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The Effect of Motor Learning Theory to Speech of an ESL Student: A Single-Subject Study

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Purpose: The purpose of the current research was to explore whether a motor learning theory-based protocol that emphasized specific practice structures and feedback schedules would be more effective in improving English pronunciation of a nonnative English speaker.
Methods: The protocol consisted of six sessions over a five-week period and trained eight sets of stimuli that included 10 items for each set.
Results: Results revealed improvement in the participant's English pronunciation abilities. The one-way repeated analysis of variance showed statistically significant mean differences among pre-treatment, treatment, and post-treatment. Both intelligibility and naturalness during pre-treatment to treatment and pre-treatment to post-treatment measures was significant. Treatment to post-treatment scores were not significant for both intelligibility and naturalness. The participant yielded better intelligibility and naturalness scores after the treatment and once treatment was removed, suggesting that the use of motor learning principles may be a possible intervention method for managing or improving an accent in nonnative speakers.
Conclusions: The study indicated significant differences between the three treatment groups in speech intelligibility and speech naturalness, but not substantial enough to reach a generalization effect as there was a small sample size. Further research is needed to examine significant differences. Given the single-subject design, the findings are unable to reach a generalization effect. Future investigations in a broad-spectrum of nonnative English-Second language speakers are needed to further validate these findings.

Keywords: Accent modification, speech motor intervention, motor learning theory, motor learning principles, adult intervention

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Ⅰ. Introduction

Motor learning has been applied in various evidence-based research experiments. Commonly, it has been experimented in a multitude of kinesiology practices. Motor learning is theorized as a motor system configuration and the ways in which it may reconstruct itself to learn or relearn a motor task (Maas et al., 2008). Previous research investigations established optimal approaches of learning a limb motor movement with the application of motor learning principles (Maas et al., 2008). In more recent years, motor learning theory has become increasingly prominent in the speech realm. With this developing research, it is important to consider how motor learning principles affect both the speech and nonspeech domains. Investigating how these various principles influence impaired or intact motor systems can be key to determining treatment approaches for individuals who are learning or relearning a motor task. This evidence can facilitate novel approaches to clinical implications and how motor learning principles may be used in practice (Mass et al., 2008).

1. Random and Variable Practice Structures

Research pertaining to speech motor movements have been designed based upon analyzations of certain structures of practice that have been effective in prior limb motor movement studies. These research structures of practice include practice distribution, practice variability, practice schedules, the complexity of practice, and attentional focus factors in practice structure (Maas et al., 2008). Given the effectiveness of certain structures of practice in prior research, this current study encompasses a random practice schedule and variable structure of practice.

A random practice schedule provides different targets being practiced, but with each target being mixed in each trial (Bislick et al., 2012). Prior research on limb and speech motor movements have explored the effects of random and blocked schedules (Maas et al., 2008). From these previous findings, blocked practice has shown to be effective during performance, whereas random schedules have been proven effective for retention rates (Maas et al., 2008). A study that explored treatment of relearning speech production skills in acquired apraxia of speech, looked at the influences of random versus blocked order of practice (Knock et al., 2000). The two participants within the study each had targeted stimulus sets designed based on the uniqueness of deficits and speech behaviors. Each stimulus set represented target behaviors for each speech task. The findings in this study were consistent with limb motor studies. Blocked practice was more successive during acquisition phases but lower in retention phases. Whereas, random practice had slower acquisition but greater retention of speech behaviors (Knock et al., 2000). In motor learning research and clinical applications, retention is a critical aspect of intervention rather than acquisition.

