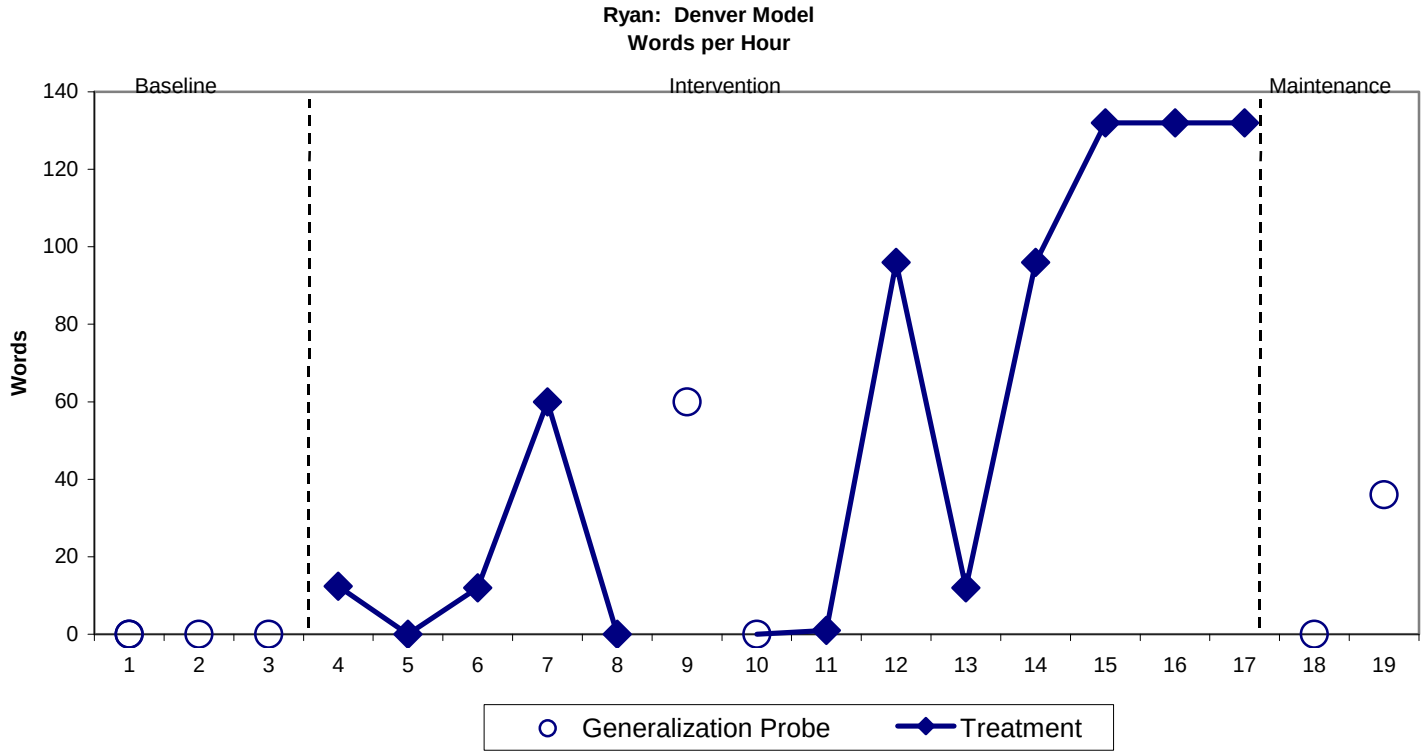
Figure 1. Graphs of each individual subject's total number of spoken words used, averaged per hour, across at baseline, therapy sessions, and follow-up, calculated from 10 minute samples.

