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Technology to Guide Data-Driven Intervention Decisions: Effects on Language Growth of Young Children at Risk for Language Delay

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Abstract
Data-driven decision making (DDDM) helps educators identify children not responding to intervention, individualize instruction, and monitor response to intervention in multitiered systems of support (MTSS). More prevalent in K–12 special education, MTSS practices are emerging in early childhood. In previous reports, we described the Making Online Decisions (MOD) web application to guide DDDM for educators serving families with infants and toddlers in Early Head Start home-visiting programs. Findings from randomized control trials indicated that children at risk for language delay achieved significantly larger growth on the Early Communication Indicator formative language measure if their home visitors used the MOD to guide DDDM, compared to children whose home visitors were self-guided in their DDDM. Here, we describe findings from a randomized control trial indicating that these superior MOD effects extend to children's language growth on standardized, norm-referenced language outcomes administered by assessors who were blind to condition and that parents' use of language promotion strategies at home mediated these effects. Implications and limitations are discussed.

The use of outcome data to inform instructional decisions, often referred to as data-driven decision-making (DDDM), has been promoted as an evidence-based practice in general education (U.S Department of Education, 2014) and special education policies (IDEA, 2006) and by early childhood professional organizations (Division for Early Childhood [DEC], 2014; National Association for Education of Young Children, 2018). Within general and special education, DDDM is a key component of the multitiered system of support (MTSS) approach to early intervention services (D. Fuchs & Fuchs, 2006). MTSS is made possible by the advent of formative progress-monitoring measures of students' growth in the school curriculum (Deno, 2003; L. S. Fuchs & Deno, 1991). DDDM and MTSS have extended to early childhood general and special education programs for children 3 to 6 years of age (Greenwood et al., 2014; McConnell & Missall, 2008; VanDerHeyden & Snyder, 2006) and to programs serving birth to 3 (Carta et al, 2010; Greenwood et al., 2008).

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Core MTSS principles common to K–12 classrooms (Merrell & Buchanan, 2006) are being applied to early childhood programs to promote outcomes of all children (Carta & Young, 2019). MTSS principles include universal screening and DDDM, intervening before delays become disabilities with evidence-based interventions, differentiating interventions for individual needs, and monitoring progress and fidelity of implementation. For example, MTSS supports in Head Start and preschool classrooms are similar to K–12 in terms of core curriculum (Tier 1), use of small-group instruction (Tier 2), and individualized instruction (Tier 3) Carta et al, 2014. MTSS supports for infant and toddler services may be less standardized because of variations in service delivery models (center based, family child care, or home visiting).

Infant and toddler Individual Growth and Development Indicators (IGDI) are used for DDDM of infants and toddlers' growth in cognitive (Greenwood et al, 2006), communication (Greenwood et al, 2019), social, and movement (Greenwood et al, 2018) outcomes (Carta et al., 2010; Greenwood et al., 2011). An example of an evidence-based standard, Tier 2 intervention for promoting infant/toddler language growth is the Promoting Communication Tools for Advancing Language in Kids (PC TALK) intervention (Walker & Bigelow, 2012). Tier 3 individualized interventions for infants and toddlers are delivered through problem solving by pediatricians, behavior analysts, or other early intervention specialists (e.g., speech-language pathologists, occupational therapists, etc.).

Implementing MTSS with fidelity is challenging because of its many components, including tracking children's progress and using data to help inform instructional and intervention decisions (Carta et al, 2016). Technology applications have emerged to support data management and DDDM. For example, Assessment to Instruction (A2i; Connor et al., 2007) provides K–3 teachers with individualized literacy instruction guidance based on children's vocabulary, decoding, and comprehension scores on standardized assessments. A2i recommends a type and amount of instruction from the Individualizing Student Instruction (ISI) curriculum for each child. Students whose teachers used A2i with ISI demonstrated higher scores on standardized literacy assessments, and the effect grew stronger with longer and higher-fidelity exposure to ISI (Ingebrand & Connor, 2016).

Implementing MTSS with fidelity is challenging because of its many components, including tracking children's progress and using data to help inform instructional and intervention decisions. (p. 2)

Making Online Decisions (MOD) Technology to Guide DDDM for Infant and Toddler Services

The infant and toddler IGDI web application provides data management and progress-monitoring supports for infant-toddler programs. Embedded within the IGDI web application, the MOD (Buzhardt et al., 2010) provides individualized DDDM guidance to educators serving children performing below expected age-based benchmarks on the Early Communication Indicator (ECI), one of four infant and toddler IGDIs. The MOD's design is based on principles of progress monitoring (Deno, 1997; L. S. Fuchs & Deno, 1991) and the clinical problem-solving model described by Tilly (2002, 2008). The steps in the Tilly model are (1) Is there a problem? (2) What is causing the problem? (3) What should be done? (4) Is it being implemented? and (5) Is it working? Based on this approach, the MOD uses quarterly universal screening data and algorithms to identify children likely to benefit from additional language intervention support (Is there a problem?). When a child's ECI falls below benchmark for their age, the MOD recommends evidence-based PC TALK strategies (What intervention should be used?). In a home-visiting context, a home visitor reviews the strategies with parents and follows up with them on their use during daily routines (Is the intervention being implemented?) and monitors the child's growth on the ECI over time (Is it working?).

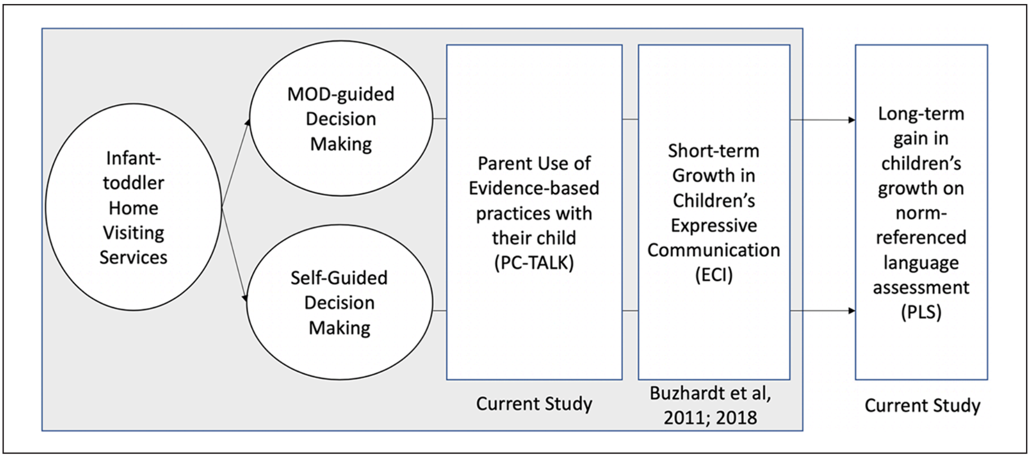

Figure 1. Making Online Decisions theory of change within an infant-toddler home-visiting context.