Variable practice is defined as targeted practice with one or more variants of a given movement (Maas et al., 2008). Meaning, it is a practice target elicited in a variety of contexts rather than one context (Bislick et al., 2012). Previous literature has shown variable practice conditions produce more positive outcomes compared to constant practice in limb motor learning. One study reviews limb motor learning literature that addresses the effects between constant versus variable practice in individuals with Alzheimer's Disease. In this article, the participants were instructed to throw beanbags to a target at a different distance each time. They had better performances when the target was varied and randomized (Bislick et al., 2012). Though, it is noteworthy to consider that the effects of practice variability may also depend on the type of learning task. Research conducted by Kaipa (2016) examined the interaction effects among practice variability and task complexity. Although results revealed that there was no indication of any interaction effects among the two levels of motor learning, there was surprisingly no significance in the levels of practice variability, which is contradictory of previous findings (Kaipa, 2016). On the contrary, a study conducted by Adam and Page (2000) investigated random practice, variable practice, and reduced feedback and the effects these three variables have on acquisition and retention of a novel speech task. The findings demonstrated consistency with the findings of prior limb motor learning studies in that the variable practice group exhibited significantly lower absolute error scores of the novel speech task compared to the constant practice group (Adam & Page, 2000). Both these studies investigated the influences of constant and variable practice and both revealed different effects. Given these differences, research should address the nature of the task (Kaipa, 2016). Kaipa's study was researched based upon the accuracy of the targeted motor movements. Whereas, the participants in the Adam and Page (2000) study looked at the timing of the motor movements produced. Therefore, the insignificance of practice variability comes to no surprise in Kaipa's study since it was based on learning a task spatially rather than temporally (Kaipa, 2016). In sum, variable practice has been proven to be most effective in many cases. Though, analyzing how the type of learning task may influence different results of practice variability is essential to consider in research.

2. Low Feedback Frequency and Feedback Schedules

The structure of augmented feedback has a surplus of investigations in motor learning research. When delivering services to individuals who are learning or relearning motor abilities, clinicians should understand effective and optimal ways to provide feedback on an individual's performance (Bislick et al., 2012). Professionals can utilize the evidence pertaining to an optimal range of augmented feedback when their clients are learning to master a motor skill. The different feedback types that have been investigated in motor learning include knowledge of result, knowledge of performance, feedback timing, and feedback frequency (Bislick et al., 2012). Given the consistencies of prior research on feedback schedules, the scope of this study discusses knowledge of result, low feedback frequency, and reduced feedback schedules.

Previous research in motor learning examine the effectiveness of knowledge of result when acquiring a novel motor movement (Schmidt & Lee, 2005). Knowledge of result is referred to as having the result provided by an instructor in which pertains to the individual's own movement outcome and its relation to the task provided after the movement has been completed. This involves receiving general, spatial, or temporal information from an instructor. Knowledge of result serves as a basis for error correction and as a guide for participants experiencing a given task (Schmidt & Lee, 2005). Knowledge of results feedback can provide improvements in many cases during acquisition but can show negative effects to motor performance in retention phases (Kilduski & Rice, 2003). This may have to do with the fact that individuals may depend on the feedback to guide their own performance leaving little to no room for self-assessment in acquiring a motor skill. However, if the feedback of knowledge of result is decreased, the less the chances are of dependency behaviors in individuals learning or relearning a motor skill. It is important to note that timing of knowledge of result may also influence the performance of a motor skill. Research has shown that knowledge of result that is given during the task itself, has hindered motor learning effects. Whereas, feedback of knowledge of result given after the completion of a task is most effective in motor performances (Kilduski & Rice, 2003).

Low feedback frequency in research has yielded positive results rather than high frequency feedback schedules (Zwicker & Harris, 2009). A study conducted by Adams et al. (2002) investigated the effects of two kinds of feedback schedules on the retention and acquisition of a novel speech motor skill in a group of participants with Parkinson's disease. The participants had Parkinson's disease with mild to moderate speech and limb symptoms. Everyone was placed in one of the two groups within the study. Both groups had to produce a certain speech utterance at a speech rate that was two times slower than average. One group received feedback results after every fifth trial while the other group received feedback results after every single trial. Both groups exhibited reduction in error scores. Though the group which received feedback after every fifth trial performed significantly better in acquisition and 2-day retention phases. Based on this finding, a low frequency type of schedule promotes more benefits as oppose to high frequency feedback in speech motor learning for individual's with Parkinson's disease. This article demonstrated how the optimal levels of feedback in novel limb motor tasks can also be considered in novel speech motor tasks (Adams et al., 2002).

Furthermore, a recent empirical investigation examined feedback schedules and its impact on acquisition and retention of the production of novel speech motor abilities in participants with adequate speech motor systems (Lowe & Buchwald, 2017). The study revealed that between acquisition and retention, feedback frequency was most effective when feedback was reduced (Lowe & Buchwald, 2017). In addition, the current study measured brain activity of the prefrontal cortex of an English-language learner using the Functional Near Infrared Spectroscopy (fNIR). The fNIR device has been employed to evaluate cognitive processes regarding language in infants and adults (Soltanlou et al., 2018). There is a need to investigate cognitive processes using the fNIR device on individuals who are English-second language speakers. Currently, prior fNIR research does not examine reading abilities and brain activation of individual who speak English as a second language. Understanding the processes underlying second-language acquisition and learning, such as English, are of interest for clinical and neurological research. These comparisons and justifications of prior studies are necessary to consider as they shape the decisions of future motor learning research.