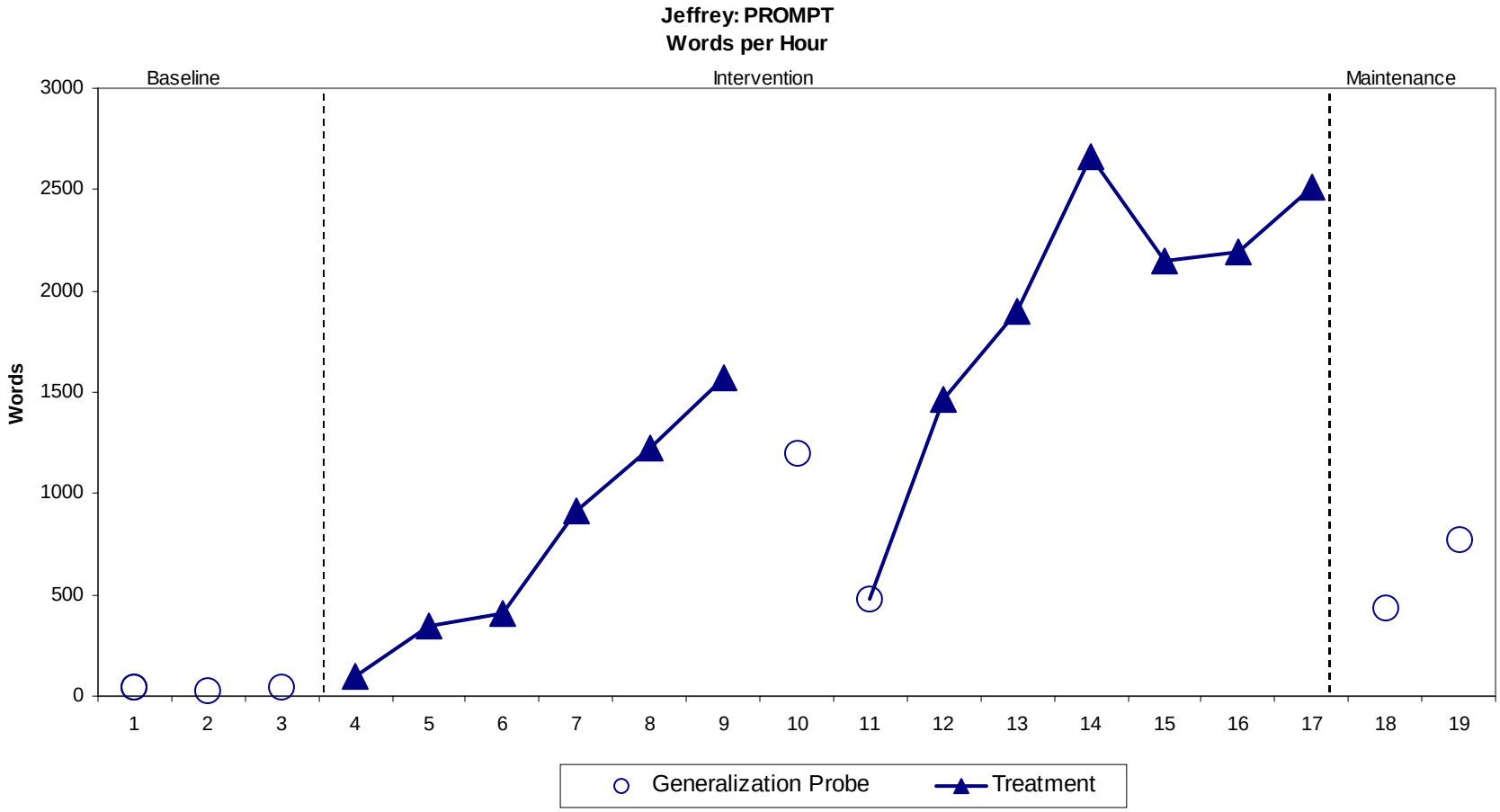


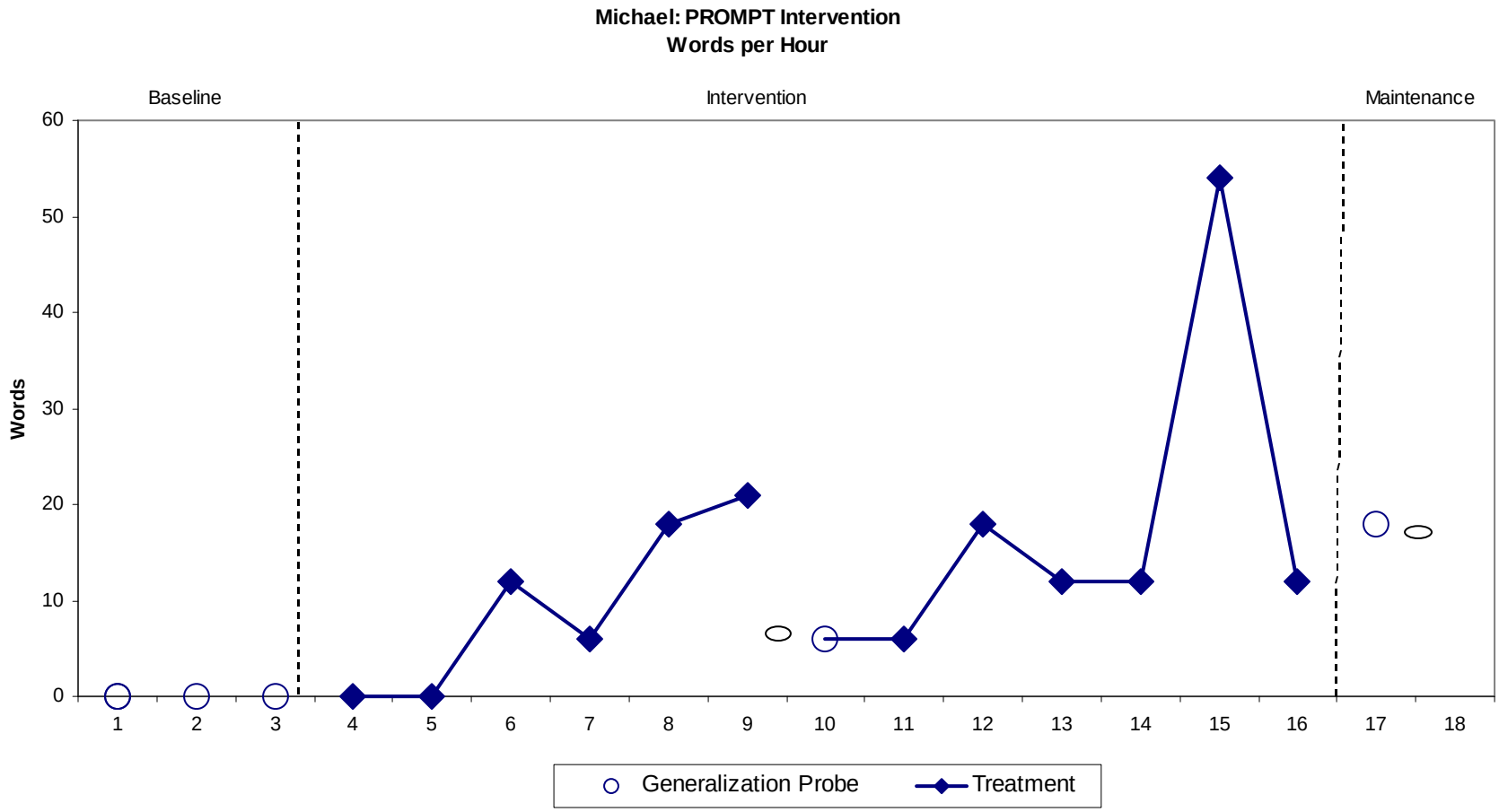

Justin: Denver Model Intervention
Words per Hour
Baseline
Intervention
Maintenance
Words
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Generalization Probe
Treatment

