



Virtual Training of Dental Students in Zambia To Improve the Care of Patients with Neurodevelopmental Disabilities

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Abstract

Many individuals with neurodevelopmental disabilities (NDD) lack sufficient dental care. The global scarcity of dental providers with specialized training to care for this population is a key barrier to appropriate and timely treatment. Research suggests that training dental professionals to use behavioral interventions to increase the comfort of individuals with NDD during dental exams would help address oral health disparities. The purpose of the study was to examine the outcomes of an approach to effectively disseminate and sustain this training to professionals residing in Zambia. Fifteen dental students participated in a group virtual training to learn how to implement a package of behavioral interventions, including noncontingent breaks, reinforcement for cooperation, and patient access to preferred stimuli. Effects of the training on performance were evaluated via a concurrent multiple-baseline across participants design with four participants and a pre- and post-training design with the remaining participants. Results replicated and extended prior research (Matteucci et al., 2023) by including a larger number of participants, evaluating participants' performance with actual patients, assessing maintenance, and preparing an on-site dental professional to continue the training with future students. Nearly all participants improved their performance following the training. These findings have implications for utilizing cross-disciplinary collaborations to scale up the dissemination of behavior-analytic technologies to professionals across the globe.

Keywords Behavioral skills training · Dental professionals · Dissemination · Oral health · Remote training · Virtual training

Routine dental exams are considered vital to maintaining good oral health. However, individuals with neurodevelopmental disabilities (NDD) have difficulty accessing necessary dental care compared to those without disabilities (Angelova et al., 2025; Chavis & Macek, 2022; Milano, 2017). Caregivers report challenges in finding den-

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tists who are willing to treat this population and who have the requisite training to do so effectively (Bastani et al., 2022; Duker et al., 2017; Hassona et al., 2021). As a result, many individuals with NDD do not receive regular dental care and may be unnecessarily exposed to risky interventions, such as restraint, sedation, and general anesthesia, when undergoing dental exams (Berens et al., 2022; Lim & Borromeo, 2019). Consistent with caregivers' concerns, dental students and professionals worldwide report receiving little if any specialized training on treating individuals with NDD and express a desire for more hands-on experience in this area (Balkaran et al., 2022; Byrappagari et al., 2018; Casamassimo et al., 2004; El-Yousfi et al., 2019; Mandasari et al., 2021; Tobis et al., 2024; Zare et al., 2025).

Difficulty managing uncooperative and challenging behavior (e.g., refusal to follow instructions, aggression, self-injury) during dental procedures is reportedly one of the most significant barriers to treating this population (Derbi & Borromeo, 2016; Duker et al., 2017; Milano, 2017; Sarvas et al., 2024; Zahran et al., 2022). These behaviors, along with anxiety and fear, are commonly evoked by aversive stimuli associated with dental clinic visits, such as loud sounds and uncomfortable dental procedures (Kupzyk & Allen, 2019). As such, dental professionals would particularly benefit from focused training on strategies to increase the comfort and cooperation of patients with NDD.

In recognition of oral health disparities experienced by individuals with NDD, U.S. government agencies and professional associations have enacted policies intended to increase their access to dental care. Most notably, the Commission on Dental Accreditation (CODA) now requires accredited dental schools to provide training on how to manage treatment for patients with disabilities (CODA, 2018). This mandate provides an opportunity for behavior analysts to disseminate evidence-based behavioral interventions to dental professionals. A variety of approaches, such as graduated exposure, escape extinction, and differential reinforcement, have been found to improve cooperation with health care routines and procedures (see reviews by Kupzyk & Allen, 2019; McAdam & Zhou, 2023). Among these interventions, several seem feasible for dental professionals to embed within routine dental exams. These more practical strategies include the use of noncontingent breaks, reinforcement for cooperation, and patient access to distracting stimuli (Allen & Wallace, 2013; American Academy of Pediatric Dentistry, 2024; Floríndez et al., 2025).

To help reduce barriers to care, practical strategies also are needed to effectively disseminate these types of behavioral interventions to large numbers of health care professionals. A few studies have evaluated the efficacy of behavioral skills training (BST) for preparing dental students and professionals to implement behavioral interventions with patients (e.g., Gaudins et al., 2012; Matteucci et al., 2023; Tufenk et al., 2015). Tufenk et al. (2015), for example, combined lectures, video models, role-play, and in-vivo practice with feedback to train three dental hygiene students to embed prompts and reinforcement into routine dental cleanings for children with developmental disabilities. Participants received a total of 9 to 11 h of training. Results showed that all participants implemented the skills with a high level of procedural integrity.

Matteucci et al. (2023) examined the efficacy of virtual, small-group BST to teach the use of "tell-show-do" (i.e., describing and modeling the dental procedure before

implementing it), noncontingent reinforcement in the form of access to a preferred toy, and praise plus breaks for cooperation during routine dental exams. The skills acquired during the virtual training transferred to an in-person mock exam in the absence of experimenter feedback for six of seven participants. The seventh participants' performance met the mastery criterion after the experimenter provided feedback. Participants' responses on a post-training survey indicated that they found the training content and interventions to be highly acceptable. One key limitation, however, was that the experimenters observed just one participant implement the interventions with an actual patient due to restrictions related to the COVID-19 pandemic at the time of the study. Thus, it wasn't clear whether the skills generalized from mock patients to actual patients.

Although promising, most training models that incorporate BST may not be sufficient to scale up the dissemination of behavior-analytic technologies to the large number of dental professionals across the globe who would benefit from this training. Prior studies with health care professionals utilized relatively intensive BST, including one-on-one or small-group practice with feedback from an expert until the participant met a performance criterion (e.g., Graudins et al., 2012; Hoang et al., 2024; Matteucci et al., 2023; Mery et al., 2022; Tufenk et al., 2015). Such training models may not be practical to embed within existing dental school curricula, particularly in areas of the world with limited experts on behavioral interventions for individuals with NDD, such as low- and middle-income countries (LAMICs). Although an estimated 80% of people with disabilities worldwide live in LMICs (World Health Organization, 2022), most prior research on teaching health care professionals to implement behavioral interventions with this population have occurred exclusively with those residing in the United States. Furthermore, specialized services for individuals with NDD are relatively scarce in LMICs.

