Research Article

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

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Running title: DTTC efficacy in stroke patients with AOS

Abstract

Background: To introduce Dynamic Temporal and Tactile Cueing (DTTC), which is one of the treatment methods for Childhood Apraxia of Speech (CAS), and it seems the characteristics make it a suitable option for the treatment of AOS patients. Additionally, no documented treatment protocol has been published in Iran for the treatment of AOS patients so far, so this study protocol intends to investigate the DTTC efficacy in the treatment of Persian-speaking patients with acquired AOS who will be allocated to this study using a non-probability and convenience method.
Material and Methods: A single subject study with multiple baseline design across participants was designed to obtain detailed information about 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.
Conclusions: This study describes the first research for investigating efficacy of DTTC on AOS patients' speech and the first treatment protocol in the field of treating Persian-speaking patients with AOS.
Keywords: Acquired apraxia of speech; dynamic temporal and tactile cueing; stroke

Introduction

Apraxia of Speech (AOS) is a motor speech disorder that has 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 and minor sound distortions to an inability to produce speech. AOS usually coexists with non-fluent aphasia and rarely occurs in a "pure" form, and 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 a variety of techniques to treat AOS. Wambaugh et al. (2006) have divided the underlying approaches in the treatment of AOS into four main categories: 1) articulatory-kinematic approaches, 2) rate and/or rhythm control treatments, 3) augmentative and alternative communication techniques, 4) intersystemic facilitation and reorganization techniques (6, 7). Various studies have shown that by far, the articulatory-kinematic approach is the most used in the treatment of AOS (6, 8, 9). The positive results of treatments based on the articulatory-kinematic approach have been reported in terms of retention, generalization to untreated targets, and increased social validity in various studies (10-13). This group of treatments focuses on motor planning by using intense 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 about the sound production accuracy, a stable manner, and place of articulation and voiced/voiceless sounds (14, 16). Using sensory cueing methods, such as Integral Stimulation (IS), involving intense repetition and articulatory cues, can enhance the accuracy of producing words and phrases (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 the practice of 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 will be 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 in a week indicates mass practice, while three one-hour sessions in a 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. On the other hand, KR involves the clinician informing the client whether their production is correct or not. Finally, practicing a learned task in different contexts enables the application of the skill in new situations and facilitates the transfer of learning to other movements (17, 18).

Among different treatment approaches of AOS, Motor Learning Guided (MLG) and Sound Production Treatment (SPT) are two articulatory-kinematic approaches that have reported replications of treatment effects in AOS. 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, and delayed KR feedback, and practice of stimuli in successive random order (9, 19). This approach uses oral reading, which may be challenging for apraxia patients who often have aphasia, and using it as a dependent variable may obscure the results. It also seems that the generalization to untreated targets in the studies based on this approach is 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 seems that this treatment method focuses on refining error sounds (13) and doesn't target the fundamental aspect of the disorder, which is difficulties in sensorimotor planning and programming of speech movements.

Considering the advantages and disadvantages of the mentioned approaches, it seems that the effective treatment for acquired apraxia should have certain characteristics and components. Darley et al. (1975) believed that the goal of AOS treatment is to help the patients re-learn the motor sequences required for sound production accuracy (20, 21). Most of the researchers who have studied the treatment of AOS have outlined six general and important principles to help AOS individuals in relearning motor speech (21). These principles are:

1) Not all apraxic people are considered suitable candidates for treatment. According to Duffy (2013), aphasia can be so severe in some patients that treatment would not be beneficial for them (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 important part of most treatment programs. The repetitive nature of treatment is a consequence of brain damage. Patients with brain damage should practice more and longer than patients without brain damage (21, 23).

4) The program should be designed in a way that the patient can achieve and retain a high level of success. For this purpose, the patient should start from simple activities and go forward towards more complex activities. The progress will take place when the patient can consistently complete 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). The feedback from speech therapists can facilitate this ability in many patients. If the therapist provides the patient with information about acceptable production, the patient will be better able to realize whether or not their production is accurate (21).

