RESEARCH ARTICLE

Interaction of Treatment Intensity and Autism Severity on Frequency and Maturity of Spontaneous Communication in Toddlers with Autism Spectrum Disorder

Paul Yoder, Sally Rogers, Annette Estes, Zachary Warren, Jeff Munson, Gerhard Hellemann, and John McEachin

This study tested whether the effect of treatment intensity or treatment style on children's frequency and maturity of spontaneous communication varied by initial severity of disability. Eighty-seven toddlers with autism spectrum disorders were randomly assigned to either (a) 15 hrs per week of discrete trial teaching (DTT), (b) 25 hrs per week of DTT, (c) 15 hrs per week of a naturalistic developmental behavioral intervention (NDBI), or (d) 25 hrs per week of NDBI. Trained research staff implemented the 1:1 treatments in homes or educational centers over 12 months. We quantified the frequency and maturity of spontaneous communication during monthly 6-min communication samples. We quantified disability severity at Time 1 using the developmental quotient from the Mullen Scales of Early Learning and the total calibrated severity score from the Autism Diagnostic Observation Schedule-second edition. Higher levels of treatment intensity (i.e., more hours per week) benefited frequency and maturity of spontaneous communication growth rate only in children with relatively mild autism symptoms. Other results were nonsignificant. ***Autism Res*** *2020, 00: 1–11.*

Lay Summary: Eighty-seven toddlers with autism spectrum disorders were randomly assigned to 15 hrs per week of discrete trial teaching (DTT), 25 hrs per week of DTT, 15 hrs per week of a naturalistic developmental behavioral intervention (NDBI), or 25 hrs per week of NDBI. Trained research staff implemented the treatments in homes or educational centers over 12 months. More hours of treatment per week benefited frequency and maturity of spontaneous communication growth rate only in children with relatively mild autism symptoms. Other results were nonsignificant.

Keywords: autism spectrum disorders; treatment style; treatment intensity; severity of autism; developmental delay

Introduction

Treatment style (i.e., the manner in which teaching episodes are delivered) and treatment intensity (e.g., the number of treatment hours per week) are two ways early interventions for children with autism spectrum disorder (ASD) vary. Intensive comprehensive treatments are those that address many areas of development and occur for many hours per week (e.g., 20) and for many months per year (e.g., 12). Parents and policy makers have long sought empirical guidance on which treatment styles and treatment intensities might be most efficacious for children with ASD.

Rigorously testing the relative efficacy of different treatment styles requires directly comparing varying styles in the same study sample while keeping treatment intensity constant. In children with ASD, intensive implementation of different treatment styles has rarely been compared using internally valid research designs [Eisenberg, 2011]. In this paper, the phrase "treatment style" refers to a particular treatment and the phrase "treatment approach" refers to a class of treatments. Two treatment approaches that are common in the United States are discrete trial teaching (DTT) and naturalistic developmental behavioral intervention (NDBI). These approaches generally differ in the extent to which teaching episodes in the early treatment sessions are initiated by the child vs. the adult and the degree to which materials and activities are selected by the child.

In the current study, we compared the effects of Early Start Denver Model (ESDM), as an example of the NDBI class of interventions, and Early Intensive Behavioral Intervention (EIBI), as an example of the DTT class of interventions. ESDM practice is defined by a treatment manual, curriculum, and fidelity measurement tool [Rogers & Dawson, 2010]. ESDM was selected because past work indicated that it had significant and moderate effect

From the Vanderbilt University, Special Education, Nashville, Tennessee, USA (P.Y., Z.W.); University of California, Davis MIND Institute, Berkeley, California, USA (S.R.); University of Washington, UW Autism Center, Seattle, Washington, USA (A.E., J.M.); Department of Biostatistics, University California, Los Angeles, Los Angeles, California, USA (G.H.); Huntington Beach, California, USA (J.M.)
Received December 30, 2019; accepted for publication October 5, 2020
Address for correspondence and reprints: *Paul Yoder, Vanderbilt University, 1804 Linden Ave, Nashville, TN 37235. E-mail: paul.yoder@vanderbilt.edu
Published online 00 Month 2020 in Wiley Online Library (wileyonlinelibrary.com)
DOI: 10.1002/aur.2416

sizes on subscales in a distal measure of development when compared to a community treatment [Dawson et al., 2010]. However, a later study found that ESDM's effect on distal measures varied by site [Rogers et al., 2019], and no effects were seen on several of these distal measures. EIBI is guided by *A Work in Progress* [Leaf & McEachin, 1999]. EIBI was selected because it has been considered an efficacious intervention [Smith, Groen, & Wynn, 2000], is very widely used, has a comprehensive manual, and was written by two of Lovaas' graduate students who are actively treating children with ASD. Additionally, EIBI is arguably a contemporary application of applied behavior analysis principles (e.g., it changes treatment techniques to become more child-oriented and naturalistic after children gained a threshold level of skill). Both styles have detailed teaching methods and curricula.

Similarly, rigorously testing the relative efficacy of different treatment intensity levels requires directly comparing varying treatment intensities in the same study sample while keeping treatment style constant [Yoder & Woynaroski, 2015]. The autism research community has recommended that children with ASD receive 25 hrs of active engagement per week for 12 months a year [National Research Council, 2001] across all their treatments. This recommendation was based on professional consensus, which was in turn informed by a review. However, no extant study has conducted a rigorous test of the same comprehensive treatment style at different intensity levels in children with ASD.

We chose to compare 25 hrs per week vs. 15 hrs of treatment per week. Twenty-five hours per week was selected because it is the recommended level of treatment by a professional consensus group [National Research Council, 2001]. We selected 15 hrs per week as the comparison intensity level because it was the actual average hours per week that was delivered and had positive effects in the Dawson et al.'s [2010] study.

