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Ultrasound Visual Biofeedback Training for Speech Language Pathology Students: A Single Case Design

Ahmed Rivera Campos
Texas Christian University, a.r.campos@tcu.edu

Jyl Ristau
Texas Christian University, j.ristau@tcu.edu

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Abstract

This study examined the effectiveness of an ultrasound visual biofeedback (UVB) training on speech-language pathology (SLP) students' assessment of sonographic tongue configuration. This study examined the presence of a functional relation between an ultrasound visual biofeedback (UVB) training within the Participatory Adult Teaching Strategy framework and speech-language pathology (SLP) students' assessment of sonographic tongue configuration. Method: This study employed a multiple baseline, single-case design across participants and behaviors for data collection and analysis. Four graduate and three undergraduate level SLP students participated. Results: Percentage of goal obtained indicated that training was effective across participants and behaviors for teaching SLP students in the assessment of sonographic tongue shape for remediation of speech sound errors. Differences were found between undergraduate and graduate SLP students in the accuracy of assessment of sonographic tongue section configuration. Conclusions: The study establishes preliminary effectiveness of UVB training for SLP students. Although results demonstrate the effectiveness, special considerations should be applied when training graduate and undergraduate students in implementation of UVB training in order to accommodate knowledge and clinical experience differences between graduate and undergraduate students.

Keywords

ultrasound training, students, single case design, biofeedback

Introduction

Ultrasound visual biofeedback (UVB) is a promising tool in the remediation of speech sound errors. Ultrasound imaging provides visual information on the tongue shape used for speech sound production. SLPs use the visual information to assess which articulatory errors and their corresponding tongue section positioning need to be addressed to remediate speech sound errors. Most advantageous is the ability to have data on inaccuracies in tongue sections that cannot readily be identified through standard observation (e.g., looking at the mouth of the child during articulation). This information includes the positioning of the tongue root, tongue dorsum, tongue blade, or tongue lateral sides. Given its capacity to facilitate this information, UVB has been the focus of various intervention studies analyzing its effectiveness for treating production errors on hard-to-fix speech sounds (Cleland et al., 2015; Preston, McCabe, et al., 2014). Additionally, results from a systematic review by Sugden et al. (2019), and a randomized controlled trial by McAllister et al. (2020) support its implementation as an evidence-based clinical strategy for the remediation of speech sound errors.

To use UVB effectively, SLPs must be trained. Most UVB training programs are developed for SLPs and offered at national conferences (Preston, Hitchcock, et al., 2014; Preston et al., 2016) or through journal article tutorials (Lee et al., 2015; Preston et al., 2017). These opportunities limit access to UVB training to SLPs and do not provide opportunities for SLP students to be trained. SLP students are expected to acquire and successfully implement intervention strategies aimed at remediating speech sound disorders. For example, students must successfully implement strategies that promote changes in an individual's speech sound production behavior, such as using phonological approaches to promote internalization of the phonological rules that govern their language (e.g., cycles, phonological contrast) and articulatory approaches to aid in the production of a target sound when production errors are assumed to stem from motor difficulties (American Speech Language and Hearing Association, n.d.). Information on these intervention practices is typically presented in courses and subsequently reinforced in clinical practicum at the graduate level. Despite this, given the numerous articulation- and phonological-based strategies (American Speech Language and Hearing Association, n.d.; Koch, 2019; Williams et al., 2010), most students will not have the opportunity to practice every strategy, and the ones that do are unlikely to do so for an extended period of time due to the number of speech sound goals (up to ten goals; Farquharson et al., 2014) that a school-age child with speech sound errors must target.

However, there is a paucity of evidence for training pre-service speech-language pathology (SLP) students. As such, it is important to examine pedagogies for training students in the effective use of UVB. The present study assessed the effectiveness of a pedagogical strategy for training SLP students within a university program to use UVB for assessment of tongue configuration.

Training in Ultrasound Imaging

Ultrasound imaging has been part of the medical field for a considerably longer time than it has the field of SLP; thus, it is reasonable to look to the medical student training literature for a roadmap for training students. Based on the literature on undergraduate medical student training in ultrasound imaging, pedagogical approaches used include lecture-type presentation and instruction (Gogalniceanu et al., 2010; Mullen et al., 2018; Wright & Bell, 2008), application of newly acquired skills with teacher feedback (Mullen et al., 2018; Wright & Bell, 2008), appropriate amount of training time that meets or exceeds training time recommendations for acquisition of a single-competence in ultrasound assisted tasks (minimum of 8 hours) based on international health entities (e.g., the World Health Organization and European Federation of Societies for Ultrasound in Medicine and Biology) for training professionals in critical and emergency care medicine (e.g., physicians, nurses, and paramedics; Neri, et al., 2007), and lastly, multiple proctored practice exams (Neri et al., 2007). Although access to UVB training for SLPs have been made available, it is unclear whether attendees acquired a single-competence in ultrasound assisted tasks for speech sound production. These workshops expose trainees to a significant amount of new knowledge and skills within a total amount of training time ranging from 150 minutes (Preston, 2013) to 180 minutes (Preston, Hitchcock, et al., 2014; Preston et al., 2017). Topics presented to trainees include (a) introductory knowledge and new terminology; (b) interpretation of the sonographic data; (c) ultrasound equipment set-up; (d) articulatory phonetics; (e) examples; and (f) hands-on practice across multiple instances during training (Preston, 2013; Preston, Hitchcock, et al., 2014; Preston et al., 2016). Though these workshops attempt to increase SLPs preparedness in the implementation of UVB for speech sound production, there is an absence of empirical evidence on their effectiveness for training SLPs in a single-competence in ultrasound assisted tasks for speech sound production. As such, there is uncertainty whether these trainings can be continued to be used.