6) Treatment should be focused on meaningful words in the early stage of treatment 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 one of the types of IS methods, which is designed for children with severe problems in praxis for speech and it does not require long-term use for effectiveness (25). This approach in several studies using 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, which focused on school-age children with moderate to severe CAS. The authors found that in four studies, DTTC resulted in positive changes, while in Maas et al.'s two studies, the results were mixed. In both of them, one child did not show clear improvement (31). It seems that the DTTC method has stages and components that can well lead to the re-learning of motor sequencing to produce phonemes accurately in AOS patients. 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 and progressing them towards KR feedback and gradually removing them, the patients will learn to monitor their articulation and gradually gain independence in this task. Focusing on the child's attention to self-controlled production, avoiding the pictorial stimulation and emphasis on 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, it seems that the PML are 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, so, DTTC has addressed this issue at every stage of this protocol. DTTC initially teaches the treatment targets in constant practice, and when the accurate movement gestures are established, adds variation in speed and prosody, which is consistent with the findings of a study conducted by Rosenbek et al. (1973) in the field of acquired AOS (23, 25). Also, in DTTC, the treatment targets is taught in block practice in the early stages, and it is practiced randomly in the last stage (spontaneous speech) (25). The reason for using this method in the DTTC approach is that when the tasks are difficult or the learner is inexperienced, the random practice requires more attention, memory, and movement and overloads the nervous system (25, 32). This point is in consistent with the results of the study conducted by Shea et al. (1990), which showed that block practice in learning motor speech leads to faster acquisition, and after initial learning, random practice leads to better retention of these movements (33). Better maintenance of treatment results using random practice were also shown in Knock et al.'s (2000) study conducted on 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 CAS children (25, 34). Researchers have also shown that feedback frequency is beneficial for learning complicated motor skills until degrees of accuracy are achieved (25, 35).
In summary, the differences of the DTTC with MLG and SPT are: MLG presents treatment targets in a random order. No cues are given to the patient in MLG to correct the speech movements, and 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 production speed of the therapist is the same in all stages of treatment (2, 13). In SPT's protocol, if a patient is unable to accurately produce the target, the next target will be 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 finally, after the correct production of the whole word or phrase, the patient produces it in different prosody (see Appendix 1) (25). SPT and MLG do not practice the treatment targets in different prosody (11, 13). Given that in AOS, there is mainly disruption in articulation and prosody (8), emphasis on the modifying prosody in the DTTC approach is important and is one of the highlights 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 needed 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 convert them to neuromuscular contractions needed for producing words in an utterance (21). Therefore, it may be possible to use a developed CAS treatment for treating AOS, in the same way Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT) is a treatment method developed for CAS treatment, and after modification, it was used in treating AOS successfully (37).

In addition to the mentioned advantages of the DTTC treatment method, the developer has designed a perceptual scoring system that takes into account and assigns importance to the 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 the 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 language 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

This research will be conducted as a single subject study and with a multiple baseline design across participants. These types of single-case designs have been named demonstration designs. That is, they allow researchers to demonstrate an intervention is effective for changing an intended behavior. 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: 1) sufficient internal validity, 2) observed behavior change only when the intervention is introduced at each target tier, and 3) having 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 AOS patients for the first time, so we will select a single subject design for obtaining detailed information about what will happen to the participants and data. Also we will select multiple baseline design because 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 the implementation of this research plan is that a group of participants (at least 3 individuals) start the baseline measurements at the same time. The first participant will attend a minimum of 8 sessions during the baseline measurements. If the level and trend are stable of baseline data in 3 consecutive probes immediately preceding the treatment across all participants, 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 in the treated targets in 3 consecutive data points in the treatment phase that does not overlap with the data in the baseline, the second participant will enter the treatment (38). This criterion will be followed for the rest of the participants. Therefore, in this research, each participant will attend at least 8 sessions in the baseline phase and 24 sessions in 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 will not alter the condition until the data stabilizes. These threats can be identified by observing any changes in dependent scores in the baseline that do not occur simultaneously with a condition change. To address attrition bias, researchers will randomly assign participants to different tiers to mitigate this threat (38). It can be accomplished by rolling a die and disregarding rolls 4, 5, and 6 (39). Inconsistent effects, that is, there are variations in changes across different tiers, or in some tiers, there may be no changes at all, will be addressed by including participants with similar characteristics in the study as much as possible (38).