When treatment styles or intensity levels have been compared in other populations or within targeted treatments (i.e., short-term, limited hours of treatment per week) in children with ASD, effects have sometimes varied by pretreatment characteristics of the children [Fey, Warren, Yoder, & Bredin-Oja, 2013; Yoder & Stone, 2006]. However, past findings in other populations or other contrasts may or may not generalize to children with ASD or to the treatment contrasts in the current study.

We predicted that differences in child progress related to treatment style or intensity differences would vary by participants' severity of overall developmental delay or autism symptoms prior to treatment. Examining the statistical interaction between moderator and treatment (e.g., style or intensity) group is the first step toward identifying the characteristics of children who benefit most from one treatment vs. another. Once detected, the statistical interaction needs to be probed to identify the disability severity subgroup in which significant style or intensity effects occur. We did not have an *a priori* prediction related to which subgroup of children would benefit more from 15 vs. 25 hrs per week of treatment or EIBI vs. ESDM because the existing research base was not adequate to form a strong directional hypothesis. However, we did not predict that any subgroup of children would benefit more from 15 hrs per week of treatment.

Although severity of disability did not moderate the effects of ESDM on distal outcomes in a study completed after the onset of the current study [Rogers et al., 2019], this current report focuses on generalized spontaneous communication measured frequently, as is done in progress monitoring procedures. Unfortunately, many investigators have used progress monitoring probes that are conducted within treatment sessions and thus may represent only change in communication that is restricted to the high level of supports that are present in therapy sessions. Measuring spontaneous communication in communication samples that differ on multiple dimensions from the treatment sessions is a far more informative and ecologically valid approach than are treatment session probes. Frequent probes of directly measured behavior are expensive to gather and thus need to be brief. Using a standard toy set and a semi-structured interaction style reduces measurement error [Yoder, Lloyd, & Symons, 2018].

Extant literature has not yet demonstrated that using frequent, brief, semi-structured communication samples that differ from treatment sessions on multiple dimensions produces a measure of communication that is sensitive to change related to treatment effects in children with ASD. If such a finding was obtained, it would be particularly important because a recent meta-analysis showed that treatment effects on highly generalized measures of skill acquisition have rarely been demonstrated in children with ASD [Sandbank et al., 2020]. Additionally, proximal measures, such as the one investigated in the current paper, have been found to be more likely to show treatment effects than distal measures in children with ASD [Sandbank et al., 2020].

This study examined whether treatment style or treatment intensity effects on the frequency and maturity of spontaneous communication vary by disability severity prior to treatment. A secondary goal was to examine whether brief monthly communication samples would be sensitive to change and demonstrate moderated treatment effects in children with ASD.

Methods

Design

We conducted an intent-to-treat, single-blind RCT at three geographic sites. The current study's focus is on a secondary dependent variable from a study that was reported in Rogers et al. (2020). Children were recruited, screened, qualified, consented, stratified by developmental quotient (DQ) and age, and randomized to one of four cells: 15 or 25 hrs of the ESDM, and 15 or 25 hrs of the EIBI. Because an independent, data-coordinating center conducted random assignment of participants to one of the four groups using a computer program and because the evaluation team and the treatment team at each site worked independently, allocation concealment was successful. The project was approved by the appropriate Institutional Research Boards and design and data were routinely reviewed by an independent Data Safety and Monitoring Board. The primary study was registered in ClinicalTrials.gov under identifier NCT02272192.

Participants

We enrolled 87 toddlers with DSM-5 ASD recruited from three sites with 28, 30, and 29 participants each. The inclusion criteria were as follows: 15–30 months old; ambulatory without primary motor impairments affecting hand use; ASD using DSM-5 criteria, consensus of two independent staff (one of whom is a licensed psychologist), and autism spectrum cutoff on the *Autism Diagnostic Observation Schedule*-second edition (ADOS-2) [Lord, Luyster, Gotham, & Guthrie, 2012]; overall developmental quotient of 35 or higher on *Mullen Scales of Early Learning* [Mullen, 1995]; parental agreement to participate in parent coaching once per month at home, to have therapy assistants in the home upto 25 hrs per week, to attend a clinic meeting once each month and to videotape regularly at home with project provided equipment; English as a primary language spoken to the child (60% or more at home as reported by parents); and hearing and vision screening within the normal range. We included children with other health or genetic conditions (i.e., fragile X syndrome, seizures, and prematurity) as long as they met inclusion criteria stated above. There were no enrollment restrictions on services being received outside those provided by the research team. Fifty-four percent of the children were White and 80% were nonHispanic. The average income was $89,386 per year (SD = $34049). The average maternal formal education was 16.2 years (SD = 2.7 years). All participants signed consent letters approved by the institutional review boards of the three institutions involved in the trial. Other participant description is summarized in Table 1. Attrition information in CONSORT format is presented in Figure 1.

Treatment

Each child in the study was scheduled to receive either 15 or 25 hrs a week of the assigned treatment style in their homes or care settings, delivered individually by trained research staff, for 12 months. Depending on the assigned treatment intensity, sessions were either 1.5 or 2.5 hrs blocks that occurred two times/day, 10 or 15 blocks per week, fitted carefully around each child's sleep schedule and family scheduling needs.

Therapy assistants (TAs) had Bachelor's or Master's degrees. Most had previous experience in DTT with young children with autism. With few exceptions, TAs worked in only one approach. All TAs were trained full time in their assigned treatment style until they achieved rigorous standards of clinical competency in using the assigned teaching method. During the study, TAs were supervised live, by video recordings, discussion, or via live-streaming every 2 weeks. Supervisors were extensively trained in their respective teaching style and had either Ph.D., BCBA or MS degrees. Supervisors were educated in clinical psychology, developmental psychology, early childhood education, behavioral analysis, or speech-language pathology disciplines.

