

Comparing the efficiency of speech and language therapy and transcranial magnetic stimulation for treating Broca's aphasia

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Objectives: Aphasia is an acquired language-cognitive disorder that highly affects an individual's speech, language, and communication skills. Recovery from aphasia requires attentive treatment since it is a long and dynamic process. This study aimed to show interactive benefits of combining classical intervention strategies with new technological approaches and demonstrating their effectiveness. *Materials and methods:* A total of 40 individuals with Broca's aphasia were included in the study. The participants were divided into Application-1 Speech and Language Therapy, Application-2 Transcranial Magnetic Stimulation, Application-3 (consecutive Transcranial Magnetic Stimulation and Speech and Language Therapy), and Application-4 (Control Group) experimental groups, with 10 participants in each group. *Results:* Analysis indicated that individuals in the group in which Transcranial Magnetic Stimulation and Speech and Language Therapy were applied consecutively had further increases in speech fluency, repetition, and naming scores from pre-test to post-test ($p < 0.01$). Picture naming and quality-of-life communication scores of individuals in the group in which Speech and Language Therapy was performed increased further from pre-test to post-test ($p < 0.01$). *Conclusions:* The results of the study showed a positive effect on language skills, naming scores, and participation in social life of Turkish-speaking aphasic individuals with the Speech and Language Therapy and Transcranial Magnetic Stimulation methods. The use of Transcranial Magnetic Stimulation alone is insufficient in this context. Although Speech and Language Therapy alone is effective in naming ability, Transcranial Magnetic Stimulation in addition to Speech and Language Therapy significantly increases the gain obtained with therapies.

Keywords: Broca's aphasia—Transcranial magnetic stimulation (TMS)—Speech and language therapy (SLT)—Speech and language skills

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Introduction

Stroke, which can occur at any time in a person's life, is one of the most prevalent causes of death and disability. This clinically impactful disorder may evolve as a process and affects an individual's language functions and the quality of life. Aphasia, as a consequence of stroke,^{1,2} is a cognitive-linguistic disorder that affects communication capacity as a result of partial and/or total damage to brain regions related to language and speech.³ Some patients with aphasia may show mainly problems in using the correct words in speaking whereas others may have more severe problems such as the inability to understand and/or express a simple message.⁴

Aphasia directly limits independence (e.g., managing own's bank account), life activities and daily routines (e.g., using the phone, shopping, bathing), and social life participation.⁵ When it becomes chronic, aphasia causes long-term disability,⁶ low quality of life,⁷ and high social burden.⁵

Recovery from aphasia requires attentive treatment.⁸ Available treatment methods have not yet been approved for repairing the damaged parts of the brain⁹ or restoring aphasia.¹⁰ However, Speech and Language Therapy (SLT) and Transcranial Magnetic Stimulation (TMS) approaches have been used in the treatment of aphasia independent one from another. In aphasia treatment, SLT still remains as a good option, but other forms of promoter therapy are desirable to maximize, accelerate and recovery, particularly in the chronic phase. Studies show that TMS can significantly improve language outcomes in patients with aphasia.¹¹⁻¹³ However, there is not currently a single universally accepted method to treat aphasia. All therapies should be adjusted to the individual needs of the patient.¹⁴

The intensity of treatments and the aphasia profile of the patients undoubtedly influence the success of the approach on picture naming performance. However, not all therapy approaches used to treat aphasia yield in equal outcomes.¹⁵ Timing, intensity, duration, service delivery are factors that influence the success of treatments.^{3,16,17}

SLT interventions more broadly generates positive treatment outcomes. A recent review of the literature reveals several studies regarding the influence of SLT and TMS on the treatment of aphasia. Quique et al.¹⁸ reviewed 12 studies and found a positive correlation between the amount of therapy and individual performance on semantically related words. In another review of 10 studies¹⁹ found SLT to be effective in the ability to name words. Brady et al.²⁰ analyzed 53 studies to examine the effect of SLT on aphasia and concluded that a higher intensity of SLT is more beneficial for aphasia treatment. Several other studies indicated the positive effect of SLT on naming, use of meaningful sentences, informative accuracy, and object naming level,²¹ word naming,^{22,23} communication and sentence production,²⁴ quality of life, psychological well-being,²² and neuroplastic change.²⁵