Further research is needed on effective and efficient training models to employ with large groups of dental professionals. In particular, research is needed on models that could be easily incorporated into dental school curricula, reach students and professionals across the globe, align with the undergraduate and postgraduate curricula in special care dentistry recommended by the International Association for Disability and Oral Health (iADH, 2014), and use cross-disciplinary collaboration to ensure that dental professionals can sustain the training. Although asynchronous training in the form of manuals, videos, and computer-based instruction does not require the presence of a trainer, results of research on this approach have been somewhat inconsistent (see Marano et al., 2020 for a review). On the other hand, a voluminous literature has demonstrated the efficacy of synchronous, virtual training (see Tomlinson et al., 2018; Unholz-Bowden et al., 2020, for reviews), as well as train-the-trainer (i.e., pyramidal training) models (see Risse & Blair, 2025, for a review).

The purpose of this study was to extend the virtual training described by Matteucci et al. (2023) to dental students in Zambia, a LMIC in Sub-Saharan Africa where services for individuals with NDD are particularly limited (Pierucci et al., 2023; Saran et al., 2020; Scherer et al., 2024). The primary aim of the study was to replicate and extend Matteucci et al. by (a) including a larger number of participants, (b) evaluating the participants' fidelity to use the behavioral interventions with both simulated and actual patients, and (c) assessing performance several months after the training

to evaluate maintenance. The study also had two secondary aims. One secondary aim was to collaborate with an on-site dental professional to obtain input on the feasibility of the training and to prepare them to continue training future dental students. The other secondary aim was to evaluate the accuracy of participants' self-reported performance following exams with patients to determine if dental faculty may be able to rely on students' self-reports as a measure of training outcomes.

Method

Participants

Participants were 15 dental students (8 female and 7 male), aged 23 years to 25 years, enrolled in a Bachelor of Science in Dental Surgery program. They were recruited through a medical school in Zambia. To be eligible, participants had to be enrolled in their final year (6th year) in the Dental Surgery program, had completed all core preclinical and clinical coursework, and had to be willing to participate in both virtual and in-person sessions. All participants were fluent in English and Bemba, the native language of Zambia. Participants had previously received a lecture on how to conduct dental exams with pediatric patients that briefly discussed the use of praise, sporadic breaks, explanations of procedures, and labeling of tools, but had received no structured instruction or hands-on experience with patients with NDD. During the informed consent process, an experimenter informed participants about all study procedures, including the need for participants to conduct mock exams, for the experimenter to observe their exams with actual patients, and for the experimenter to video record all exams for the purpose of data collection. We randomly selected four out of 15 participants for an evaluation of the training via a concurrent multiple baseline design across participants; the remaining 11 participants experienced a pre- and post-training evaluation of the training (see Experimental Design section for further description). Participants received a certificate of training completion after the study. The study was reviewed and approved by the Institutional Review Board of the first and second authors' university (IRB#24–078).

Two experimenters conducted the study, hereafter designated as the “primary” and “secondary” experimenters. The primary experimenter was a graduate student in applied behavior analysis who resided in the United States and provided all training remotely. The secondary experimenter was an on-site dental professional who resided in Zambia. The secondary experimenter was the executive director of a non-governmental organization (NGO) that provided cost-free oral health promotion and preventive services for individuals with NDD in Zambia to combat oral health disparities. At the time of the study, the NGO operated within one town and served approximately 300 patients annually, including children and adults with a range of disabilities, most commonly autism spectrum disorder, cerebral palsy, hydrocephalus, and Down syndrome. Services included routine oral screenings, preventive and curative dental treatments, caregiver education, and oral health awareness campaigns tailored to individuals with special needs. In addition to direct care, the NGO collaborated with a medical school to offer annual clinical training in special care dentistry to

final-year dental students, thereby enhancing local capacity for inclusive oral health care delivery. The secondary experimenter had earned a Bachelor of Science in Dental Surgery from The Copperbelt University-School of Medicine in Zambia but had no prior experience in training others to implement behavioral intervention strategies during dental exams.

We recruited 16 patients for the baseline and post-training generalization probes through flyers and word of mouth. Patients received cost-free dental services through the NGO. All patients were informed of the research and consented to video recording. No information was collected on the patient's age or diagnoses. Data were collected on the participants' cooperative and uncooperative behavior during the exam.

The primary experimenter conducted the training virtually over a HIPAA-compliant version of the teleconferencing software Zoom (<https://www.zoom.com>). Participants received the virtual training at their residences in Zambia, and the primary experimenter delivered the training from her residence in the United States. Baseline, post-training, and generalization exams occurred at a dental facility located at the participants' medical school. Exams took place in a large room with exam chairs and all the dental tools needed to serve patients.

Materials

During all mock exams and generalization probes, participants had access to a visual, a quick reference guide, a task analysis of the dental exam procedures, and a squishy small pink toy that was placed on a table with the dental tools necessary to conduct the dental procedures. The visual consisted of six photographs depicting individuals receiving various dental procedures (i.e., inspection, brushing, flossing). The visual served to provide a model of the dental procedures for the patient. The quick reference guide provided a simplified description of the targeted behavioral interventions (see Table 1). The purpose of the quick reference was to serve as a self-mediated stimulus to increase the likelihood of generalization of the skills across patients and maintenance of the skills over time (Stokes and Osnes, 1989). We modified the dental exam task analysis used by Matteucci et al. (2023) with input from a dental professional in the United States and the secondary experimenter (see Table 2). Because dental professionals work in quadrants, the mock exam procedures focused on each of the four quadrants of the mouth for inspection, brushing, and flossing to match the preexisting training of the dental students. The dental tools included a dental probe and mirror for inspecting, a toothbrush for brushing, and floss for flossing. Immediately before and after the training, we also gave participants a handout (slightly modified from Matteucci et al., 2023) describing the behavioral interventions.

Table 1 Quick reference form provided to participants

Provide access to a preferred item for the entire exam
Before any procedure: tell them about the procedure, show them the tools, and show them what the procedure looks like
Praise any cooperation from the patient and thank them for coming
Provide 15-second breaks after each step, after working for 15 s, and when you finish a procedure
Provide 5-second breaks following uncooperative behaviors and move on after the third attempt

Table 2 Mock exam procedures

Inspection
1. Touch bottom left teeth
2. Touch the bottom right teeth
3. Touch top left teeth
4. Touch top right teeth
Brushing
1. Brush bottom left teeth
2. Brush bottom right teeth
3. Brush top left teeth
4. Brush top right teeth
Flossing
1. Floss between bottom left teeth
2. Floss between bottom right teeth
3. Floss between top left teeth
4. Floss between top right teeth

The primary experimenter created seven patient scripts for the mock patient to follow during the baseline and post-training mock exams. The scripts randomized the occurrence of cooperative and uncooperative behavior (e.g., stating “no,” or engaging in challenging behavior) during specific procedures of the mock exam (e.g., “engage in noncompliance with top teeth brushing”). The scripts ensured an equal number of opportunities to respond to both behaviors during each mock exam. However, it should be noted that some opportunities were dependent on the participant’s responding. For example, if the participant immediately moved to the next step in the exam following one instance of problem behavior, they did not contact the next opportunity for problem behavior or cooperation in that step as specified in the script.