The location of the study will be determined based on the preferences of the participants.

The study population includes patients with acquired AOS of any gender, and sampling will be done in speech therapy clinics, hospitals, and medical centers in Tehran. After ensuring that the inclusion criteria are met, this research will study at least 3 AOS patients.

The inclusion criteria for participating in this study is:

- 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 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 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 the Persian language. 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.

The 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 convenient. The Figure 1 illustrates the stages of the study that will be completed after finishing it.

This study holds the ethical code of ID IR.TUMS.FNM.REC.1402.087 from the Ethics Committee Office of Tehran University of Medical Sciences and the registration number of IRCT20240224061099N1 from Iranian Registry Clinical Trails (IRCT). To translate, first the permission to translate the DTTC treatment protocol will be received from the developer of this protocol and the Persian version of the protocol will be prepared. This process will be done according to Beaton et al.'s (2000) translation and cultural adaptation protocol. Based on this protocol, first, the DTTC treatment protocol will be translated 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 will translate the integrated Persian version of DTTC into English. In the fourth step, after reviewing all the translations by an expert committee, the final version of the Persian DTTC protocol will be created (46).

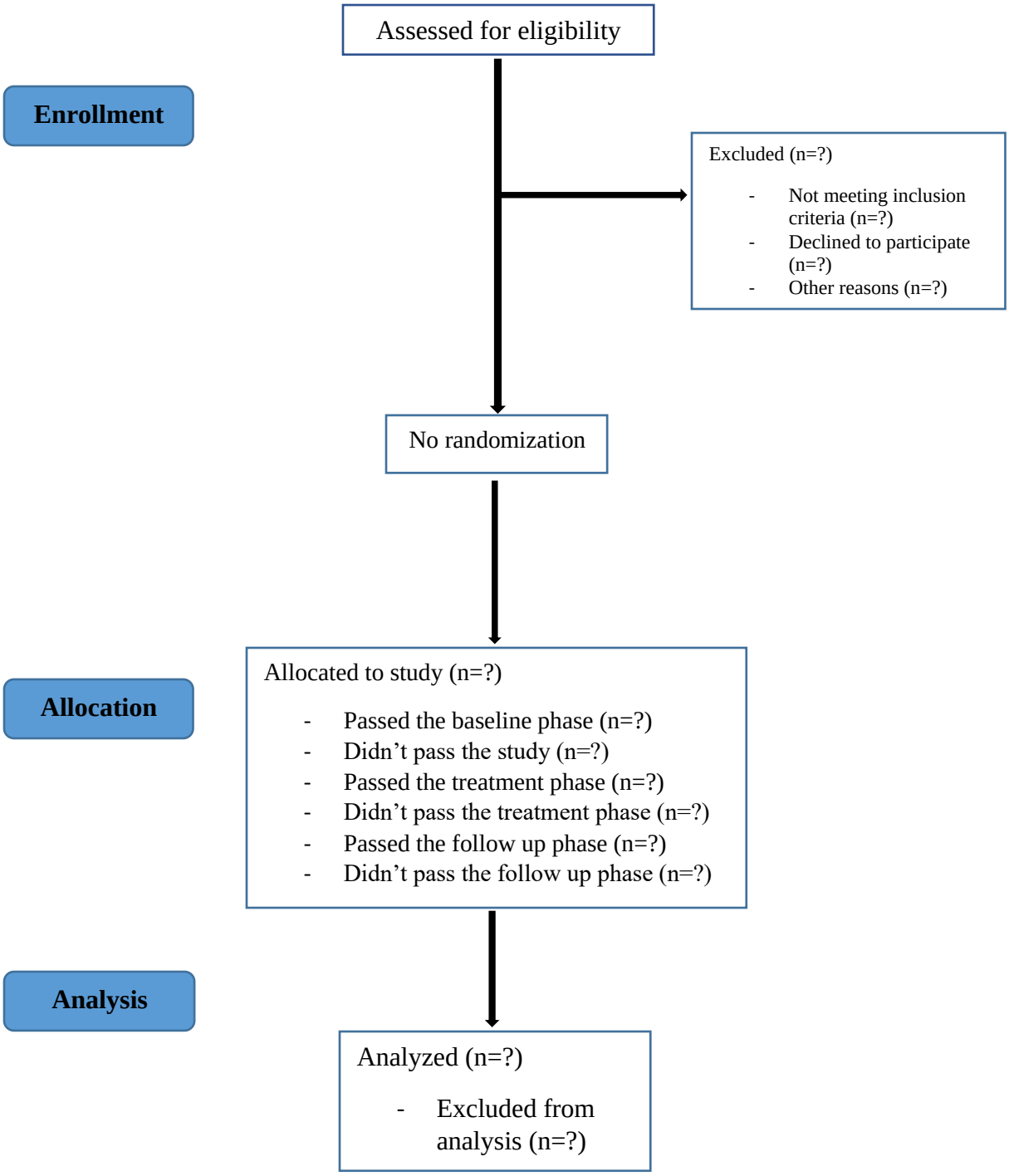


Figure 1. Steps of the study

To determine the effectiveness of the DTTC treatment approach on the speech skills of people with AOS, treatment targets will be designed for each participant after entering the study. The target items of treatment in this study will be ten words and short phrases that will be selected for

each participant by interviewing the patient and family from the words and phrases of personal relevance and interest. The target list of each participant will also include ten untreated words and phrases, which will match the list of treated words and phrases as much 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 dependent variables (outcome measures). 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 performed at least eight times for each participant for continuous measurement in 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, 3 times a week, each session lasting 60 minutes (not including the time for the probe session), which is recognized as a traditional dose frequency (7). Each of the treated words and phrases will be written on a card. The order of presentation of words and phrases will be the same at consecutive sessions in each treatment session, 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 (see Appendix 1). In the stage of spontaneous speech, which is the last step of the protocol, this will be done 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 90% accuracy in the articulation of treated words and phrases in three consecutive probe sessions (4, 25, 26). Each participant will be followed up 1 and 4 weeks after the completion of the treatment phase.

