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Increasing intervention fidelity among special education teachers for autism intervention: A pilot study of utilizing a mobile-app-enabled training program

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ABSTRACT

Background: This study was a follow up pilot study to investigate whether the mobile app *Map4speech* (Law, Neihart, & Dutt, 2018), originally developed for parent training, could also increase intervention fidelity among preschool special educators.
Method: A multiple baseline design was conducted with four preschool teachers to examine the effects of the mobile-app-enabled program in improving their intervention fidelity in naturalistic developmental behavioral intervention (NDBI) for young children with ASD.
Results: Results indicated that teachers who participated in the post training intervention attained high intervention fidelity of implementation (84–97%) compared to their baseline percentage of intervention fidelity (42–54%). Teachers' acceptability of mobile-app-enabled training program was moderate, between 60–70%. Results indicated that mobile-app-enabled training can be a promising means to raise teachers' intervention fidelity in autism intervention. Results also highlighted the usefulness and importance of having an effective andragogical framework in mobile learning design to produce lasting change of intervention behaviors.
Conclusions: Technology-enabled training has the potential to serve as an innovative solution to the shortage of ASD professional training.

1. Introduction

Training teachers to use evidence-based practices with high fidelity remains a significant challenge. Intervention fidelity, or the degree to which the intervention is delivered as intended (Bumbarger & Perkins, 2008), is the indicator for quality in intervention.

It is common for people to make errors when implementing complex interventions. Although some errors may be inconsequential, others may negatively impact children's outcomes. Teachers in particular have many distractions and priorities, which makes intervention fidelity less likely when compared to interventions in more controlled settings. High intervention fidelity, however, improves the effectiveness of evidence-based interventions (EBIs). It has a direct effect on children's behavioural outcomes and thus is the key in interpreting the effectiveness of the intervention (McConachie, Fletcher-Watson, Working Group 4, & COST Action' Enhancing the Scientific Study of Early Autism', 2015). Durlak and DuPre (2008) observed an effect size on outcomes 2–3 times higher for EBIs conducted with fidelity monitoring protocols. However, the persistent shortage of qualified and effective teachers in special education leaves untrained and mostly novice teachers who tend to use techniques that are not effective and evidence-based in the classroom (Billingsley & Scheuermann, 2014; Boe, 2014; Stahmer, Collings, & Palinkas, 2005).

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Monitoring intervention fidelity strengthens confidence in the validity and reliability of intervention outcomes, permits the early detection and correction of errors that can potentially affect treatment outcomes, facilitates theory testing and even improves staff retention (Aarons, Sommerfeld, Hecht, Silovsky, & Chaffin, 2009). Nevertheless, fidelity is not routinely monitored or reported, and no gold standard exists for whether fidelity data has been measured adequately. There are, however, essential procedures for fidelity measurement. These include identifying essential steps or the specific behaviors that are to be demonstrated, defining all the behaviors that are to be measured and determining a measurement system. Definitions are critical because they facilitate reliability. The most common measurement method is the use of a dichotomous checklist with direct observation (Ledford & Gast, 2014). Since there is good evidence that implementers consistently overestimate the fidelity with which they implement procedures, self-report measures of fidelity should never be used (Ledford & Gast, 2014).

McConachie et al. (2015) found that 19 out of the 33 controlled trials in preschool autism intervention did not report any intervention fidelity in parent-mediated autism interventions. Mandell et al. (2013) reported that the intervention fidelity of the autism community intervention program in a large-scale comprehensive randomized controlled trial was highly variable, ranging from 12 to 92%. Poor intervention fidelity calls attention to the need for and priority of disseminating evidence-based practices through effective teacher training.

However, typical teacher trainings usually engage outside consultants or experts to provide one-off workshops to in-service teachers in hopes that their intervention skills or intervention fidelity will be improved. This practice continues despite the evidence that didactic lectures and workshops for disseminating evidence-based practices, either face to face or via technology, do not produce any sustained change in intervention practice (Marturana & Woods, 2012; Mohr, Weingardt, Reddy, & Schueller, 2017; Suhrheinrich, 2011). Suhrheinrich (2011) found that only 15% of teachers met the mastery criteria of pivotal response training (PRT) after attending a didactic workshop, while remaining teachers showed additional improvement *only after individual coaching*. She concluded that coaching is a critical component in skill improvement. In the literature of adult education and training, it has been found that meaningful changes occur when *evidence-based adult learning strategies* are applied in training, such as active learning, provision of multiple learning episodes, opportunities for self-reflection, self-assessment using performance criteria and performance-based feedback (Dunst & Trivette, 2009; Silberman & Biech, 2015). Ongoing coaching and feedback are key training components to bring about intervention mastery and quality (Cornett & Knight, 2009). Stahmer et al. (2015) argue that teachers can learn to implement evidence-based practice, but that they require extensive training and coaching in order to reach moderate intervention fidelity. Coaching teachers to high fidelity and sustaining their efforts to maintain that fidelity requires extra time and cost. Hence, there is a great need to develop and test innovative strategies to provide lower cost implementation support.

One avenue for implementation support is the use of mobile technology. Mobile technology for education and training offers exciting possibilities for enhancing effectiveness in training special education personnel, especially in the area of provision of supervision, coaching and performance feedback (Billingsley & Scheuermann, 2014; Marturana & Woods, 2012; Pianta, Mashburn, Downer, Hamre, & Justice, 2008). Digital health research suggests that trainers' feedback and interactions with trainees are essential in the delivery of technology-enabled training because mere technologies can rarely be primary agents of behavioural change in comparison to human-supported technologies (Mohr et al., 2017). The use and benefits of technology-based programs with human support are significantly greater than self-guided, unsupported technology-based programs (Schueller, Tomasino, Lattie, & Mohr, 2016).