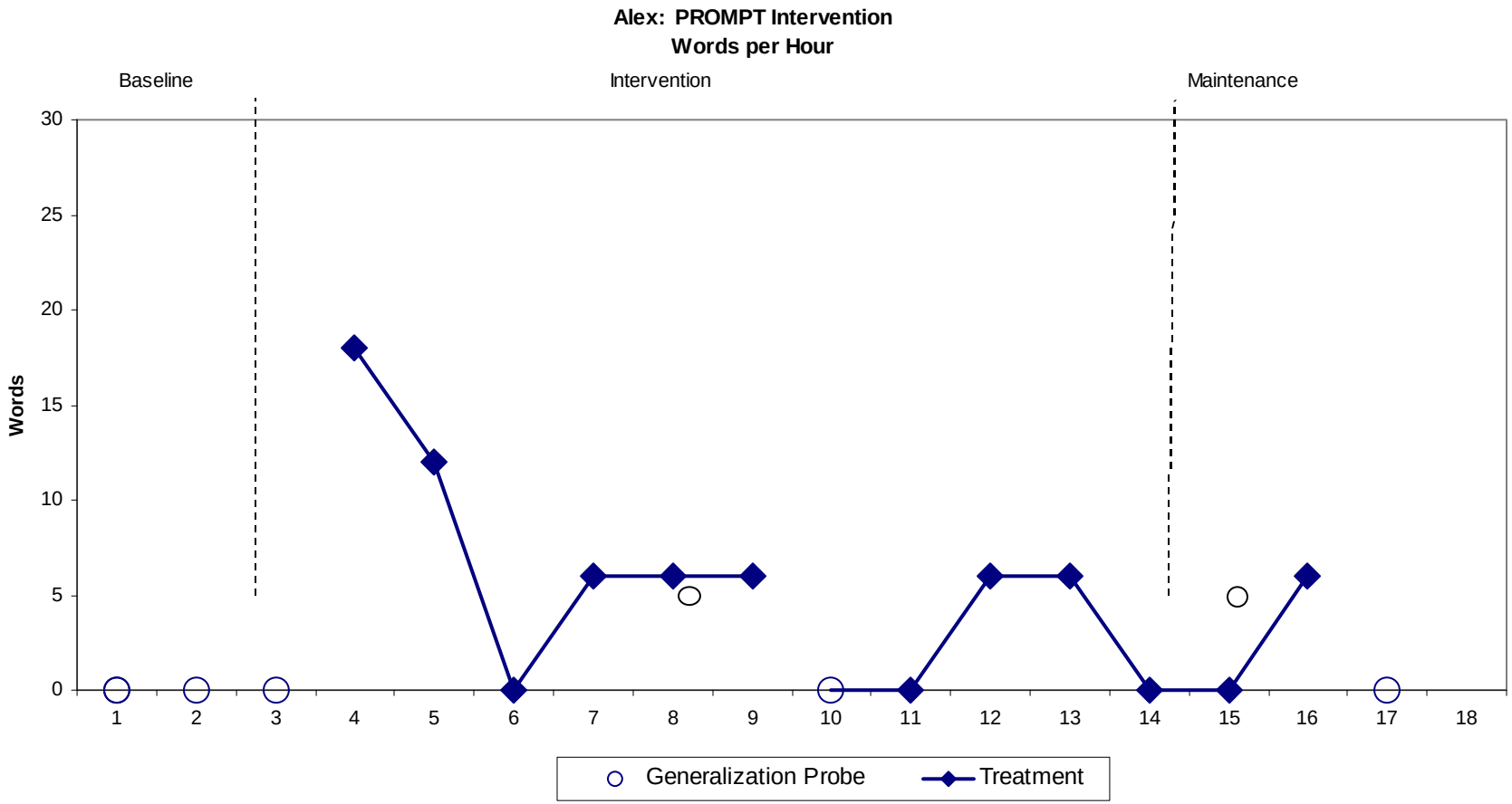

Freddie: Denver Model Intervention
Words per Hour
Baseline
Intervention
Maintenance
Words
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Generalization Probe
Treatment