Intervention intensity. A child was scheduled for either 15 or 25 hrs of treatment each week. All delivered hours were recorded and reported weekly. Mean attendance to treatment sessions were 12.42 hrs per week (SD = 1.45) and 20.82 hrs per week (SD = 1.40) for low and high intensity groups, respectively. Both groups received an average of 83% of the treatment hours scheduled with 10% and 6% as the SDs for low and high intensity groups, respectively. As designed, there were large differences in the treatment hours per week that children received depending on the intensity group to which they were assigned (Cohen's between-group $d = 5.9$).

Individual intervention plans (IIPs). IIPs were constructed for each child using a broadly similar process, regardless of style. For the ESDM group, treatment objectives were written for each set of skills to be taught in the quarter informed by the pattern of passes, failures, and ceiling on the ESDM Curriculum Checklist in Rogers and Dawson [2010]. For the EIBI group, treatment goals for each quarter were based on skills identified as not mastered from the curriculum assessment published in Leaf and McEachin [1999].

EIBI. The Leaf and McEachin's [1999] *A Work in Progress* manual guided the EIBI sessions. McEachin was a consultant on the project and oversaw the training and delivery of EIBI teaching via live consults on a quarterly basis and video conferencing on a monthly basis. In general, EIBI involved alternating periods of instruction and play breaks. The instruction periods were of sufficient duration (typically 3 to 5 min) to provide multiple opportunities to practice a specific target skill, but in the early stages of teaching could be as brief as 1 min. There was typically

Table 1. **Participant Description by Treatment Style and Intensity Groups**

	Style						Intensity					
	EIBI			ESDM			15 h/wk			25 h/wk		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Age in months	45	22.8	4.1	42	24.1	3.8	43	23.4	4.2	44	23.4	3.8
ADOS calibrated severity score	45	8.38	1.5	42	8.02	1.9	43	8.05	1.8	44	8.4	1.6
ADOS total diagnostic score	45	20.3	4.2	42	19.6	5.2	43	19.8	4.8	44	20.1	4.7
Developmental age on Mullen in months	44	14.0	4.3	42	15.0	4.5	43	14.7	4.2	43	14.3	4.6
Developmental quotient on Mullen	44	63.6	17.9	42	63.9	19.3	43	65.1	19.8	43	62.4	17.2

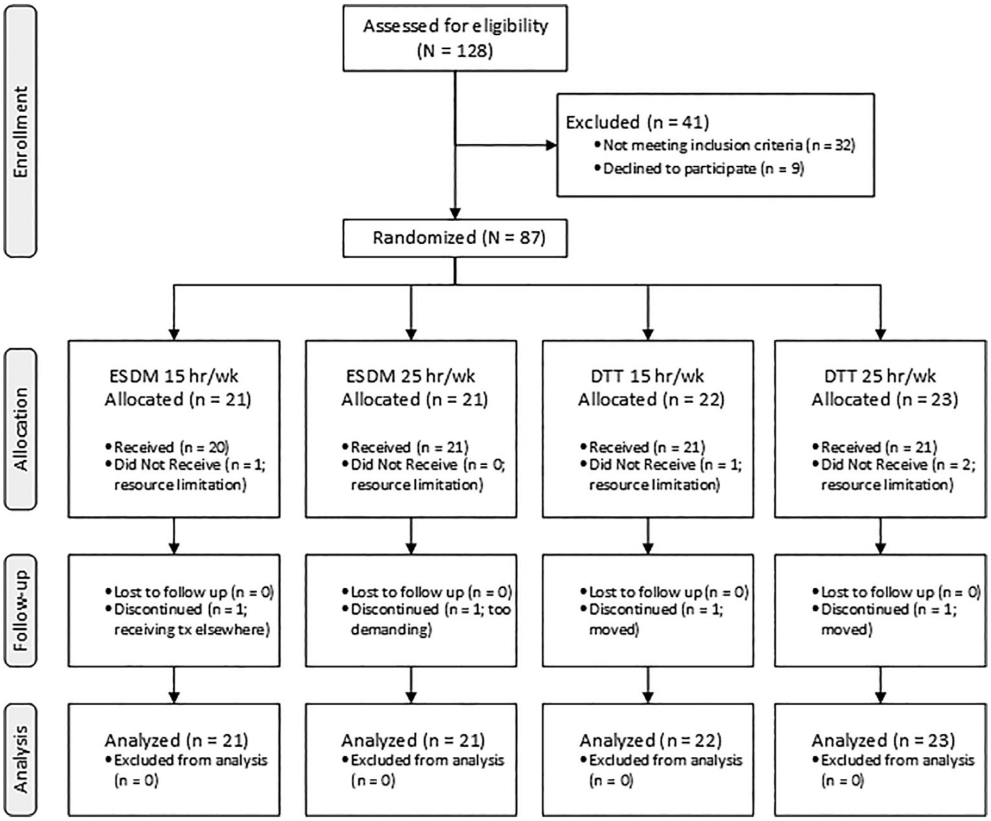

Figure 1. Participant flow in the randomized control trial using CONSORT conventions.

very brief reinforcement during the teaching rounds that consisted of praise, delivery of a token, or very brief access to a tangible reinforcer. Upon completion of the instruction period, there was a 2- to 4-min play break that served as reinforcement for cooperation with and successful completion of the teaching activity. The teaching trials were presented in a child-friendly manner (i.e., natural language and tone of voice) but the teaching staff (TS) attempted to maintain a steady pace of instruction. The child was expected to pay attention to the TS, but this was accomplished indirectly rather than by cueing the child. Teaching occurred both at the table and on the floor, mostly in one area of the home (e.g., child's bedroom or playroom), but also in other natural teaching locations (e.g., living room or kitchen). About once per hour, there was a longer play break (typically 10 to 15 min) that allowed an opportunity to engage in longer activities such as outdoor play.