The small number of studies in this area limit conclusions regarding the efficacy of technology for training special education teachers. But individual studies show positive promising results in improving teachers' performance in the area of interacting with children and coaching caregivers (Billingsley & Scheuermann, 2014). Still, little is known about the andragogy of integrating mobile learning in teacher education and its related challenges (Baran, 2014).

Andragogy is the science of adult learning. It can be explained as "the dynamic relationship between teaching, learning, and culture" (Livingston, Schweisfurth, Brace, & Nash, 2017, p.3) and plays a central role in achieving educational targets. Failure to consider a framework for learning is a common oversight of intervention training and can result in ready-made formulas based on models of learning that carry implicit assumptions about the quality and potential for behavioral or educational change (Livingston et al., 2017). There is limited evidence regarding when or how individual adult learning strategies or components should be organized in a way in order to produce changes and impact intervention fidelity among special education teachers. It is possible that the use of technology can reduce the cost and increase the efficiency of coaching.

Preliminary results of a mobile app training program, *Map4speech*, illustrated the effectiveness of the app in training parents to use naturalistic intervention strategies to a high level of fidelity (Law, Neihart, & Dutt, 2018). *Map4speech* is a mobile application that was originally developed for parents of children with ASD and used as a tool to provide high-quality, interactive learning, coupled with online performance feedback and coaching. The app program trained parents to use naturalistic intervention strategies to improve communication outcomes of children with ASD.

Numerous studies have supported the use of naturalistic developmental behavioural interventions (NDBIs) as empirically validated treatment for ASD (Schreibman et al., 2015), especially in initiating speech in non-verbal children and enhancing generalization and spontaneity of speech (e.g. Ingersoll & Wainer, 2013; Kasari et al., 2014). For example, Suhrheinrich (2011) examined the efficacy of using a workshop and individual coaching to train 20 teachers to do pivotal response training (PRT). The workshop, together with individual coaching with observation and feedback, facilitated most of the teachers to master the intervention skills. The current study examines the use of mobile-app-enabled training, including online observation and online individual coaching and feedback, to improve teachers' fidelity in intervention.

The current study was a follow-up pilot study using the *Map4speech* mobile app to provide training and coaching for pre-school teachers online. The four aims of the study were to examine the effects of the app as a cross-training program for teachers, to

strengthen treatment fidelity among teacher providers in an early intervention preschool, to test the prototype of the mobile-app enabled training program for teachers, and to evaluate the acceptability of the training program to the teachers. The key objective of the study was to examine whether mobile-app enabled training could effectively help teachers improve and maintain intervention fidelity at 80% or above.

2. Methods

2.1. Design & setting

A multiple-baseline single case design was conducted across four teacher-child dyads to evaluate the effects of the *Map4speech* mobile-app-enabled training program on teacher intervention skills in terms of percentage of intervention fidelity (Kazdin, 2011). There were three phases in the experiment: baseline, teacher training (TT), and post training intervention (PTI). Each phase of the study was conducted when sessions for the previous phase were completed.

All phases of the experiment were conducted in the teacher's classroom at a local pre-school center in Singapore. Singapore is a city-state and island country in South-East Asia with English as the common language used in government, business, and school. The pre-school center provides three scheduled group therapy sessions per week (i.e. three days a week for 2 h each) for children with multiple disabilities, developmental delays and/or ASD. It utilizes Applied Behavioral Analysis (ABA), Treatment and Education of Autistic and Communication related handicapped Children (TEACCH), and Picture Exchange Communication Systems (PECS) as key intervention methods and modalities for their intervention. Upon inquiry, participating teachers indicated that the curriculum provided in the mobile app, i.e., naturalistic intervention, was new to them.

Individual teachers participating in the study conducted 1-to-1 intervention with a child with autism in the same classroom corner or individual room which was free from distraction from other teachers/children throughout the study. Sessions across all phases of the study were usually conducted during school days as per the convenience of the participating teachers' schedules. As the teachers had demanding teaching schedules, sessions were not conducted during all school days. The study was approved by the Institutional Review Board at Nanyang Technological University, Singapore. Administrative approval for the study was obtained from the pre-school center. Written consent was obtained from all teachers and parents of children that participated in the study.

2.2. Participants

Four teacher-child dyads were recruited from a pre-school center that provides early intervention services to children with developmental disabilities in Singapore. The research team contacted the pre-school center, which in turn disseminated information about the study to their teachers. All teachers participating had at least either a post-secondary educational degree, an advanced diploma in special needs, or certified training in ASD. Their years of working with children with ASD ranged from 1.5 to 11 years (Table 1).

Prospective child participants were identified by teachers and screened by the research team to determine their eligibility for the study. Teachers were asked to identify children who met the following inclusion criteria: a) a formal diagnosis of ASD made by a registered psychologist in Singapore, based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), b) an age between 2 and 6 years; and (c) an expressive language level of less than or equal to 18 months on the Vineland Adaptive Behavior Scales (Sparrow, Cicchetti, & Balla, 2005) and/or the MacArthur Communicative Development Inventories (CDI) (Fenson, Marchman, Thal, Dale, & Reznick, 2007). Parents of potential child participants were invited for further screening and participation of the study. Four children met the inclusion criteria and were selected for the study. Table 2 details each child's functioning and language levels.

2.3. Materials

2.3.1. Intervention content

Each teacher was loaned an iPad containing the *Map4speech* mobile app, which was developed by the authors (Law et al., 2018). The intervention program introduces naturalistic language intervention (NLI; Charlop-Christy & Carpenter, 2000) which is also considered a naturalistic developmental behavioral intervention (NDBI) (Schreibman et al., 2015). This intervention program utilized and adapted a compact curriculum from Project ImPACT (Ingersoll & Dvortcsak, 2010), which aims to elicit functional

Table 1
Teacher Participant Characteristics at Intake Assessment.