Semantic Feature Analysis is a one of the SLT technique in which patients with aphasia are asked to produce words that are semantically related to the target word that they cannot name.²⁶ Since it has been suggested that the speech production difficulty arises from an impaired semantic network, the aim of therapy is to partially restore semantic connections.²⁶ Hypothetically, semantic feature analysis improves the retrieval of conceptual information by accessing and improving semantic networks.²⁷ Increased activation of the semantic network surrounding the target word increases the likelihood of word retrieval.²⁶⁻²⁸ The present study used semantic feature analysis. This approach includes diverse language and

speaking skills such as auditory comprehension, naming, repetition, spontaneous speech production, concept knowledge, and sentence production.

Like the effects of SLT, TMS was also found to be an effective approach for treating aphasia. The positive effect of TMS on improving language performance of individuals with aphasia has been reported over the last few years.^{29,30} Ilkhani et al.³¹ found that application of 1 Hz rTMS in 10 sessions in the right hemisphere increases naming skills in individuals with aphasia following stroke. In the right hemisphere, 1 Hz rTMS application was found to be effective on speech and communication skills,³² naming skills,^{33,34} and comprehension and repetition.³⁵⁻³⁷

All these findings suggest significant influence of SLT and TMS approaches on the treatment of individuals with aphasia in terms of language skills. However, there is still limited knowledge on how SLT and TMS applied together to increase the language performance of individuals with aphasia. Thus, further investigation is needed to determine if SLT and TMS together improve language performance compared with only SLT and only TMS. Accordingly, the main purpose of the study was to investigate therapies in which a) SLT alone, b) TMS alone, and c) SLT+TMS consecutively in the treatment of individuals with aphasia. The following research questions were addressed in the study: 1) Is there a significant difference among individuals who received only SLT, only TMS, SLT + TMS together, or no treatment regarding the following comprehension language modalities (speech fluency, auditory, repetition, and picture naming), matched with quality of life (physical, communication, psychosocial and energy).

Method

Study design and participants

Our study includes 3 tests. These tests consisted of pre-test, post-test and follow-up tests and the findings were compared with the control group. The person who conducts the therapies and the person who conducts the tests are different and that the therapist who conducts the tests had any knowledge about the group assignment of the participants. To examine the individual effect of treatment methods (TMS or SLT) and combined effect of treatment methods (TMS + SLT) compared to the control group, four groups were recruited (Fig. 1). Group 1 includes individuals receiving only SLT, Group 2 includes individuals receiving only TMS, and Group 3 included individuals receiving both SLT and TMS treatments consecutively and the control group includes the individuals that did not receive any of these treatments.

Initially data from 132 patients were obtained from the neurology department of a university hospital. Of these 132 patients, 112 patients were diagnosed with aphasia following neurological examination, MR imaging and