The MOD's theory of change is shown in Figure 1. From left to right, infant-toddler home visitors' DDDM is either self-guided or MOD guided, which influences parents' use of PC TALK strategies with their child, leading to improvements in short- and long-term language growth. Prior reports have demonstrated the effect of the MOD on children's growth in expressive communication measured by home visitor–administered ECI assessments (Buzhardt et al., 2011, 2018). The child's sustained growth in early communication then provides a hypothesized effect measured by a gain in standardized, norm-reference language skills on the Preschool Language Scale 5th Edition (PLS-5; Zimmerman et al., 2011). Both prior studies were conducted in the context of Early Head Start (EHS) home-visiting services, a federally funded early intervention program for infants and toddlers at risk due to poverty or other factors. Both earlier studies also tested the hypothesized benefit provided by MOD's automated DDDM guidance for home visitors versus self-guidance (business as usual).

In the first study (Buzhardt et al., 2011), 48 home visitors in five EHS programs used the ECI for universal screening and progress monitoring and were randomly assigned to use either the MOD or self-guidance for children (*N*= 132) who scored at least one standard deviation below benchmark on the ECI. Results indicated that children with home visitors who used the MOD grew statistically significantly more on the ECI by 36 months of age than the children whose home visitor did not use the MOD. The second study (Buzhardt et al., 2018) replicated the first with 45 home visitors from 13 EHS agencies across four states with 146 children scoring below benchmark on the ECI. Again, MOD home visitors produced measurably superior ECI outcomes (Buzhardt et al., 2018), but effects were found only for children whose home visitor implemented the MOD with high fidelity, with effect sizes of d= 0.56 at 6 months postintervention and increasing to d= 1.12 at 12 months. Despite these promising findings, the effects of the MOD on standardized language assessments administered by independent assessors masked to condition is unknown. Also unknown is how parents' use of the PC TALK strategies recommended by the MOD contributes to the MOD's effects on children's language growth.

Purpose of the Current Study

The purpose of this study was to test the effects of the MOD on children's standardized language outcomes and how much those effects are mediated by parents' use of PC TALK strategies recommended by the MOD. Like prior analyses, the MOD was the independent variable, with parents' use of PC TALK strategies considered a mediator of children's distal language outcomes on the PLS-5 (dependent variable). We investigated these research questions:

1. Were there differential effects of MOD implementation by home visitors on children's expressive and receptive language outcomes as measured by the PLS-5?
2. To what extent did parents implement the PC TALK strategies at home?
3. Did parents' use of PC TALK strategies with their child mediate the effects of MOD implementation on children's expressive and receptive language outcomes?

Method

Overview

To prepare for the study, all home visitors were trained and certified to use both the ECI for universal screening and progress monitoring (see Buzhardt et al., 2018) and PC TALK strategies. They were then randomized to use either self-guided or the MOD-guided DDDM. Children on home visitors' caseload who scored at least one standard deviation below ECI benchmark for their age were recruited and enrolled in the study. All procedures were approved by the University of Kansas Institutional Review Board.

Participants

Home-visiting EHS programs. We recruited home visitors from EHS programs across four midwestern states. The program directors and parent advisory boards of participating programs agreed to the following study requirements: (a) ECI certification of all home visitors and annual onsite recertification, (b) quarterly administration and scoring of the ECI for all children, (c) use of PC TALK strategies with families of children with or at risk for language delay/individualized family services plan, (d) randomization of home visitors to either use the MOD or not, and (e) sharing information about the study with families of children who scored at least one standard deviation below benchmark. Each EHS program received an annual $1,000 stipend to compensate for time spent coordinating annual home visitor trainings with research staff and monthly phone calls with research staff to discuss implementation.

Home visitors and families. All home visitors ($N = 163$) consented to participate. All but one home visitor were female, and one from each experimental group had high school degree or GED as their highest level of education. They did not receive additional financial compensation for participation and carried an average caseload of about 10 families.

All families ($N = 214$) received weekly home visiting services from participating EHS agencies. In addition to the below-benchmark criterion for child participation, only children whose families reported speaking primarily English or Spanish were eligible. Home visitors described the study to the parent or caregiver, provided a one-page overview of the study, and informed parents that they would receive $30 compensation for each assessment battery completed in the home. If the family expressed interest, the home visitor forwarded the family's contact information to research staff, who then scheduled a home visit with the family to seek informed consent and administer the first round of assessments. To minimize attrition during follow-up, families were encouraged to inform research staff when they moved and received a postcard to send to research staff with updated contact information if they moved. To support timely updates, families received $20 if they sent updated contact information. Additional demographics for home visitors and families are available in online supplemental materials.

Formative Measure of Expressive Communication: The ECI

One of four infant-toddler IGDI measures, the ECI (https://igdi.ku.edu/) is a formative measure of expressive communication for children 6 to 42 months of age. The ECI is a general outcome measure in the tradition of curriculum-based measurement designed for early childhood practitioners who serve infants and toddlers (Carta et al., 2010; Greenwood et al., 2011). It measures children's use of four key communication skills: gestures, nonword vocalizations, and single and multiple word utterances. The ECI's psychometric properties include reliability, criterion validity, and sensitivity to individual differences in children's growth over time and intervention (Greenwood et al., 2010; Walker et al., 2008). All EHS home visitors were trained and certified to administer and code ECIs for the children on their caseload using the ECI's standard training protocol (Buzhardt & Walker, 2010). Training involved a 1-day workshop in which home visitors were taught how to administer and score the ECI and how to use the web application to enter data and interpret the progress-monitoring graphs/reports (only home visitors in the MOD condition were given access to the MOD). All home visitors were required to score two ECI videos with at least 85% reliability, where percentage agreement = [100(agreements/agreements + disagreements)] with the master scores for each video.