The primary experimenter created two different types of data collection sheets for participants to use during the study. A self-report data collection sheet instructed the participant to indicate whether they had implemented each of the targeted behavioral interventions during the immediately preceding exam (see further description in the Response Measurement, Procedural Integrity, and Reliability section). The second data sheet was identical to the self-report data sheet, but it instructed the participant to indicate whether one of their classmates had implemented each of the targeted behavioral interventions during a mock exam.

The primary experimenter created a 52-min video presentation that included a lecture covering applicable research (i.e., statistics of oral health for individuals with NDD, caregivers and dental practitioners’ perception of dental care challenges, behavior analytic strategies used in dental exams), how to incorporate the recommended behavioral interventions, and how to collect data on the accuracy of implementation. The presentation informed participants that they would be asked to collect data on the accuracy of their peers’ implementation of the interventions, provide their peers with performance feedback during the role-play portion of the training, and self-report similar data on their own performance following some exams. We embedded video models for each behavioral intervention throughout the presentation, along with a full exam that provided examples of both correct and incorrect implementation. To demonstrate accurate data collection, we displayed a model depicting how to collect data via Qualtrics (<https://www.qualtrics.com>) alongside a model of a full

dental exam. A final video model demonstrated how to practice the targeted interventions with a mock patient via Zoom to help prepare participants for the virtual practice portion of the training. In the video models, the mock patient engaged in cooperative behavior, uncooperative behavior (e.g., turning away, saying “no,” refusing to follow instructions), and challenging behavior (e.g., attempting to hit the dental professional, hitting their own head).

The experimenters recorded all baseline, post-training, and generalization exams using a HIPAA-compliant version of Zoom via a laptop placed on a nearby table or a cellular device held by a research assistant.

Response Measurement, Procedural Integrity, Reliability, and Social Validity

The primary experimenter collected primary data for the baseline and post-training exams. The secondary experimenter collected primary data for the generalization probes because the participants spoke in the native language of Bemba during these exams.

The primary dependent variable was the participants’ percentage of opportunities to correctly implement the behavioral interventions (see Table 3) while completing mock dental exams or when providing dental services to patients (i.e., generalization exams). Data collectors used paper and pencil, a computer, or a tablet to collect data on the implementation of the behavioral interventions for each exam during baseline, training, post-training, and generalization. Data collected during training were used to provide behavior-specific feedback to participants only (i.e., they were not graphed). For each dental exam, we divided the number of individual interventions implemented correctly by the dental professional by the total number of opportunities for that intervention and multiplied by 100. We then calculated the mean percentage of correct implementation across all interventions by adding the percentages for the individual interventions and dividing by the total number of interventions scored.

The secondary dependent variable was the participant’s accuracy to self-report if they had or had not implemented each behavioral intervention. We collected these data during baseline and post-training generalization probes. The participant used a self-report data collection sheet that instructed them to indicate “yes” if they had implemented the behavioral intervention for every possible opportunity during the exam (e.g., provided praise every time the patient cooperated with a step) and to indicate “no” if they had failed to implement the intervention for one or more of the

Table 3 Behavioral interventions

1.	Provide access to preferred item (e.g., sensory toy)
2.	Label material or instrument (e.g., mirror)
3.	Show and point to picture of the procedure
4.	Provide praise contingent on cooperation
5.	Provide a 5-s break following non-compliance or aggression
6.	Move to next procedure following the third attempt
7.	Provide a 15-s break after implementing a dental procedure for longer than 15 s
8.	Provide a 15-s break between procedures
9.	Provide praise for completing the exam

possible opportunities (i.e., a dichotomous or all-or-nothing form of data collection). The data collection sheet consisted of nine behavioral interventions that overlapped with those scored by the experimenter (see Table 3). The participant's data were compared to experimenter's data to calculate the participant's accuracy to self-report. To calculate accuracy, we converted the experimenter's data to be comparable to the participant's data by summing the total number of interventions the participant implemented correctly on every possible opportunity and then dividing by the total number of interventions. For each exam, we divided the number of interventions with agreement between the participant and experimenter by the total number of interventions and multiplied by 100.

The primary experimenter remotely trained two research assistants to collect data on the secondary experimenter's procedural integrity. One research assistant was a dental professional who worked with the secondary experimenter and the other research assistant was an undergraduate student with prior data collection experience. They collected data on the secondary experimenter's procedural integrity for 100% of baseline and post-training mock exams and 47% of generalization probes. The assistants scored the accuracy with which the secondary experimenter provided the materials listed previously, withheld feedback from the participants on their performance, and ended the exam when the participant vocally stated they were finished or would use restraint. Although we also intended to collect data on the accuracy of the secondary experimenter's feedback to participants at the end of each generalization exam, this aspect was not captured on the video and, thus, could not be scored. For each exam, the number of individual components implemented correctly by the secondary experimenter was divided by the total number of components and multiplied by 100. The secondary experimenter's procedural integrity was 100% for all exams.

The primary experimenter also trained the two research assistants to measure interobserver agreement (IOA) by independently scoring the correct implementation of the behavioral interventions. For the multiple baseline design participants, the assistants independently collected data on the participants' performance during at least 50% of baseline exams, during 100% of post-training exams (except for one participant), and during 100% of generalization exams. For the pre- and post-training design participants, the assistants collected data during 27.3% of baseline mock exams, 36.7% of baseline generalization probes, 36.4% of post-training mock exams, and 27.3% of post-training generalization probes. We calculated IOA by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. An agreement was defined as both observers scoring an intervention as implemented correctly or incorrectly on that opportunity. Table 4 displays the mean IOA for each participant across conditions. An assistant collected data on the secondary experimenter's procedural integrity for 15% of mock exam exams, and IOA was 100% across all exams. IOA for the secondary experimenter's procedural integrity was not measured for the generalization probes because one research assistant who understood Bemba instead scored primary data on the procedural integrity of the secondary experimenter during those probes.

