Research Article

Investigating the Efficacy of Dynamic Temporal and Tactile Cueing in Stroke Patients with Apraxia of Speech: A Study Protocol Using a Single-Subject Design

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ABSTRACT

Introduction: Dynamic temporal and tactile cueing (DTTC) is a treatment method for childhood apraxia of speech (AOS), and its characteristics make it a suitable option for treating patients with AOS. Additionally, no documented treatment protocol has been published in Iran for the treatment of patients with AOS. This study protocol aims to investigate the efficacy of DTTC in the treatment of Persian-speaking patients with acquired AOS, who will be recruited using non-probability, convenience sampling.

Materials and Methods: A single-subject study with multiple baseline designs across participants was designed to obtain detailed information about the intervention procedure on at least three participants' performance, and a perceptual scoring system was introduced to measure the accuracy of treated and untreated words and phrases as a dependent variable.

Results: The results of a visual analysis will be provided based for the assessment of participants at three phases of baseline, treatment, and follow-up, and the effect sizes will be reported.

Conclusion: This study describes the first research investigating the efficacy of DTTC on the speech of AOS patients and the first treatment protocol for Persian-speaking patients with AOS.

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Introduction

Apraxia of speech (AOS) is a motor speech disorder of a neurological origin. This disorder is characterized by slowed speech rate, articulatory imprecision, and dysprosody [1, 2]. The severity of AOS varies from relatively fluent speech with minor sound distortions to an inability to produce speech. AOS usually coexists with non-fluent aphasia and rarely occurs in a 'pure' form. Stroke is the most common cause of AOS [3, 4]. Esmailzadeh et al. (2021) found that the frequency of oral apraxia in Persian-speaking patients suffering from stroke (first time) and in the acute phase was 35.7%, the frequency of verbal apraxia was 2.3%, and 4.7% were suffering from verbal and oral apraxia [5].

Speech-language pathologists use various techniques to treat AOS. Wambaugh et al. (2006) divided the underlying approaches in the treatment of AOS into four main categories: articulatory-kinematic approaches, rate and/or rhythm control treatments, augmentative and alternative communication techniques, and intersystemic facilitation and reorganization techniques [6, 7]. Various studies have shown that the articulatory-kinematic approach is the most used in the treatment of AOS [6, 8, 9]. Positive results of treatments based on the articulatory-kinematic approach have been reported across various studies in terms of retention, generalization to untreated targets, and increased social validity [10-13]. This group of treatments focuses on motor planning through intensive repetition and articulatory cues. Intense repetition is necessary for the recovery of people with brain damage and stroke because it increases long-term neurological changes [14, 15]. Also, providing articulatory cues increases the patient's awareness of sound production accuracy, a stable manner, place of articulation, and voiced/voiceless sounds [14, 16]. Using sensory cueing methods, such as integral stimulation (IS), with intense repetition and articulatory cues, can enhance the accuracy of word and phrase production [14].

Many motor-based treatment approaches, including articulatory-kinematic techniques, incorporate at least some principles of motor learning (PML). These principles have been designed to facilitate the learning of a new motor task and include precursors to learning, blocked versus random practice, mass versus distributed practice, and knowledge of results (KR) versus knowledge of performance (KP). Also, PML emphasizes practicing speech targets in various contexts that evoke real-life situations. Precursors to learning include informing the client about the goal of a treatment and understanding the task to establish the patient's trust in what is done and how. In block practice, one target is practiced at a time, and in random practice, more than one target is practiced at a time. Mass and distributed practice refer to the duration and the timing of sessions within a week. For example, a single three-hour session per week indicates mass practice, while three one-hour sessions per week indicate distributed practice. KP refers to the clinician providing specific feedback on the client's articulation and guidance on how to improve their speech production. In contrast, KR involves the clinician informing the client whether their production is correct. Finally, practicing a learned task in different contexts enables the application of skills in new situations and facilitates the transfer of learning to other movements [17, 18].

Among different treatment approaches for AOS, motor learning-guided (MLG) and sound production treatment (SPT) are two articulatory-kinematic approaches that have reported replications of treatment effects. Replication is essential for scientific research to ensure external validity and has been lacking in AOS treatment studies [9]. MLG includes clinician modeling, immediate and delayed repeated practice, oral reading, delayed KR feedback, and practice of stimuli in successive random order [9, 19]. This approach uses oral reading, which may be challenging for patients with apraxia who often have aphasia, and using it as a dependent variable may obscure the results. The generalization to untreated targets in the studies based on this approach is also limited [9]. SPT includes modeling, repetition, minimal pair contrast, IS, cueing about the place of articulation, repetitive practice, and KP feedback [7, 13]. This therapeutic approach has shown improvements in treated and untreated targets [9], but it focuses on refining error sounds [13] rather than targeting the fundamental aspect of the disorder, which is difficulty in sensorimotor planning and programming of speech movements.