The Evidence-Based Language Promotion Strategies for Parents: PC TALK

PC TALK (http://www.talk.ku.edu/tools/manuals/) is an evidence-based naturalistic language intervention for strengthening an infant's or toddler's early language-learning environment (Walker & Bigelow, 2012) used in prior research (Bigelow et al., 2020; Buzhardt et al., 2011, 2018). Eight evidence-based strategies are included: (a) arranging the environment, (b) following the child's lead, (c) commenting and labeling, (d) imitating and expanding, (e) using open-ended questions, (f) time delay, (g) positive attention, and (h) providing choices. Each strategy is indexed to infants, toddlers, and young children who are at the early stages of communication versus those who are communicating using more complex language. The strategies encourage service providers and parents to embed the intervention strategies across multiple routines (e.g., meals, play, book reading), to increase frequency and to use the examples provided in the manual as suggestions for how to make communication and language goals more intentional.

Experimental Groups and Procedures

We used a cluster-randomized controlled group design to compare the effects of treatment, wherein clusters were the children nested within home visitors serving their families. Randomization to either the self-guided DDDM (comparison) or MOD-guided DDDM (experimental) condition occurred after home visitors consented and were trained on the use of the ECI. To control for differences between EHS agencies, home visitors were randomly assigned to experimental conditions within agencies. Although this increases potential contamination between home visitors in the same agency, MOD guidance is limited to user accounts with MOD privileges, thus making access by comparison group members unlikely.

Randomization was accomplished by asking home visitors to pick a blank envelope from a container of envelopes equal to the number of home visitors at the training. Each envelope contained either a "MOD" or "Non-MOD" label evenly distributed among the envelopes. If a home visitor left an agency, their replacement was trained and assigned to the same condition as the departing home visitor. Research staff assigned MOD privileges to the user accounts of home visitors randomly assigned to the MOD. Nonetheless, without continuous, ongoing observation of home visitors, contamination cannot be completely ruled out. After training and randomization, home visitors assessed all children on their caseload with the ECI quarterly. Parents whose child scored at least one standard deviation below benchmark on the ECI were recruited for participation. Throughout the course of the study, this resulted in 99 home visitors assigned to the MOD condition, and 122 families on their caseloads consented to participate; 64 home visitors were assigned to the self-guided condition, with 92 families consenting to participate.

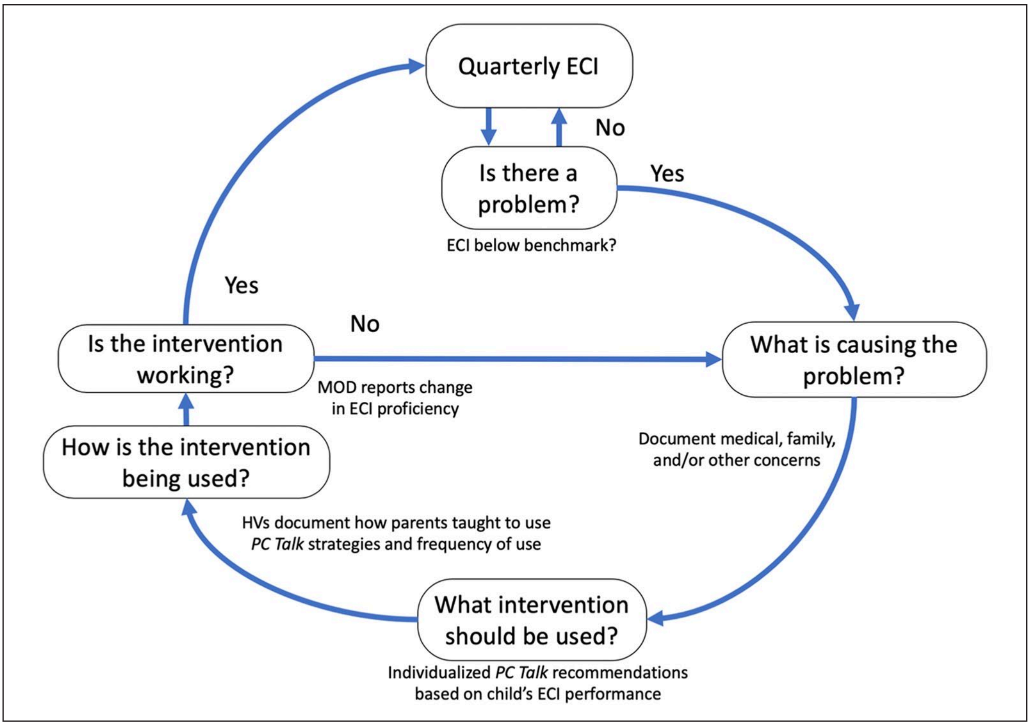

Figure 2. The Making Online Decisions five-step decision-making framework.

MOD group. Figure 2 illustrates the MOD's decision-making steps described next.

Step 1: Is there a problem? Children whose quarterly total ECI total communication score was at least one standard deviation below benchmark were identified as not making adequate progress (i.e., below benchmark). Based on child performance, the home visitor was required to decide what action was needed and either conduct another ECI assessment to confirm or move to Step 2.

Step 2: What is causing the problem? Clinical issues commonly linked to poor progress were considered and documented by the home visitor. Specifically, the MOD asked the home visitor if they believed the child's performance may be influenced by a medical change (e.g., hearing loss), family change (e.g., recent parent separation or change of residence), or change in child or family services (e.g., new center-based care or caregiver change). If the home visitor confirmed any of these concerns, then the MOD encouraged the home visitor to use appropriate agency resources to address needs in these areas (e.g., set up an audiology appointment if hearing loss is suspected) and conduct more frequent ECI assessments to monitor short-term progress.

Step 3: What should be done? After responding to Step 2 questions, the MOD algorithms recommended targeted PC TALK strategies to the home visitor based on the child's ECI performance. For example, home visitors for children demonstrating gestures and vocalizations below benchmark received strategies to promote these prelinguistic forms of communication, whereas home visitors for a child beginning to use words would receive more advanced strategies to build vocabulary and short phrases. From the list of recommended strategies (usually three to five), the home visitor used their clinical judgment to determine how many strategies to begin teaching parents (i.e., some might begin with one or two at first, depending on the parent's preference). After selecting strategies, the MOD provided home visitors with general information about the strategies, how to promote language growth, specific examples of strategies, and a fidelity checklist to document how they supported parents' use of the strategies.