The primary experimenter asked the participants to complete the social validity surveys from Matteucci et al. (2023) at two different points in time to obtain their opinions of the training and the behavioral interventions. To learn about their

Table 4 Mean interobserver agreement for participants

Participants	Baseline		Post-Training	
	Mock Exams	Generalization Probes	Mock Exams	Generalization Probes
Bennie	80.0%	81.8%	N/A	80.8%
Link	88.9%	80.0%	85.7%	80.8%
Mina	85.4%	81.8%	84.9%	90.5%
	(range, 83.3%–87.5%)			
Teddy	87.6%	91.3%	90.3%	100.0%
	(range, 86.7%–88.5%)			
All Pre-Post	88.4%	88.0%	89.8%	84.4%
	(range, 84.2%–91.7%)	(range, 82.6%–90.9%)	(range, 82.7–100.0%)	(range, 83.3%–85.7%)

Table 5 Mean ratings (with Ranges) on social validity survey completed Post-Training

Items	Score
1. Most dental/dental hygiene students would find this training acceptable	6.22 (1–7)
2. This training should improve my effectiveness when conducting a routine dental exam with patients diagnosed with IDD	6.47 (6–7)
3. I would suggest this training to others	6.17 (1–7)
4. This training will benefit the patients/future patients in my clinic	6.41 (6–7)
5. This training is consistent with other types of trainings I have received	5.29 (1–7)
6. I liked this training	6.00 (1–7)
1 = Strongly Disagree; 7 = Strongly Agree	

opinions of the training, participants completed one Qualtrics-based survey after the virtual group training (see Table 5). After all participants had completed their final generalization probe, they also completed a second Qualtrics-based survey so that we could learn their opinions of the behavioral interventions (see Table 6).

Experimental Design

We evaluated the effects of the training on participants' performance using a concurrent multiple-baseline across participants design with four participants and via a pre- and post-training design with 11 participants. We conducted the multiple-baseline across participants design by staggering the number of baseline exams across four participants who completed all mock baseline exams on the same day. To avoid elongated baselines and increase the practicality of the study, the participants in the pre- and post-training design completed a single baseline exam. This approach made it more practical to embed the study within the context of a natural training setting

Table 6 Mean ratings (with Ranges) on social validity survey at study completion

Items	Score
1. How acceptable do you find the behavioral procedures? (1 = not at all acceptable; 7 = very acceptable)	6.15 (5–7)
2. How likely is the behavioral procedures to make permanent improvements in your patient's behavior during future dental appointments? (1 = unlikely; 7 = very likely)	5.92 (4–7)
3. How costly will it be to carry out this these behavioral procedures with your patients? (1 = not at all costly; 7 = very costly)	3.08 (1–7)
4. How willing are you to carry out these behavioral procedures? (1 = not at all willing; 7 = very willing)	6.77 (5–7)
5. How much appointment time will it be needed for you to carry out these behavioral procedures with you patients? (1 = little time; 7 = much time)	3.69 (1–7)
6. How confident are you that these behavioral procedures will be effective for your patients during future appointments? (1 = not at all confident; 7 = very confident)	6.23 (5–7)
7. How willing would you be to change your exam routine to carry out these behavioral procedures? (1 = not at all willing; 7 = very willing)	6.69 (6–7)
8. How disruptive will it be to your practice to carry out these behavioral procedures? (1 = not at all disruptive; 7 = very disruptive)	2.67 (1–5)
9. How effective are these behavioral procedures likely to be for your patients during future appointments? (1 = not at all effective; 7 = very effective)	6.38 (5–7)
10. How well will these procedures fit into the typical dental routine? (1 = not at all well; 7 = very well)	6.23 (4–7)

(for similar examples, see Hinkle & Lerman, 2023; Shore et al., 1995), particularly because conducting the exams required help from the secondary experimenter. Prior research findings also provide evidence that participants are unlikely to use the targeted behavioral interventions before training (see Hoang et al., 2024; Matteucci et al., 2023). We introduced the training simultaneously for all participants after the baseline mock exams were completed. Except for those who completed maintenance exams, all participants completed just two post-training exams (one exam with a mock patient and one with an actual patient) to increase the practicality of the study.

Procedures

Secondary Experimenter Training

The primary experimenter trained the secondary experimenter to perform the following responsibilities: (a) recruit participants and patients, (b) complete the informed consent process and obtain informed consent from the participants and patients, (c) schedule all mock exams and generalization probes, (d) serve as a simulated patient for all baseline and post-training mock exams, (e) serve as a simulated patient for practice exams during the group training, (f) collect primary data on participants' performance during all generalization probes, and (g) conduct follow-up training for

two participants who were unable to complete the virtual group training due to connectivity issues. All training occurred via Zoom.

The primary experimenter gave them a handout with detailed task analyses of each stage of the research (i.e., baseline, training, post-training) and instructions to conduct exams (e.g., materials needed, the setup of exams, how to collect procedural integrity data). The handout also instructed them when to review forms with participants (i.e., consent to participate and observe) and included email templates to send to the participants at each stage of the study so that participants would have all required materials links to forms (e.g., social validity survey). The primary experimenter then reviewed the handout, consent forms, and all other materials needed to conduct exams (e.g., scripts for mock exams, scoring protocol for procedural integrity) with the secondary experimenter.

To train the secondary experimenter to serve as a simulated patient, the primary experimenter provided a video model of an exam conducted with a participant from a previous evaluation in the United States and also modeled the procedures in role play with the secondary experimenter acting as the dental participant. The secondary experimenter then practiced reviewing consent forms and conducting exams in role play with the primary experimenter acting as the dental participant. The secondary experimenter continued to role play exams with all patient scripts until achieving 100% accuracy across three role-play exams. The secondary experimenter also was given access to the training video described previously. The primary experimenter then trained the secondary experimenter to collect data on participants' implementation of the behavioral interventions using the procedures described previously. Throughout the duration of the study, the primary experimenter remained in frequent contact with the secondary experimenter to ensure completion of the planned number of exams for each participant and to provide feedback on procedural integrity.

Baseline

The secondary experimenter gave each participant all dental tools (i.e., dental explorer, mirror, toothbrush, and floss), the visual, the quick reference (Table 1), and a copy of the task analysis (Table 2). We included the quick reference to evaluate whether written instructions alone would be adequate to produce the desired outcomes. The secondary experimenter instructed the participant to complete a dental exam to the best of their ability and to pretend to do the dental work. The participant then completed an in-person mock dental exam with the secondary experimenter acting as the patient, and with no other participants in the room. The mock patient randomly followed one of the seven scripts described previously. To save time, the participant completed only two of the four main portions of the dental exam (e.g., flossing and brushing), which the experimenter randomly selected. The secondary experimenter terminated exams when the participant stated that the exam was finished or that they would use sedation or restraint. However, the secondary experimenter did not tell participants about these termination criteria to ensure the most naturalistic performance and did not provide performance feedback after exams.