ESDM. The Rogers and Dawson's [2010] ESDM manual was the guide for the ESDM treatment approach. There were certified ESDM therapists at each site. In general, ESDM instruction was embedded in children's preferred play activities and daily activity routines (e.g., snacks, play, and dressing). Within teaching activities, teaching objectives were embedded inside the play to provide continued access to the play or preferred items as the reward whenever possible. In general, teaching sequenced goals using normative information and teaching followed naturalistic ABA principles, such as antecedent-response-consequence teaching episodes. Ideally, activities involved shared control between child and adult in the form of turn-taking in which the leader and responder alternated roles. When the activity did not involve play (e.g., handwashing), skills were taught at times at which the skill would normally be needed (e.g., before meals, when hands were dirty, before the next desired activity). Skills were typically shaped using least to most physical prompts followed by prompt fading. Most activities used functional and social reinforcers. Activities occurred in multiple locations in the home, including a separate room or in a separate area of a room. The child and adult changed positions frequently. Data were recorded on child responses every 15 min during a few minutes' break from active interaction.

Fidelity of treatment (FOT) measurement. Thirty minutes of treatment was recorded twice per month. One of these recordings was randomly selected for FOT coding. With "five" as the score that indicated highest compliance with the assigned treatment style, means were 4.73 (SD = 0.24) and 4.33 (SD = 0.15) for EIBI and ESDM, respectively. A second coder independently rated a random sample of 20% of the FOT sessions to estimate reliability. The primary coder did not know which sessions were selected for reliability checks. The mean percentage agreement on the EIBI FOT average rating was 98% (SD = 3%). The mean percentage agreement on the ESDM FOT average rating was 97% (SD = 3%).

Measures

The Mullen Scales of Early Learning (MSEL) [Mullen, 1995] is a standardized assessment of development in four domains normed from early infancy until age 5. Because many of the participants had standard scores at the floor on the MSEL, we used a developmental quotient (DQ) as our measure of overall developmental delay at Time 1. DQ was computed by averaging developmental ages (DA) from the four MSEL subscales excluding gross motor, dividing by child chronological age (CA) and multiplying by 100. In our sample, the scores at Time 1 varied from 35 to 133. The overall developmental age, and expressive language age equivalency scores at Time 1 were analyzed as potential correlates with the severity of disability measures that might explain any severity of disability x treatment group interactions.

Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) [Lord et al., 2012] was administered according to the procedure manual. The appropriate module was given as judged by the administrator. The total calibrated severity scores were generated to quantify the severity of autism symptoms at Time 1. In our sample, Time 1 scores varied from three to ten. Lab personnel were trained to 85% reliability on the full range of scores and met research criteria. Inter-observer reliability at individual sites was assessed on at least 15% of administrations, and any deviation from standards led to retraining.

Individual Growth and Development Inventories-Early Communication Indicator (IGDI-ECI) [Carta, Greenwood, Walker, & Buzhardt, 2010], a 6-min play-based measure, uses a standard toy set and a responsive interaction style to interact with the child. Because the toys, location, examiner, interaction style, and activities differed from the treatment sessions, the procedure was considered a strong test of generalization. The IGDI-ECI was given monthly throughout the 12-month intervention period. Using a timed event sampling method, trained coders identified intentional communication acts and classified each communication act as non-symbolic (i.e., imitated words or phrases, non-word vocalizations, and gestures; for a weight of one point), single non-imitated word utterances (two points), or multiple non-imitated word utterances (three points). This weighted sum of instances of intentional communication reflects maturity of the form of communication and the frequency of communication. Because explicit prompts to communicate were avoided, all coded communication was considered spontaneous. The coding manual includes detailed communication act coding rules and is available from the first author. A random sample of 20% of sessions was recoded to estimate inter-observer reliability. Reliability coders were blind to assignment and primary coders were blind to which sessions were checked for reliability. The intraclass correlation coefficient using a two-factor random analysis and the absolute agreement method was 0.98.

In previous research, the IGDI-ECI was repeatedly administered to almost 6000 Head Start children who did not receive special education services [Greenwood, Walker, & Buzhardt, 2010]. Such data provide a "low-normal" growth trajectory against which the current study's growth trajectories can be compared. In the current study, the initial average developmental level of the children was 12 months and the duration of the treatment phase in the current study was 12 months. Thus, to estimate the low-normal growth trajectory for comparable children over a comparable period, we used the structural equation from the Greenwood, et al.'s study to compute the estimated weighted frequency of communication (i.e., their "total communication" score) at 12 and 24 months. This low-normal growth trajectory is presented along with the growth trajectories for the current study in Figure 2.

Analysis Plan

First, we identified the longitudinal mixed level (LML) that best fit the data to model growth in the frequency and maturity of spontaneous communication. We used the deviance statistic and the correlation of the intercept and slope to select among the linear growth models (e.g., fixed and random intercept with a fixed slope vs. fixed and random intercept and slope). We used a full maximum likelihood estimation (FMLE) method because this method minimizes bias when data are missing at random [Enders, 2010]. Time in study was analyzed as a continuous variable and was centered at the first measurement period so that the intercept would represent the best estimate of initial status on the dependent variable. Doing so made the test for differences in the estimated intercept parameters equivalent to testing whether there were between-group mean differences on the initial dependent variable level and whether the magnitude of group differences varied by severity of disability at Time 1.

When intensity or style effects on growth in the dependent variable did not vary by site, we used four separate LML models to examine whether the effects of group (style or intensity) on the growth of the frequency and maturity of spontaneous communication varied by the moderator (autism severity or developmental delay at Time 1). These models had eight predictors (i.e., intercept, time in study, group, moderator, group × moderator, time × group, time × moderator, and time × group × moderator). At this step, we also tested whether random assignment produced comparable groups on the initial status of the dependent variable regardless of moderator (i.e., the group fixed effect on the intercept), and at varying levels of disability severity (group × moderator interaction effect on intercept). Although not expected, these analyses also tested for group × time in study interaction effects, which is the test of the main effect of group on growth of the dependent variable. The four-way interaction between style × intensity × time in study × moderator was not modeled because of sample size restrictions and because we had no predictions that required this complex analysis.