Step 4: How are the PC TALK strategies being implemented? The MOD prompted home visitors to document how they supported parents' use of the PC TALK strategies and their reported use of the strategies. If the home visitor reported using less than 80% of the strategies to support parents or key support strategies were not used (e.g., they did not leave information about the strategies with the parent), then the MOD encouraged them to follow up with parents on the next home visit. Prior analyses found no statistically significant differences between MOD and self-guided groups in the amount of self-reported support parents received from home visitors on their use of the PC TALK strategies (Buzhardt et al., 2018).

Step 5: How is the child responding? Home visitors were expected to monitor the child's response to PC TALK by reviewing the child's ECI scores to determine if the child was improving or not. After entering a new ECI assessment, the MOD immediately displayed the child's graph to the home visitor and provided a general description of the child's progress. The MOD also recommended parents continue using the PC TALK strategies if ECI growth was greater than before starting the MOD, or it recommended continued use of the strategies plus more intensive language intervention if the child was not improving. Step 5 continued until the child stopped receiving ECI assessments, and PC TALK strategies recommended by the MOD continued to adjust as the child's language became more advanced.

Home visitor training and support. In trainings separated by experimental group, all home visitors received professional development on the PC TALK strategies, review of these strategies with parents, and how to use ECI to individualize strategies for parents. However, MOD home visitors also learned to use the MOD web application, reviewed how ECI data inform recommendations for PC TALK strategies, and were presented a case example of a home visitor using the MOD with a family through all steps of the framework shown in Figure 2. Additional details about home visitor training were reported by Buzhardt et al. (2018).

Following initial home visitor training, research staff held monthly follow-up calls with directors or home visitor coordinators to review their implementation of the ECI, PC TALK strategies, and MOD implementation. Annually, research staff provided onsite retraining on the ECI, PC TALK strategies, and MOD in the format described earlier. Home visitors who had been certified in a prior year were recertified by coding a full ECI administration video (different from those used for initial certification) using the same criterion (85% agreement with a master coding). New staff completed training and informed consent.

Measurement

MOD implementation stages (all research questions). Whenever a home visitor engaged with the MOD, the user activity was automatically stored in the MOD database. We used these data to create a MOD implementation score for each child that reflected the last MOD step completed for each child. Children receiving MOD home visitor services received a score of 1 if Steps 1 through 3 of the MOD were completed (Stage 1), 2 if Steps 1 through 4 were completed (Stage 2), and 3 if all five steps were completed (Stage 3). The validity of these stages was reflected in the differential outcomes achieved by children's ECI total communication (Buzhardt et al., 2018). For example, children at Stage 3 experienced the greatest strength of treatment and achieved greater ECI outcomes.

Parents' observed use of PC TALK Strategies (Research Questions 2 and 3). Trained research staff who were masked to condition conducted

15-min home observations of parents' interactions with their child during daily routines. Observations were adapted from Walker et al.'s (2014) Promoting Communications Strategies Fidelity Checklist (PC TALK Checklist), designed to measure the frequency that parents used the strategies with their child. Prior to observation, the assessor read a script explaining their intent to observe how the parents and their child interacted during daily activities, such as playing, reading, talking, or listening to music, that also might include any daily care or household routines, like changing or dressing the child, preparing a snack, cooking, or cleaning. These assessments were administered at pretest and repeated at 4, 6, and 12 months posttest.

PLS-5 (Research questions 1 and 3). The PLS-5 (Zimmerman et al., 2011) was used to measure children's receptive and expressive language skills. The PLS-5 is a widely used norm-referenced standardized measure of language in children up to 7 years 11 months of age. The PLS-5 provides raw and standard scores for auditory comprehension (i.e., receptive communication), expressive communication, and total language (Total Language). Split-half reliabilities range from .80 to .97. Sensitivity of the Total Language score is .83; specificity is .80. The standardization sample matches 2008 U.S. Census data for region, race-ethnicity, and level of caregiver education and consisted of 1,400 children. Children whose parents reported Spanish as the primary language spoken at home were administered the Spanish version of the PLS-5. The Spanish version norms were based on 1,150 monolingual and bilingual Spanish-speaking children in the United States and Puerto Rico.

Research staff blind to condition were trained to administer and score the PC TALK Checklist and PLS-5 by a combination of didactic instruction and viewing video samples of assessment administration. Interrater reliability of assessors on both measures was documented by having a second assessor code video recordings of individual assessment administrations and comparing scores between assessors. Reliability was assessed for 35% of the PC TALK Checklist administrations and 32% of the PLS-5 and assessments. Reliability for each of these observations was calculated using the following formula: percentage agreement= [100 (agreements/agreements + disagreements)]. Mean agreement was 94% for PC TALK Checklist observations and 98% for PLS-5 administration.

Analytic Methods

We addressed the research questions by examining under what conditions the intervention was effective using a mediation model (Whittle et al., 2017). The model examined hypothesized direct and indirect effects on children's language outcomes, as illustrated in Figure 3. The MOD construct captured the variability in home visitor implementation of DDDM as reported by Buzhardt et al. (2018) and its relationship to growth in children's ECI total communication rate. The PLS-5 random slope and intercept reflected children's language growth and outcome status after 6 and 12 months of exposure to the intervention. Parents' use of PC TALK strategies at home reflected parents' understanding of the strategies via the home visitor and their actual application at home with their children.

To address the first research question, we examined the effects of MOD implementation fidelity on PLS-5 receptive and expressive scores using a two-level linear growth model. Because standard scores are often less sensitive to growth, we analyzed both standard and raw PLS-5 scores. Level 1 units represented the repeated measures at preassessment, 6-month, and 12-month time points (within level), and Level 2 units were children (between level). Level 1 captured the mean growth trajectory of all children, and Level 2 explained the variation in the linear growth parameters of intercept and slope. For all outcomes (i.e., children's raw and standard scores on PLS-5 total, receptive language, and expressive communication), the intraclass correlations between the two-level unconditional model range from 0.41 to 0.57, which implied that 41% to 57% of the variance in PLS-5 scores could be explained by clustering of observations within children (Hox et al., 2017). We did not include home visitor level