Training

About 24 h before the training, the primary experimenter emailed all participants the task analysis, visual, handout describing the behavioral interventions, the quick reference, and the paper data collection sheet with a link to the Qualtrics version of the data collection sheet to use if electronic reporting was preferred. The primary experimenter then held a virtual group training over Zoom for all participants plus six medical school staff. All participants used their cell phones to attend the training. The training lasted 1.5 h (a duration determined by the secondary experimenter), and included the 52-min prerecorded presentation, virtual role-play sessions, and a question-and-answer period.

During the virtual role-play sessions, participants volunteered to conduct a mock dental examination with the mock patient (i.e., the secondary experimenter). During the exam, the other participants collected data on the volunteer's implementation accuracy using the paper or Qualtrics-based data collection sheet. After the exam, the primary experimenter asked one participant to volunteer to give feedback to their classmate based on their data collection. The primary experimenter immediately confirmed or corrected the feedback and then provided any additional feedback needed such that the dental examiner received feedback on their implementation of all behavioral interventions during the training. Within the time available for role play, two participants conducted a dental examination with two randomized portions (as done in baseline) and two participants provided feedback. During the final 10 min of the training, the primary experimenter encouraged participants to participate in a question-and-answer period and then asked them to complete the social validity survey. Within 48 h of the training, the primary experimenter e-mailed the participants a link to the 52-min prerecorded presentation, the social validity survey (in case they did not complete it after the training), the treatment component handout, and quick reference.

Two participants missed part of the virtual group training due to connectivity issues. Thus, they attended a separate 1-hour make-up virtual training conducted by the secondary experimenter 3 days after the original training. The primary experimenter intermittently observed the training. During this make-up training, the secondary experimenter played a recording of the training at the point at which the participants lost connectivity and then both participants completed two virtual role plays with the secondary experimenter acting as the patient. The participants provided feedback to each other following each exam.

Post-training

Post-training exams occurred 1 week following the training. Procedures were identical to those in baseline. Participants received no feedback about their performance; this permitted us to assess the effects of the virtual training per se on their subsequent performance with patients.

Generalization Probes (Baseline and Post-Training)

All but one participant completed an in-person dental exam with a patient before and after training. No participant provided services to the same patient in baseline and post-training. The secondary experimenter attended all in-person dental exams. The baseline generalization probe occurred after the baseline mock exam(s). The post-training generalization probe occurred 2 weeks after the training. Participants had access to the visual, quick reference sheet, leisure items, and dental tools that were provided by the clinic associated with the NGO. The secondary experimenter terminated exams when the participant stated that the exam was finished, after 15 min, or following the use of sedation or restraint. We did not inform participants about the termination criteria to ensure the most naturalistic performance. Immediately after the generalization probe, participants completed the self-report data collection sheet based on their performance during the exam. The secondary experimenter did not provide performance feedback after any baseline generalization probe. However, after the post-training generalization probe, the secondary experimenter did provide positive and corrective feedback on participants' implementation of the behavioral interventions immediately after the participant completed the self-report data sheet.

Maintenance Probes

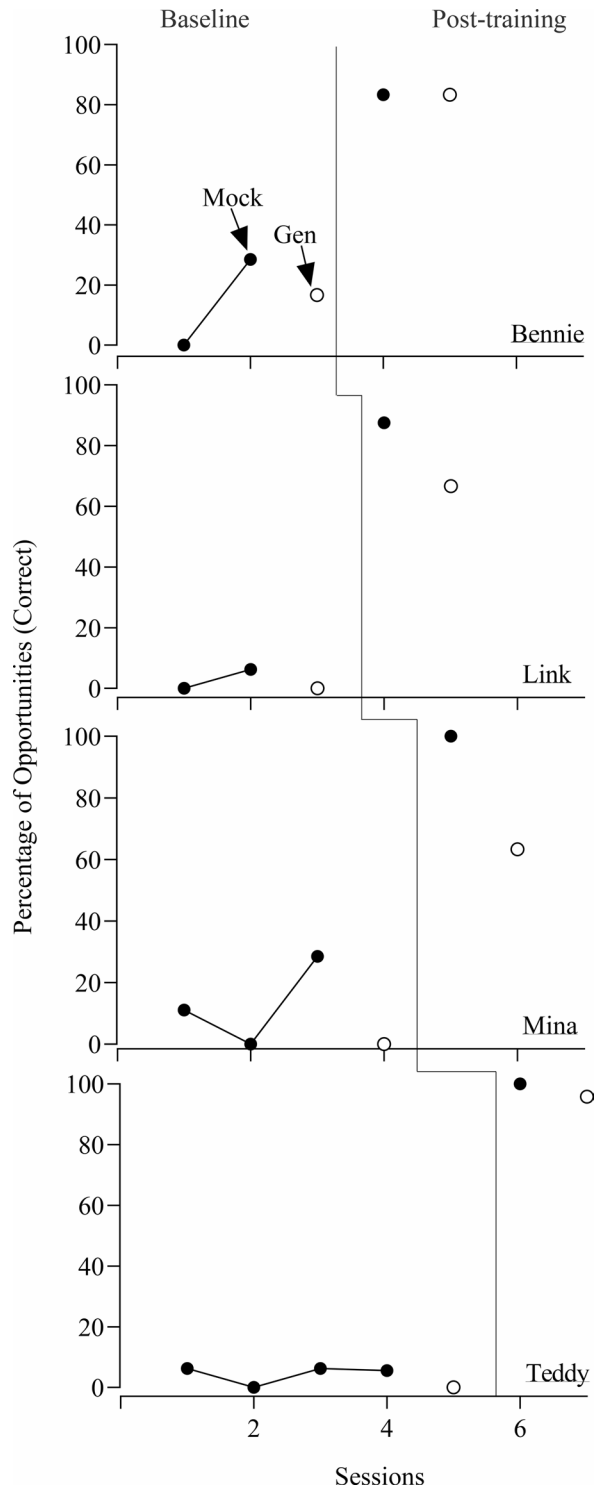
Three participants volunteered to complete an in-person dental exam with a patient 4 months after the training. The secondary experimenter attended all exams. The participants received a link to the 52-min prerecorded presentation, handout, and quick reference via e-mail 3 days before the probes. Immediately before the exams, the secondary experimenter reminded the participants to incorporate the behavioral interventions and to use the quick reference. We included the reminder because the students' supervisors typically provided this type of prompt as part of training. The participants completed dental work with a different patient than they had seen in the previous generalization probes. The secondary experimenter collected data on the participants' implementation of the behavioral interventions and provided praise or corrective feedback at the end of the patient exam.