Teacher	Age	Ethnicity	Educational level[a]	Years in teaching service	Years in teaching students with autism
Teacher 1	34	Malay	Post-secondary[b]	5	1.5
Teacher 2	26	Chinese	University degree	2.5	2.5
Teacher 3	22	Malay	Post-secondary	3	1.5
Teacher 4	48	Chinese	Post-secondary[b]	11	11

[a] All teachers were trained with *Certificate in Autism*.
[b] Teachers trained in *Advanced Diploma in Special Needs*.

Table 2
Child Participant Characteristics at Intake Assessment.

Child	Chronological Age	Adaptive Behavior Composite - Standard Score (Overall adaptive level) on Vineland[a]	Age Equivalent on Vineland Receptive and (Expressive) Language	Age Equivalent on MacArthur CDI[b] Receptive and (Expressive) Language	DSM-5 Classification
Child 1	4 years 5 months	Not obtained	13 months (3 months)	13 months (9 months)	ASD
Child 2	4 years 9 months	58 (Low)	19 months (8 months)	> 18 months (9 months)	ASD
Child 3	3 years 6 months	64 (Low)	11 months (16 months)	16 months (13 months)	ASD
Child 4	5 years 1 month	54 (Low)	18 months (14 months)	14 months (13 months)	ASD

[a] Sparrow et al. (2005).
[b] Fenson et al. (2007).

communication in young children with ASD. The adoption and selection of key naturalistic and behavioral strategies was a careful process which considered local customization and the minimum skills necessary for effectiveness in implementation (Neta et al., 2015). The curriculum has four key parts (See Table 3): TT1: Follow your child's lead; TT2: Imitate and animate; TT3: Make moments for togetherness; and TT4: Prompt, reward and expand. The intervention program involves developmental elements such as conducting an intervention within the context of the child's daily routine and environment, setting goals in relation to typical child development, and increasing teacher's responsiveness to child's communication and behaviors. It also involves behavioral components that emphasize of using strategies based on the principles of ABA with the use of direct prompting strategies and natural reinforcers to teach and encourage communication in children with ASD. The four parts of the curriculum were organized into eight learning stages in the mobile app (See Table 3) so that teachers only learned 1–2 intervention skills at each time. Further details can be found in Law et al. (2018).

2.3.2. Instructional design and andragogy

Within the app, teachers were trained to use the intervention procedure with the instructional framework of Behavior Modeling Training (BMT; Decker & Nathan, 1985) in the following sequence – modeling, retention, behavioral rehearsal and feedback, and transfer of training. BMT derives from Bandura and Walters' (1977) social learning theory and is widely used for adult skill training. BMT is similar to Behavioral Skills Training (BST) (Dib & Sturmey, 2012). Both BST and BMT involve training components such as instructions, modeling, rehearsal, and feedback. However, compared to BST, BMT utilizes a fixed sequence of training components in order to achieve training outcomes. Research shows that BMT is effective in producing long lasting behavioral change after training (Taylor, Russ-Eft, & Chan, 2005). The andragogical sequence was translated to the mobile app interface structure for training and learning. In each training stage, there are five application features that correspond to the BMT sequential process. These include: (a) *instructional videos* (modeling and retention), (b) *quick check* (retention), (c) *interactive game* (retention), (d) *practice video* (behavioral rehearsal), and (e) *feedback* (feedback and transfer of training). Each iPad was also installed with Skype™, an application software for free video chat and voice call. Skype™ served as a means to provide feedback and coaching to teachers on their acquisition of intervention skills, primarily in Phase 2 of the study (i.e. Teacher Training). Teachers worked through the training components and the stages sequentially. They were not able to access other components or stages because the components were locked. They had to pass each component/stage successfully (e.g. 100% usage or 100% of correct entries) in order to unlock the next training component. See Law (2016) for further details of the instructional design.

2.3.3. Toys used for intervention materials

Teachers were provided with a unique set of six to eight highly preferred toys that were developmentally appropriate and stimulating for each child as determined by the results of a preference assessment. These toys were used throughout all phases in the study, and included a train set, toy cars, soap bubbles, building blocks, and a spinning top, among others.

Table 3
Map4speech Curriculum & Corresponding Mobile App Stage.

Curriculum	Mobile App Stage	Number of Culminated Intervention Skills to be taught
Introduction	Stage 1: Introduction*	0
Part 1: Follow your child's lead	Stage 2: Follow your child's lead	4
Part 2: Imitate and animate	Stage 3: Imitate and animate	6
	Stage 4: Expand your child's language	7
Part 3: Make moments for togetherness	Stage 5: Make moments for togetherness	8
Part 4: Prompt, reward and expand	Stage 6: Prompt, reward and expand 1	10
	Stage 7: Prompt, reward and expand 2	10
Summary	Stage 8: Putting it altogether*	10

Note. All stages are supported with five application features, i.e., instructional videos, quick check, interactive game, practice video and feedback except for Stage 1 & 8 with no interactive game.

2.4. Procedures

Before the commencement of the study, each parent and each teacher of a participating child attended an individual intake assessment session in the pre-school center. The goals of this session were to obtain written consent for child and teacher participation, collect demographic data on the participants, conduct a preference assessment to identify highly preferred toys, collect baseline data, and orient the respective teachers to the *Map4speech* mobile app program. Teachers also signed a loan agreement for using the iPad in the study. Following this, a multiple baseline design was initiated.