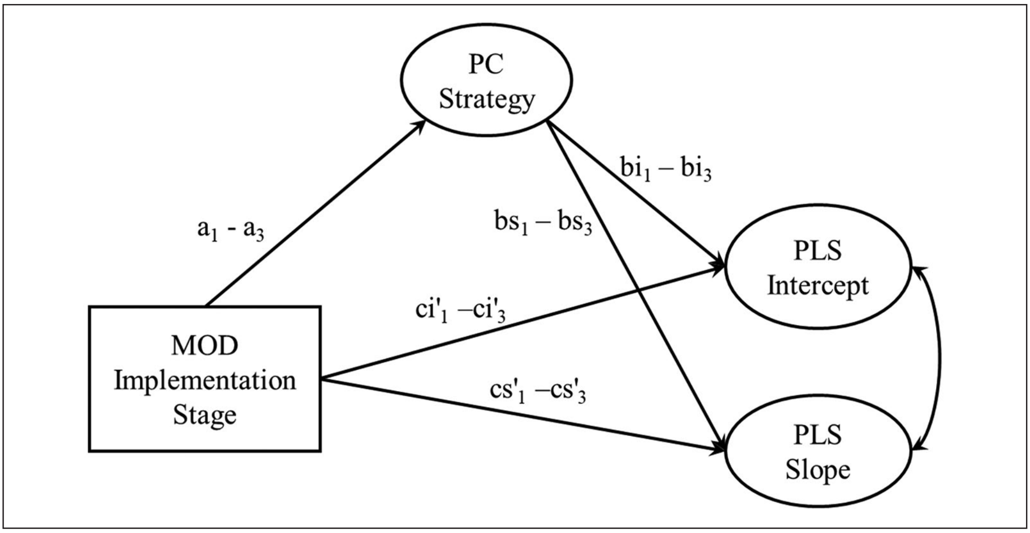

Figure 3. Mediation model illustrating potential causal pathways under investigation for the effects of Making Online Decisions implementation and Promoting Communication Tools for Advancing Language in Kids strategies on Preschool Language Scale outcomes.

in the analyses because we randomized home visitors to self-guided or MOD groups, so there was no expectation of statistically significant variance at this level. We treated the duration of the treatment (i.e., time in months since children first fell below benchmark) as the primary time variable in the growth curve model. The time variable was centered at 6 months after the child scored at least one standard deviation below benchmark on the ECI and then at 12 months.

To eliminate the potential confounding effect of children's chronological age, we also included age at preassessment (mean centered) as a between-level covariate. We created dummy variables to represent MOD implementation Stages 1, 2, and 3. The self-guided group served as the baseline reference group in analyses. The predictor, MOD implementation, was added in the between level for both intercept and slope. Models were estimated for each of the six PLS-5 scales (auditory comprehension, expressive communication, and total) and scores (raw and standard). Because Buzhardt et al. (2018) found effects only for Stage 3 MOD and to reduce potential Type I error, we analyzed only Stage 3 MOD effects for this research question. Three demographic variables—home visitor education level, home visitor caseload size, and primary caregiver education level—were included as covariates. Missing data on the covariates were handled using full information maximum likelihood (FIML; Enders, 2010). All analyses were conducted using Mplus v.7.

We addressed the second research question using ordinary linear regression to examine the effects of MOD Implementation Stages 1 to 3 on the parents' use of PC TALK strategies (a_1–a_3, Figure 3). For the PC TALK outcome, we used the mean of each parent's frequency counts across the 4-, 6-, and 12-month measurement occasions. To recover information loss due to missing values at measurement occasions, instead of computing the mean number of PC TALK strategies from the raw data, we estimated the mean using effect coding (Koslowsky, 1988) and simultaneously examined the effect of MOD implementation on parents' PC TALK use. The number of PC TALK strategies that parents used at preassessment was included as a control variable. Home visitors' attained education level and caseload size and primary caregiver education level were used as demographic covariates.

To address the third research question, we modeled the relationships among MOD stages, parents' use of PC TALK strategies, and children's PLS-5 scores (see Figure 3).

Table 1. PLS-5 Scores and PC TALK Use by Group and Assessment Time Point.

	Preassessment			6-month follow-up					12-month follow-up				
Group	*M*	*SD*	*N*	*M*	*SD*	Gain[a]	*N*	% attrition	*M*	*SD*	*N*	Gain[a]	% attrition
PLS-5													
Raw score													
Self-guided	42.7	11.8	86	52.6	12	9.9	68	20.93	53.8	11.5	25	11.1	63.24
MOD Level 1	44.8	11.5	39	52.8	11.3	8.0	19	51.28	60.7	11.9	7	15.9	63.16
MOD Level 2	43.1	11.3	52	50.8	13.5	7.7	37	28.85	55.2	14.0	13	12.2	64.86
MOD Stage 3	40.8	8.4	35	54.3	10.6	13.5	34	2.86	60.6	13.7	22	19.8	35.29
Standard Score													
Self-guided	83.9	15.4	86	85.4	14.5	1.5	68	20.00	82.5	14.4	25	-1.4	63.24
MOD Level 1	83.3	10.8	39	82.6	9.4	-0.6	19	51.28	89.3	13.0	7	6.0	63.16
MOD Level 2	82.8	14.5	52	83.0	17.2	0.3	37	28.85	81.8	13.8	13	-0.9	64.86
MOD Stage 3	86.5	10	35	95.2	9.4	8.7	34	2.86	94.1	12	22	7.6	35.29
PC TALK use													
Self-guided	72.7	46.5	86	80.1	44.9	7.4	70	18.60	93.7	44.3	21.0	26	62.86
MOD Level 1	64.5	39.4	41	107.2	58.4	42.7	18	56.10	119.9	42.9	55.3	7	61.11
MOD Level 2	71.9	45.7	52	93.4	54.2	21.4	36	30.77	84.6	52.5	12.7	13	63.89
MOD Stage 3	84.9	42.7	35	102.8	50.1	17.9	34	2.86	110	51	25.1	22	35.29

Note. PLS-5 = Preschool Language Scale 5th Edition; PC TALK = Promoting Communication Tools for Advancing Language in Kids; MOD = Making Online Decisions.
[a]Represents gain since preassessment.

We examined the effects of parents' use of PC TALK strategies on PLS-5 intercept and slope (*bi* and *bs*, Figure 3), controlling for MOD implementation. We computed the products of the *a* (from the second analysis) and *b* paths, the indirect effects of MOD implementation on PLS-5 intercept and slope. The significance of the indirect effects was determined using confidence intervals (CIs) constructed through the distribution-of-product method (Preacher et al., 2010). If the CI of an indirect effect does not contain zero, we conclude that the effect is statistically significant and that mediation exists. In Figure 3, the paths ci'_1–ci'_3 and cs'_1–cs'_3 represent the direct effects of MOD implementation on PLS-5 intercept and slope after controlling for the *a* and *b* paths. We used the same demographic covariates as those used in the first and second analyses.