Recently, Rivera Campos and Ristau (2022) utilized a Participatory Adult Learning Strategy (PALS; Dunst & Trivette, 2009) framework with practicing SLPs to evaluate the effectiveness of a UVB training modeled. PALS uses a series of phases for the promotion of learning and maintenance of new knowledge and skills (Dunst & Trivette, 2009). The first phase of PALS presents the new information and skills to be learned. The second phase provides the learner with opportunities to apply the new knowledge and skills (e.g., real life application or problem solving) as well as providing evaluative feedback on the learner's performance. The third phase requires the trainee to reflect on their evaluative feedback to promote an informed understanding on what is understood and mastered versus what requires a better understanding and mastery. Lastly, in phase four, the trainee uses their evaluative feedback and their self-reflection to make an informed decision and plan the next steps in the learning process with the trainer.

Rivera Campos and Ristau (2022) used the PALS framework to train two SLPs in the use of UVB for assessing tongue configuration and use of facilitative context to promote changes in tongue configuration. The participants received a total of 18 hours of training divided between four days. Each day targeted one tongue section (tongue root, tongue dorsum, tongue blade, and tongue lateral sides) and teaching potential facilitative contexts that could promote changes in that specific tongue section's configuration. The authors measured and tracked changes over time in each participant's accuracy to correctly assess tongue shape as well as their accuracy in applying a facilitative context that would promote changes in tongue section positioning if needed before and after the introduction of a PALS-based UVB training. Results showed that a PALS-based UVB training was highly effective in teaching licensed SLPs how to implement UVB for assessing tongue shape and use of facilitative contexts for remediation of speech sound errors. Thus, it is possible that a PALS-based UVB training may also be effective for SLP students.

The Present Study

Evidence from Sugden et al. (2019) highlights the value of dedicating resources to training in UVB because (a) it is unlikely that UVB skills would easily be gained or adapted from other types of skills in traditional articulation remediation approaches; and (b) UVB helps promote change in difficult-to-remediate speech sound errors in a way that other strategies do not. As such, it is essential to train SLP students to acquire a single-competence in ultrasound assisted tasks for the remediation of speech sound errors and to examine teaching approaches that go beyond the traditional lecture style used in many courses. Although Rivera Campos and Ristau's (2022) UVB training modeled within PALS framework was successful in training licensed SLPs, their results are not generalizable to SLP students due to the discrepancies in knowledge and clinical experiences between students and practicing SLPs. Additionally, the total time of training provided by Rivera Campos and Ristau (2022)—although exceeding the minimum training time suggested by Neri et al. (2007) and international health entities—might not be a sustainable option for SLP programs due to time constraints. On the other hand, their work can be used as a point of reference for training SLP students and for considering potential training differences to further assess best practices for training SLP graduate and undergraduate students.

By using a PALS training model and training time guidelines for a single-competence ultrasound assisted task, a training option for SLP graduate and undergraduate students can be explored. The purpose of this study was to collect empirical data to assess the presence of a functional relation between a PALS-based UVB training and SLP students' assessment of sonographic tongue configuration during speech sound production. Specifically, the study attempts to answer the following research questions:

1. Is there a functional relation between SLP student identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section and an UVB training modeled within the PALS framework?
2. Is an UVB training modeled within the PALS framework more effective in training graduate SLP students in identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section when compared to undergraduate SLP students?

It is hypothesized that an UVB training within the PALS framework will be effective for training SLP students in assessment of sonographic tongue section configuration and use of facilitative contexts to promote repositioning of tongue section.

Method

Participants and Setting. Institutional Review Board approval by Texas Christian University was obtained for this study. The inclusionary criteria for participation in the study included enrollment as an SLP student in an undergraduate or graduate speech-language pathology program and no previous experience with the use of UVB. All participants consented prior to data collection and were enrolled at the same institution with a Basic Carnegie Classification of R2: Doctoral Universities-High Research Activity (American Council on Education, n.d.). Seven female SLP students participated in the study. Participant information is presented on Table 1. Prior to their participation in this study, all undergraduate students had completed courses on the anatomy and physiology of the speech mechanism, speech and hearing sciences, phonetics, and speech sounds disorders. Similarly, all graduate students had completed courses on the anatomy and physiology of the speech mechanism, speech and hearing sciences, and phonetics. Only two graduate students had completed an undergraduate level course on speech sound disorders (P1 and P2).

The training was provided in a classroom with access to tables, chairs, multimedia resources, and an Articulate Instrument Micro portable ultrasound scanner with a convex 2-4MHz transducer. The ultrasound scanner was plugged to a desktop possessing the specifications required for the ultrasound scanner. A 10-hour UVB training modeled within the PALS framework was used. With a 10-hour training, (a) the minimum training time recommendations for acquisition of a single-competence in an ultrasound assisted task was met; and (b) a more sustainable option for SLP programs is assessed when compared to the 17-hour UVB training time used by Rivera Campos and Ristau (2022). The training was divided into four sessions. Each session focused on one tongue section. To promote participant recruitment and accommodate for variability of time constraints across students, participants were allowed to choose between two options for completing the 10-hour training. One option required completion of all training sessions on ten weekdays, while the second allowed for completion of one training session per week across four weeks. Three SLP graduate students (training group 1) completed all training sessions across ten days while one SLP graduate student and three SLP undergraduate students (training group 2) completed one training session per week for four weeks.

Table 1

Participant Demographic Information

Participant	Type	Training group	Race/Ethnicity	Education
P1	G	1	Caucasian	*FYGS*
P2	G	1	Caucasian	*FYGS*
P3	G	1	Hispanic	*FYGS*
P4	G	2	Caucacian	*FYGS*
P5	UG	2	Caucasian	*FYUGS*
P6	UG	2	Caucasian	*FYUGS*
P7	UG	2	Caucasian	*FYUGS*

Note. G= Graduate. UG= Undergraduate. FYGS= First year of graduate school.
FYUGS= Fourth year of undergraduate school.