Results

Results for the four participants in the multiple baseline design (Bennie, Link, Mina, and Teddy) are shown in Fig. 1. All participants correctly implemented the behavioral interventions during a low percentage of opportunities during baseline mock exams ($M = 14.3\%$ [range = $0\% - 28.6\%$] for Bennie; $M = 3.1\%$ [range = $0\% - 6.2\%$] for Link; $M = 13.2\%$ [range = $0\% - 28.6\%$] for Mina; and $M = 4.5\%$ [range = $0\% - 6.2\%$] for Teddy). Only Bennie implemented any of the behavioral interventions correctly during baseline generalization probes by correctly providing praise at the end of the exam.

We considered a post-training performance level of at least 80% to be feasible and sufficient because, in prior relevant research, the majority of participants met

Fig. 1 Percentage of opportunities with correct responding during baseline and post-training mock and generalization (gen) exams for participants in multiple baseline design



or exceeded this level after a brief training (Lehardy et al., [in press](#)) and because patients' cooperation improved when dental professionals implemented these procedures with 80% of greater accuracy (Berens et al., [2022](#)). Following the training, all participants demonstrated the behavioral interventions on at least 83% of the opportunities during the mock exam. (Bennie and Link were the two participants who had connectivity issues during the initial virtual training and attended the 1-hr virtual make-up session with the secondary experimenter.) Bennie, who implemented the behavioral interventions correctly on 83.3% of opportunities, did not consistently label the instrument and never displayed the visual. Link, who implemented the interventions on 87.5% of opportunities, did not always move to the next procedure when the mock patient was uncooperative on three attempts. Both Mina and Teddy always implemented 100% of interventions correctly.

Reductions in fidelity occurred for all participants except for Bennie during the post-training generalization probes. Bennie implemented the behavioral interventions correctly on 83.3% of opportunities and only failed to provide behavior-specific praise for completing the exam. Link correctly implemented the behavioral interventions on 66.7% of opportunities and never displayed the visual, nor provided a longer break when the patient cooperated with a lengthy dental procedure. Mina, who correctly implemented the behavioral interventions on 63.3% of opportunities, also never provided a longer break when the patient cooperated and did not provide behavior-specific praise for completing the exam. Teddy implemented the behavioral interventions on 95.8% of opportunities, failing to provide praise for cooperation on just one opportunity.

Results for the remaining 11 participants in the pre- and post-training design are shown in Fig. 2. During baseline mock exams, the mean percentage of correct implementation across participants was 11.2% (range=0%–35.1%). The behavioral interventions implemented correctly were providing access to a preferred item (three participants) and labeling the material or instrument used before beginning the procedure (two participants). During baseline generalization probes with patients, the mean percentage of correct implementation across participants was 10.6% (range=0%–33.3%). Interventions implemented correctly were labeling the material or instrument used before beginning the procedure (three participants) and providing praise at the end of the exam (four participants).

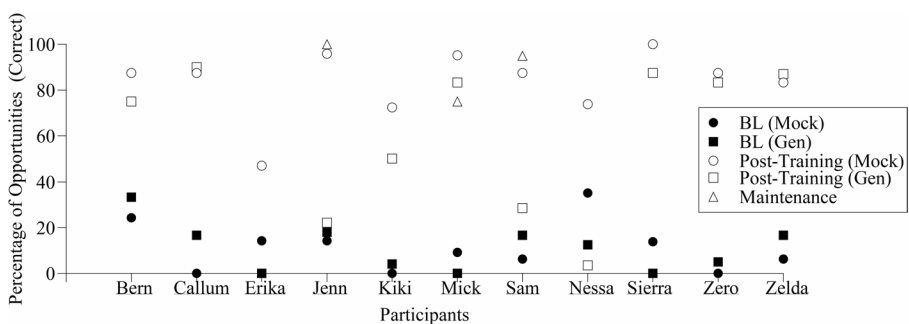


Fig. 2 Percentage of opportunities with correct responding during baseline, post-training and maintenance exams for participants in pre-post design

During the post-training mock exam, mean performance increased to 83.4% (range=46.9% – 100%), with eight of 11 participants exceeding 80%. Interventions implemented inconsistently or incorrectly across participants included labeling the material or instrument (three participants), displaying the visual (two participants), providing praise for cooperation (four participants), delivering a 5-s break following uncooperative behavior (three participants), moving to the next dental procedure after multiple unsuccessful attempts (three participants), and providing a longer break following cooperation with a procedure (five participants). During post-training generalization probes with patients, performance remained above 80% for five of the 10 participants ($M=60.5\%$; range=3.6% – 88.6%). Interventions implemented inconsistently or incorrectly included providing the preferred item (three participants), labeling the material or instrument (two participants), displaying the visual (one participant), providing praise for cooperation (six participants), delivering a 5-s break following uncooperative behavior (one participant), providing a longer break following cooperation with a procedure (eight participants), and delivering praise at the end of the exam (five participants). It should be noted that just seven patients engaged in uncooperative behavior during the exams.

Interestingly, two participants whose performance declined during post-training generalization probes volunteered to participate in the maintenance probes (Jenn and Sam). Performance for both increased to high levels when working with another patient 4 months after the training. Sam implemented the behavioral interventions on 95.5% of opportunities, only failing to consistently deliver praise. Jenn implemented all interventions correctly on 100% of opportunities. The performance of the third participant who conducted the maintenance exam (Michael) decreased slightly to 72.5%. He never provided the preferred item or a 15-s break when the patient cooperated with lengthier dental procedures.

Table 7 displays the percentage of agreement between participants' self-report and experimenter-collected data. These data exclude Erika, who did not complete the post-training generalization probe. Recall that the experimenter's data on the accuracy of the behavioral interventions for each opportunity were converted to dichoto-

Table 7 Percentage of agreement between participants' Self-Report and Experimenter-Collected data

Participants	Baseline Generalization Probes	Post-Training Generalization Probes
Bennie	77.8%	66.7%
Link	66.7%	55.6%
Mina	55.6%	66.7%
Teddy	55.6%	100%
Bern	66.7%	88.9%
Callum	33.3%	55.6%
Jenn	66.7%	55.6%
Kiki	44.4%	66.7%
Mick	77.8%	88.9%
Sam	88.9%	66.7%
Nessa	11.1%	Not Completed
Sierra	88.9%	77.8%
Zero	77.8%	77.8%
Zelda	77.8%	100%