2.4.1. Phase 1 - baseline

Baseline had two purposes: a) to evaluate teachers' current skill levels in communication intervention in children with ASD before initiating training, and b) to orient teachers to the *Map4speech* mobile app after the completion of baseline sessions. Baseline sessions for each teacher-child dyad were chosen a priori between 5 and 14 sessions (i.e., 5, 9, 11, & 14 sessions accordingly). Participants were assigned to a different number of baseline sessions according to their time preferences and availability. During baseline, teachers were asked to engage in play with their respective child participant using selected toys. They were encouraged to play with their respective child as they usually would in their classroom settings. Specifications on the type and process of play were not provided to the teachers. Each session lasted for two minutes and was recorded via the *Map4speech* "Record Video" facility. The shortest baseline period lasted for 1 day with 5 sessions and the longest baseline period lasted 4 days with 14 sessions. Baseline sessions ended when a decreasing or stable trend was observed in the teachers' intervention fidelity data.

At the end of baseline, teachers were asked to set a communication goal for intervention for their respective child. Communication goals for each of the four children included increasing the frequency of independent requests using gestures (i.e., pointing with index finger) and/or single words (e.g. bubbles). Then the teachers were introduced to the *Map4speech* mobile app in a face-to-face session. A username and password were provided to log onto the mobile app. Each teacher practiced using the mobile app Stage 1 under the researcher's guidance, including how to watch the instructional video, how to participate in the quick check and the interactive game, how to record and send a practice video, and how to use skype™ to participate in a feedback session with the researcher. They were also asked to produce a simulated practice video and send it to the research team via the 3G network service.

2.4.2. Phase 2 – teacher training

The purpose of Phase 2 Teacher Training was to train teachers to implement the naturalistic language intervention in a progressive and sequential manner, utilizing the mobile app features (i.e., Instructional Video, Quick Check, Interactive Game, Practice Video and Feedback) across the four curriculum content areas (i.e., Mobile App Stage 2–7). During Phase 2, the effects of the mobile app training were evaluated using data that was collected on teacher behaviors by the app. Teachers were coached and given live feedback via Skype after each submission of the practice videos.

Teacher training started at Stage 2 immediately after baseline sessions were conducted and after the orientation. In each stage, teachers followed the learning sequence independently at their own pace but were encouraged to complete viewing of the Instructional Video and do the Quick Check and the Interactive Game within 1–2 days. No restrictions were placed on the number of times the teachers viewed an instructional video, or attempted the quick check quiz and interactive game as long as they fulfilled the passing requirement to go to the next component or stage (i.e., 100% video view-through rate or 100% correct answers). Teachers were to find a 15-min time slot to do 1-to-1 intervention with their new learned skills with their respective child, up to three times per week. From these 15-min intervention sessions with their student, they were to record two or three, 2-min video clips and send them to the researcher via a one-press button in the mobile app with the 3G mobile network. Given restrictions on the university server space for this project and observations from a previous study conducted with parents using the Map4speech mobile app (Law et al., 2018), the research team determined that 2-min videos would be adequate to capture the teachers' intervention skills. Video clips were sent and saved securely in a server where only members of the research team were notified and could access them via a user name and password.

Upon receiving the practice video clips from the teachers via the app, the research team scored both teacher and child behaviors for each video clip. The primary trainer (i.e., the first author) who provided the feedback was a psychologist with more than 15 years of experience in autism assessment and intervention. She followed a standard format for feedback and coaching to teachers across all videos (Law et al., 2018). In this way, each teacher's gains in intervention skills and its corresponding impact on their child's communicative responses were evaluated. The practice video clips were used to provide constructive feedback to teachers about how they could improve and strengthen their intervention skills in subsequent practice sessions. All feedback sessions were conducted via Skype™. The key components of a feedback session included having a scored teacher practice video, using the 'share screen' function in Skype™ to watch the practice video together with the teacher, affirming the teacher's correct application of skills, and highlighting as well as demonstrating any missing intervention skills.

The average teacher training period across all four teachers was approximately 7 weeks (Range = 5.5–8 weeks). On average, each teacher produced 26.5 videos in Phase 2 (Range = 25–30 videos) (See Table 4). The average number of feedback sessions provided across all four teachers was 9 sessions in Phase 2. Teacher 1 received 11 feedback sessions (M = 16 min; Range = 10–25 min). Teacher 2 received 8 feedback sessions (M = 13 min; Range = 6–23 min). Teacher 3 received 9 feedback sessions (M = 14 min; Range = 8–22 min). Teacher 4 received 8 feedback sessions (M = 12 min; Range = 7–18 min).

Intervention skills across the eight learning stages or four curriculum content areas (i.e., Part 1–4) were cumulative. Hence, teachers were required to be fluent with the application of intervention skills in the previous stages before learning new skills. Teachers were required to attain 90–100% intervention fidelity of intervention skills in two consecutive practice videos in order to

Table 4
Number of Practice Videos Produced and the Time Spent by Each Teacher Across Phases.

	Number of Practice Videos produced	Days/weeks Used	Average Number of Videos Per Day
Phase 2 Teacher Training			
Teacher 1	25	10 days/8 weeks	2.5
Teacher 2	25	9 days/8 weeks	2.8
Teacher 3	26	9 days/5.5weeks	2.9
Teacher 4	30	11 days/7 weeks	2.7
Phase 3 Post Training Intervention			
Teacher 1	12	6 days/4 weeks	2
Teacher 2	6	2 days/1 week	3
Teacher 3	12	4 days/3.5weeks	3
Teacher 4	–	–	–

successfully complete a learning stage. For instance, in Stage 2, teachers were required to perform all four intervention skills with accuracy in two practice videos to reach at least 90% performance criterion before moving to the next learning stage. Similarly, in Stage 3, teachers were required to perform all six intervention skills in two consecutive practice videos before meeting the performance criterion to move to the next learning stage. A stringent performance criterion was put in place to ensure adequate fluency and practice of intervention skills until Stage 8. This also helped ensure better chances of sustaining high levels of intervention fidelity across all 10 intervention skills in the post training intervention phase. After achieving success with the previous learning stage, the teachers were required to follow the same five pedagogical components in a sequential manner in the next learning stage. Successful completion of teacher training occurred when teachers could apply all 10 intervention skills at 90–100% intervention fidelity (i.e., at least 9 of the 10 intervention skills) over two consecutive practice videos.