UVB within PALS Framework. All PALS-based UVB training sessions were led by the same trainer: the second author. The trainer was a graduate level student in speech-language pathology from the same institution the study took place. Prior to the study, her experience with UVB for speech sound production consisted of one-on-one training sessions—led by the first author—where she was trained on the implementation of UVB for speech sound production and 18-month clinical experience with implementing UVB with children with residual speech sound errors. Additionally, her instructional knowledge on UVB training consisted of providing an 18-hour PALS-based UVB training workshop to school-based SLPs.

PALS is composed of four phases. These phases provide the learner with the presentation of the new knowledge and skills (Phase 1), application of the new knowledge and skills with individualized feedback based on their performance (Phase 2), learner's reflection on their performance and feedback (Phase 3), and planification of the trainee's next learning steps based on input from the trainee and trainer (Dunst & Trivette, 2009).

The PALS-based UVB training predominately focused on errored and accurate tongue shapes for the rhotic approximant /ɹ/. This is because this late developing sound (McLeod, 2007) is a common target for speech sound remediation in children with residual speech sounds errors. Furthermore, their erred productions are characterized by a variety of articulatory inaccuracies in tongue section placement (Boyce, 2015). This sound is additionally unique in that native speakers of English from various regions of United States, use a variety of tongue shapes for its production (Boyce et al., 2009). This variability in tongue shape in both correct and errored productions of /ɹ/ is ideal for visualizing a variety of tongue section placements. During the training, additional vowel and consonant sounds were shown for comparative tongue section positioning. Such comparisons included demonstrating similarities in tongue root positioning between /ɹ/ and the vowel /a/, differences in tongue root positioning between the vowels /a/ and /u/, and differences in tongue lateral side positioning between /s/ and /l/.

The analysis of tongue positioning was divided into four tongue sections, including tongue root, tongue dorsum, tongue blade, and tongue lateral sides, each of which received a dedicated training session. Only one training session was provided per day, hence a total of 4 training days. The introduction and illustration of newly acquired knowledge, or Phase 1, consisted of "lecture"-style presentations with multimedia visuals (e.g., sonographic tongue images and videos) aimed at teaching terminology, reviewing advanced speech sound phonetics, methods for interpreting sonographic tongue imaging and tongue movement, and methods for using facilitative concepts to promote changes in tongue configuration. These introductory lectures staggered new information, allowing each topic (i.e., tongue section) to completely cycle through the four PALS phases before proceeding to the subsequent topic. Participants were encouraged to ask questions as they arose during the presentation of the information. Phase 1 spanned from 40 to 60 minutes per day, with five-minute breaks offered during each phase.

Knowledge application and evaluation of performance, Phase 2 of the PALS framework, was incorporated by asking trainees targeted questions about short video clips that exemplified that lecture material. Participants were first encouraged to work together to apply the knowledge learned to answer questions such as describing the positioning of different parts of the tongue, evaluating facilitative contexts, etc. Trainees then carried out similar tasks individually, at which time five *within-training* probes were administered, each lasting approximately five minutes. Each participant's performance was evaluated and recorded, and individualized feedback was verbally provided by the trainer in real time as participants worked on the tasks.

During Phase 3, a brief question and answer session allowed participants to comment, request clarification, and ask the trainer questions about the material covered. This trainee reflection on assessment of knowledge learning or practice, included a trainer-prompted reflection in which the participants reflected on their level of comfort with regard to interpreting images of the targeted tongue section and tongue sections targeted in previous sessions.

Phase 4, or trainee use of informed understanding to decide next stps in the learning, was targeted in a brief discussion between the participant and trainer regarding the participant's performance. At the end of each day of training, the trainer made observations and provided data from Phase 2 and Phase 3. Following this, each participant chose whether they preferred to continue on to the next topic or re-train that day's lesson. Progression to next topic was allowed when the trainee's application performance and reflection showed readiness for upcoming new knowledge and skills based on the trainee's reflection and performance feedback and trainer's input. If readiness was not demonstrated, all PALS phases were repeated for the target tongue section training by scheduling with the trainer. The PALS-based UVB training had an average duration of 150 minutes per training session for a total of 10 hours of in-person UVB training. Only the participants and trainer were present for each session.

Overview of Topics Presented During Training. During training, participants were provided with knowledge and skills that targeted the presentation and comprehension of: (a) advanced articulatory phonetics (e.g., tongue section positioning for a variety of speech sounds); (b) set-up and proper use of the ultrasound scanner; (c) ultrasonography terminology (e.g., transducer, sound waves, echogenicity); (d) sonographic display interpretation in both the sagittal and coronal planes of view (e.g., tongue sections, bone shadows); and (e) tongue section configuration and positioning relative to other oral structures during speech sound production (e.g., tongue root retraction during typical production of /ɹ/, forward tongue root positioning in errored production of /ɹ/). Participants were also trained in strategies to promote tongue section repositioning and how to provide individualized feedback to the client based on the clinician's interpretation of the sonographic tongue display. There were no adverse events during any of the training sessions and data collection process.

Experimental Design. A multiple baseline design across participants and behaviors was used to assess the presence of a functional relation between SLP student identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section and an UVB training modeled within the PALS framework. Changes to the SLP students' assessment of sonographic tongue shape across time were capture by probes administered during baseline (prior to the introduction of UVB training) and experimental phases (after the introduction of UVB training). To minimize form effects due to the order of presentation of topics, the order was varied across participants. For P1, P2 and P3, the order of topics was: tongue root, tongue dorsum, tongue blade, and tongue lateral sides. For P4, P5, P6, and P7, the order was tongue root, tongue lateral sides, tongue blade, and tongue dorsum.

Probe Assessments. This study tracked changes in the student's assessment of sonographic tongue section across time and phases through probes. Probe assessments were designed to evaluate the participants' skills in assessing tongue shape from sonographic tongue videos, and in suggesting facilitative contexts to promote improved positioning of target tongue sections for an accurate production of the target sound. Probe assessments included baseline probes, within-training probes, and maintenance probes.