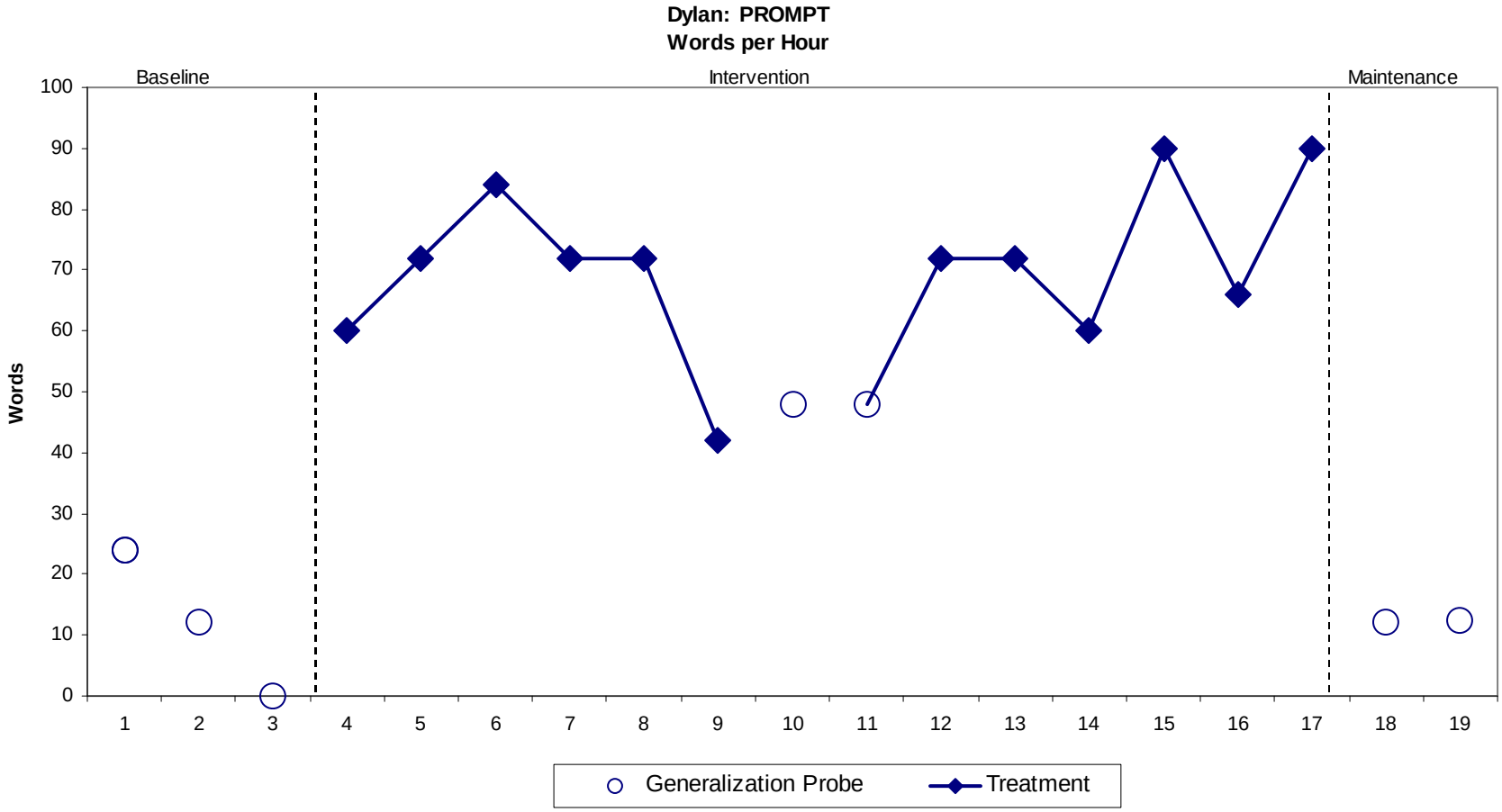

Max: Denver Model Intervention
Words per Hour
Baseline
Intervention
Maintenance
Words
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Generalization Probe
Treatment