The primary objective of motor learning principles is that through practice and experience a motor movement can be learned or relearned over time. Literature has determined a range of optimal structures of practice and feedback schedules in motor learning intervention. More recently, it has extended into the speech motor domain and further proven its effectiveness on retention of a motor performance. Though, future research is needed to provide more coherent and consistent effects on speech motor learning. The purpose of the current research is to explore the optimal levels of speech motor learning and its influence on retention of English phrases for an English Second Language speaker who is Saudi Arabian.

The structure of practice and feedback schedules that have been examined in prior motor learning research have also been considered in the present study. The current study's protocol has been structured to administer a variable and random practice schedule. The feedback schedule is consisted of low frequency and reduced feedback with knowledge of result (KR). Based on the previous nature of speech or limb motor learning research, the current study hypothesizes to show significant, if not, improved performance in the participant's English proficiency of English sentences.

It is increasingly common for many individuals among different populations to speak more than one language or be identified as nonnative speakers (Schmid & Yeni-Komshian, 1999). Many research studies have investigated a range of factors that contributed to accented speech (Schmid & Yeni-Komshian, 1999). Administration of accent intervention or English-language services have been supported by the speech-language and hearing association (Fritz & Sikorski, 2013). Measurements of accent intervention or English-language learning approaches continue to improve and appear in the field of speech research (Fritz & Sikorski, 2013). As the number of nonnative speakers of English will likely rise over the next decade, speech-language pathologists and other professionals who work closely with English language learners may benefit from effective accent management techniques at their disposal (Behrman, 2014).

While motor learning principles have generally focused on limb or speech motor disorders, incorporating the optimal levels of these principles in accent management or English-Second language learning cases may facilitate positive outcomes for individuals who are seeking to alter an accent or learn English pronunciation. Research that surrounds intervention approaches for intelligibility and naturalness of second-language speakers' pronunciation is minuscule (Kim et al., 2016). Kim and his colleagues (2016) utilized a motor learning treatment approach to examine how it influences speech intelligibility, naturalness, and precision of adult Korean-speaking second-language learners. Results yielded significance during treatment sessions suggesting that the motor learning treatment may improve English pronunciation of second-language speakers (Kim et al., 2016). These results indicate promising implications of motor learning principles for individuals seeking to improve English pronunciation abilities (Kim et al., 2016). There is a need to further examine motor learning principles that may benefit English-Second language speaking individuals who are learning to manage their accent. Given the findings of previous motor learning studies, the selected feedback and practice conditions were applied in this current research investigation in hopes to facilitate retention of English pronunciation in a bilingual speaker without impairment. The goal of this study was to explore whether a motor learning theory-based protocol that emphasized specific practice structures and feedback schedules would be effective in improving English pronunciation of a nonnative English speaker.

II. Methods

1. Procedure

1) Participant

In this single-subject design, the participant undergoes all treatment conditions and serves as his own control. The participant for this study was OM, a man who is Saudi Arabian and had been learning English as a Second Language over the course of one year. He also had been living in the United States for one year. On a 7-point rating scale (1-lowest level to 7-highest level), he rated his English-speaking abilities to be a 3 on the rating scale. He listed his English-reading abilities as a low-medium level. His highest level of education was a bachelor's degree and he was currently enrolled in English-Language services. The aforementioned background information was obtained via a participant questionnaire.

2) Treatment

The motor learning theory-based protocol consisted of a pre-treatment phase, four treatment phases, and a post-treatment phase. There were six sessions over a period of five weeks, with 1-2 sessions per week. The duration of each session was between one and two hours. Participant practices 2 sets of stimuli per session. Each set consists of 10 cards (20 cards total). Each card has one unique sentence written orthographically. There were a total of eight sets of ten sentence stimuli. The treatment schedule is provided in Table 1.