Each day of training, probe assessment administration followed the same framework. For each of the four tongue sections, five sonographic tongue video clips of a target word were shown, and two questions were asked for each video regarding the tongue section in question. The design of the questions assessed the accuracy of each student's assessment of target tongue segment positioning (e.g., tongue root) in a selected sonographic imaging video clip, as well as the appropriateness of identification of a facilitative context to promote repositioning of the target tongue section, as needed. For example, in a probe assessment for the tongue blade, each participant was instructed, "In video clip #[insert clip code here], describe the positioning of the tongue blade during the production attempt of /ɹ/." The participant would then write an open-ended response, and proceed to answer the second question, "If the tongue blade requires repositioning, what strategy or facilitative context would you use to achieve it?" The same two questions were asked for each of the five video clips for each of the four tongue sections (tongue root, tongue blade, tongue dorsum, and tongue lateral sides).

A score of "1" was used for correct application of new knowledge and skill by answering both questions—per sonographic tongue video clip—correctly, while a score of "0" was used for answering either or both questions incorrectly. The maximum score per tongue section per probe was a 5 if all questions were answered correctly. Sonographic video clips used for probes were not presented during phases 1 and 2 of the training. During UVB training of tongue root, tongue dorsum, and tongue blade, as well as their respective probes for measuring changes in the student's assessment of tongue root, tongue dorsum, and tongue blade, midsagittal sonographic tongue video clips were used. During UVB training of tongue lateral sides, as well as its respective probes for measuring changes in the student's assessment of tongue lateral sides, coronal sonographic tongue video clips were used.

Sixty-five midsagittal and coronal sonographic video clips were used for measuring changes of students' assessment of tongue section across time and phases (baseline, within-training, and maintenance). The same sixty-five midsagittal video clips were used for probe data collection on tongue root, tongue dorsum, and tongue blade. Since participants focused on a specific tongue section when assessing tongue section positioning, use of the same sonographic tongue video clip for tongue root, tongue dorsum, and tongue blade were not considered to promote memorization effects for the participants.

Baseline Probes. Nine baseline data points were gathered for each participant before introduction of the UVB training. The initial baseline probes for each tongue section were gathered at the consent collection visit while the remaining eight baseline data points were completed online due to scheduling conflicts for in-person baseline data collection. At the initial baseline probe measure participants were also provided with instructions on how to complete the remaining baseline probes prior to the initiation of the first UVB training session, and that no more than one baseline probe for each tongue section could be completed each day. For completion of the remaining eight baseline probes, participants were given access to an online file storage platform. The file contained various folders (a folder for each baseline probe) containing the necessary materials to complete each remaining baseline probe. For example, the folder labeled Baseline 2 contained the baseline probe document and its associated sonographic video clips. The procedure for completion of the initial baseline probes were identical to the remaining baseline probes to be completed. Participants were given the opportunity to ask question during the collection of the initial baseline probes in order to addressed gaps in the understanding on how to complete the remaining baseline probes. At the end of each UVB training for each tongue section, baseline data continued to be gathered for tongue sections yet to be introduced. For example, if training for tongue root was completed, baseline probe data was collected for tongue dorsum, tongue blade, and tongue lateral sides.

Within-training Probes. Within-training probes for each training day were completed following the session's lecture topic (Phase 1) and the group practice portion (Phase 2) in order to measure changes in the student's assessment of sonographic tongue configuration for the tongue section that was trained. Questions of within-training probes were shared with baseline probes. However, sonographic tongue videos related to the questions presented were not the same. No within-training probe was completed online.

Maintenance Probes. In sessions following instruction on each tongue section, maintenance probes were administered for each tongue section previously introduced. For example, if the first, second, and third training sessions taught the tongue root, tongue dorsum, and tongue blade, respectively, the maintenance probes administered on day three of the training would include an assessment of knowledge on the tongue root and tongue dorsum. Again, the probe questions mirrored those in the baseline and within-treatment probes, but the sonographic imaging video clips varied. Maintenance probes were not gathered for the final tongue section trained for each participant, as the UVB training ended once the last tongue section was trained. No maintenance probe was completed online.

Interobserver Agreement. One of the researchers administered and independently scored all probes once UVB training had initiated. A trained research assistant with over one year of experience in the use of UVB for the remediation of speech sound errors also independently assessed the sonographic imaging video clips for each targeted tongue section. Point-by-point agreements were calculated across probes. The interobserver agreement was 100%.

Data Analysis. Data from each probe across phases were plotted on a line graph for each participant. To assess the presence of a functional relation, a visual analysis of the data was completed to assess changes in the data pattern across phases, participants, and behaviors. For effect size measure, percentage of goal obtained (PoGO) was used to quantify the effectiveness of the training per participant for each tongue section by defining a performance goal across participants for each of the trained tongue section. PoGO was calculated based on Ferron et al. (2020) guidelines. The desired level of performance goal for each tongue section after introduction of the training was determined to be 100% (a score of 5 out of 5 on all within-treatment and maintenance probes). The estimated level of the behavior without training was determined by the average score of baseline probes for each tongue section for each participant. The obtained level of the behavior for each participant for each tongue section was determined by the average score on probes after introduction of training for each tongue section.

Results

To answer our first research question, participants' skills in identification of tongue shape and use of facilitative contexts to promote repositioning of tongue sections was assessed across time prior and after introduction of the PALS-based UVB training. Each participant's performance for each probe type (circle mark for *baseline probes*, square mark for *within-training probes*, and triangle mark for *maintenance probes*) and tongue section are shown on Figures 1 through 3. For training group 1 (P1, P2 and P3), visual inspection of the baseline data pattern across participants and tongue sections shows that probe scores for all tongue sections was 0 prior to the introduction of the PALS-based UVB training. Thus, baseline *phase level*—or mean value of probe scores—is 0. After introduction of the training, data pattern across tongue sections shows that within-training and maintenance probe scores for each tongue section are higher when compared to baseline probe scores. Thus, *within-phase level* per tongue section after the introduction of the training is higher. See Table 2 for more detailed information on *within-phase levels* per tongue section per participant.