Considering the advantages and disadvantages of the mentioned approaches, an effective treatment for acquired apraxia should possess certain characteristics and components. Darley et al. (1975) believed that the goal of AOS treatment is to help patients relearn the motor sequences required for accurate sound production [20, 21]. Most researchers who have studied the treatment of AOS have outlined six general and important principles to help individuals with AOS relearn motor speech [21]. These principles are:

1) Not all individuals with apraxia are considered suitable candidates for treatment. According to Duffy (2013), aphasia can be so severe in some patients that treatment is not beneficial [21, 22].

2) The patient and the family should be familiar with the characteristics of AOS and the logic of treatment practices.

3) Repetitive and intensive drills are crucial to most treatment programs. The repetitive nature of treatment is a consequence of brain damage. Patients with brain damage should practice more and for a longer duration than those without brain damage [21, 23].

4) The program should be designed such that the patient can achieve and retain a high level of success. For this purpose, the patient should start with simple activities and progress to more complex ones. Progress is made when the patient consistently completes the tasks correctly at each stage [21].

5) Patients should learn to monitor their speech. The importance of this topic is emphasized by many writers [21-23]. Feedback from speech therapists can enhance this ability in many patients. If the therapist provides the patient with information about acceptable production, the patient can better determine whether their production is accurate [21].

6) Treatment should focus on meaningful words in the early stages because meaningful stimuli are more reinforcing than meaningless words, and it is easier for the patient to realize the accuracy of their articulation of real words [21, 24].

Among all the treatment approaches used in childhood apraxia of speech (CAS), dynamic temporal and tactile cueing (DTTC) is an IS method designed for children with severe problems in speech praxis and does not require long-term use for effectiveness [25]. This approach, in several studies using a single-case experimental design, showed the most supporting evidence among treatment approaches for CAS [4, 25-29]. The usefulness of this approach has also been shown in the treatment of two Spanish-English bilingual children, and it was effective for both languages [28, 30]. Also, Kung and Ugas (2021) conducted a critical review to examine the effectiveness of DTTC on CAS. They analyzed six studies, comprising two single-case studies and four single-subject studies, all focused on school-age children with moderate-to-severe CAS. The authors found that in four studies, DTTC led to positive changes, while in Maas et al.'s two studies, the results were mixed. In both studies, one child did not show clear improvement [31]. The DTTC method has stages and components that can lead to the re-learning of motor sequencing to produce phonemes accurately in patients with AOS. Getting familiar the patient with the logic of therapeutic drills, implementing this approach 3 or 4 days a week, targeting lexical items, practicing them over a time hierarchy, and considering a criterion of repeated and accurate productions for entering the next stage will result in learning real words in a hierarchy of easy to more complex practices and increase the patient's success in articulation. Also, by providing KP feedback, progressing to KR feedback, and gradually removing it, patients learn to monitor their articulation and gradually gain independence in this task. Focusing on the child's attention to self-controlled production, avoiding pictorial stimulation, emphasizing visual and auditory imitation of the therapist in a face-to-face mode, and the possibility of going forward or backward to the previous stage according to the patient's changes and needs are other key components of this method [25].

In addition to the advantages mentioned above, the PML is well considered for learning and retaining speech motor control in the DTTC protocol. For example, the therapist explains each step and reminds the patient that "we're working on movement patterns to make speech easier" or periodically reminds the patient to "feel" the movements [25]. On the other hand, children with severe CAS have a lot of difficulty in making correct speech movements, and the variety in practices increases this problem; therefore, DTTC has addressed this issue at every stage of this protocol. DTTC initially teaches the treatment targets through constant practice and, once accurate movement gestures are established, adds variation in speed and prosody, consistent with the findings of a study by Rosenbek et al. (1973) in the field of acquired AOS [23, 25]. Also, in DTTC, the treatment targets are taught in block practice in the early stages, and they are practiced randomly in the last stage (spontaneous speech) [25]. The reason for using this method in the DTTC approach is that, when tasks are difficult or the learner is inexperienced, random practice requires more attention, memory, and movement and overloads the nervous system [25, 32]. This is consistent with the results of Shea et al. (1990), who showed that block practice in learning motor speech leads to faster acquisition, and that after initial learning, random practice leads to better retention of these movements [33]. Better maintenance of treatment results with random practice was also shown in Knock et al.'s (2000) study of AOS subjects [12]. In terms of the feedback, DTTC initially

begins with repeated feedback on the inaccurate movement gestures and explains how it should be corrected (KP); as the movement accuracy increases, this type of feedback is changed to KR feedback (about the accuracy or inaccuracy of the produced target), and finally, this type of feedback is also eliminated [25]. Strand et al. (2006) have shown that using repeated KP feedback initially and eliminating it as early as possible is beneficial in retaining speech movements in children with CAS [25, 34]. Researchers have also shown that feedback frequency is beneficial for learning complex motor skills until a desired level of accuracy is achieved [25, 35].