When a significant moderator × group × time interaction was detected and the groups were comparable on the initial levels of the dependent variable, we probed the interaction using an adaptation of the Johnson-Neyman technique for mixed level models [Preacher, Curran, & Bauer, 2006]. This probing method allows us to identify the range of disability severity scores that define the subgroup in which significant between-group differences on the end point dependent variable scores occurred (Preacher et al., 2006).

When there was an interpretable moderated treatment effect on the frequency and maturity of spontaneous communication, we planned to examine whether selected pretreatment variables could account for the results. These pretreatment variables for these analyses were age, overall developmental age, expressive age equivalency, and treatment intensity as actually delivered.

Results

The Best Fitting Linear Unconditional Change Model

There was significant change in the frequency and maturity of spontaneous communication. A fixed and random baseline-centered intercept and fixed and random slope model was selected because it fit the data better the random intercept and fixed slope model ($-2LL(1) = 186$, $P < 0.01$) and because the intercept and slope were not significantly correlated. Quadratic and cubic models did not improve the model fit to the data. A significant fixed effect for time in study was demonstrated, $F(1,83) = 79.2$, $P < 0.01$, indicating significant positive change, regardless of treatment group or initial disability severity.

Tests of Site Effects

The site × intensity (or style) × time in study effects were not significant for the dependent variable, $F(1,990) = 0.31, 2.21$, $P = 0.31, 0.58$, respectively. That is, there was no evidence that the magnitude of intensity or style effects on frequency and maturity of spontaneous communication varied by site. Therefore, site was not included in subsequent models.

Tests of whether Randomization Produced Nonsignificant Differences between Groups at Time 1

Frequency and maturity of spontaneous communication at Time 1 was not significantly different between style and intensity groups, when controlling for main effects and interaction effects involving autism severity at Time 1, $F(1,83) = 0.15, 1.21$, $P = 0.70, 0.27$, respectively, and developmental delay at Time 1, $F(1,83) = 0.61, 2.1$, $P = 0.44, 0.15$. Thus, random assignment was successful at creating comparable groups on the dependent variable at T1.

Tests of the Main Effects of Style and Intensity

Treatment style did not affect the frequency and maturity of spontaneous communication growth rate when controlling for main effects and interactions involving autism severity at Time 1, $F(1,82) = 1.23$, $P = 0.27$, or developmental delay at Time 1, $F(1,82) = 2.13$, $P = 0.19$. Similarly, treatment intensity did not affect frequency and maturity of spontaneous communication growth when controlling the main and interaction effects involving developmental delay at Time 1, $F(1,82) = 0.36$, $P = 0.55$.

The significant treatment intensity effect on frequency and maturity of spontaneous communication growth, $F(1,82) = 4.8$, $P = 0.03$, was not interpretable because, as later results indicated, there was a significant three-way interaction involving initial severity of disability on frequency and maturity of spontaneous communication growth rate. To

Table 2. Means and SDs on the Dependent Variable by Group and Time

	Treatment style				Treatment intensity			
	ESDM		EIBI		25 hrs/wk		15 hrs/wk	
Weighted frequency of intentional communication from the IGDI-ECI	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Month 1	8	12	11	16	8	14	11	15
Month 12	44	42	48	41	48	40	44	43

aid future meta-analysis that might include the current study, the means and SDs are provided by group at the first and last measurement period. See Table 2.

Tests of the Primary Research Question: The Moderated Style or Intensity Effects

Treatment style did not affect frequency and maturity of spontaneous communication at any level of disability severity. That is, the style × moderator × time in study when autism severity at Time 1 was analyzed as the moderator, $F(1,82) = 1.14$, $P = 0.29$, or when developmental delay at Time 1 was analyzed as the moderator, $F(1,82) = 0.72$, $P = 0.84$, were nonsignificant.

However, treatment intensity did affect the growth rate of frequency and maturity of spontaneous communication differently depending on the children's autism severity at Time 1. That is, the intensity × autism severity at Time 1 × time in study interaction on frequency and maturity of spontaneous communication was significant, $F(1,82) = 4.37$, $P = 0.04$. In contrast, the intensity × developmental delay at Time 1 × time in study interaction on frequency and maturity of spontaneous communication was not significant, $F(1,82) = 3.76$, $P = 0.06$. Although this interaction is nonsignificant using the arbitrary alpha of 0.05, we determined whether there were regions of significance along the developmental delay continuum at which the between-treatment-group difference is statistically significant. Neither region of significance was within the range of developmental delay scores in the current sample. The coefficients for the fixed effects (and their standard errors) for the models involving treatment intensity are provided in Table 3. The Pearson's r for the association between autism severity and developmental delay at Time 1 is −0.54, $P < 0.01$.

Figure 2 illustrates the intensity × autism severity at Time 1 × time in study interaction on frequency and maturity of spontaneous communication over the 12-month treatment phase.

The figure indicates that the children with the mildest autism severity scores at Time 1 benefited more from 25 hrs per week than from 15 hrs per week. The adaptation of the Johnson-Neyman [Hayes, 2013] technique for mixed level models [Preacher et al., 2006] further specified that the subgroup who benefited from more treatment were those with initial calibrated autism severity scores between three and five inclusive. Using the marginal means at the maximum range of the region of significance and the SD at the end point, the Cohen's d for the between-group difference was 0.49. Ten percent of the sample in each intensity group fell into this range. The region of significance also indicated that apparent differences between intensity groups on the frequency and maturity of spontaneous communication growth rate in children with moderate to severe levels of autism were nonsignificant (i.e., the intensity groups' confidence interval around the association between the predicted endpoint dependent variable scores overlapped when predicted by severe levels of autism at Time 1).