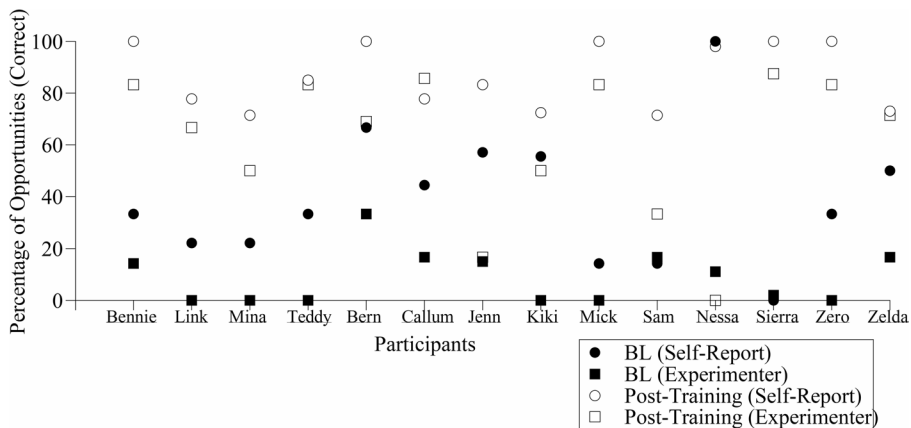


Fig. 3 Participants' self-report and experimenter-collected data on performance during baseline and post-training

mous scoring (i.e., whether the intervention was implemented correctly on every opportunity) to be comparable to the participants' self-reported data. Mean agreement prior to training was 63.5% (range=11.1% – 88.9). Just two participants (Sam and Sierra) had a level of agreement that exceeded 80% during baseline. Mean agreement after training was 69.0% (range=0% – 100%). Seven of the 14 participants showed an increase in agreement, but just four participants exceeded 80% agreement.

To evaluate more closely whether self-report data might be an adequate substitute for experimenter- or instructor-collected data, we plotted the data collected by the participant and experimenter prior to and following training. Figure 3 displays each participant's self-reported data on performance and the experimenter's data on their performance for the baseline and post-training generalization probes. The experimenter's data indicated that performance improved for 12 participants from baseline to post-training (i.e., everyone but Jenn and Nessa). The self-reported data from all 12 participants also indicated that their performance improved from baseline to post-training. For the two participants who did not improve, one reported that they had improved (Jenn) and the other reported 100% fidelity in both baseline and post-training (Nessa). Overall, 12 of the 14 participants overestimated their performance relative to the experimenter's data during baseline. The mean percentage of overestimation was 35% (range=14.3% – 88.9%). Similarly, 11 of the 14 participants overestimated their performance following training. The mean percentage overestimation was 31.6% (range=11.1% – 100%). These results suggest that the training did not improve participants' accuracy to self-report their behaviors after dental examinations.

Another way to compare participant- and experimenter-collected data was to determine the number of participants who agreed with the experimenter that their post-training performance with the patient met or exceeded 80%. After the experimenter's data were converted to the dichotomous form of recording, performance exceeded 80% for six participants (Bennie, Teddy, Callum, Mick, Sierra, Zero). This matched the outcomes obtained with the more precise data collection system for all

participants except Zelda, whose performance decreased to 71.4% under the dichotomous data collection system. All but one of those participants (Callum) reported that they correctly implemented at least 80% of the interventions. Callum reported that they implemented 77.8% of the interventions, a slight underestimation. Zelda's data matched that of the experimenter (both were 71.4%). For the seven participants who did not implement at least 80% of the interventions correctly, four agreed with the experimenter that their performance fell below that level. Thus, overall, 10 of the 14 participants (71%) accurately reported whether they had met a mastery level of 80% following the training.

On the social validity survey, participants' responses indicated high levels of agreement with statements about the acceptability and efficacy of the training (see Table 5). The statement about the similarity of the training to other types of trainings received the lowest mean rating. On the social validity survey completed immediately after the generalization exam with the patient (see Table 6), participants' responses indicated that (a) they found the behavioral interventions acceptable and feasible to incorporate into their practice, (b) they thought the interventions were likely to be effective and beneficial for their patients, and (c) they would be willing to use them in the future.

Discussion

These findings suggest that virtual group training with the assistance of an on-site professional may be an effective, efficient approach for disseminating behavioral interventions to dental professionals across the globe. Results replicate and extend those of Matteucci et al. (2023) by including a larger number of participants, evaluating the participants' fidelity during exams with both simulated and actual patients, assessing a subset of participants' performance 4 months after the training, and preparing an on-site dental professional to assist with the training. Nearly all participants showed substantial improvements in their performance during mock exams following a brief, virtual group training that could be readily incorporated into dental school curricula. Furthermore, half of the participants continued to perform at the desired level when working with an actual patient in the absence of instructor feedback. When the secondary experimenter reminded three participants to use the behavioral interventions with a patient 4 months later, they did so with high levels of accuracy. These findings suggest that dental faculty could readily incorporate this training within the model that is typically used for preparing dental professionals (i.e., delivering lectures, observing practice with patients). Post-training performance outcomes varied widely, however, suggesting that this initial training will not be sufficient for all dental students and professionals.

Our findings also provide some support for the use of cross-disciplinary collaboration to disseminate behavioral interventions via a pyramidal training model. Preparing the professional to complete the responsibilities of the secondary experimenter with a high degree of fidelity took approximately eight 1-hour virtual meetings. We increased the ease with which the dental professional could continue the training in the future by providing her with the video recording of the didactic presentation

and all materials (e.g., visual, quick reference, handouts). Going forward, the dental professional would only need to conduct post-training mock or generalization exams with dental students after delivering the 1.5-hour, largely didactic group training. In fact, following this project, the collaborating medical school formally adopted the training content and now collaborates with the NGO to annually offer clinical training in special care dentistry to final-year students. This partnership demonstrates a sustainable model that could continue without external experts through a train-the-trainer approach. Given its virtual delivery and minimal resource requirements, the model could be readily adapted by other dental schools in low- and middle-income countries to strengthen capacity in special needs oral health care. With that said, it is likely important for dental professionals to have continued access to behavioral experts to consult on individual cases and to help promote continued use of evidence-based behavioral interventions.