Determining 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, score 2 means accurate production, score 1 means close to accurate production, and zero score means inaccurate production of a word or phrase (4, 25, 26, 29, 34). These scores have been operationally defined in Maas's articles (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 individually, often using graphs during the data collection process. This enables the researcher 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 initiated simultaneously across all tiers. By doing so, it allows for 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 are 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 a minimum of 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 if 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 range of data point values in the baseline 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). If the PND is above 90%, it indicates a very effective treatment. A percentage between 71% - 90% suggests an effective treatment. A percentage between 50% - 70% suggests a questionable effective treatment, while a percentage less than 50% indicates an ineffective treatment (48, 49). To calculate the effect size, this equation will be used for treated targets:

$ES = (M_{A2} - M_{A1})/SD_{pooled}$. 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 value, and SD_{pooled} is a measure of variability of data in 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). Such as visual analysis, the C statistics, PND, and effect size will be calculated for each participant individually.

Given that the scoring criteria in DTTC are subjective, it is important to avoid potential issues that can arise 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 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 this re-scoring. In the end, a point-to-point agreement will be calculated for each word or phrase and finally for each probe session (2). A value of 80% or better for the agreement will be acceptable. To avoid chance agreement, occurrence agreement, and non-occurrence agreement 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 who will evaluate the fidelity measurement using a checklist provided in Appendix 2. The analyst will then score fidelity based on this checklist (25).

Ethical considerations will be followed in all stages of research. The information obtained during the research, individual characteristics and evaluation results will be preserved. All participants will participate after signing the consent form by themselves or their legal guardian and be able to withdraw from, or leave, the study at any stage without feeling an obligation to continue. The evaluations and intervention do not harm the participants and they will not be charged for them.

In this research, by meeting all the conditions, it is expected to take 2 months for the translation of the DTTC treatment protocol, 4 months for the sampling and implementation of the treatment intervention, 3 months for data analysis, and it will take 4 months to publish the research results.

Results

The characteristics of the participants and results from the pretreatment assessments will be shown in tables, such as Table 1 and Table 2.