For training group 2 (P4, P5, P6 and P7), visual inspection of the baseline data patterns across participants and tongue sections prior to the introduction of the training, show that all but 2 baseline probe scores had a value of 0 (tenth tongue dorsum baseline for P4 and P7 show a score of 1). Within-phase levels prior to introducing the training was 0 for all tongue sections across training group 2 participants but P4's and P7's tongue dorsum's *within-phase level* of 0.08. After introduction of the training, data pattern shows that probe scores for each tongue section are higher when compared to baseline probe scores. Thus, for training group 2, the *within-phase level* per tongue section after the introduction of the training is higher when compared to *within-phase level* prior to introducing the training (See Table 2).

Effect size measures. To answer if a PALS-based UVB is more effective in training graduate SLP students in identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section when compared to undergraduate SLP students, PoGO was used to determine the effectiveness of the training across participants per tongue section. Since accurate evaluation of sonographic tongue configuration is important for UVB use for remediation of speech sound errors, a high level of mastery in UVB implementation after training is needed. As such, a desired level of performance for each participant for each trained tongue section was determined a priori to be 100% (a score of 5 out of 5 in within-training and maintenance probes). Since a high level of proficiency is desired for each tongue section after training, three different proficiency categories were established to describe a participant's performance based on their PoGO. A PoGO of 80% or greater (of the desired level of performance of 100%) was determined by the research team to be reflective of a high level of mastery in assessment of sonographic tongue section during speech sound production. A PoGO of 60% or greater but lesser than 80% was determined to be reflective of a proficient level in assessment of sonographic tongue section during speech sound production. Lastly, a PoGO of less than 60% was determined to be reflective of an emergent level of performance. See Table 3 for more detailed information on PoGO values per tongue section per participant.

After training, all graduate students acquired and mastered the necessary skills for sonographic tongue section assessment during speech sound production in at least 2 out the 4 tongue sections. P3 achieved a mastery performance on all tongue sections. P2 achieved a mastery performance for tongue root, tongue dorsum, and lateral sides with tongue blade showing a performance level of proficient. P1 achieve a mastery performance for tongue root, tongue blade, and lateral sides with tongue dorsum showing a performance level of proficiency.

Figure 1

Participant 1's (Left), Participant 2's (Center), and Participant 3's (Right) Probe Score Across Baseline, Experimental, and Maintenance Phases.

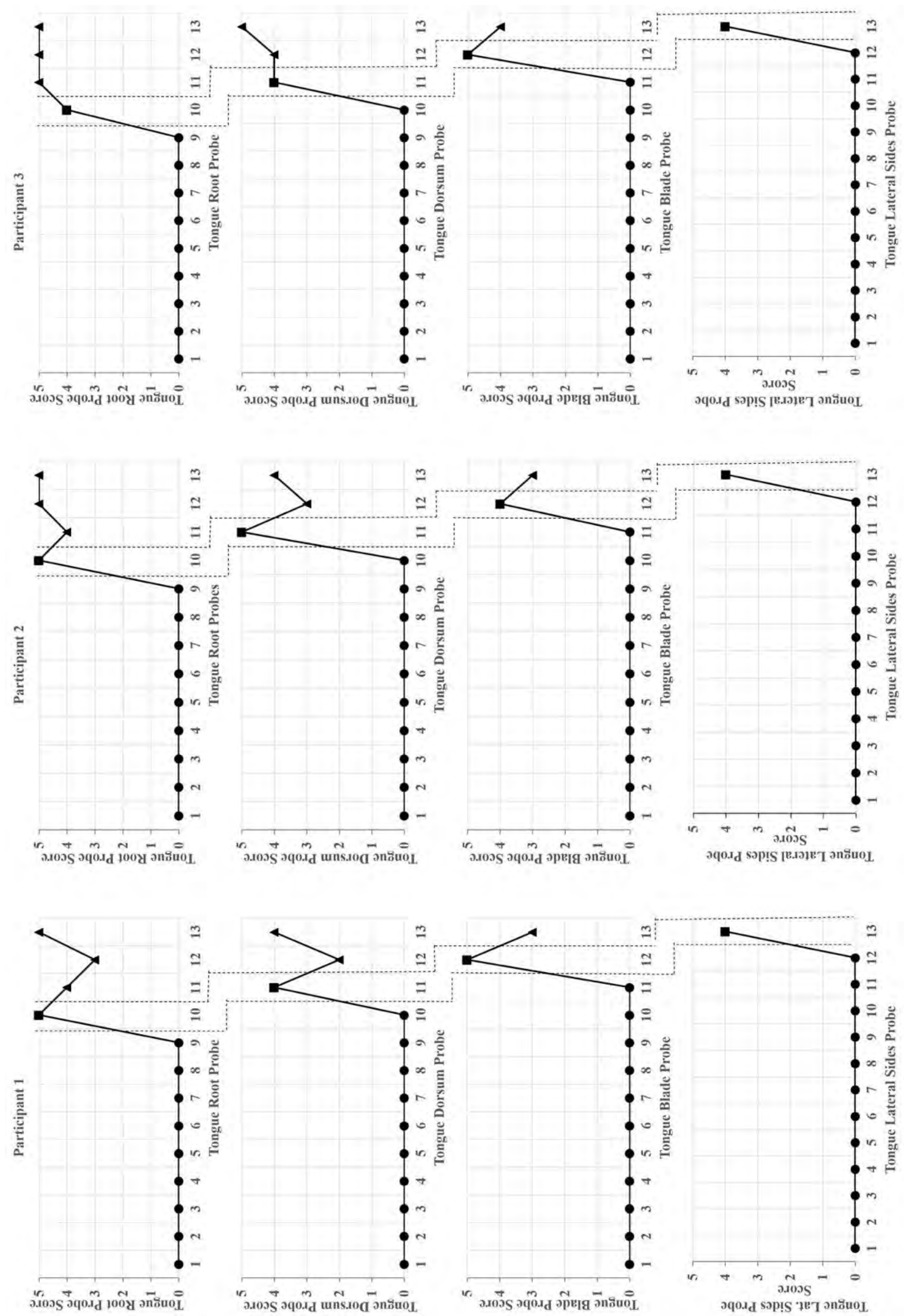

Figure 2

Participant 4's (Left) and Participant 5's (Right) Probe Score Across Baseline, Experimental, and Maintenance Phases.