In summary, the differences between the DTTC and MLG/SPT are: MLG presents treatment targets in a random order. No cues are given to the patient in MLG to correct speech movements; the patient only receives KR feedback. Also, the therapist's production speed is the same in all stages of the protocol, and the patient does not practice the target word or phrase in different prosody. The targets are presented using written and auditory stimulation. Auditory stimulation fades with progression through stages [11]. In SPT, the goal is to correct a specific sound or group of sounds in the word, and the production of a specific sound is corrected using written stimulation (reading grapheme), auditory discrimination (minimal pair contrast), and articulatory cues. Also, the therapist's production speed is the same across all stages of treatment [2, 13]. In SPT's protocol, if a patient is unable to accurately produce the target, the next target is presented to him/her [13]. While in DTTC, the protocol hierarchy includes simultaneous production, immediate imitation, delayed imitation, and spontaneous production, during which the patient practices the target word or phrase from slow to natural speed. The emphasis is on modifying the articulatory movement, and the therapist uses a variety of visual, gestural, and tactile cues to teach the desired movement. Indeed, DTTC focuses on the movement of articulators, rather than the sound, to form vocal tract shapes and achieve fluent transitions between them. In this protocol, the frequency of cues and feedback is gradually reduced, and, after the correct production of the whole word or phrase, the patient produces it with different prosody (Appendix 1) [25]. SPT and MLG do not practice the treatment targets in different prosody [11, 13]. Given that AOS mainly involves disruption of articulation and prosody [8], the emphasis on modifying prosody in the DTTC approach is important and a highlight of this treatment method [25]. In DTTC, the ultimate objective is to achieve precise articulation and prosody of the target (word or phrase). It contains specific criteria for advancing or regressing based on the patient's production [25].

Given the definitions of CAS and AOS, using DTTC for AOS seems reasonable. CAS is caused by a deficiency in sensorimotor planning and programming, which translates linguistic data to motor execution codes required for acoustic output [25, 36]. In AOS, the "motor speech programmer" is a neural network in the brain that receives information from different areas, such as cognition, language, motor, sensory, and emotion, and converts it into the neuromuscular contractions needed to produce words in an utterance [21]. Therefore, it may be possible to use a developed CAS treatment for AOS, as prompts for restructuring oral muscular phonetic targets (PROMPT) is a treatment method developed for CAS and, after modification, was successfully used to treat AOS [37].

In addition to the advantages of the DTTC treatment method, the developer designed a perceptual scoring system that accounts for and assigns importance to articulation and prosody errors associated with verbal apraxia [4]. As a result, improved accuracy in producing treated and untreated targets based on this scoring system and higher scores in the probe sessions may suggest a reduction in verbal apraxia symptoms among participants.

Given the characteristics of the DTTC approach and its effectiveness in treating children with severe CAS, the primary and secondary aims of this research are to translate this protocol into Persian and to use it in the treatment of patients with acquired AOS, respectively. This study protocol presents the different steps of this research.

Materials and Methods

A single-subject study with a multiple-baseline design across participants will be conducted. These single-case designs have been called demonstration designs. That is, they allowed researchers to demonstrate that an intervention was effective for changing an intended behavior. A multiple baseline design across participants is appropriate for clinical and educational research when three or more individuals exhibit similar behaviors or deficits that require intervention. In studies using multiple baseline designs, experimental control can be demonstrated if three conditions are met: sufficient internal validity, observed behavior change occurring only when the intervention is introduced at each target tier, and at least three tiers with the same starting point in the baseline [38]. In A-B-A-B designs, if experimental control is demonstrated for some participants but not all, it can be concluded that the intervention worked for some but not for others. In multiple baseline designs across participants, if behavior

change occurs for some participants, experimental control is at risk for all, as this change may be due to history, maturation, and other factors. In this study, DTTC method will be implemented on patients with AOS for the first time; therefore, we will select a single-subject design to obtain detailed information about what will happen to the participants and data. Also, we will select a multiple baseline design because the independent variable (intervention) is an irreversible behavior and threats to internal validity can be recognized and controlled by this design [38]. The researchers are going to implement this plan concurrently in the present study. The condition for implementing this research plan is that a group of participants (at least three individuals) begin baseline measurements simultaneously. The first participant will attend at least eight sessions during baseline measurements. If the level and trend of baseline data in three consecutive probes immediately preceding the treatment across all participants are stable, the first participant will receive the treatment. This is because, to demonstrate experimental control, stability in levels and trends must be considered before making any changes to conditions. In case of an increase in the percentage of accuracy for the treated targets over 3 consecutive data points during the treatment phase, provided that the data does not overlap with the baseline, the second participant enter the treatment phase [38]. This criterion will be followed for the remaining participants. Therefore, in this research, each participant will attend at least eight sessions during the baseline phase and 24 during the treatment phase. Each participant will be followed up 1 and 4 weeks after the last treatment session [12]. There are five threats to internal validity that are specifically related to multiple baseline designs across participants: history, maturation, testing effects, attrition bias, and inconsistent effects. In this study, if a threat due to history, maturation, or testing effects occurs in any tier, researchers do not alter the condition until the data stabilized. These threats can be identified by observing any changes in dependent scores in the baseline that do not occur simultaneously with a change in condition. To address attrition bias, researchers will randomly assign participants to different tiers to mitigate this threat [38]. This can be accomplished by rolling a die and disregarding rolls 4, 5, and 6 [39]. Inconsistent effects, that is, variations in changes across different tiers or no changes in some tiers, will be addressed by including participants with similar characteristics in the study as much as possible [38].