Results

Table 1 provides descriptives for the PLS-5 and PC TALK strategies by experimental group as well as the sample sizes and attrition percentage at each measurement point. At preassessment, there was no statistically significant difference between groups on PLS raw Total Language, $F(1, 210) = 0.44$, $p = .51$, nor the number of PC TALK strategies by parents, $F(1, 212) = 1.20$, $p = .28$.

Research Question 1: Were There Differential Effects of MOD Implementation on Children's Expressive and Receptive Language Outcomes as Measured by the PLS-5?

Analyses of effects on PLS-5 scores considered differences in both intercept (at 6 months) and growth (slope) raw and standard score outcome units after home visitors had been implementing DDDM. Positive differences in estimates indicated larger outcomes were achieved by the MOD group. The MOD Stage 3 group versus self-guided group at 6 months was statistically greater in nearly all cases. PLS-5 raw scores at 6 months were all statistically significantly larger for the MOD

Stage 3 compared to the self-guided group: $ci_3 = 4.2$, $SE = 1.5$, $p = .01$, for total scores; $ci_3 = 2.2$, $SE = 0.9$, $p = .01$, for receptive scores; and $ci_3 = 2.0$, $SE = 0.8$, $p = .01$ for expressive scores. Similarly, the intercept differences at 12 months postintervention were all statistically significant: $ci_3 = 7.5$, $SE = 2.1$, $p < .01$, for total scores; $ci_3 = 4.6$, $SE = 1.2$, $p < .01$, for receptive scores; and $ci_3 = 3.0$, $SE = 1.1$, $p < .01$, for expressive scores. Similar patterns were found for standard scores. No statistically significant differences were found between MOD Stage 1 or 2 and the self-guided group, in either intercepts or slopes. See the online supplemental table for complete results of growth curve analyses on children's raw and standard scores on PLS-5 total, auditory comprehension, and expressive communication.

Children's slope (growth) on the PLS-5 was also statistically significantly greater for the MOD Stage 3 group compared to self-guided. PLS-5 total raw scores of children served by MOD Stage 3 home visitors grew faster than children served by self-guided home visitors ($cs_3 = 0.5$, $SE = 0.2$, $p < .01$). Similarly, a statistically significant difference was found in the growth rate of receptive raw scores between MOD Stage 3 and the self-guided group ($cs_3 = 0.4$, $SE = 0.1$, $p < .01$). Statistically significant differences were not found for growth of expressive communication raw scores ($cs_3 = 0.2$, $SE = 0.1$, $p = .06$). Similar patterns were found for the PLS-5 standard scores. The demographic covariates were not statistically significant.

PLS-5 total raw scores of children served by MOD Stage 3 home visitors grew faster than children served by self-guided home visitors. Similar patterns were found for the PLS-5 standard scores. (p. 11)

Similar to prior findings based on formative ECI outcomes (Buzhardt et al., 2011, 2018), Cohen's d effect sizes grew larger for children who remained in intervention for at least 12 months. Effect sizes at 6 months were $d = 0.30$ for total, receptive, and expressive PLS-5 raw scores, which is a small to moderate effect. By 12-month follow-up, effect sizes increased to $d = 0.60$, $d = 0.60$, and $d = 0.50$, respectively, which are moderate to large effects.

Research Question 2: To What Extent Did Parents Implement the PC TALK Strategies at Home?

The mean, skewness, and kurtosis of the ordinary linear regression residual were 0, 0.44, and 2.66, respectively, suggesting that the normality assumption was met. The mean number of strategies that parents used increased for all groups following preassessment. Parents served by self-guided home visitors increased their use of the strategies from a mean of 72.7 at preassessment to 80.1 six months later (10.2% increase), whereas parents served by MOD Stage 3 home visitors increased from a mean of 84.9 strategies to 102.8 (17.4% increase). After controlling for the preassessment observation, the frequency of PC TALK strategy usage for parents whose home visitor reached Stages 1 and 3 implementation were statistically significantly greater than the self-guided group at 6-month follow-up ($a_1 = 1.57$, $SE = 0.64$, $p = .02$; $a_3 = 1.32$, $SE = 0.50$, $p = .01$). None of the demographic covariates (home visitor education level, home visitor caseload size, and primary caregiver education level) were associated with observed outcomes. See the online supplemental table for complete descriptives of parents' observed use of the PC TALK strategies by group and time point.

Research Question 3: Did Parents' Use of PC TALK Strategies With Their Child Mediate the Effects of MOD Implementation on Children's PLS-5 Outcomes?

Figure 4 illustrates statistically significant pathways between MOD, PC TALK strategies, and PLS-5 outcomes (see online supplemental table for complete results of the mediation model). The use of PC TALK strategies mediated the effects of MOD implementation on children's PLS-5 total and receptive scores at 6 months. Parents of children in MOD Stage 1 and Stage 3 groups used more