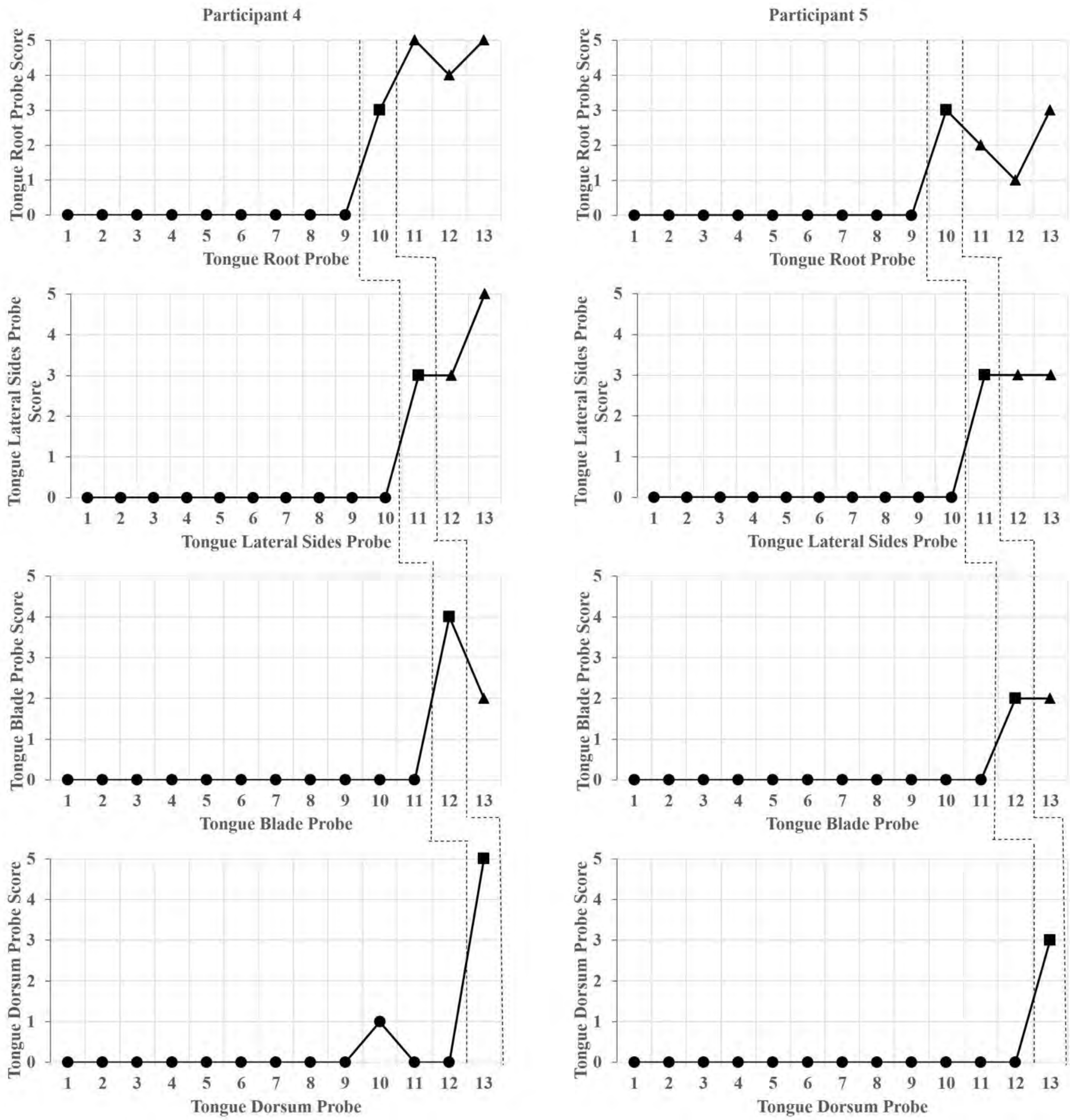

Figure 3

Participant 6's (Left) and Participant 7's (Right) Probe Score Across Baseline, Experimental, and Maintenance Phases.