The study location will be determined based on participants' preferences.

The study population included patients with acquired AOS of any gender, and sampling will be performed in speech therapy clinics, hospitals, and medical centers in Tehran City, Iran. After ensuring that the inclusion criteria are met, this study will be conducted on at least three patients with AOS.

The inclusion criteria for participating in this study are:

History of a stroke in the dominant hemisphere for the language that has been at least 6 months since its occurrence

Being monolingual Persian: Passing the pure tone audiometry screening test at the threshold of 35 dB at frequencies of 500, 1000, and 2000 for at least one ear; if the patient uses a hearing aid, it is necessary to confirm the hearing adequacy at the conversational level by an audiologist.

Normal or corrected (using lenses or glasses) visual ability

Absence of alcohol or drug abuse, psychological and neurological disorders other than one stroke, based on self-report and confirmation by their medical records.

Obtaining a normal range score of the non-verbal intelligence test using Raven's progressive matrices [40]

Being right-handed by Edinburgh handedness questionnaire [41]

Absence of dysarthria or mild dysarthria according to the Frenchay Dysarthria assessment 2 (FDA-2) [42]

Auditory comprehension above 50% in Persian Mississippi aphasia screening test (MASTp) and Persian diagnostic aphasia battery (P-DAB-1) [43, 44]

Has a literacy level of 8th grade and above

Diagnosis as AOS based on the supplemental verbal apraxia test [45]

Obtaining a minimum score of 32 (moderate to severe) and above (severe) in the verbal apraxia test [45]

All tests are valid and reliable in Persian. The Raven test, P-DAB-1, and verbal apraxia test have been standardized in Persian and have established cutoff scores for diagnosis and determining severity [40-45].

The first author will diagnose AOS, which will be confirmed by the corresponding author, who is experienced in diagnosing and treating AOS

Exclusion criteria will be include receiving speech therapy during the study, occurrence of stroke, and unwillingness to participate in the study for any reason. The sampling method in this research will be non-probability and convenience. Figure 1 shows the stages of the study that will be completed after finishing it.

This study holds the ethical code from the Ethics Committee Office of Tehran University of Medical Sciences and the registration number from Iranian Registry Clinical Trails (IRCT).

First, permission to translate the DTTC treatment protocol will be obtained from the developer of this protocol, and the Persian version of the protocol will be prepared. This process will be conducted according to the translation and cultural adaptation protocol of Beaton et al. (2000). Based on this protocol, first, the DTTC treatment protocol will translate into Persian by two translators. Second, the translations will be reviewed by an expert committee, and a unified version will be created. Third, two other translators translated the integrated Persian version of DTTC into English. In the fourth step, after reviewing all the translations by an expert committee, the finalversion of the Persian DTTC protocol will be created [46].

To determine the effectiveness of the DTTC treatment approach on speech skills in individuals with AOS, treatment targets will be designed for each participant upon study entry. The target items for treatment in this study will be 10 words and short phrases, will be selected for each participant by interviewing the patient and family regarding words and phrases of personal relevance and interest. Each participant's target list also will included 10 untreated words and phrases, will match to the treated list as closely as possible based on their variables [26]. The percentage of the accurate production of treated and untreated words and phrases in the probe sessions will be used as a dependent variable (outcome measure). Treated words and phrases will be used to measure the acquisition effects of treatment (retention), and untreated words and phrases will be used to measure the response generalization effects of treatment [2, 4]. The list of treated and untreated words and phrases will be presented at least eight times to each participant for continuous measurement during the baseline phase. Also, the probe sessions will be performed at the beginning of each treatment session to quickly identify threats to internal validity. During the follow-up phase (1 and 4 weeks after the end of the treatment), these two lists will be presented to the participants. In each probe session, the words and phrases of these two lists will be presented to the patient in random order. The examiner (the first author) will ask the participant to carefully look and listen to the model and repeat each word as accurately as possible. No feedback will be provided regarding the accuracy of the production [2, 4]. During the treatment phase, each participant will attend 24 treatment sessions, three times a week, each lasting 60 minutes (excluding the probe session), which is considered a traditional dose frequency [7]. Each treated word and phrase will be written on a card. The order of presentation of words and phrases will be the same across consecutive sessions in each treatment, because, based on the DTTC method, the treatment targets should be taught in block practice in the early stages. The therapist (the first author) will implement the hierarchy of the DTTC protocol for each target (Appendix 1). In the spontaneous speech stage, the last step of the protocol, this will be performed randomly during the session (while working on other words) [25]. There will be two criteria for completing the treatment phase: completion of 24 treatment sessions or achieving 90% accuracy in articulating treated words and phrases across three consecutive probe sessions [4, 25, 26]. Each participant will be followed up 1 and 4 weeks after the completion of the treatment phase.