2.4.3. Phase 3 - post training intervention

The purpose of Phase 3 post training intervention was to evaluate whether teachers could implement all 10 intervention skills after completion of the teacher training program and in the absence of support from the research team. Teacher behaviors continued to be scored and monitored via practice videos uploaded via the *Map4speech* mobile app. Feedback sessions via Skype™ were only provided upon teacher request. The post training intervention phase followed immediately after the teacher training phase.

Three of the four teacher-child dyads participated in Phase 3 of the study. Teacher 4 could not continue with Phase 3 of the study due to time constraints imposed by reaching the end of school term. The average post training period across the three teachers was approximately 4 days. On average, each teacher produced 10 videos in Phase 3. Teacher 1 produced 12 intervention videos, Teacher 2 produced 6 intervention videos, and Teacher 3 produced 12 intervention videos. In terms of feedback, only one feedback session of 12 min was provided to Teacher 1 upon her request and none were provided to Teacher 2 and Teacher 3.

At the conclusion of the *Map4speech* mobile app training program, teachers were asked to complete the *Treatment Acceptability Rating Form-Revised* (TARF-R; Reimers, Wacker, & Cooper, 1991).

2.5. Measurement outcomes

2.5.1. Teacher intervention fidelity

Ten teacher behavior variables were measured in discrete categorization of occurrence/nonoccurrence in each 2-min practice video (i.e., yes/no). Refer to Table 5 for teacher-related behavioral definitions. Behavior occurrences were converted into a summary score of percentage (0%–100%) for intervention fidelity. The percentage of intervention fidelity indicated the extent of application of the 10 teacher intervention behaviors in each practice video (i.e. each session) across each of the eight learning stages or four curriculum content areas and across all three phases of the study.

2.5.2. Inter-observer agreement (IOA)

All practice videos and the performance criteria for feedback sessions were scored by the first author. In addition, a reliability data collector scored at least 33% of all practice videos in each phase to obtain the IOA for teachers' intervention behaviors. This individual was trained in behavioral recording procedures prior to collecting data for this study. She had a doctorate in Education and was blind to the various phases of teacher training when recording data. She also scored at least 25% of the feedback sessions for the IOA on the performance criteria. Inter-Observer agreement (IOA) was calculated using a frequency ratio. It was calculated by dividing the number of agreements of both data collectors by the total number of agreements and disagreements and multiplying the result by 100. The percentages of IOA across teachers ranged between 85% and 98% for teachers' intervention behaviors, and between 87.5% and 100% for the performance criteria for feedback sessions across participants.

2.5.3. Social validity

Social validity and treatment acceptability were measured with the *Treatment Acceptability Rating Form-Revised* (Reimers et al., 1991). TARF- R is commonly used to measure treatment acceptability in clinical settings and consists of 21 items, using a Likert-type seven-point scale. It has an internal consistency of 0.92 (Carter, 2007).

Table 5
Teacher Behavior Variables and Definitions.

	Teacher Variables	Definitions
1	Wait and follow the child	Teacher *waits* for the child to choose his activity as long as the child is taking time to choose his toys or activities. Teacher must wait for child to start playing with his preferred toy or activity first before he joins in, especially at the beginning of the play session.
2	Stay face to face with your child	Teacher stays within child's line of sight. Teacher may need to *sit at* child's level and orientate herself toward the child so that she may make eye contact with him occasionally for at least 45 seconds.
3	Join in child's play	Child *initiates* play with the preferred item or activity and Teacher *joins in* and facilitates child's play as he/she engages in these items/ activities. E.g. Teacher can hand play items to child or add something to his play.
4	Give comment	Teacher *says* something related to the toys child is playing with (e.g. say "bubbles"), child's actions (e.g. "up"), comments on his/her own actions (e.g. "teacher stacks"), or the situation ("We are having so much fun") for at least once in 2 min. It can be a sentence.
5	Imitation	Teacher fulfil 5a or 5b or 5c
5a	Imitate child's play	Teacher imitates what child is doing with a toy (excluding imitating inappropriate behavior) for at least 12 seconds intermittently (Note: not the child imitating the Teacher).
5b	Imitate child's gestures/ body movements	Teacher imitates and exaggerates child's gestures or body movements (excluding imitating inappropriate behavior) for at least once in 2 min.
5c	Imitate child's word or vocal sounds	Teacher imitates child's vocalizations or words (excluding imitating inappropriate behavior) at least once in 2 min.
6	Animate in play	Teacher *exaggerates* her *gestures* (e.g. point with a bigger movement), *facial expressions* (e.g. make smiles more obvious and bigger) or *vocal quality* (e.g. by increasing the volume, or the tone) to attract child's attention, for at least 12 seconds intermittently or 4 distinctive instances. (E.g. say "uh-oh", "oh-no", "Wow" sound effects, audible gasps
7	Expand child's language	Teacher uses the predetermined set goals and words which are suggested by the psychologist to model and expand child's language for at least once in 2 min.
8	Communication Temptations	Teacher fulfils 8a or 8b or 8c
8a	Use playful obstruction	While child is actively playing with a toy, Teacher triggers child's communication using the following steps 1. *Use the same anticipatory phrase (e.g. "1-2-3-stop")* 2. *"Playfully" obstruct his play* 3. *Pause and provide a target word before letting child resume his play*
8b	Use balance turn taking	While child is actively playing with a toy, Teacher triggers child's communication using the following steps: 1. *Say "Child name's turn" while child is playing with the toy* 2. *Use an anticipatory phrase to get a turn (e.g. "Teacher's turn)* 3. *Take a turn for a few seconds* 4. *Pause and provide a target word before returning the toy to child (e.g. it can be Johnny's turn)*
8c	Use other communicative temptations	Teacher triggers child's communication using the following steps *1. Put child's favorite item within his visual sight but out of his reach (out of reach) OR* *Withhold parts of toys (e.g. fruits without knife)(Missing portion) OR* *Hold toys up in front of her own face (control access) OR* *Provide materials/opportunities child needs to help to play(Assistance) then* *2. Pause, provide a target word before giving the child the favorite item/activity*
9	Prompt	Teacher fulfils 9a or 9b or 9c
9a	Verbal prompt	Teacher prompts by using words or phrases for child to imitate for request. Verbal prompts can include verbal modelling (e.g. "say bubbles"), verbal delay (e.g. Teacher pauses, gasps and delays in saying the target word, "I want …… bubbles"), verbal choice (e.g. "do you want blue or red?"), verbal instruction (e.g. "point!"), or verbal question (e.g. what do you want?). This is different from giving comments as Teacher will continue to give prompts (e.g. verbal prompt, physical prompt) to pursue child's response to use the target word or gesture.
9b	Gesture prompt	Teacher prompts by showing a gesture to child (within his line of sight) so that child will imitate for request (e.g. pointing to an object)
9c	Physical prompt	Teacher prompts by holding the child's hand to produce a gesture for request (e.g. shape his hand to point to an object)
10	Reward or praise	Teacher fulfil 10a or 10b
10a	Reward child	Teacher rewards child *immediately* with what he asks for (i.e. give the *tangible item* within 5 seconds).
10b	Praise child	Teacher praises the child immediately (within 5 seconds) after he has made a request (prompt or without prompt) with much enthusiasm and animation, like "yay!", "well done". Praise can be given to spontaneous requests of the child.