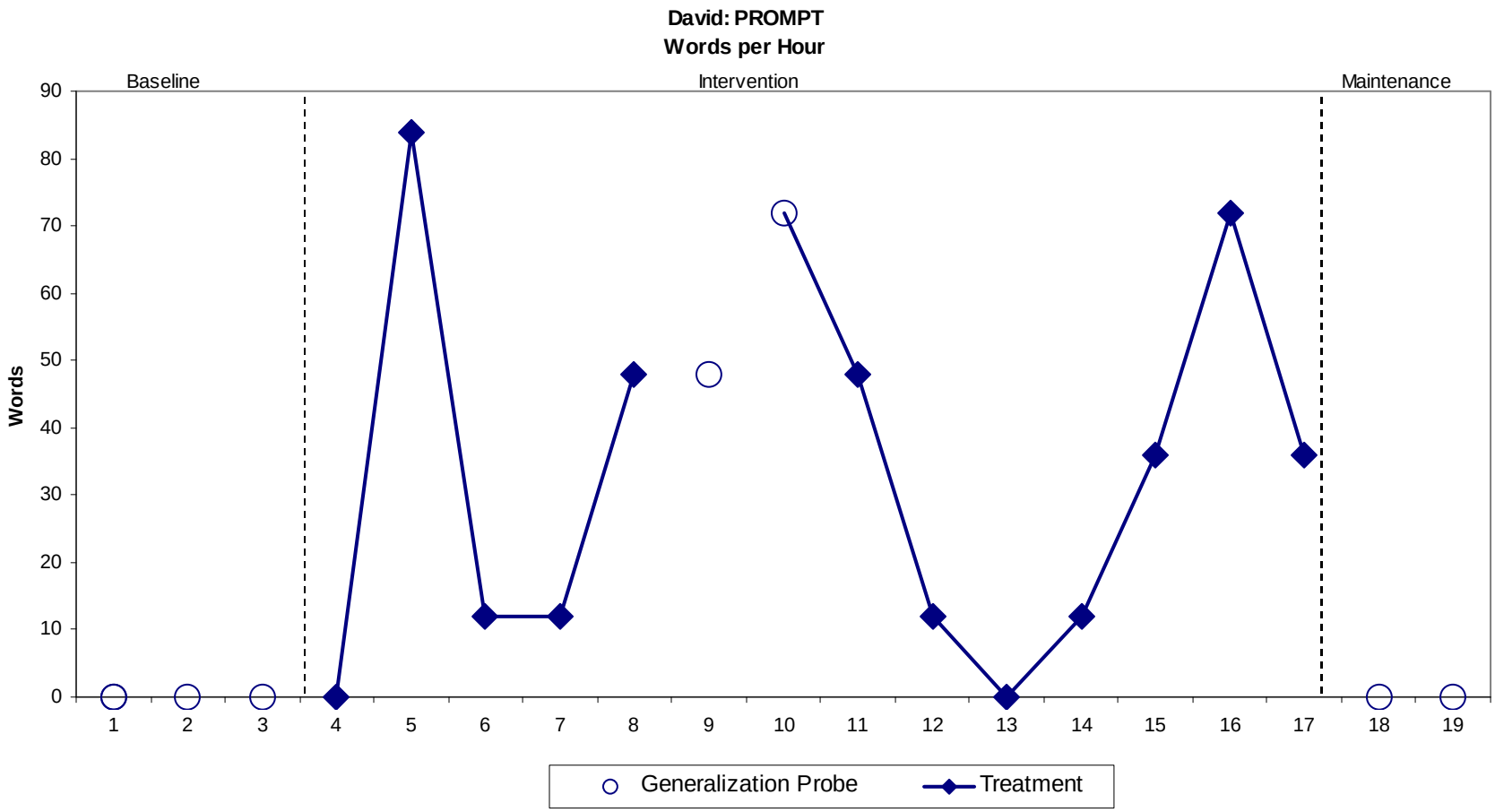

Ryan: Denver Model
Words per Hour
Baseline
Intervention
Maintenance
Words
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Generalization Probe
Treatment


Jeffrey: PROMPT
Words per Hour
Baseline
Intervention
Maintenance
Words
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Generalization Probe
Treatment


Michael: PROMPT Intervention
Words per Hour
Baseline
Intervention
Maintenance
Words
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Generalization Probe
Treatment


Alex: PROMPT Intervention
Words per Hour
Baseline
Intervention
Maintenance
Words
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Generalization Probe
Treatment


Dylan: PROMPT
Words per Hour
Baseline
Intervention
Maintenance
Words
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Generalization Probe
Treatment


David: PROMPT
Words per Hour
Baseline
Intervention
Maintenance
Words
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Generalization Probe
Treatment