The percentage of the accurate production of treated and untreated words and phrases in the probe sessions will be based on a perceptual scoring system. This system includes both segmental and suprasegmental aspects of word articulation. In this system, a score of 2 indicates accurate production, a score of 1 indicates close to accurate production, and a score of 0 indicates inaccurate production of a word or phrase [4, 25, 26, 29, 34]. These scores have been operationally defined by Maas's et al. [4, 26].

The primary reason for conducting a single-subject study is to gather detailed information about a participant's performance when subjected to factors, such as specific intervention procedures. In statistical analysis, data from single-subject studies are typically presented for each participant, often using graphs during data collection. This enables researchers to use the data for clinical decision-making [39]. In a single-subject study with a concurrent multiple baseline design (true multiple baseline design), participants' graphs should be presented so that the first data collection session for each tier should align with the first session along the horizontal axis. This approach shows that baseline data were initi-

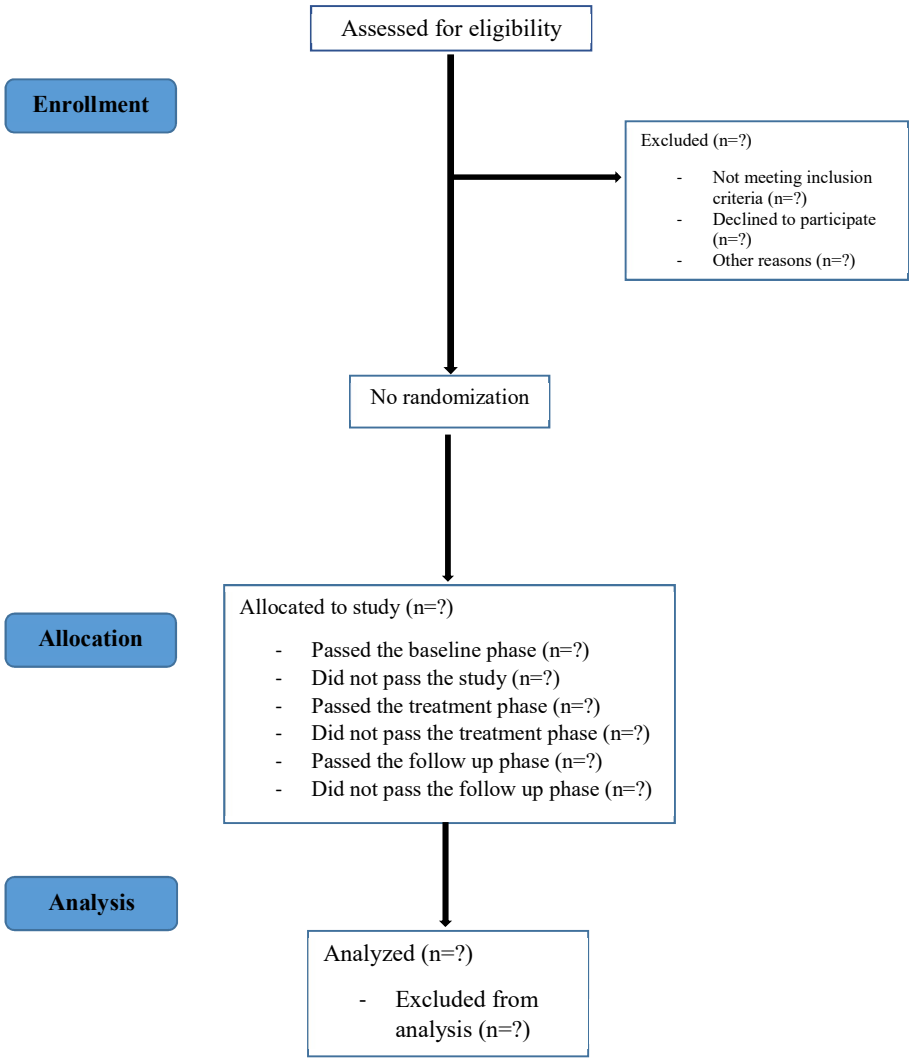

Figure 1. Steps of the study

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ated simultaneously across all tiers. This allows for an accurate visual analysis of the results while considering potential threats, such as maturation, history, testing effects, and inconsistent effects, which are essential for demonstrating experimental control [38]. The celeration line analysis, level, trend, and slope analysis, and the two-standard deviation band analysis approach will be the visual analyses based on the graph [39]. C-statistics will be used to assess the significant effects of the treatment. This analytical method requires at least eight data points. It is first applied to the baseline data. If no significant trend is observed during this phase, the baseline and treatment data will be combined, and the C statistics will be recalculated to determine whether a statistically significant change has occurred [47]. Treatment effectiveness will be assessed by percentage of non-overlapping data (PND) and effect size. PND will be calculated by dividing the number of data points in the treatment phase that fall outside the baseline range by the total number of data points in the treatment phase. The quotient obtained from this division will be multiplied by 100 to represent one percent [38]. A PND above 90% indicates a very effective treatment. A percentage between 71% and 90% suggests an effective treatment. A percentage between 50% and 70% suggests a questionable effective treatment, while a percentage below 50% indicates an ineffective treatment [48, 49]. To calculate the effect size, Equation 1 will be used for treated targets:

1. $ES=(M_{A2}-M_{A1})/SD_{pooled}$

Here, M_{A1} represents the mean of the consecutive eight data values in baseline immediately before the treatment phase, M_{A2} represents the mean of the treatment values, and SD_{pooled} is a measure of the variability of the data across baseline and intervention conditions [4, 38, 50].