3. Results

3.1. Teacher intervention fidelity

Fig. 1 illustrates gains in intervention skills across the four teachers during baseline, teacher training and post training intervention. The x-axis denotes the number of sessions and the y-axis indicates the percentage of teacher intervention fidelity. All teachers performed below 80% for intervention fidelity across all baseline sessions. Mean percentages for teacher intervention fidelity was 48% (Range - 30%–70%). Mean percentages for intervention fidelity for Teacher 1 was 48% (Range - 40%–60%), Teacher 2 was 54% (Range 40%–70%), Teacher 3 was 50% (Range 40%–60%), and Teacher 4 was 42% (Range - 30%–50%).

During teacher training, mean percentages for intervention fidelity gradually increased for all four teachers (M = 65%; Range -

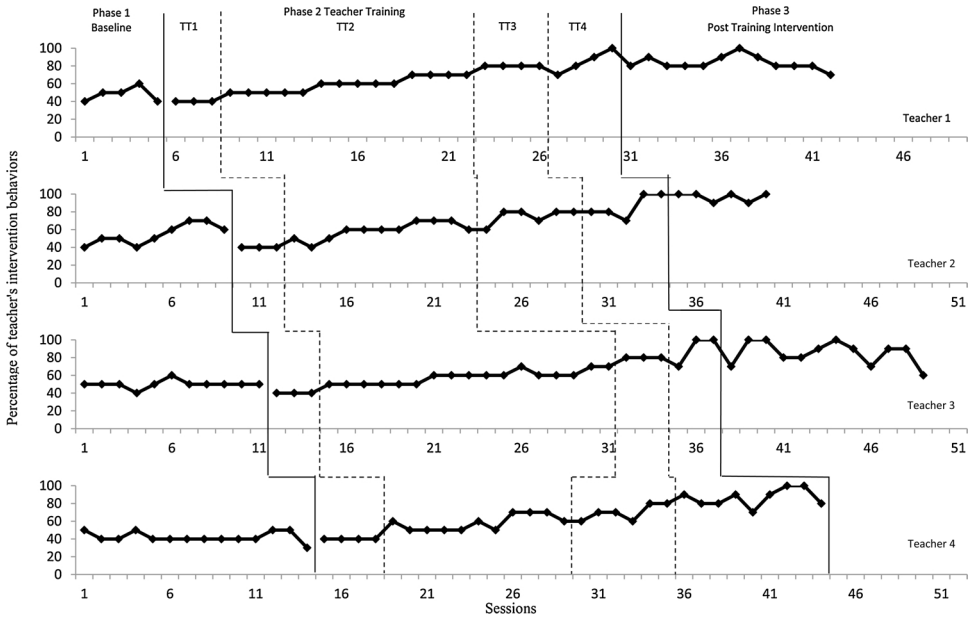

Fig. 1. Percentages of intervention skills attained across four teachers from Phase 1 to Phase 3.
Note. TT1 = Part 1: Follow Your Child's Lead; TT2 = Part 2: Imitate and Animate; TT3 = Part 3: Make Moments for Togetherness; TT4 = Part 4: Prompt, Reward & Expand.

40%–100%). Substantial increases were observed during TT3 (M = 75%; Range - 70%–80%) and TT4 (M = 87%; Range = 70%–100%). Participation in the mobile-app-enabled training resulted in higher mean percentages of intervention fidelity in Teacher 1 (M = 64%; Range - 40%–100%), Teacher 2 (M = 66%; Range - 40%–100%), Teacher 3 (M = 62%; Range - 40%–100%), and Teacher 4 (M = 67%; Range - 40%–100%).