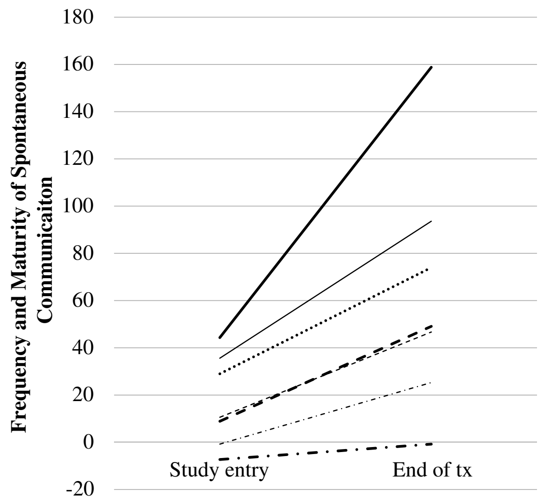

Figure 2. Growth rate of weighted frequency of intentional communication across the 12-month treatment phase by initial severity of autism and treatment intensity. *Note*. Thick and thin lines are for 25 hrs and 15 hrs per week, respectively. Solid, dashed, and dash and dotted lines are for children at three (sample minimum), eight (sample median), and ten (maximum) ADOS calibrated severity scores, respectively. The dotted line is the low-normal trajectory from the extant data reported in Greenwood et al. [2010]. The contrast between 25 vs. 15 hrs for the least severely affect children is significant. The other contrasts are not.

Using the growth rates depicted in Figure 2, it is apparent that those who received 25 hrs per week of treatment for 12 months and had mild autism symptoms at Time 1 had growth rates that exceeded that of the Head Start

Table 3. Fixed Effects Estimates (SEs) for Models with Significant Intensity Effect on Frequency and Maturity of Spontaneous Communication Growth That Is Conditional on Severity of Disability at Time 1

	Autism severity as the moderator[a]	Developmental delay as the moderator[b]
Intercept	51.5(12)**	−14(9)
Time in study	5(2)*	1.3(1.6)
Moderator	−5.0(1.5)**	0.39(0.1)**
Intensity	−27(19)	−11(14)
Time × moderator	−0.27(0.2)*	0.03(0.02)
Time × intensity	6.7(3)*	−4(2.4)
Moderator × intensity	3(2)	0.12(0.2)
Time × moderator × intensity	−0.77(0.4)*	0.07(0.04)

[a]Total calibrated severity score from ADOS-2 at Time 1.
[b]Developmental quotient from the MSEL at Time 1.
*$P < 0.05$; **$P < 0.01$.

children who did not receive special services (an estimate of low-normal growth rate). For children with initially mild autism symptoms who received 15 hrs per week of treatment, their frequency and maturity of spontaneous communication growth rate was essentially equal to the low-normal growth rate of the Head Start children.

Potential Correlates of Autism Severity at Time 1

Because a correlational design element was used to characterize the subgroup responding to different levels of treatment intensity, it is possible that other Time 1 correlates of autism severity would better describe the responders to differential treatment intensity than does autism severity. Except for MSEL expressive age-equivalent scores (r values = −0.26), the selected Time 1 variables did not covary with Time 1 autism severity. The MSEL expressive age-equivalent scores did not interact with intensity to predict frequency and maturity of spontaneous communication growth rate ($t(80) = 1.6$, $P = 0.10$). Thus, the selected Time 1 variables cannot explain the intensity × autism severity × time in study interaction on frequency and maturity of spontaneous communication growth rate.

Discussion

The current study was conducted to test whether the effect of different treatment styles or different treatment intensities on child progress on frequency and maturity of spontaneous communication varied by children's initial severity of disability. A secondary goal was to examine whether the IGDI-ECI is sensitive to change and moderated treatment effects in these young children with ASD.

We confirmed that the magnitude of treatment intensity effects on frequency and maturity of spontaneous communication growth varies by the severity of children's ASD symptoms at the start of treatment. An exploratory finding revealed that children with initially milder autism symptoms, 10% of the whole sample, benefited more from 25 hrs per week of treatment than 15 hrs per week regardless of treatment styles. Although there was a nearly significant statistical interaction between severity of developmental delay and intensity group, concluding that severity of developmental delay moderates the effects of intensity of treatment requires at least one region of significance to occur within the sample range on the moderator [Hayes, 2013]. This was not the case for baseline developmental delay severity variable. Several selected potential correlates of autism symptom severity, such as developmental level or developmental quotient, did not describe the subgroup for whom intensity levels mattered. The growth rates of children with milder autism in 25 hrs per week of treatment exceeded low-normal growth rates, which is evidence that the moderated treatment effect had practical significance. The findings confirm that the weighted frequency of spontaneous intentional communication from the IGDI-ECI procedure is sensitive to change and moderated treatment effects. However, for most children, intensity differences did not matter.

Limitations

The results cannot be generalized to treatment styles or treatment intensities or treatment durations other than those compared in the current study. Additionally, the effects of treatment style or treatment intensity effects on other dependent variables may differ from those reported here. Finally, the progress monitoring measure used in the current study was not administered after the treatment phase ended. Thus, tests of maintenance of the effects is a topic of future research. Although the primary paper [Rogers et al., 2020] addresses potential maintenance of effects, neither the current paper nor the primary paper does so for the dependent variable used in the current paper.