Responses on the social validity surveys were similar to those obtained in prior research (Matteucci et al., 2023), despite likely cultural differences between participants residing in Zambia versus the United States. Participants may have found the training and its content acceptable because it focused on increasing cooperation and comfort of individuals with NDD during dental procedures. In surveys, dental professionals have described behavioral difficulties as one of the most significant barriers to providing care to individuals with NDD and reported a desire for more training in behavioral strategies (e.g., Balkaran et al., 2022; Byrappagari et al., 2018; El-Yousfi et al., 2019; Tobis et al., 2024). Further, dental students and professionals have reported a desire for more hands-on training in the care of individuals with developmental disabilities (e.g., Takeshita & Srinivasan, 2024). The content and modality of our training align with the special care dentistry undergraduate and postgraduate curricula recommended by the International Association for Disability and Oral Health (iADH, 2014). The virtual modality also increased the accessibility of this training to a country with a limited number of relevant behavioral professionals. Our results have broader implications for using this training model to disseminate evidence-based interventions to professionals worldwide. It should be noted, however, that the participants completed the social validity surveys in the presence of the experimenters, which may have led to some reactivity.

Participants had little to no prior experience or coursework that focused on using behavioral interventions during dental exams, except for a prior lecture on strategies to use with pediatric patients. Interestingly, during baseline, the most frequently observed omission was labeling the dental tools before using them (three participants) and providing praise (five participants), both of which were included in the prior lecture. However, elements of the virtual group BST responsible for the improvements in performance during exams were not delineated. Due to time constraints, participants engaged in limited active responding following the didactic portion of the training. Only a small portion of participants had the opportunity to engage in virtual role play or provide feedback to their classmates, although the experimenter prompted all participants to collect data on their classmates' performance during the virtual role play. Furthermore, the role play included just two randomly selected portions of a typical dental exam. Prior research has demonstrated the efficacy of such brief BST when training health care professionals to implement these behavioral interventions

(Lehardy et al., [in press](#)). However, the variable post-training performance of participants – both in role play and with actual patients – indicates that further research is needed to determine if an expanded version of this training, with more extensive and greater opportunities for practice, would lead to improved outcomes.

This evaluation was limited in other respects. First, most participants were observed with just one mock patient and one actual patient following training, which restricted our evaluation of the outcomes. This is particularly problematic because only about half (i.e., seven) of the participants encountered uncooperative behavior during the exam with an actual patient. As such, we had no opportunity to determine whether those participants would have responded correctly to the behavior. Furthermore, we could not determine the extent to which the patient sample in this study represented the population who would most benefit from these practices.

Second, we did not collect data on the accuracy of the secondary experimenter's feedback to participants or measure the reliability of the secondary experimenter's procedural integrity data for generalization exams. The experimental design also was somewhat limited because we collected repeated baseline measures for just four of the 15 participants. As noted previously, our goal was to embed the study within the context of a natural training setting and recruit the assistance of an on-site dental professional who had limited time. Utilizing a single baseline measure for the remaining participants and just two post-training measures for all participants increased the practicality and feasibility of the research. Results of prior research utilizing the same design provide some support for this approach (e.g., Hinkle & Lerman, 2023; Shore et al., 1995). Furthermore, prior research indicates that dental and medical students are unlikely to use the targeted behavioral interventions prior to training (e.g., Allen et al., 1992; Graudins et al., 2012; Hoang et al., 2024; Matteucci et al., 2023), suggesting that extensive baselines may have been unnecessary in this case.

We established a desired post-training performance level of at least 80% based on prior work training health care professionals (e.g., Berens et al., 2022; Hoang et al., 2024; Lehardy et al., [in press](#); Matteucci et al., 2023). Although prior findings suggest that this level of performance is both realistic and adequate, no research has directly evaluated the necessary and sufficient level of procedural integrity when implementing interventions to improve the comfort and cooperation of individuals with NDD.

We also found limited success when evaluating the participants' accuracy using the self-report data collection system. We expected the training to improve their self-reported accuracy in implementing the targeted behavioral interventions, but most participants overestimated their performance by similar amounts when working with patients before and after the training. The most promising finding was that 71% of participants accurately reported whether they had met or exceeded the desired performance level following the training. Given the preliminary nature of this evaluation, further research is needed to determine if dental faculty can rely on students' self-report as a rough measure of training outcomes.

In particular, further research is needed on ways to improve the accuracy of students' self-report. The dichotomous form of data collection used in this study may have contributed to the inaccuracy of the reporting. That is, students were asked to report accurate implementation *only* if they implemented the intervention on every opportunity. Students may have had difficulty differentiating whether they had some-

times implemented a particular behavioral intervention versus always implemented it (i.e., delivered praise following *some* instances of cooperation versus *all* instances of cooperation). The tendency for students to overestimate their accuracy is consistent with this possibility. Thus, future research might examine the accuracy of a system that permits students to report whether they never implemented, sometimes implemented, or always implemented each behavioral intervention. In addition, future research could target the accuracy of self-report per se via BST.

Continued research is needed to determine if this model would be effective and acceptable to health care professionals across the globe, including dentists, nurses, and physicians and, if adopted, whether this model would lead to more successful outcomes for patients. Future research on educating health care professionals should be competency based; involve direct, clinical practice; and include cross-disciplinary collaboration to ensure the sustainability of the training (Ailey et al., 2024). Closer attention to and refinement of asynchronous forms of training, such as instructional manuals and videos, also might help efforts to scale up the dissemination of behavioral interventions to larger numbers of professionals. It will be important to evaluate the impact of health care provider training on the accessibility and quality of care for persons with NDD in future research. Related to the impact is the need to identify the level of procedural integrity necessary to increase the comfort and cooperation of patients with NDD during health care exams.

The global prevalence of health care disparities for individuals with NDD has prompted numerous calls for more research and education in this area (Ailey et al., 2024; Weitzman et al., 2024; World Health Organization, 2022). As a result of these disparities, individuals with NDD experience higher levels of disease and health complications than those without disabilities. Most alarming, the higher mortality rate in individuals with NDD has been linked to inadequate healthcare intervention and lack of preventative care (Hosking et al., 2016; O’Leary et al., 2018). Individuals with disabilities have the right to receive accessible, high-quality health care using the least restrictive interventions (United Nations Convention on the Rights of Persons with Disabilities, 2006). Research has identified a number of factors that make it difficult for this population to access appropriate, high-quality care (e.g., Alholimie et al., 2025; Balkaran et al., 2022; Milano, 2017; Malik-Soni et al., 2022; Morris et al., 2019; Mukhtar et al., 2025). Given the finding that a key barrier is lack of available, properly trained providers, experimenters should prioritize research on ways to disseminate best practices for improving the comfort and care of individuals with NDD and to determine whether these best practices lead to better access to dental care and successful outcomes for patients.

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Data Availability Data are available upon request by contacting the corresponding author.

Declarations

Ethical Approval The study was approved by the university's institutional review board. We certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Consent to Publish All participants signed informed consent regarding publishing their data.

Competing interests The authors declare no competing interests.

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