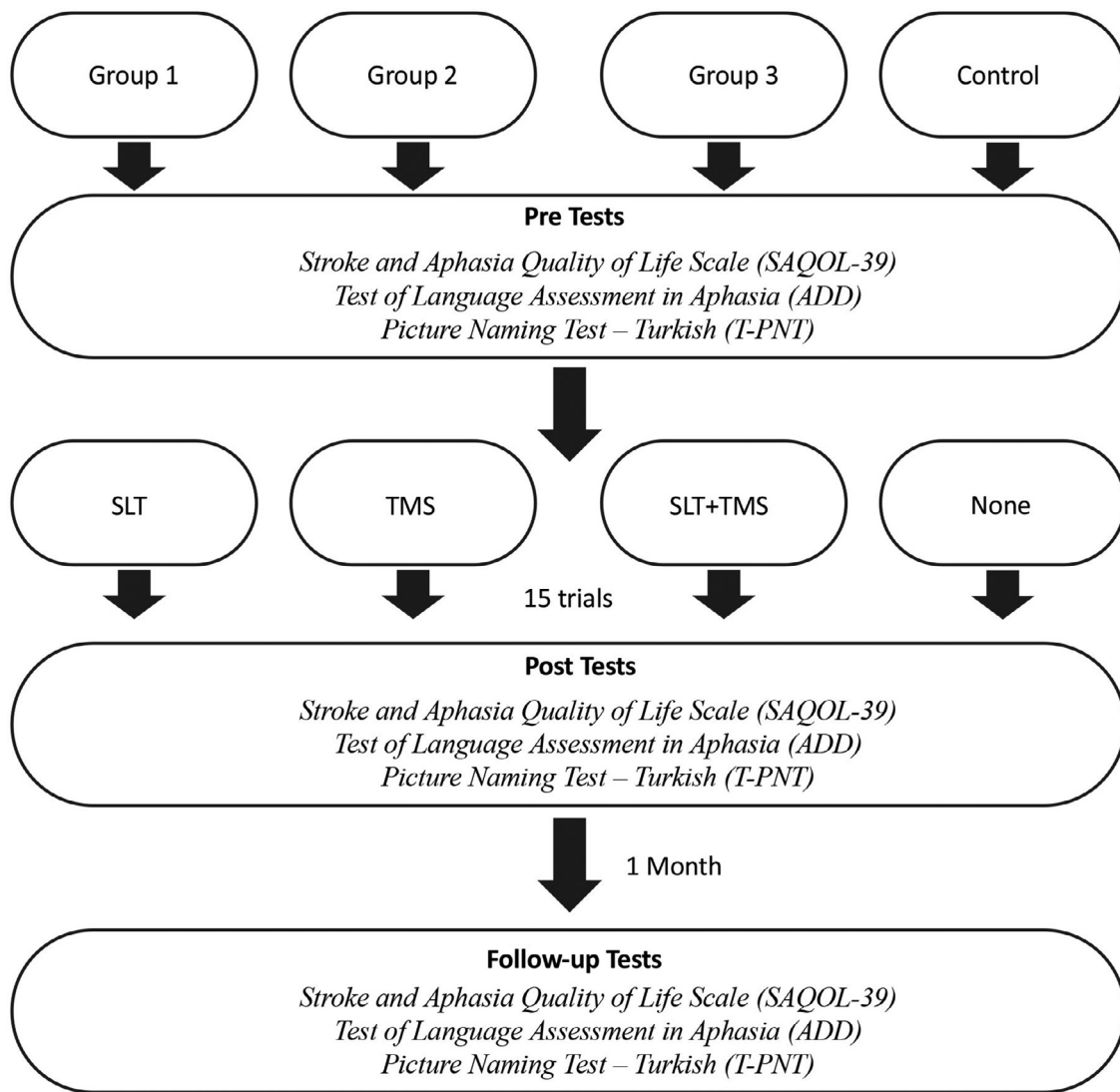


Fig. 1. Experimental implementation process of the study.

EEG, and a speech and language therapist evaluation. Participants were at least nine months post stroke, and their native language was Turkish. All participants were above 18 years of age, were literate and able to understand task instructions. They were right-handed, have never taken psychotropic medication, and not diagnosed with cognitive disorders that affected their daily life. Of the 112 screened patients 40 were available to participate in the study. The rest had a history of epilepsy or aneurysm, used a pacemaker, already recovered from aphasia or died, could not be reached, or did not wish to take part in the study. The selection process of the participants appears in Fig. 2.

The participants were randomly assigned into four groups, each of which included ten individuals with aphasia. Fig. 4 illustrates the randomization process of the grouping and assignment of the groups.

Demographics of the participants are given in Table 1. Group efficacy was assessed with variables as sex, age,

level of education and tests of Beck depression, the handedness preference test and a Turkish version of Test Your Memory TYM-TR.³⁸ A significant difference among the groups was not observed for scores. Two-way ANOVA test was performed and the p value was found as < 0.05.

Ethical approval was received from the Clinical Research Ethics Committee of Üsküdar University (Desion N.:99102440-/2019-13). Voluntary informed consent was obtained from all the participants, and SLT and TMS treatments were provided free of charge to all participants.