Because we were able to predict that initial autism severity would moderate the treatment intensity effect on frequency and maturity of spontaneous communication growth, it is likely that future studies will find that autism severity is a relevant predictor of children who differentially benefit from varying treatment intensities. However, because we were not able to confidently predict the directionality of the relationship between autism severity, treatment intensity, and rates of gain in communication frequency and maturity, our finding regarding the cut point for the particular subgroup in which intensity effects occur needs to be replicated before they are used to guide practice.

Contributions to the Field

No other studies have examined whether treatment intensity of the same treatment styles has an effect on frequency and maturity of spontaneous communication. Similarly, this is the first study to demonstrate that the IGDI-ECI is sensitive to change and moderated treatment effects in children with ASD. The primary paper on this study sample did not find that autism severity or development delay moderated the intensity effect on expressive communication [Rogers, Yoder, Estes, et al., 2020]. However, there are several differences between the current paper's analysis and that of the primary paper. The primary paper examined gain through both a 12-month treatment period and a 12-month post-treatment follow-up period. The current paper's IGDI-ECI was not given at or during the follow-up period. The component variables in the primary paper's expressive communication composite are either global variables (e.g., MSEL expressive communication age equivalent scores) measures or are based on fewer communication samples (i.e., four samples). Additionally, the component variable from the communication sample in the primary paper is the number of different words, which does not afford demonstrating growth on preverbal intentional communication. The current findings add to the extant literature that has shown that weighted frequency of intentional communication is more sensitive to growth than unweighted frequency of intentional communication in infant siblings of children with autism [Yoder, Stone, Walden, & Malesa, 2009].

There are three advantages of using the IGDI-ECI as a sampling procedure and weighted frequency of intentional communication as a metric to measure change in frequency and maturity of spontaneous communication. First, the IGDI procedure is brief and thus affords frequent use. Second, the interaction style used in the IGDI does not require much training. Third, the weighted frequency of intentional communication is a single index that enables showing growth for low-verbal children who vary in their initial communicative level while showing growth over a 12-month period.

Strengths

One strength of the current study's dependent variable measure, which is the combined result of the ECI procedure and the weighted frequency of communication variable, deserves special emphasis. It is clearly a generalized measure of a highly functional skill that is a known weakness for children with ASD. Some have called for demonstrations that comprehensive treatments can have an effect on such functional outcomes because many past tests of comprehensive treatments have focused on global measures of degree of delay, such as intelligence quotients [Lord, Wagner, Rogers, et al., 2006]. Finally, it is more difficult to show treatment effects on measures of generalized skills than on context-dependent behaviors [Yoder, Bottema-Beutel, Woynaroski, & Sandbank, 2013].

Another strength of the current study's dependent variable is that it is a proximal measure of the treatments' goals. Both treatments explicitly target frequency and maturity of spontaneous expressive communication. A recent review has demonstrated that treatments are more likely to show effects on proximal measures than distal ones in children with ASD [Sandbank et al., 2020].

Potential Explanations for the Findings

Although we do not have sufficient evidence to confirm potential explanations for the results, at least two classes of explanations for the current findings exist. First, children with mild autism might benefit from more treatment than do children with more severe autism because the former have more emotion regulation, executive function, and developmental skills to continue to engage in and uptake information from the active ingredients of the treatment, even after a long treatment day. In contrast, for children with more severe autism, inhibiting their impulses, sustaining their attention, and cooperating with an interactive adult for long treatment sessions may be more taxing than for children with milder ASD. Second, tutors may have been less able to provide high-quality communication instruction at the end of a long treatment day with children with severe autism because of the children's greater need for behavior management.

It is tempting to interpret growth during treatment as evidence that a treatment style facilitates frequency and maturity of spontaneous communication development. This is especially true when a treatment style has shown efficacy in past studies. However, the current study's findings do not necessarily mean that the two styles or the two intensities are equally effective. The absence of a treatment-as-usual control group prevents such conclusions. Even though we did not find differences in the efficacy of the two styles, and even though we found significant differences in the efficacy of treatment intensity for a small subgroup (10%), we cannot claim that both treatment styles or both intensity levels benefited most children's communication.

A finding from the primary paper may be relevant to the absence of style effects, even moderated ones [Rogers et al., 2020]. Because modifications in treatment delivery were guided by children's progress and progress was logically related to initial severity of disability, we empirically examined relationships between modifications in the treatment style and initial disability severity. The results from the primary study showed that for some children assigned to the DTT group who had milder developmental delay (and thus made relatively rapid gains), EIBI is designed so that its methods change to become more like NDBI styles. Similarly, for some children assigned to NDBI group who had more severe delays (and thus made slow gains), ESDM is designed so its methods change to become more like DTT styles.

Implications

By itself, the current study does not refute the National Research Council's recommendation for 25 hrs per week of treatment in children with moderate to severe autism symptoms. Interpreting nonsignificant differences in treatment intensity levels as evidence that high treatment intensity is not needed is inappropriate because there are multiple explanations for nonsignificant differences between intensity groups. In other fields, it takes consistent failure to confirm predictions for current wisdom to be questioned. Only if future work also shows that more than 15 hrs per week of direct treatment, still quite intensive, produces similar results to 25 hrs per week, should new standards for appropriate intervention intensity be considered for children with initially severe autism. It is also possible that the effects of treatment intensity are not linear. Perhaps intensities greater than those tested here produce exponentially greater treatment effects than does 21 hrs per week. Future work is required to test this latter possibility.

It would also be a mistake to conclude that the children who benefited from the extra ten treatment hours per week were those who least needed it. All of the children in the study had an ASD with its associated communication delays and impairments. For the children with relatively mild autism symptoms, the 25 hrs per week of treatment produced greater-than-low-normal acceleration in frequency and maturity of spontaneous. This is exactly what we hope intensive treatment will accomplish for young children with ASD.