Teachers exhibited at least 80% intervention fidelity for most sessions in Phase 3 of the study, however, the intervention fidelity levels of three of the four teachers were not at the ideal of 90%. At least 80% intervention fidelity was observed for 12 of 14 sessions for Teacher 1 (M = 84%; Range - 70%–100%), although a decreasing trend was observed for the last few sessions. For teacher 2, over 90% intervention fidelity was observed across all five sessions (M = 97%; Range - 90%–100%). For Teacher 3, a variable decreasing trend was observed across the 12 sessions during post training intervention (M = 85%; Range - 60%–100%).

3.2. Social validity

Teachers completed the TARF-R after the completion of all phases of the study. Teacher acceptability ratings ranged between 60–70% with mean ratings of 60.3% for Teacher 1, 70% for Teacher 2, and 60% for Teacher 3. A TARF-R score was not obtained for Teacher 4 as there were many missing items. These ratings suggest that the *Map4speech* mobile app program was moderately acceptable to the teachers.

4. Discussion & implications

This study evaluated the effects of a mobile-app-enabled training program, *Map4speech*, to improve fidelity in naturalistic intervention among four preschool teachers working with young children with ASD. Results indicated that the mobile-app-enabled training was effective in raising teachers' intervention fidelity, though only to an average of 86%, and not the targeted 90%, and not to a level of consistency needed to achieve enduring, effective outcomes with children (Law et al., 2018).

The study makes three important contributions to improving efforts to address the need for effective, evidence-based intervention for children with ASD. First, results demonstrate the potential benefits of mobile learning (mlearning) to train intervention agents and to improve their intervention fidelity. Second, consistent with results of an earlier study with parents (Law et al., 2018), this study highlights the usefulness of behavioral modeling training (BMT) as an effective andragogical framework for both the design of future training apps and for training parents and teachers to do naturalistic intervention. Finally, this study points to several important implications for teacher training in the context of EBI implementation and dissemination in school contexts. Here we elaborate on these contributions, discuss the limitations of the study and consider next steps for improving mobile app enabled training for teachers.

4.1. Benefits of Map4Speech as an effective training tool

The positive results of teachers' increments in intervention skills demonstrate the potential for mobile-app-enabled training to produce high fidelity of intervention implementation. The mobile-app-enabled program was effective in raising teachers' intervention fidelity to an acceptable level of at least 86% in Phase 3, although we aimed to train teachers to achieve 90%. In the previous study with parents, clear evidence of the combination of the distinctive skills was only apparent at Phase 2 when skills such as increasing a child's social engagement and prompting and rewarding the child are taught. Intervention only began to affect children's communication when parents' intervention fidelity reached 80%. These results suggested that 80% was the minimum fidelity needed to achieve effective outcomes.

In the present study, fidelity levels at baseline for the four teachers ranged between 30% and 70%, with an average of 48%. Unlike parents, teachers clearly already had some skills at baseline but their fidelity was low because they could not implement all 10 intervention skills. They were using some skills effectively, but not all, and their use was inconsistent. Results suggested that the teachers' skills began to consolidate toward the end of Phase 2 of the program because average fidelity rose to 84–97% in Phase 3. These findings are congruent with Stahmer et al. (2015) who demonstrated that teachers already possessed some naturalistic intervention skills but were not at a level of intervention fidelity necessary to achieve the desired outcomes in children with ASD.

Dissemination of naturalistic intervention in school environments has been very challenging. Traditionally, considerable training and resources have been needed in school settings to train teachers to implement evidence-based practices. Little is known about intervention fidelity of implementation by teachers in school settings and few interventions have been systematically tested in school contexts (Mandell et al., 2013; McConachie et al., 2015; Suhrheinrich et al., 2013). Results of this pilot study suggest that mlearning may be an effective approach to training because the current mobile-app-enabled training provides standardized video instructions on intervention, quiz tests, and a video game and thus helps maintain proper fidelity throughout the training process without added variation of training facilities or personnel (Wainer & Ingersoll, 2013). However, replication with larger samples is needed to identify ways to improve the app enabled learning so that intervention fidelity is maintained over longer periods of time.

4.2. Behavioral modeling training (BMT) is an effective andragogical framework

A missing piece of many mlearning training studies is an androgogical framework for training (Dunleavy et al., 2019). There is not a one-size-fits-all andragogy for all contexts and cultures, but one framework that has been considerably researched in adult learning contexts is Behavior Modeling Training (BMT; Taylor et al., 2005). We used and tested BMT as the framework for the andragogical design of the training program embedded in *Map4Speech*. Embedded in the app, the framework is systematic in utilizing components such as modeling, retention, behavioral rehearsal, feedback and transfer of training. App components were designed according to the framework and provided a standard format and an exact training protocol to ensure consistency and fidelity across training of different individuals (Law et al., 2018). We believe *Map4speech* was effective and efficient in raising intervention fidelity in this study because of *both* the highly customized, immediate feedback from the quick checks and game components of the app, as well as the personalized and focused feedback on specific skills delivery. The results are consistent with Suhrheinrich's (2011) conclusion - that individual coaching with observation and feedback helps teachers master intervention techniques.

Mobile-app-enabled training programs for fidelity maintenance have implications for professional training and development in ASD intervention. Training effectiveness can potentially reduce the waiting time for intervention of children with ASD and their families as many more teachers could be trained in less time with the use of technology. Since teachers vary in the time they need to master intervention skills (Stahmer et al., 2015), the personalized customization of an app allows each teacher to spend only the time he or she needs to achieve the desired level of fidelity. Teachers in the current study were surprised that they could be trained and demonstrate all ten intervention behaviors in a 2-min video in six to eight weeks, given that they only saw their individual student three times a week for 15 min each. In view of this, the use of mobile app enabled training might significantly reduce financial, organizational, personal and societal costs (Neta et al., 2015).