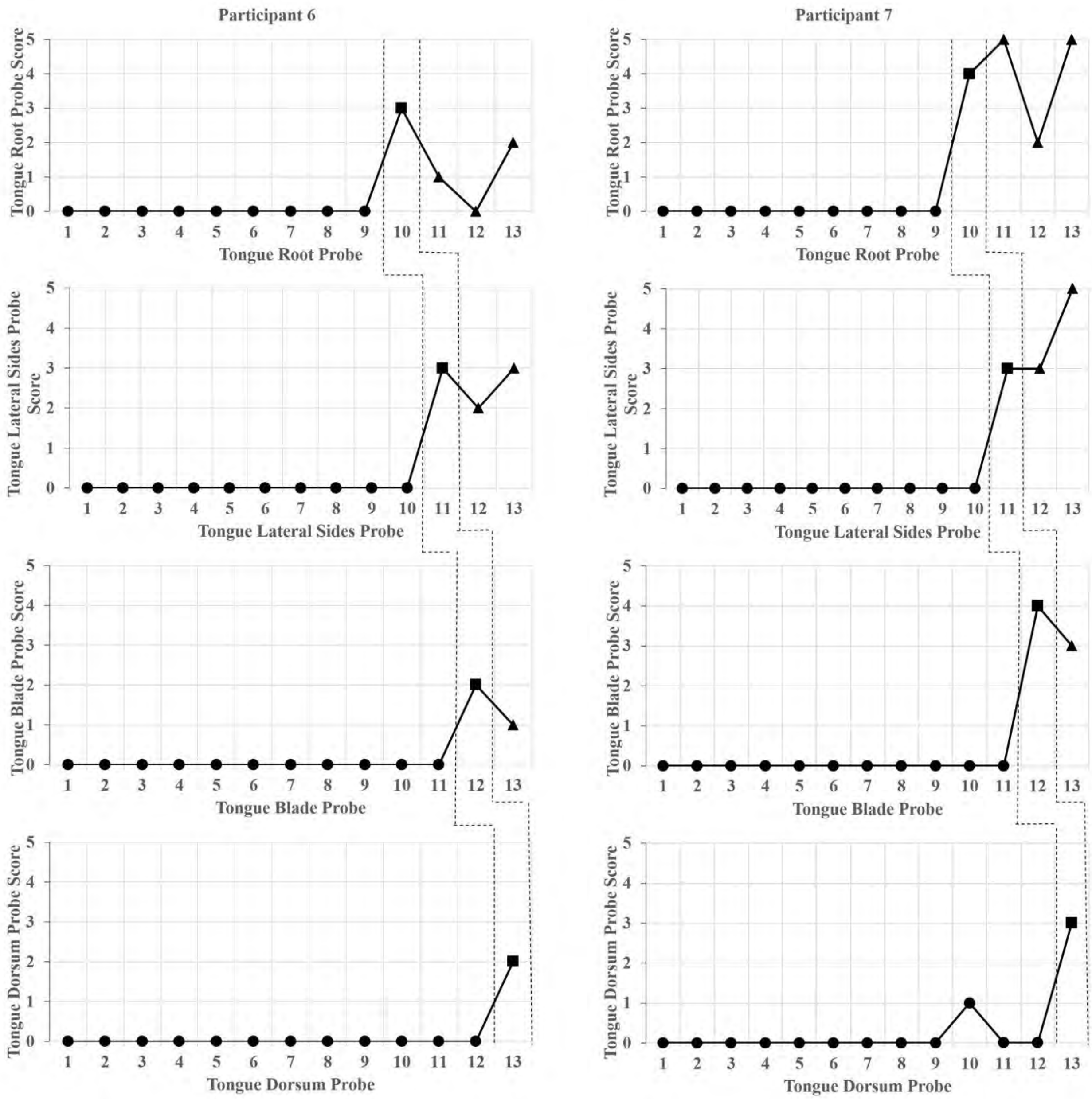

Table 2

Within-Phase Levels across Tongue Sections per Participant

Tongue section	Baseline	Experimental
Tongue Root		
P1	0	4.5
P2	0	4.75
P3	0	4.75
P4	0	4.25
P5	0	2.25
P6	0	1.5
P7	0	4
Tongue Dorsum		
P1	0	3.33
P2	0	4
P3	0	4.33
P4	0.08	5
P5	0	3
P6	0	2
P7	0.08	3
Tongue Blade		
P1	0	4
P2	0	3.5
P3	0	4.5
P4	0	3
P5	0	2
P6	0	1.5
P7	0	3.5
Lateral Sides		
P1	0	4
P2	0	4
P3	0	4
P4	0	3.66
P5	0	3
P6	0	2.66
P7	0	3.66

Table 3

Percentage of Goal Obtained per Participant per Tongue Section

Participant	Level	PoGO Root	PoGO Dorsum	PoGO Blade	PoGO Lateral Sides
P1	G	85%	67%	80%	80%
P2	G	95%	80%	70%	80%
P3	G	95%	87%	90%	80%
P4	G	85%	100%	60%	73%
P5	UG	45%	60%	40%	60%
P6	UG	30%	20%	30%	53%
P7	UG	80%	59%	73%	70%

Notes. G= Graduate. UG= Undergraduate.

After training, only one undergraduate student, P7, acquired and mastered the necessary skills for sonographic tongue section assessment during speech sound production in at least one tongue section—the tongue root. For tongue blade and lateral sides, P7, achieved a performance level of proficient with a performance level of emergent for tongue dorsum. P5 achieved a performance level of proficient for tongue dorsum, and lateral sides with a performance level or emergent for tongue root and tongue blade. Lastly, P6, achieve an emergent level of performance across all tongue sections.

Discussion

The purpose of this study was to collect empirical data to assess the presence of a functional relation between a PALS-based UVB training and SLP students' assessment of sonographic tongue configuration during speech sound production.

To answer our first research question, there was a functional relation between a PALS-based UVB training and SLP students' assessment of sonographic tongue section during speech sound production. This was evidenced by the changes in *within-phase levels* prior and after training as well as the within-training and maintenance probe scores across all participants and tongue sections. Additionally, training effect was demonstrated across all participants and tongue sections.

To answer our second research question, PoGO descriptively assessed whether there were differences in the effectiveness of an UVB training modeled within the PALS framework for training identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section between graduate and undergraduate students. Based on the PoGO measures, a PALS-based UVB training for sonographic tongue assessment during speech sound production is most effective for graduate students. Although all participants learned a significant amount of new knowledge and skills, the graduate students demonstrated the highest proficiency level across multiple tongue sections. None of the graduate students demonstrated a proficiency level of emergent on any of the trained tongue sections. In contrast, the proficiency level of emergent was the most common for the various tongue sections for most of the undergraduate students.

During Phase 2 of PALS in which evaluative feedback was provided and discussed with each learner, questions from the learner were addressed, and erred answers were further reviewed with their correspondent sonographic video clip, each undergraduate student was successful in providing accurate revised answers for each of the erred answers. However, undergraduate student's maintenance probe scores did not improve over time beyond their performance at the introduction of training for the target tongue section. One potential explanation for this is the differences in academic and clinical background between the participants. Although the graduate student participants have had limited experiences with graduate level coursework and clinical experiences, these experiences might have positively impacted their performance. Graduate students were having experiences that provide with relevant background information that could have positively impacted their performance on their probe scores (e.g., a course in speech sound disorders, guided clinical practice experiences that promote clinical critical thinking). In contrast, the undergraduate SLP students had not met their academic requirements to complete their degree and are not experiencing similar guided clinical experiences. These differences could account for the probe performance difference between our graduate and undergraduate participants. Determining which factors (e.g., specific academic or clinical experiences) have a relationship in better understanding and maintaining the new knowledge and skills needed for implementation of UVB for remediation of speech sound errors is beyond the scope of this research. Nevertheless, it may be of interest to academic programs that would like to implement training on sonography as it relates to SLP in their curriculum.