During the pre-treatment phase, the participant vocally produced all eight sets for a total of 80 sentences while being audio-recorded. Audio-recording of each of the participant's productions were used to monitor progress throughout the study. All 80 sentences were obtained from Harvard's phonetically balanced sentences of which are sentences that utilize specific phonemes at the same frequency they appear in English (Harvard Sentences, 1969). Each sentence was presented one-by-one on a notecard.

During the treatment phase, two stimulus sets were administered per treatment session. Meaning, the experimenter provided two sets of ten sentences in each of the four treatment sessions. Each treatment session had two different sets that the participant practiced each time. Given this treatment arrangement, the participant engaged in variable treatment sessions. After each treatment session, the participant would read aloud each of the two sets that were practiced in the previous treatment session. This would be audio-recorded for speech measuring purposes. The different sets of stimuli were practiced throughout and are presented in Table 6. Completion of one stimulus set was required to progress onto the second stimulus set in each treatment session. Treatment followed the same motor learning theory-based protocol each time during training. It consisted of a series of repetition tasks followed by knowledge of result. This included a 2-3 second delay followed by one of the following types of general feedback: (1) That was good, (2) That was not so good, (3) I know that was tough.

The procedure of each treatment session is provided in Table 2.

Post-treatment was audio-recorded one day after the final treatment session. This entailed the participant to produce vocally all 80 sentences while being audio-recorded.

Table 1. Treatment schedule

Phase type	Session number	Stimulus items (1 Set=10 sentences or phrases)
Pre-treatment	1	Set 1, Set 2, Set 3, Set 4, Set 5, Set 6, Set 7, Set 8
Treatment	2	Set 1, Set 2
Treatment	3	Set 3, Set 4
Treatment	4	Set 5, Set 6
Treatment	5	Set 7, Set 8
Post-treatment	6	Set 1, Set 2, Set 3, Set 4, Set 5, Set 6, Set 7, Set 8

Table 2. Treatment protocol

Step 1 : The experimenter shuffles the cards. The experimenter and participant produce the sentence at the same time.	Step 1A : Participant attempts the sentence with no feedback Step 1B : Participant attempts the sentence 4 times with a 2-3 second pause between attempts Step 1C : Experimenter repeats the sentence, waits 2-3 seconds, and provides KR feedback *Note.* Practice each entire step with one sentence for a total of 5 sentences
Step 2 : The experimenter produces the sentence once, waits 2-3 seconds, and the participant produces the sentence.	Step 2A : Participant attempts the sentence with no feedback Step 2B : Participant produces the sentence 4 times with a 2-3 second pause between attempts Step 2C : Experimenter repeats the sentence, waits 2-3 seconds, and provides KR feedback. *Note.* Practice each entire step with one sentence for a total of 5 sentences
Step 3 : The participant produces the sentence once independently	Step 3A : Participant attempts the sentence with no feedback Step 3B : Participant produces the sentence 4 times with a 2-3 second pause between attempts Step 3C : Experimenter repeats the sentence, waits 2-3 seconds, and provides KR feedback. *Note.* Practice each entire step with one sentence for a total of 5 sentences
Step 4 : Repeat steps 1-3 with the second set of 5 sentences	
Step 5 : After 10 sentences have been practiced, shuffle the 10 cards, and prompt the participant to produce each sentence	Step 5A : Participant says the sentence with no feedback Step 5B : Participant says the sentence 4 times with a 2-3 second pause between attempts Step 5C : Experimenter says the sentence, waits 2-3 seconds, and provides KR feedback. *Note.* Practice each entire step with one sentence for a total of 10 sentences
Step 6 : Repeat step 5 with the 10 cards	

2. Analysis

The one-way repeated analysis of variance (ANOVA) was used to assess significance in pre-treatment, treatment, and post-treatment measures.

Seven undergraduate and graduate student listeners participated in the scoring of speech intelligibility and speech naturalness. Listeners were currently attending Communication Disorders Program as either undergraduates or graduate students. All were native English speakers. Therefore, college-level literacy abilities were assumed. All listeners were explained their role from the experimenter. The listeners were encouraged to listen and orthographically write down the ten sentences within each recording and score the speaker's naturalness. The listeners were advised that they will hear a total of 24 recordings and hear each of these recordings one time only. Prior to the initial trial, a single practice trial of ten audio-recorded sentences was conducted to ensure the listeners understood their role in the scoring process. The independent variable is the English pronunciation abilities of the participant. The dependent variables are the speech intelligibility, speech naturalness of the participant, and the fNIR data regarding brain activation levels of the participant.