Improvement will be defined as effect sizes greater than 1.00, which means mean differences exceed the standard deviation [4, 26, 50]. Visual analysis, the C statistics, PND, and effect size will be reported for each participant.

Given that the scoring criteria in DTTC are subjective, it is essential to avoid potential issues arising from human observers, such as errors, bias, and drift. To address this, one-third of all sessions in all conditions for each participant involved in the single-subject study during the probe sessions will be reported re-scored by an independent speech and language pathologist, alongside the initial assessor. The researchers will visually analyze secondary data to identify any potential bias or drift. The second pathologist will be unaware (blinded) of the study phase and the list of words being tested [38]. The recorded sessions will be used for rescoring. In the end, a point-to-point agreement will be calculated for each word or phrase and finally for each probe session [2]. An agreement value of 80% or better will be acceptable. To avoid chance agreement, occurrence, and non-occurrence agreements will be also calculated [39].

During the intervention implementation, treatment fidelity for all participants will be measured by randomly selecting at least 25% (6 sessions) of videos recorded during treatment sessions [11]. These videos will be viewed by an independent analyst evaluating the fidelity measurement using the checklist in Appendix 2. The analyst will then score fidelity based on this checklist [25].

Ethical considerations will be followed throughout the study. The information obtained during the study, individual characteristics, and evaluation results will be preserved. All participants will sign the consent form themselves or with their legal guardians and will be able to withdraw from or leave the study at any stage without feeling obligated to continue. The evaluations and interventions do not harm the participants, and they are will not be charged for them.

In this study, assuming all conditions will be met, it will be expected to take 2 months to translate the DTTC treatment protocol, 4 months to sample and implement the treatment intervention, 3 months for data analysis, and 4 months to publish the research results.

Results

Tables 1 and 2 present the participants' characteristics and the results of the pretreatment assessments.

A visual analysis will be conducted based on the participants' graphs. Figure 2 shows a true multiple-baseline design across participants, based on their tier assignments. In these Figures, blue markers will represent the accuracy for treated targets, while red markers will indicate the accuracy of the untreated targets. The horizontal axis for all participants will be labeled as follows: B: Baseline-phase probes; T: Treatment-phase probes; and F: Follow-up-phase probes. Each probe session will be numbered on the horizontal axis. The vertical axis will display the percentage of target accuracy for all participants.

Tables 3 and 4 will present the results of calculating effect sizes in treated targets and C statistics, respectively. The results of the PND will be reported in the text.

Table 1. Participant descriptive characteristics

Participant	Gender	Occupation	Native and Dominant Language	Other Languages	Injury Hemisphere	Injury Location of the Brain	Age (y)	Number of Strokes	Months Post Onset From 1st Stroke	Years of Education
1										
2										
3										

Table 2. Pretreatment assessment results

Assessments		P1	P2	P3
The non-verbal intelligence test	IQ			
	Grade			
FDA-2				
MASTp	Expressive index (50)			
	Receptive index (50)			
P-DAB-1	AQ			
	Aphasia severity			
	Score of auditory comprehension subtests (20)			
The verbal apraxia test	Score			
	Severity			

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Abbreviations: IQ: Intelligence quotient; FDA-2: Frenchay dysarthria assessment 2; MASTp: Persian Mississippi aphasia screening test; P-DAB-1: Persian diagnostic aphasia battery.

Table 3. Effect sizes for treated targets in treatment and follow-up phases

Participant	M_B	M_T	M_F	Effect Sizes	
				ES (T&B)	ES (F&B)
P_1					
P_2					
P_3					

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Abbreviations: M_B: Mean of the consecutive eight data values at baseline immediately before the treatment phase; M_T: Mean of the intervention value; M_F: Mean of the follow-up value; ES (T&B): Effect size for treatment acquisition; ES (F&B): Effect size for treatment retention.