Data collection tools

Three data collection tools were used for assessing aphasia level, the quality of life, and naming skills. In addition, the Edinburgh Handedness Preference test (EHPT),³⁹ Beck Depression Scale (BDS) (adapted by⁴⁰), and Test Your Memory – Turkish (TYT-TR)³⁸ were used

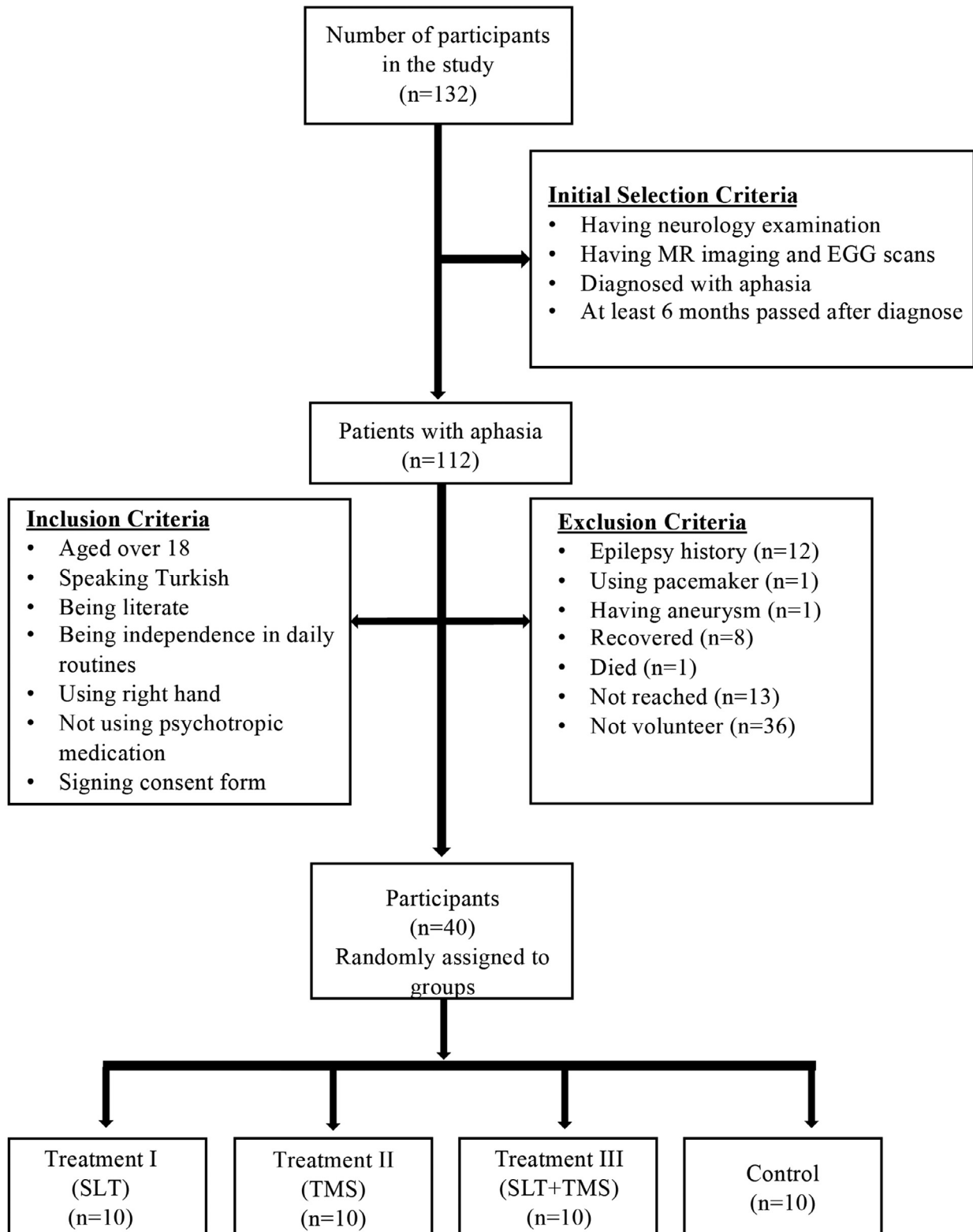


Fig. 2. Selection process.

Table 1. Demographics.