1) Speech intelligibility

The listeners were instructed to transcribe orthographically each audio-recording. This method of scoring intelligibility had similarly followed Hustad et al.

(2003) study which had measured speech intelligibility of speakers with dysarthria. The study reported differences in speech intelligibility and speech rate when the speakers engaged in various cues compared to non-cued speech (Hustad et al., 2003). The listeners for the current study were given the following instructions.

> “As a listener, you will be prompted by the experimenter to listen auditorily to the audio recordings that will be presented one-by-one. Each recording that will be presented will have 10 sentences total. During this time, you will also orthographically transcribe (write down in words) what you heard. You will have to write down what you think you heard to the best of your ability. The experimenter will present the recorded sentences once.”

The experimenter then tallied the number of words correctly identified by each of the listeners (Hustad et al., 2003). Misspelled words and homonyms were counted as correct. This number was then divided by the total number of words within each audio-recorded set and multiplied by one hundred to yield a percent intelligibility score for each task (Hustad et al., 2003). These computations were plotted onto a line graph (x-axis=sessions, y-axis 0=intelligibility percentages) and calculated to report averages of the results.

2) Speech naturalness

The listeners were instructed to determine the naturalness of the audio-recordings of the participant. Martin et al. (1984) reported promising results when using a 9-point rating scale for measuring speech naturalness. This study implemented the same scoring system with the use of a 7-point rating scale instead. The listeners were given the following instructions.

> *Highly Unnatural 1, 2, 3, 4, 5, 6, 7 Highly Natural*

> “Your task is to rate the naturalness of each speech sample. If the speech sample sounds highly natural to you, circle the 7 on the scale. If the sample sounds highly unnatural, circle the 1 on the scale. If the sample sounds somewhere between highly natural and highly unnatural, circle the appropriate number on the scale. Do not hesitate to use the ends of the scale (1 or 7) when appropriate. "Naturalness" will not be defined for you. Make your rating based on how natural or unnatural the speech sounds to you.” (Martin et al., 1984, p. 54)

Findings have suggested this approach to measuring speech naturalness can be at a medical advantage to clinicians, specifically for analyzing and modifying speech quality (Ingham et al., 1985). In terms of listener reliability, another study utilizing this exact method indicated that on average, 88% of second scorings were plus or minus one unit of the first scorings. This demonstrates a great level of accuracy and consistency this method delivers when quantifying speech naturalness (Ingham et al., 1985).

3) Functional Near Infrared Spectroscopy (fNIR)

The fNIR is a non-invasive instrumentation measuring real-time concentration levels of oxygenated and deoxygenated hemoglobin in the prefrontal cortex. This current study utilized this instrument to examine brain activity in the participant's frontal lobe by measuring total hemoglobin (Hbt). The greater the levels of total hemoglobin indicates an increase in brain activation. The fNIR was administered during a pre-treatment, post-treatment, and a post-extended phase. In each of the three phases, the participant was asked to read aloud an English reading passage. The fNIR sensor was fitted on the participant's forehead. Prior to the administration of the reading passage, the participant was asked to look straight at an empty wall for 40 seconds for the baseline. Afterwards, he was prompted to read aloud the passage.

Ⅲ. Results

1. Speech Intelligibility and Speech Naturalness

The one-way repeated analysis of variance (ANOVA) was used to determine whether there were any statistical significances between the means of pre-treatment, treatment, and post-treatment. The findings of speech intelligibility data of the current study are presented graphically in Figure 3. The findings of speech naturalness of the present study are summarized in Figure 2. Table 4 depicts, for comparison purposes, the mean scores reported from pre-treatment, treatment, and post-treatment.

Results from the one-way repeated ANOVA indicated that the between group measures of speech intelligibility and speech naturalness were both significant. These results are displayed in Table 2. Intelligibility resulted in a significance of .002 ($p<.05$). Naturalness resulted in a significance of .000 ($p<.05$). Meaning, the participant's English pronunciation abilities significantly increased among the three group measures. When looking at the multiple comparisons, listed in Table 3, the three treatment groups in the two dependent variables yielded that, in both intelligibility and naturalness measures, treatment to post-treatment scores were not significant.