Table 4. C statistics analysis for the treated targets

	P_1	P_2	P_3
Baseline			
z			
p			
Baseline and treatment			
z			
p			

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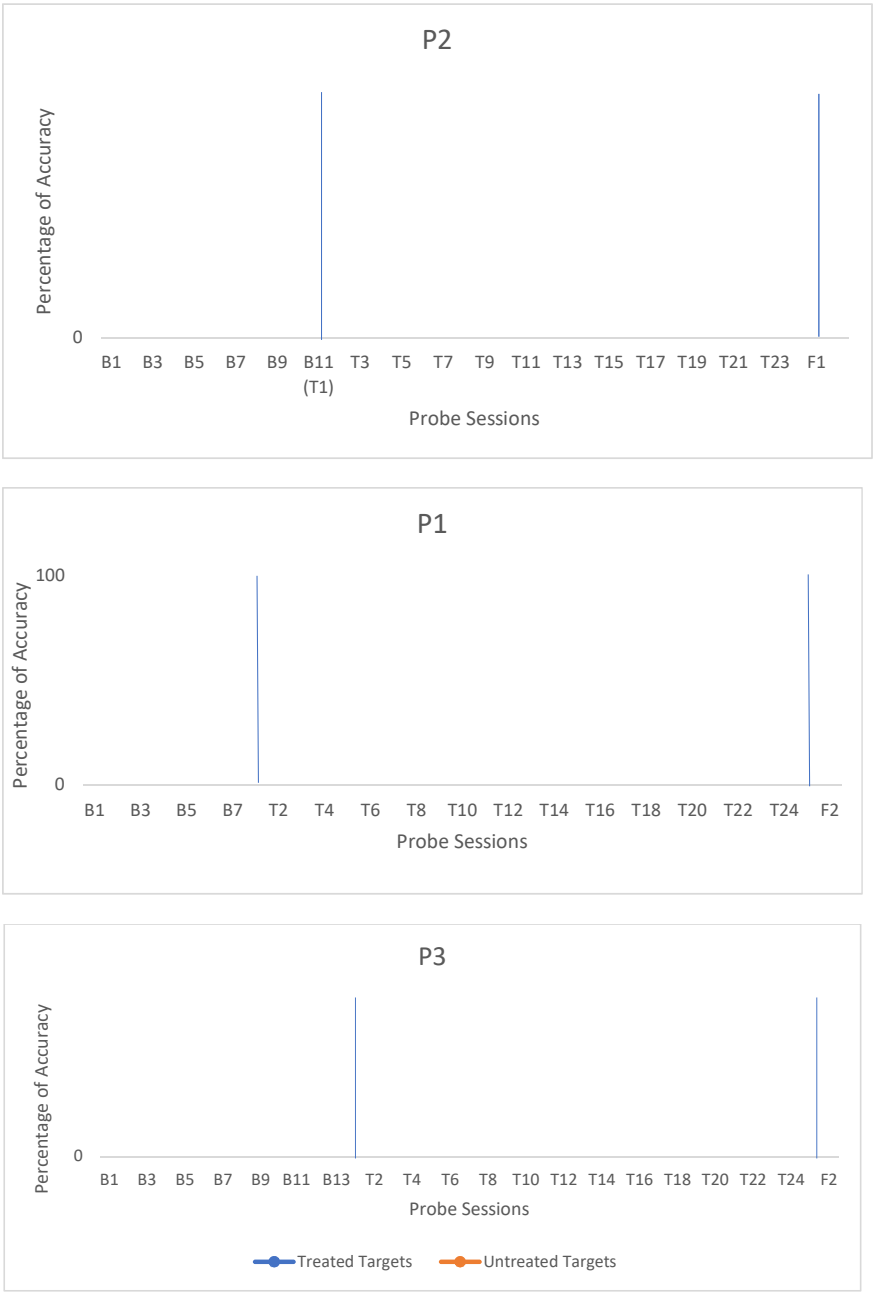

Figure 2. Percentage of accuracy in participants

P: Participant.

Discussion

This study will be conducted to determine the efficacy of the DTTC approach in improving the symptoms of acquired AOS in Persian-speaking patients. No treatment protocol has been developed for Persian-speaking patients with AOS to date, and this study is the first of its kind in Iran. Also, the researcher's investigations showed that no study has been conducted on the efficacy of DTTC on speech skills among people with AOS. Studies show that the most common treatments in AOS are articulatory-kinematic approaches, and their effectiveness has been demonstrated in various studies [8, 9]. We hypothesize that in the treatment of people with moderate to severe and severe AOS, DTTC leads to significant learning and acquisition of speech skills to produce treatment targets, as well as to retention and generalization of treatment results in functional communication for patients. If this hypothesis can be demonstrated, we will

compare the efficacy of the DTTC protocol and current treatments for AOS in future studies.

Despite the merits of this study in designing the first treatment approach for Persian-speaking patients with AOS, it has some limitations. One of the main limitations of this study is the strict inclusion criteria, which will probably lead to a small number of participants. We have to use the verbal apraxia test to determine the severity of AOS, and one of its sub-tests involves reading different items. Therefore, illiterate patients and those with insufficient reading skills will be excluded from this study. Also, due to the long-term study, there will be a high risk of participant attrition.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee of Tehran University of Medical Sciences, Tehran, Iran (Code: IR.TUMS.FNM.REC.1402.087). This study was registered by the Iranian Registry of Clinical Trials (IRCT), Tehran, Iran (Code: IRCT20240224061099N1).

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Authors' contributions

Conceptualization and study design: Maryam Alizadeh, Azar Mehri, and Edythe Strand; data analysis and interpretation: Maryam Alizadeh and Shohreh Jalaie; data acquisition, and writing the original draft: Maryam Alizadeh; review, editing: Azar Mehri; Final approval: Azar Mehria, Shohreh Jalaie, and Edythe Strand.