Table 1. Participant descriptive characteristics

Participant	Gender	Occupation	Native and dominant language	Other languages	Injury hemisphere	Injury location of the brain	Age (years)	Number of strokes	Months post onset from first stroke	Years of education
1										
2										
3										

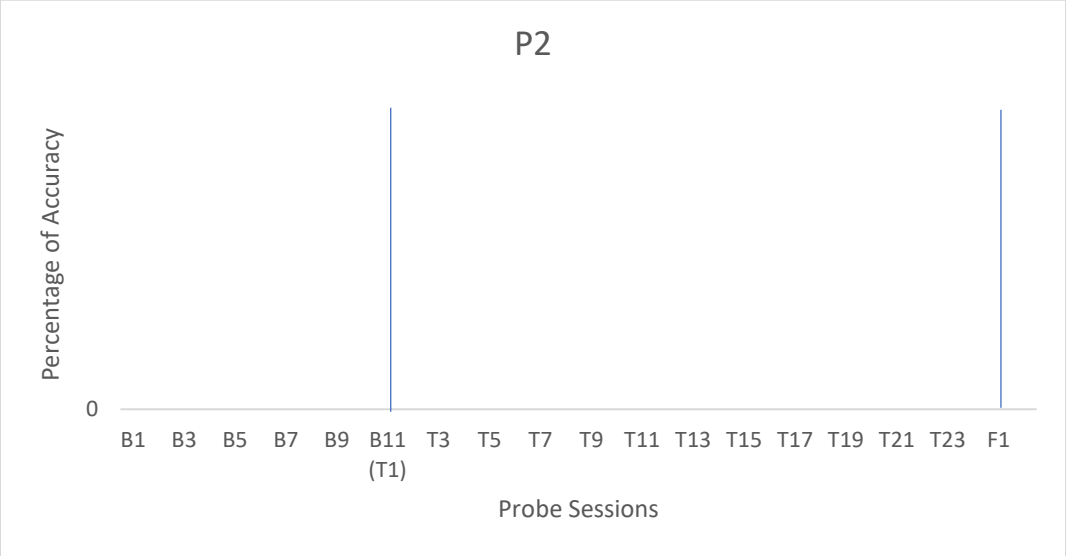
Table 2. Pretreatment assessment results

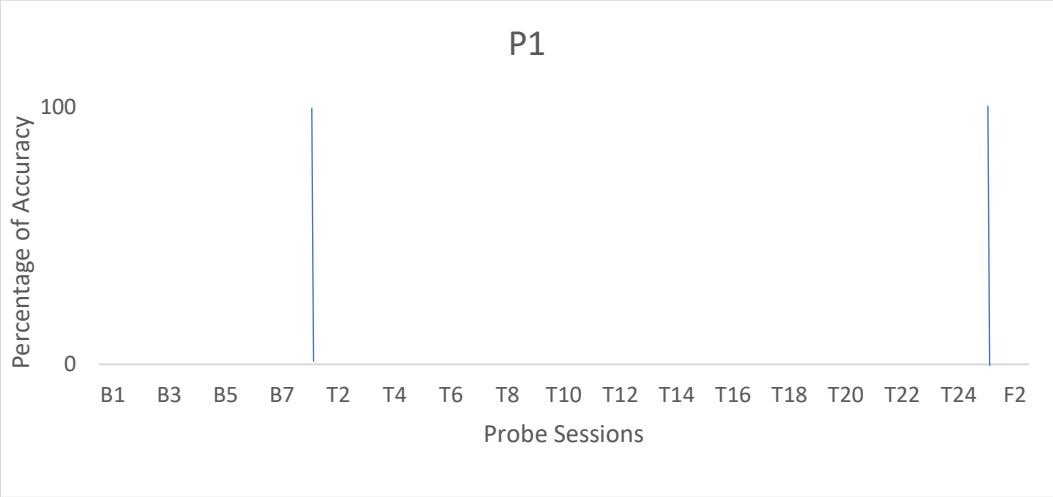
Assessments		P1	P2	P3
The non-verbal intelligence test	IQ			
	Grade			
FDA-2				
MASTp	Expressive Index (50)			
	Receptive Index (50)			
P-DAB-1	AQ			
	Aphasia severity			
	Score of auditory comprehension subtests (20)			
The verbal apraxia test	Score			
	Severity			

Note. IQ = Intelligence Quotient; FDA-2 = Frenchay Dysarthria Assessment 2; MASTp = Persian Mississippi Aphasia Screening Test; P-DAB-1 = Persian Diagnostic Aphasia Battery

Visual analysis will be conducted based on the graphs of the participants. Figure 2 illustrates a true multiple baseline design across participants, based on their assignment to tiers. In these graphs, blue markers will represent the percentage of accuracy for treated targets, while red markers will

indicate the percentage of accuracy for untreated targets. The horizontal axis for all participants will be labeled as follows: B for baseline phase probes, T for treatment phase probes, and F for follow-up phase probes. Each probe session will be numbered on the horizontal axis. The vertical axis will display the percentage of accuracy in targets for all participants.