Further, given the group means in Table 4, the results indicated that pre-treatment to post-treatment yielded a 11.15 percent increase in speech intelligibility. Whereas, the intelligibility scores in pre-treatment to treatment yielded a 7.76 percent increase. Additionally, the listeners' data revealed a mean naturalness rating of 5.01 for post-treatment, and a mean naturalness rating of 5.91 in pre-treatment. Given these differences between mean scores, the findings examined in Table 3 showed that both intelligibility and naturalness during pre-treatment to treatment and pre-treatment to post-treatment were considered significant. These findings indicate that the participant yielded better intelligibility and naturalness scores during the provided treatment and once treatment was removed.

2. fNIR

The Kruskal-Wallis Test, a rank-based nonparametric test, was used to determine differences between pre-treatment, post-treatment, and post-extended measures. The FNIR instrument, measuring the Hbt in the prefrontal cortex, revealed a general improvement trend in the independent treatment variables. The results listed in Table 5, yielded no significant differences in the three treatment measures in Hbt. When examining Figure 1, fNIR yielded Hbt concentration values to be higher in the left hemisphere than the right hemisphere during post-treatment and post-extended treatments. In pre-treatment, Hbt values were observed to be equally distributed between the left and right hemispheres. These visual representations of brain activity during a speech motor task indicated a general increase in activation shifting toward the left hemisphere of the prefrontal cortex area. Despite increases in brain activation, the findings observed no statistically significant differences.

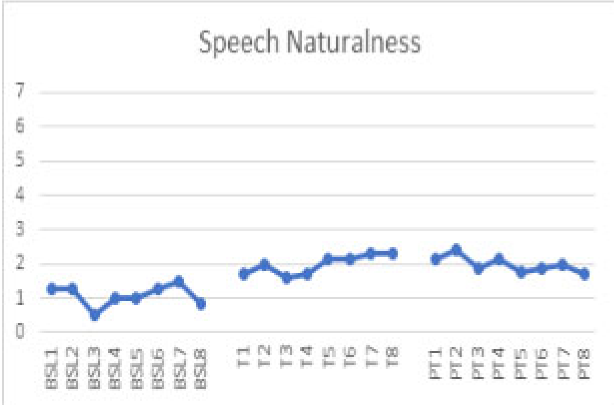

Figure 1. Results of speech naturalness

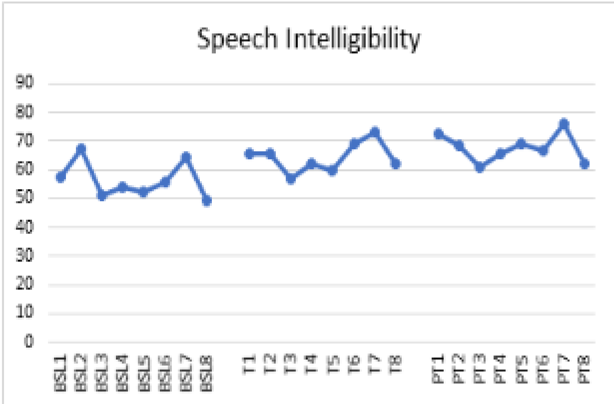

Figure 2. Results of speech intelligibility

Table 3. Analysis of variance

Dependent variables	Sum of squares	*df*	Mean square	*F*	Sig.
Intelligibility-between groups	523.144	2	261.572	8.51*	.002
Naturalness-between groups	4.291	2	2.146	27.292*	.000

*$p<.05$

Table 4. The results of intelligibility and naturalness in pre-treatment, treatment, and post-treatment

Dependent variable	(I) time	(J) time	Mean difference (I-J)	Sig.
Intelligibility	Pre-treatment	Treatment	-7.76100*	.011
	Treatment	Pre-treatment	11.15475*	.001
	Treatment	Pre-treatment	-3.39375	.234
Naturalness	Pre-treatment	Treatment	.89750*	.000
	Pre-treatment	Pre-treatment	-.89650*	.000
	Treatment	Pre-treatment	-.00100	.994