4.3. Implications for teacher training and dissemination in school settings

The current mobile-app-enabled training program can potentially fill the gap because psychological interventions (e.g. autism interventions) are hard to disseminate and implement because face-to-face training, supervision and coaching are expert-based, labor-intensive and costly (Fairburn, Allen, Bailey-Straebler, O'Connor, & Cooper, 2017). Digitalizing training can potentially meet the worldwide demands for children who need autism intervention. Digital psychological treatments and interventions have been the focus of considerable research recently (Fairburn & Patel, 2017) and can be similar to digital training as they involve training components for skill practice. A consistent finding is that digital interventions that are supported by coaching demonstrate greater effectiveness than unsupported ones, possibly because supportive interventions achieve better treatment adherence, enhance accountability and improve motivation with a therapeutic bond (Mohr, Burns, Schueller, Clarke, & Klinkman, 2013). Supported digital interventions have been as effective as face-to-face treatments, but most studies are small scale. Needed are larger scale studies and studies that compare digital interventions with traditional face-to-face interventions for the same concerns to evaluate their relative merits for effectiveness and cost-effectiveness. There is also a need to evaluate the impact of functionality of a digital intervention on its effectiveness as it has obvious implications for the design of future interventions (Fairburn & Patel, 2017).

The current mobile app enabled training program has the potential to be developed and established as an essential tool for a train-the-trainer model. Evidence based interventions are often not used at the community level because there are problems with training

teachers and with developing a system which can disseminate the practice of intervention knowledge and skills (Stahmer et al., 2015). Suhrheinrich (2015) tested a train-the-trainer model that involved training supervisors to train teachers in order to disseminate pivotal response training to school settings. All teachers implemented almost 90% of PRT components and maintained their abilities at follow-up. A combination of technology and a train-the-trainer model could be an effective method of disseminating evidence-based practices in school settings and provide cost-effective training and ongoing support to teachers. There is good evidence that underserved groups in some countries are accessing digital trainings (Dunleavy et al., 2019), therefore there is good potential that the mobile-app-enabled training can serve as an innovative solution to the shortage of ASD professional training, in both developed and developing countries.

4.4. Limitations

This study has several limitations. First, as a pilot test, the sample size is very small. Multiple baseline single case design also has its limitations for drawing conclusions about treatment effect size (Rhoda, Murray, Andridge, Pennell, & Hade, 2011). Larger replication studies are needed to confirm the findings. Second, increased workloads toward the end of the school term meant that one participant did not completely finish the training program. Increasing workloads and end-of-year distractions may also have contributed to the decline in fidelity scores observed toward the end of the post intervention. Third, and very importantly, although teachers were provided with a rationale for the intervention as well as for the study design, their beliefs, assumptions, and expectations regarding approaches to intervention were not assessed prior to the study (Borrelli, 2011). Their views were reflected by the acceptability ratings which only ranged between 60–70% in TARF-R. Teachers may have perceived the monitoring and coaching as more oversight rather than support. We believe that we may have not adequately prepared them to understand the need for fidelity and the potential personal benefits to them as interventionists. There was limited time to build rapport with each teacher participant in early stages of the study. Fourth, the post training phase on average lasted for 4 days across the participants due to constraints in the school's calendar. Ideally, more sessions required to be conducted to ascertain post-training treatment fidelity results for three of the four teachers. Hence, extended post-training and follow-up phases would have helped evaluate maintenance effects of teacher intervention fidelity in the absence of training materials and researcher support.

4.5. Next steps for future research

Much more research is needed to examine how fidelity monitoring is perceived and conducted and how it can be designed to enhance its benefits to children and providers alike, especially in school contexts. If teachers understand that high fidelity contributes to better child outcomes and staff self-efficacy, they may be motivated to work hard to achieve them. Future research with teachers should explore ways to prepare teachers for active engagement in fidelity monitoring.

Researchers also need to understand what are the minimally essential skills needed to sustain high-quality implementation of EBIs. App embedded training programs must by their nature be limited in the scope of skills they train. Comparative studies are needed to determine a core of minimally essential skills for effective intervention. These could then be prioritized for inclusion in app embedded training programs. Comparative studies are also needed to identify the tools and strategies that make it possible to sustain EBI implementation with high quality.

4.6. Conclusion

It is clear that there is much to learn about maximizing the effectiveness of naturalistic intervention in classroom settings. Teachers sometimes feel justified in their conclusions that evidence-based intervention does not work very well because they do not understand the importance of fidelity or they do not have the means to monitor their own fidelity of intervention. Many effective intervention techniques may be abandoned, not used at all or used incorrectly due to a lack of fidelity monitoring (Benner, Beaudoin, Chen, Davis, & Ralston, 2010). This pilot study is an important step toward improving the quality of intervention for children with ASD. Results suggest that mobilizing training in a digital application may be one means to efficiently adapt evidence-based practices for community settings. Monitoring fidelity requires extra staff time and cost, but the cost is much less than that of poorly implemented treatment (Stahmer et al., 2015). Although scaling studies are needed to test the utility and effectiveness of *Map4speech* across a much larger number of users, initial results suggest that it might be possible to provide high quality training and build capacity within systems effectively and efficiently via mobile platforms.

Authors' contribution

GL conceived of the study, participated in its mobile app and single case experimental design, conducted the experiment and coordination of the study, performed the statistical analysis, and drafted and revised the manuscript. A.D. participated in its single-case experimental design, helped with analysis and interpretation of data, drafted, and revised the manuscript. MN conceived of the study and participated in its mobile app and single case experimental design, participated in revising the manuscript. All authors read and approved the final manuscript. The views expressed in this paper are the authors' and do not necessarily represent the views of NIE.

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