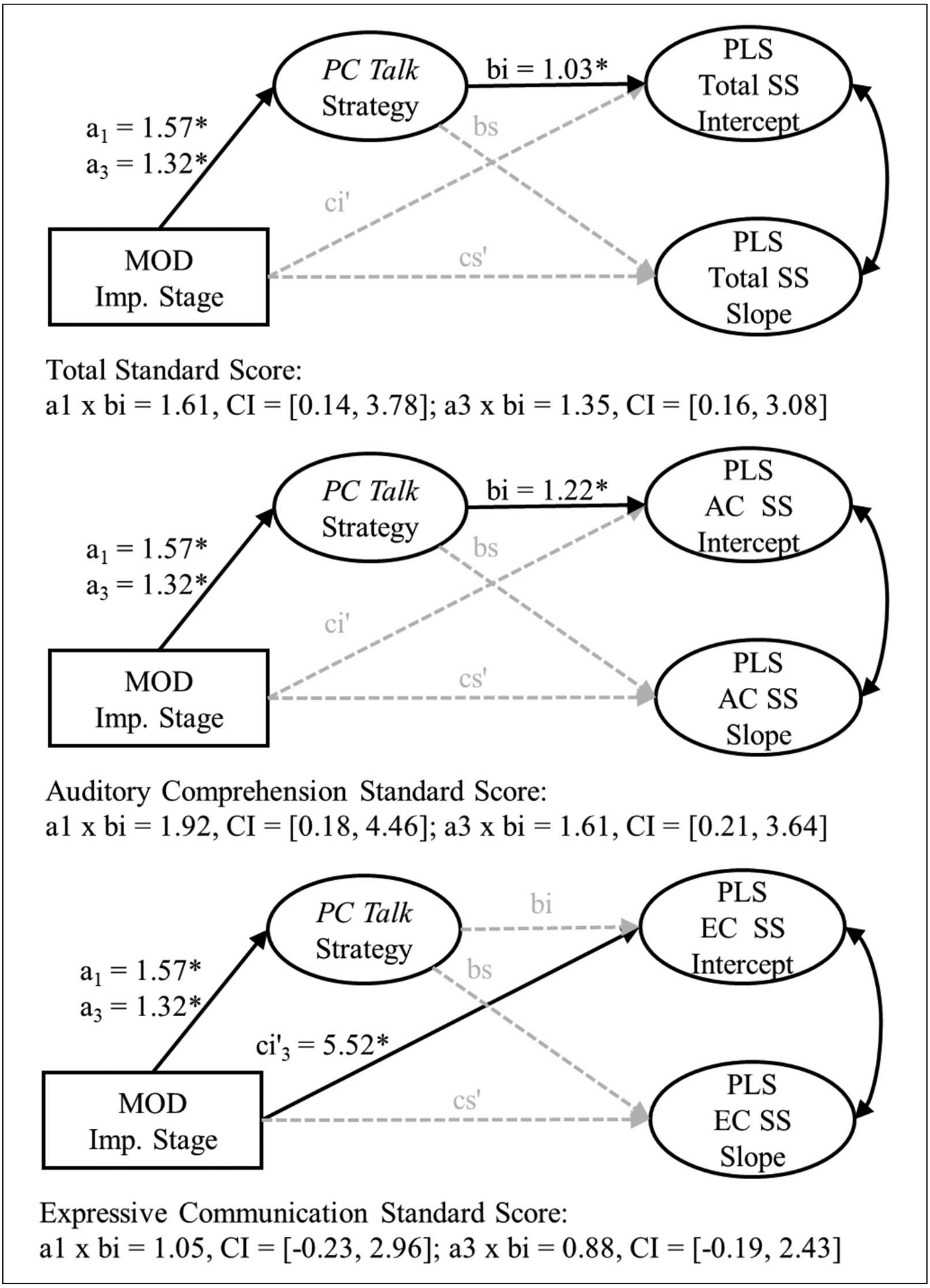

Figure 4. Mediation model illustrating potential causal pathways under investigation for the effects of Making Online Decisions implementation and Promoting Communication Tools for Advancing Language in Kids strategies on Preschool Language Scale outcomes.

PC TALK strategies with their child than the self-guided group. Also, the more PC TALK strategies that parents used, the greater were PLS-5 total ($a_1 \times bi = 0.99$, CI = [0.02, 2.48]; $a_3 \times bi = 0.83$, CI = [0.03, 2.01]) and receptive raw scores ($a_1 \times bi = 0.58$, CI = [0.01, 1.44]; $a_3 \times bi = 0.48$, CI = [0.02, 1.16]) at 6 months. Mediating effects were not found for expressive communication scores. Figure 4 shows that the same patterns emerged for the standard scores. At 12 months post intervention, the mediating effect was seen only for receptive standard scores for MOD Stage 1 and Stage 3 groups ($a_1 \times bi = 2.39$, CI = [0.07, 5.90]; $a_3 \times bi = 2.01$, CI = [0.10, 4.82]). None of the demographic covariates were statistically significant.

Discussion

Our overall conclusion from this study is that home visitors' use of the MOD led to stronger language growth for the children they served (Research Question 1), that this effect on language was mediated by parents' use of PC TALK strategies recommended by the MOD (Research Questions 2 and 3), and that effects were not moderated by home visitor or parent characteristics. These questions bear importantly on the use of DDDM within an MTSS framework by early childhood home visitors.

Findings that parents' use of PC TALK strategies mediated the relationship between MOD implementation and children's outcomes provides new support for the theory that home visitors' support of parents use of evidence-based practices can lead to improved child outcomes. These findings are consistent with earlier results (Buzhardt et al., 2011, 2018) showing positive effects on formative measures of child language. Importantly, gains were cumulative over time in that effect sizes generally doubled from 6 to 12 months postintervention. This work has theoretical and practical relevance because of the need for tools that can support MTSS models for infant and toddler services, particularly those services that occur outside of classroom settings (Akers et al, 2015; Carta et al, 2012). Previous DDDM research typically involved extensive in-service training and coaching with mixed results (van der Scheer & Visscher, 2016). The MOD web application, however, provided home visitors with automated DDDM guidance that required relatively minimal training.

MOD Effect on Parents' Use of PC TALK Strategies

A key feature of this study was to investigate change in parents' use of PC TALK strategies as a mediating pathway of the MOD's effect. Within home visiting and other family-centered service models, these strategies can provide home visitors with clear guidance for increasing opportunities for parent–child interactions during daily routines. Home visitors in both groups received general training on how to provide parents with PC TALK strategies for children who performed below benchmark on the ECI. Because we did not experimentally manipulate PC TALK, we used a regression model that permitted evaluation of the MOD-supported delivery of PC TALK. As expected, parents whose home visitor reached MOD Stage 3 implementation increased their use of the PC TALK strategies more than parents of self-guided home visitors. This was consistent with the expectation that home visitors prompted parents to use PC TALK more often because of the automated MOD recommendations.

As expected, parents whose home visitor reached MOD Stage 3 implementation increased their use of the PC TALK strategies more than parents of self-guided home visitors. (p. 13)

An unexpected finding was that parents whose home visitors completed only MOD Stage 1 increased their use of the PC TALK strategies more than the self-guided group, but parents with MOD Stage 2 home visitors did not. This was unanticipated because MOD Stage 2 home visitors completed fidelity checks indicating that they reviewed the strategies with parents and followed up with them about their use of the strategies, whereas MOD Stage 1 home visitors did not. This finding may be related to the variation in sample sizes between MOD groups. MOD Stage 1 had a small sample size at 6- and 12-month measurement occasions (n= 18 and 7, respectively), relative to Stage 2 (n= 36 and 16, respectively) and Stage 3 (n= 34 and 23, respectively). Thus, the mean number of PC TALK strategies used by parents in Stage 1 may have been influenced by parents who used the strategies at an unusually high rate, as suggested by this group's high standard deviation. Regardless of MOD stage, however, the MOD's automated guidance resulted in larger increases in parents' use of evidence-based strategies relative to self-guided home visitors.