*$p<.05$

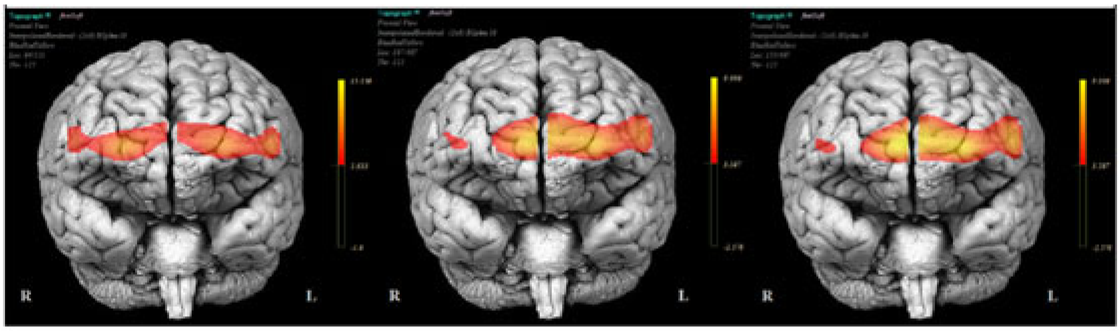

Figure 3. Total hemoglobin in pre-treatment, post-treatment, and post-extended

Table 5. The results of intelligibility and naturalness

Dependent variable	Time	Number	Mean
Intelligibility	Pre-treatment	8	56.56
	Treatment	8	64.34
	Post-treatment	8	67.74
	Total	24	62.89
Naturalness	Pre-treatment	8	5.91
	Treatment	8	5.01
	Post-treatment	8	5.01
	Total	24	5.31

Table 6. The results of a rank-based nonparametric test

Kruskal-Wallis Test	*p*-value
Left normalized mean	.368
Right normalized mean	.368
Total normalized mean	.368

Ⅳ. Discussion

The present study examined whether the application of an intensive motor learning theory-based protocol, administered by a native English speaker, would result in improvement of English pronunciation. It was predicted that, with the administration of a variable and random practice schedule with low frequency and reduced feedback with knowledge of result, the protocol would better the participant's English pronunciation skills. The current research indicated significance between pre-treatment, treatment, and post-treatment groups in speech intelligibility and speech naturalness, but not substantial enough to reach a generalization effect.

It was uncertain whether the participant, given his lower English-speaking abilities, would be able to alter his English pronunciation abilities. The study demonstrated an improvement in speech intelligibility and speech naturalness between mean scores in pre-treatment, treatment, and post-treatment. The findings exhibited significance between treatment measures in both intelligibility and naturalness suggesting a motor learning theory-based protocol can help a nonnative English speaker's ability to pronounce English phrases appropriately. Specifically, pre-treatment to treatment and pre-treatment to post-treatment was significant. Meaning, the participant improved significantly in acquisition of English pronunciation. In terms of retention, treatment to post-treatment measures yielded to be not significant. Further, fNIR measures depicted an increase of concentration levels in the prefrontal cortex. However, results demonstrated no significant differences in the three treatment groups in Hbt values. These fNIR results may be utilized in future research to further examine a type of speech motor learning treatment approach that may result in significant differences in brain activity during a speech motor task.

There are limitations in this current study. The administration of ten sentences per treatment session followed a variable practice schedule. This meant that a new set of sentences was provided for each of the following treatment sessions. The level of difficulty between each sentence set was not taken into consideration and is a possible limitation. Certain sentence sets may have been highly difficult or highly simple in comparison to another set. As a result, this inconsistency could have yielded a ceiling or floor effect in certain trained sentence sets. Additionally, a small sample size, as used in this current study, cannot be entirely representative of the many clients seen in practice. Furthermore, to prevent any subjectivity judgement in scoring listeners' data, the experimenter's computations could have been verified by an unfamiliar source. In addition, although fNIR treatment results exhibited a trend of an increase of brain activity in the prefrontal cortex, there is no research examining whether these increases lead to long-term treatment effects. Further research is warranted to determine if there are long-term changes that indicate lasting effects of this treatment. For future considerations, it is crucial to examine this approach in a broad-spectrum of nonnative English-Second language speakers to further validate these findings.

Overall, the results of this study suggest that implementing a motor learning theory-based protocol may be a useful intervention approach in therapy to individuals who are seeking services in accent management. Original research has examined the influences of limb and speech motor learning for either individuals with intact or impaired motor systems. The findings of this study indicate that nonnative English speakers may benefit from a motor learning-theory based protocol when administering several English phrases to improve their English pronunciation abilities. Despite the single-subject design, clinicians may potentially utilize speech motor learning methods and modify these methods to suit the needs of a nonnative English speaker.