Another potential factor that could partially explain the lower probe scores for the undergraduate SLP students is the requirements in our probe scoring system for acquiring 1 point and 0 points. As previously mentioned, each sonographic video clip was related to two questions (tongue section placement and facilitative context). To acquire a score of 1 for that sonographic video clip, the participant was required to provide an accurate answer to each question. If only one question out of the two was answered accurately, the participant acquired a score of 0 points for that video clip. By assessing the number of erred answers based on the type of question (identification of tongue section placement or facilitative context), there were a greater number of erred answers for questions regarding facilitative contexts when compared to questions regarding identification of tongue section positioning. These results suggest that SLP undergraduate students needed additional support for better acquisition of this skill.

Although it can be argued that timeframe for completion of training (within ten days (training group 1) or a training session once per week for four weeks (training group 2) could influence learning outcomes, it must be noted that P4, a participant from training group 2 and an SLP graduate student, demonstrated an overall score performance similar to the SLP graduate students who completed the training within 10 days. Based on this, we argue that graduate level academic and guided clinical experiences academic and probe scoring system are more likely to explain the difference in performance. Additionally, this adds information about effective treatment intensity, that the overall amount of training is more important than the proximity in the timing of the sessions.

Basic Ultrasonography as Part of SLP Education. With results from research supporting the use of UVB for remediation of speech sound errors, early training on basic sonographic concepts as it relates to our profession should be considered. Training on basic sonography at the undergraduate level has already been explored in the medical field with positive results (Gogalniceanu et al., 2010; Mullen et al., 2018). With our finding of a functional relation between our variables across graduate and undergraduate student participants, instruction in the implementation of UVB for remediation of speech sound errors within a PALS framework might be of interests for SLP programs. With research works finding positive results after the implementation of UVB for remediating speech sound production errors, an early training on the basics on UVB for speech sound production from an SLP program can promote adoption of this clinical strategy among SLPs. Adoption of UVB with individuals who might benefit from it can reduce the amount of time they spend in learning production of the target sound. Currently, licensed SLPs interested in the implementation of UVB need to find external sources for training. Furthermore, access to these sources can be challenging due to a variety of barriers that can require from the learner to allocate additional resources not readily available for them (e.g., time, accessibility, financial resources). With an early training on UVB for speech sound production at the undergraduate or graduate levels, some of these barriers can be reduced (e.g., time constraints to pursue training and accessibility to training) and promote acquisition of the necessary knowledge for a single-competence in ultrasound assisted tasks.

Based on the number of incorrect answers for facilitative contexts by the SLP undergraduate students, an UVB training for SLP students may need to be tailored based on its audience. Although an UVB aimed for licensed SLPs can be an option for graduate SLP students, a modified version might be required for undergraduate students. For example, a training that focused on how to operate an ultrasound scanner, identification of the various tongue sections, how to image tongue sections using sagittal and coronal planes of view, how to acquire an appropriate mid-sagittal or coronal sonographic tongue image, etc. may be appropriate for undergraduate students in SLP.

Limitations and Future Research. The total amount of time needed to complete our training was ten hours. Although the training was divided into more manageable blocks through five days, the amount of time may have been challenging for some of the participants as they also needed to manage their daily academic and clinical obligations which might have impacted their learning. Additionally, our training was not embedded in either the undergraduate or graduate curriculum. As such, we are unable to generalize the results of the UVB training modeled within the PALS framework to similar training that has been embedded to an undergraduate or graduate curriculum. However, an UVB training modeled within the PALS framework that is offered to students as an external source for their clinical training is a beneficial option for students.

Future work should examine the effectiveness of other evidence-based practice strategies for adult learning models to train SLP students in the acquisition of a single-competence in ultrasound assisted tasks for speech sound production. Additionally, research that compares outcomes of different adult learning models to training SLP students in UVB would be of great benefit for determining best options for training SLP students as well as allowing for programs to assess teaching approaches that might best fit their needs or the availability of resources. Additionally, future work on the effectiveness of an UVB training modeled within PALS that is also embedded in SLP student curriculum should be considered. Although many programs might not have an ultrasound scanner as standard equipment, options for increasing its accessibility to SLP programs should be explored such as networks between centers or SLP programs with access to the equipment and trainers. Increasing accessibility of other biofeedback technologies (e.g., electropalatography) for remediation of speech sound errors to SLPs has successfully been done through networks in Scotland (Gibbon et al., 1998; Gibbon et al., 1999). Similar options should be explored for UVB.

Clinical Implications and Conclusions. Using evidence-based teaching practices for adult learning (e.g., PALS) for training SLP students in the use of UVB for remediation of speech sound errors could be of great importance for the adoption of this clinical tool among licensed SLPs. If training is achieved as part of their curriculum, some of the barriers (e.g., time, accessibility, and financial resources) for acquisition of adequate training could be lessened. Thus, allowing for easier adoption and implementation of this strategy with individuals who can benefit from UVB.

The present study is the first to gather empirical data on training SLP students in the use of UVB for remediation of speech sound errors. This research addressed the lack of empirical evidence on best practices for training SLP students in the use of UVB for speech production. The data provides empirical evidence on the presence of a functional relation between SLP student identification of tongue shape and use of facilitative contexts to promote repositioning of tongue section after introduction of a PALS-based UVB training. Furthermore, based on the average increase in scores from the baseline condition probes (baseline probes) to the experimental condition probes (within-training and maintenance probes), modifications to the training must be made when training graduate and undergraduate SLP students.

Author disclosures

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