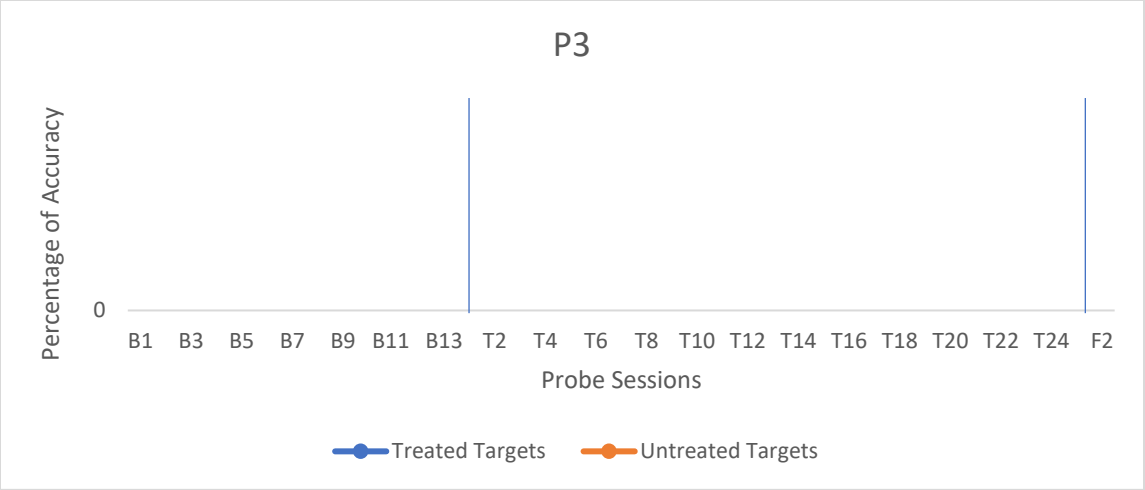


Figure 2. Percentage of accuracy in participants. P = Participant.

Results of calculating effect sizes in treated targets and C statistics will be presented in tables, such as Table 3 and Table 4, respectively. Results of PND will be reported in the text.

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)**
P1					
P2					
P3					

Note. M_B= the mean of the consecutive eight data values in baseline immediately before the treatment phase; M_T= the mean of intervention value; M_F= the mean of 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

	P1	**P2**	**P3**
Baseline			
z			
p			
Baseline and treatment			
z			
p			

Discussion

This study will be conducted to determine the effectiveness of the DTTC approach in improving the symptoms of acquired AOS in Persian-speaking patients. No treatment protocol has been designed for the treatment of Persian-speaking patients with AOS so far, 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 effectiveness of DTTC on the speech skills of AOS people. Studies show that the most common treatments in the field of AOS treatment have an articulatory-kinematic approach, and the effectiveness of this approach in the treatment of AOS has been shown in various studies (8, 9). We hypothesize that in the treatment of people with moderate to severe and severe AOS, the DTTC leads to significant learning and acquisition of speech skills to produce treatment targets, as well as retention and generalization of treatment results to functional communication of 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 AOS patients, it has some limitations. One of the main limitations of this study is the strict inclusion criteria of this study which will probably lead to a small number of participants. We will have to use the verbal apraxia test to determine the severity of AOS and one of the sub-tests of this test is to read different items of the test. For this reason, illiterate patients and patients who do not have enough reading skills cannot be included in this study. Also, due to the long-term study process, there will be a high possibility of participant attrition.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the ethical code of ID IR.TUMS.FNM.REC.1402.087 from the Ethics Committee Office of Tehran University of Medical Sciences.