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Appendix 1. Stimulus cards

Set 1	1. The birch canoe slid on the smooth planks. 2. Glue the sheet to the dark blue background. 3. It's easy to tell the depth of a well. 4. These days a chicken leg is a rare dish. 5. Rice is often served in round bowls.	6. The juice of lemons makes fine punch. 7. The box was thrown beside the parked truck. 8. The hogs were fed chopped corn and garbage. 9. Four hours of steady work faced us. 10. A large size in stockings is hard to sell.
Set 2	1. The boy was there when the sun rose. 2. A rod is used to catch pink salmon. 3. The source of the huge river is the clear spring. 4. Kick the ball straight and follow through. 5. Help the woman get back to her feet.	6. A pot of tea helps to pass the evening. 7. Smoky fires lack flame and heat. 8. The soft cushion broke the man's fall. 9. The salt breeze came across from the sea. 10. The girl at the booth sold fifty bonds.
Set 3	1. The small pup gnawed a hole in the sock. 2. The fish twisted and turned on the bent hook. 3. Press the pants and sew a button on the vest. 4. The swan dive was far short of perfect. 5. The beauty of the view stunned the young boy.	6. Two blue fish swam in the tank. 7. Her purse was full of useless trash. 8. The colt reared and threw the tall rider. 9. It snowed, rained, and hailed the same morning. 10. Read verse out loud for pleasure.
Set 4	1. Hoist the load to your left shoulder. 2. Take the winding path to reach the lake. 3. Note closely the size of the gas tank. 4. Wipe the grease off his dirty face. 5. Mend the coat before you go out.	6. The wrist was badly strained and hung limp. 7. The stray cat gave birth to kittens. 8. The young girl gave no clear response. 9. The meal was cooked before the bell rang. 10. What joy there is in living.
Set 5	1. A king ruled the state in the early days. 2. The ship was torn apart on the sharp reef. 3. Sickness kept him home the third week. 4. The wide road shimmered in the hot sun. 5. The lazy cow lay in the cool grass.	6. Lift the square stone over the fence. 7. The rope will bind the seven books at once. 8. Hop over the fence and plunge in. 9. The friendly gang left the drug store. 10. Mesh wire keeps chicks inside.
Set 6	1. The frosty air passed through the coat. 2. The crooked maze failed to fool the mouse. 3. Adding fast leads to wrong sums. 4. The show was a flop from the very start. 5. A saw is a tool used for making boards.	6. The wagon moved on well oiled wheels. 7. March the soldiers past the next hill. 8. A cup of sugar makes sweet fudge. 9. Place a rosebush near the porch steps. 10. Both lost their lives in the raging storm.
Set 7	1. We talked of the side show in the circus. 2. Use a pencil to write the first draft. 3. He ran half way to the hardware store. 4. The clock struck to mark the third period. 5. A small creek cut across the field.	6. Cars and busses stalled in snow drifts. 7. The set of china hit the floor with a crash. 8. This is a grand season for hikes on the road. 9. The dune rose from the edge of the water. 10. Those words were the cue for the actor to leave.
Set 8	1. A yacht slid around the point into the bay. 2. The two met while playing on the sand. 3. The ink stain dried on the finished page. 4. The walled town was seized without a fight. 5. The lease ran out in sixteen weeks.	6. A tame squirrel makes a nice pet. 7. The horn of the car woke the sleeping cop. 8. The heart beat strongly and with firm strokes. 9. The pearl was worn in a thin silver ring. 10.The fruit peel was cut in thick slices.

Appendix 2. Participant questionnaire

1. What ethnicity are you? (e.g., Hispanic, Korean, etc.)

____

2. How many years have you visited or lived in the United States? (circle one)

(1) (2) (3) (4) (5+)

3. On a scale of 1-7, circle what level YOU believe your English-speaking skills are (circle one)

Lowest level (1) (2) (3) (4) (5) (6) (7) Highest level

4. How many years have you spoken English? (circle one)

(〈 1) (1) (2) (3) (4) (5+)

5. What is your English ability? (circle one)

(low) (low-medium) (medium) (medium-high) (high)

6. What is your education level? (circle one)

(High school) (1st year in college) (2nd year in college) (3rd year in college) (4th year in college)