Mediating Effect of PC TALK Strategies

Parents' use of PC TALK strategies mediated the MOD's effect on most of the PLS-5 outcomes for children whose home visitors reached MOD Stages 1 and 3. Although these mediating effects sustained for receptive scores at 12 months, they did not for the total scores. The sample size concerns described in the previous section about the effects of MOD Stage 1 on parents' use of PC TALK strategies are likely relevant here, as well. Therefore, the most meaningful and methodologically sound interpretation of the mediation model is that PC TALK strategies mediated the effects of MOD Stage 3 on PLS-5 total and receptive standard scores at 6 months postintervention. A larger sample size at 12-month follow-up is needed to assess these long-term mediating effects.

These mediation analyses demonstrate that the evidence-based PC TALK strategies embedded within the MOD were an important component of the MOD framework, but the lack of mediating effects for some pathways suggests that other changes in home visitors' services prompted by the MOD may have also contributed to the MOD's effect on children's language outcomes. EHS home visitors provide a wide range of family services, and the MOD, in addition to recommending PC TALK strategies, provides a systematic structure for early identification of children at risk for language delay and monitoring children's language growth after they have been identified. Importantly, the MOD does not preclude programs from responding to children's and families' needs in other ways in addition to introducing PC TALK. Other changes to services in response to MOD recommendations could range from referral to Part C early intervention services to more subtle changes, such as increased opportunities to review ECI growth charts that prompt discussions between home visitors and parents about other ways to improve language growth. These subtle changes may in turn result in more language-rich interactions between children and parents (or other adults involved in the child's life) that were not detected on the observations of parents' use of PC TALK strategies.

Limitations

In the present study, attrition resulted in diminishing sample sizes at 6- and 12-month follow-ups (see online supplemental tables). We observed the highest dropout rates for families whose home visitor reached only MOD stage 1 implementation. The sample size in this group decreased by 56% at 6-month follow-up and 83% at 12-month follow-up relative to pretest sample sizes. Parents in this group also had the lowest mean use of PC TALK strategies at the preassessment time point (Table 1) but had the highest use at 6- and 12-month follow-up. Because these parents did not receive documented follow-up about their use of the strategies from their home visitors, an explanation for this may be that parents who used more strategies were reinforced by their child's language growth and were therefore less likely to drop out of the study. For the second and third research questions, even though we used FIML to recover the missing information and adjust for potential bias by including other variables in the models (e.g., pretest score and caregiver education level), we could not recover all information lost due to dropout. Therefore, caution is needed in interpreting of the effect of MOD Stage 1 implementation on PLS-5 outcomes.

Another limitation was a lack of direct observations of home visitor–parent engagement during weekly home visits. Home visitors provided family services, including MOD recommendations, to families in their homes, which in some cases were up to 20 miles away from the agency's central office. Because of home visitors' schedule constraints and large caseloads, it was not feasible to observe all home visits or observe parents more frequently and in a larger variety of contexts.

Implications for Education Practices and Policy

Implementing MTSS, response to intervention, and other models that involve DDDM in early childhood is more feasible, effective, and scalable using tools such as the MOD to reduce barriers to the uptake of evidence-based practices. The MOD's cloud-based infrastructure provides needed structure, consistency, and ongoing support that is often not possible or feasible using standard in-service training.

MTSS delivered within infant and toddler home-visiting services is rare and presents unique challenges due to the remote nature of services and a lack of training and professional development for DDDM, and time and resources needed for systematic assessment, all of which are crucial to MTSS implementation. This study demonstrates that DDDM can be used within family-centered service models, such as EHS, but like the medical profession, practitioners need tools to help integrate DDDM into their services in order to make meaningful point-of-care decisions. The MOD provides a framework that others can use to facilitate DDDM practices in other outcome areas. As one of very few empirical studies of the effect of DDDM practices on infant and toddler outcomes, these findings provide needed evidence to support policies (Elementary and Secondary Education Act; U.S Department of Education, 2014; IDEA, 2004) and professional organizations (DEC, 2014; National Association for the Education of Young Children, 2018) that promote DDDM practices. Unfortunately, without new policies to guide the use of systematic progress monitoring and DDDM within infant-toddler services, it is unlikely that these practices will be adopted at scale by infant-toddler agencies.

This study demonstrates that DDDM can be used within family-centered service models, such as EHS, but like the medical profession, practitioners need tools to help integrate DDDM into their services in order to make meaningful point-of-care decisions. (p. 15)

Future Directions for MOD and DDDM Research

Additional research is needed to understand how MTSS and MOD can be used in early childhood contexts beyond home visiting and with intervention recommendations beyond those that support child language. Future research and innovative observations strategies are needed to support inferences about the efficacy of home visitor services and parent-implemented intervention strategies. Also, because the number of Spanish-speaking families was too small to examine the MOD's effectiveness for this linguistic group, additional research is needed with culturally and linguistically diverse families.

Perhaps most importantly, research is needed to identify supports that promote full implementation of the MOD. Indeed, this is also a broader question for education and one that has plagued the field for decades: What is needed to support educators' use of outcome data to individualize their curriculum and services for children and students? The answer to this question depends on the context and the tool or approach used to facilitate DDDM. For the MOD in the context of home visiting, we propose that home visitors need prompts and additional means of accessing and completing the fidelity checklists to document their work with parents (e.g., access to electronic documentation during home visits rather than only in office settings). Investigations into the effects of the MOD in other contexts (e.g., center-based agencies), in other outcome areas measured by infant and toddler IGDIs (i.e., motor, cognitive, and social development), and with other intervention and curriculum materials are needed.

Conclusion

Practitioners are increasingly expected to use evidence-based interventions and use child progress data in their intervention planning and decision making. Programs, the profession, and higher education also are expected to make professional development opportunities available to learn and improve practices linked to better child outcomes. Taken together, the need and value of electronic support systems, like the MOD, make improving practices more feasible, resulting in improved outcomes for a larger proportion of children and families.

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