Conflict of interest

The authors declared no conflict of interest.

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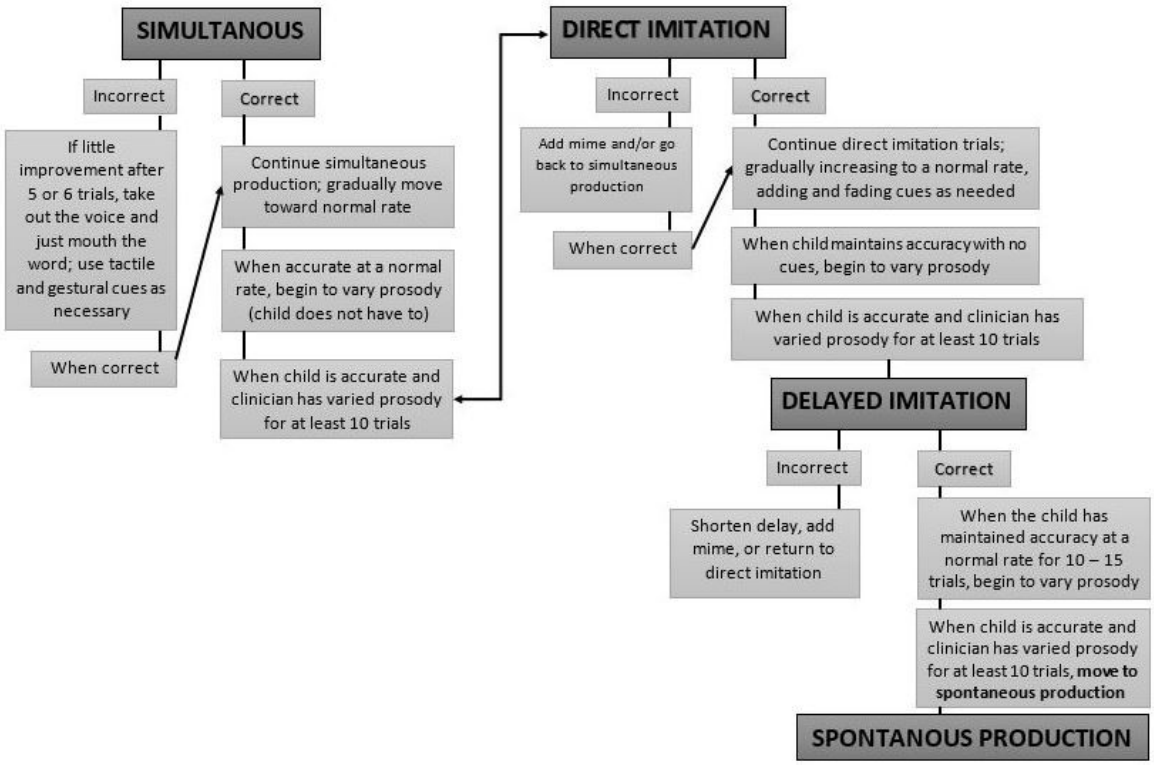
Appendices

Appendix 1. Complete dynamic temporal and tactile cueing hierarchy illustrating when and how to move up or down the hierarchy (derived from Strand, 2020 [25])



Appendix 2. Fidelity checklist for DTTC treatment session (derived from strand: DTTC, 2020, adapted to purpose of current study)

General Observations per Session (Check Those in Which the Condition Was Met)		
_____		Used 4–10 targets[a]
_____		Used a modified block organization of practice[b]
_____		Provided fading of feedback[c]
_____		Sitting facing participant; close to eye level
_____		Reduced background noise; no distracting items near participant
_____		Gave the participant reassurance and good instructions
		For each target (this would be repeated for each target practiced that session)
Observed	Not necessary	
_____		Reminded them that "we are working on moving better so that speech is easier"
_____		Drew attention to the clinician's face when needed
_____		Periodically reminded them to "feel" the configuration or movement
_____	_____	If not successful at the first or second try, went to simultaneous production
_____	_____	Used phonetic placement if necessary
_____	_____	Took out the voice and made the articulatory movement only if necessary
_____		Used tactile cues when appropriate (at least 80% of the time)
_____		Started slowly and gradually worked toward a normal rate
_____		Added cues appropriately at least 80% of the time
_____		Faded cues appropriately at least 80% of the time
_____		Moved from simultaneous to direct imitation if conditions were met
_____		Moved from direct imitation to delayed condition if conditions were met
_____		Moved from delayed condition to spontaneous production randomly if appropriate
_____		Achieved appropriate number of practice trials over the session

[a]Used a smaller set size (four to ten targets) with functionality, syllable shape, and vowel content and length appropriate to the severity AOS; [b]Practiced each target between 10 and 40 trials, with one or two targets receiving more trials than the other targets, and perhaps more than one block of practice per session; [c]Feedback was faded (in both specificity and frequency) during practice within a block, as the participant became more accurate (score if this was observed at least 50% of the time when appropriate).