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Authors' Contributions

Maryam Alizadeh: Substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data, *and* drafting the article; Azar Mehri: Substantial contributions to conception and design, *and* revising the article critically for important intellectual content, *and* final approval of the version to be published, *and* agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; Shohreh Jalaie: Substantial contributions to analysis and interpretation of data, *and* final approval of the version to be published; Edythe Strand: Substantial contributions to conception and design *and* final approval of the version to be published

Conflict of Interest

There are no concerns regarding a conflict of interest related to the paper.

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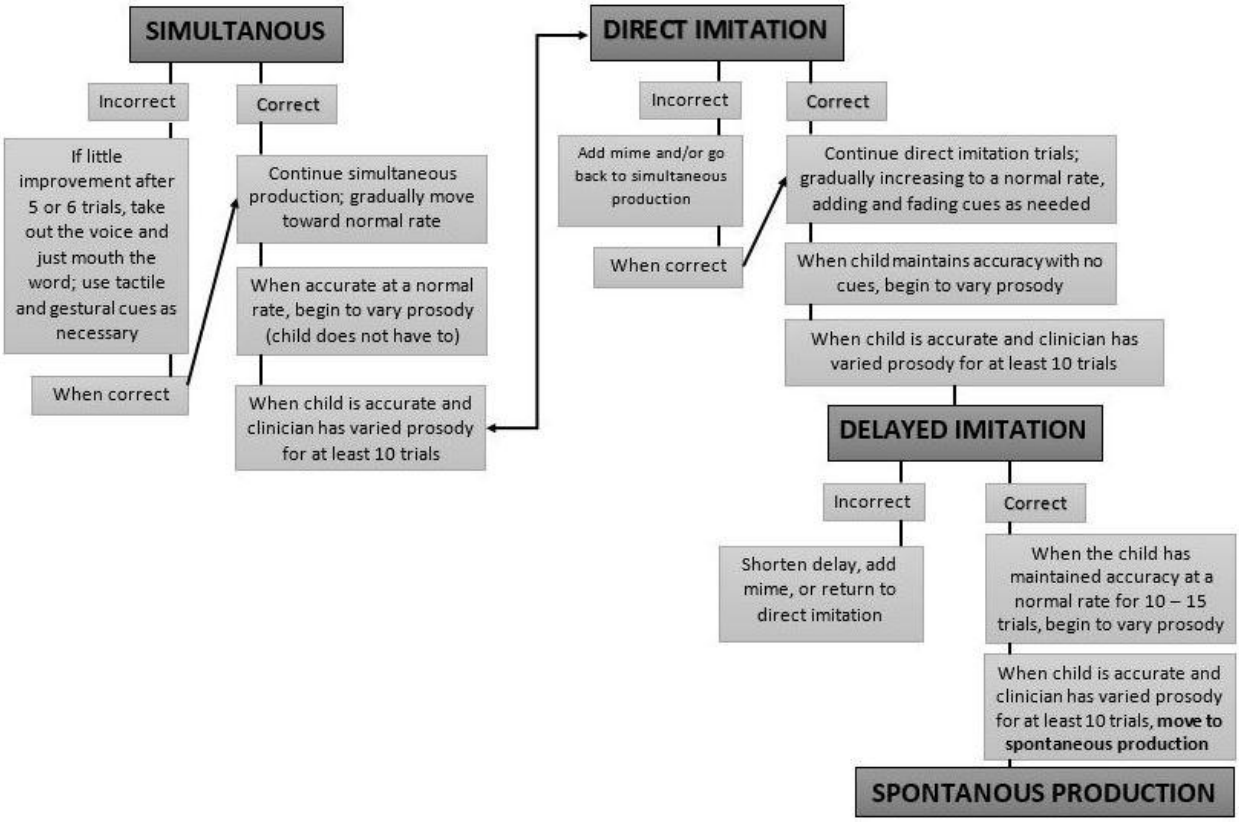
Appendices

Appendix 1. Complete Dynamic Temporal and Tactile Cueing hierarchy illustrating when and how to move up or down the hierarchy. (Derived from Strand EA. 2020)



Appendix 2. Fidelity checklist for DTTC treatment session (derived from Strand: Dynamic Temporal and Tactile Cueing (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).