In summary, the current study found that child progress on the dependent variable was not affected by differences in treatment style, and, for most of the children, was not differentially affected by either treatment intensity. For the 10% of children with the mildest autism severity scores of three to five, 25 hrs per week of treatment accelerated frequency and maturity of spontaneous communication growth rate as measured by the IGDI-ECI more than did 15 hrs per week. The findings support the future use of the IGDI in research examining effects of differing treatment styles and intensities.

Acknowledgments

This study was supported by NIMH/NICHD award number 1 R01 MH100030 (S.J.R., PI) as part of the Autism Centers of Excellence (ACE) Treatment Network. Communications should be sent to: paul.yoder@vanderbilt.edu, voice: (615) 423 5340, fax: (615) 269-8316.

Conflict of interest

The authors declare there are no potential conflicts of interest. Dr. S.R. receive royalties from Guilford Press for materials related to this work. All of Dr. S.R.' royalties related to this project were donated to charity. Royalties from A Work In Progress go to the Autism Partnership Foundation.

References

Carta, J., Greenwood, C., Walker, D., & Buzhardt, J. (2010). Using IGDIs: Monitoring progress and improving intervention for infants and young children. Baltimore, MD: Brookes Publishing Company.

Dawson, G., Rogers, S., Munson, J., Smith, M., Jamie, W., Greenson, J., et al. (2010). Randomized controlled trial of the Early Start Denver Model: A developmental behavioral intervention for toddlers with autism: Effects on IQ, adaptive behavior, and autism diagnosis. Pediatrics, 125(1), 17–23.

Eisenberg, J. M. (2011). Comparative effectiveness of therapies for children with autism spectrum disorder (pp. 1–2). Houston, TX: Agency for Healthcare Research and Quality. Baylor College of Medicine.

Enders, C. K. (2010). Applied missing data analysis. New York, NY: The Guilford Press.

Fey, M., Warren, S., Yoder, P., & Bredin-Oja, S. (2013). Is more better? Milieu communication teaching in toddlers with intellectual disabilities. Journal of Speech, Language, Hearing Research, 56, 679–693.

Greenwood, C., Walker, D., & Buzhardt, J. (2010). The early communication indicator (ECI) for infants and toddlers: Early head start growth norms from two states. Journal of Early Intervention, 32(5), 310–334.

Hayes, A. (2013). Introduction to mediation, moderation, and conditional process analysis. New York, NY: Guilford Press.

Leaf, R., & McEachin, J. (1999). A work in progress: Behavioral management strategies and a curriculum for intensive behavioral treatment of autism. New York, NY: DRL Books.

Lord, C., Luyster, R. J., Gotham, K., & Guthrie, W. (2012). Autism diagnostic observation schedule, second edition (ADOS-2) manual (Part II): Toddler module. Torrance, CA: Western Psychological Services.

Lord, C., Wagner, A., Rogers, S., et al. (2006). Challenges in evaluating psychosocial interventions for autism spectrum disorder. Journal of Autism and Developmental Disorders, 10, 695–708.

Mullen, E. M. (1995). Mullen Scales of Early Learning (AGS ed.). Circle Pines, MN: American Guidance Service.

National Research Council. (2001). Educating children with autism. Washington, DC: National Academies Press.

Preacher, K. J., Curran, P. J., & Bauer, D. J. (2006). Computational tools for probing interactions in multiple linear regression, multilevel modeling, and latent curve analysis. Journal of Educational and Behavioral Statistics, 31(4), 437–448.

Rogers, S. J., & Dawson, G. (2010). The Early Start Denver Model for Yyung children with autism: Promoting language, learning, and engagement. New York, NY: Guilford.

Rogers, S. J., Estes, A., Lord, C., Munson, J., Rocha, M., Winter, J., … Sugar, C. A. (2019). A multisite randomized controlled two-phase trial of the Early Start Denver Model compared to treatment as usual. Journal of the American Academy of Child and Adolescent Psychiatry, 58(9), 853–865.

Rogers, S. J., Yoder, P., Estes, A., Warren, Z., McEachin, J., Munson, J., … Whelan, F. (2020). A multisite randomized controlled trial comparing the effects of intervention intensity and intervention style on outcomes of young children with autism. Journal of the American Academy of Child and Adolescent Psychiatry. https://doi.org/10.1016/j.jaac.2020.06.013.

Sandbank, M., Bottema-Beutel, K., Crowley, S., Cassidy, M., Dunham, K., Feldman, J. I., … Woynaroski, T. G. (2020). Project AIM: Autism intervention meta-analysis for studies of young children. Psychological Bulletin, 146(1), 1.

Smith, T., Groen, A. D., & Wynn, J. W. (2000). Randomized trial of intensive early intervention for children with pervasive developmental disorder. American Journal on Mental Retardation, 105(4), 269–285.

Yoder, P., Bottema-Beutel, K., Woynaroski, T., & Sandbank, M. (2013). Social communication intervention effects vary by dependent variable type in preschoolers with autism spectrum disorders. Evidence-based Communication Assessment and Intervention, 7(4), 150–174. https://doi.org/10.1080/17489539.2014.917780

Yoder, P., Stone, W., Walden, T., & Malesa, E. (2009). Predicting social impairment in younger siblings of children with ASD. Journal of Autism and Developmental Disorders, 39, 1381–1391. https://doi.org/10.1007/s10803-009-0753-0

Yoder, P. J., Lloyd, B., & Symons, F. (2018). Observational measurement of behavior (2nd ed.). Baltimore, MD: Brookes.

Yoder, P. J., & Stone, W. (2006). Randomized comparison of two communication interventions for preschoolers with autism spectrum disorders. Journal of Consulting and Clinical Psychology, 74, 426–435.

Yoder, P. J., & Woynaroski, T. (2015). How to study the influence of intensity of treatment on generalized skill and knowledge acquisition in students with disabilities. Journal of Behavioral Education, 24(1), 152–166.