	Treatment I (SLT) (n=10)	Treatment II (TMS) (n=10)	Treatment III (SLT + TMS) (n=10)	Control (n=10)	Group Comparison
Sex					
Female	5	5	4	3	$\chi^2=1.125$
Male	5	5	6	7	$p=0.771$
Mean time since stroke (months)	10.4	12.3	10.6	10.1	$p=0.12$
Age (years)	60.00±5.05	59.30±5.83	59.70±5.31	57.70±3.56	$F=0.418$ $p=0.741$
Level of Education					$\chi^2=8.819$ $p=0.455$
Elementary	2	1	1	-	
Middle	1	2	-	1	
Secondary	4	7	5	5	
University	3	-	4	4	
Beck Depression	14.70±7.34	13.50±4.88	12.90±5.80	18.30±5.20	$F=1.688$ $p=0.187$
TYM-TR	19.70±2.75	19.40±4.11	23.50±3.20	18.40±3.23	$F=4.421$ $p=0.010^*$

* $p<0.05$.

for the inclusion criteria of participating into the experiment.

Demographic information form

Developed by the researchers, this form was used to determine demographics (e.g., age, gender, level of education) of the participants.

Stroke and aphasia quality of life scale (SAQOL-39)

Developed by Hilari et al.⁴¹ for investigating quality of life of individuals with aphasia, SAQOL-39 was adapted into Turkish by Noyan.⁴² SAQOL-39 includes 39 items on a 5-point Likert-type scale (5 – strongly agree to 1 – strongly disagree). Hilari et al.⁴¹ reports that psychometric analysis of the instrument reveals four dimensions as physical (17 items, $\alpha = .94$), communication (7 items, $\alpha = .77$), psychosocial (11 items, $\alpha = .86$), and energy (4 items, $\alpha = .70$). A higher total score indicates higher perceived quality of life.

Test of language assessment in aphasia (ADD)

ADD was developed for individuals with brain injury to (a) determine their performance in all language domains, (b) diagnose aphasia, and (c) select appropriate therapy goals.⁴³ The instrument, which is the standardized for language assessment of aphasia and was completed by a clinician, consists of 186 items on a three-point Likert scale (2 – correct/independent response, 1 – limited/insufficient response, and 0 – no response) and eight sub-dimensions, but only four of them were used for the present study—speech fluency (16 items, $\alpha = .94$), auditory comprehension (33 items, $\alpha = .97$), repetition (10 items, $\alpha = .97$), and naming (22 items, $\alpha = .99$), the score of which supplies language proficiency.

Test of Language Assessment in Turkish (ADD) is used routinely to evaluate aphasic language function, and has high internal consistency, test-retest reliability, and validity. ADD is also widely used to determine the presence, type, and severity of aphasia. In ADD, by evaluating language profiles for fluency, comprehension, repetition, and naming aphasia can be classified into subtypes. In addition, ADD describes severities of aphasia as aphasia quotients (AQ), the same as we observe in Western Aphasia Battery.⁴⁴⁻⁴⁶ ADD has 9 subtests. The Aphasia Quotient (AQ) is a sum of four subtest scores from the first part of the ADD (Spontaneous speech, Auditory verbal comprehension, Repetition, and Naming). The tester can use the AQ score to classify the client's aphasia severity for each subtest compared to total score of each modality. As seen in the following Table 2. The severity score is determined by dividing the total score into 4. Since we compared all ADD scores between the groups and shared the relevant changes before and after the therapies and during the follow-up test processes, the severity was not calculated again. The detailed participants severity calculation results shared in Table 3. Mean severities expressed as AQ values were; in pre-tests applications SLT+TMS 92,2, SLT 83,6, TMS 80,3 and Control 78,6; in the post-tests SLT +TMS means 137,6, SLT 111,7, TMS 97,1 and Control 86,6 scores and in the follow-up tests, SLT+TMS 141,9, SLT 115,0, TMS 101,9 and Control 94,6 scores (Table 3).

Picture naming test – Turkish (T-RAT)

T-RAT was developed in a Scientific Research Project (COST Action IS1208) to assess confrontation naming with 150 pictures in participants with aphasia.⁴⁷ The instrument included 150 words assessed based on correct (1 point) and incorrect (0 point) response, the highest score of which is 150 for naming all the pictures correctly.

Table 2. Scores determining the severity of aphasia.

AQ Score Severity	Speech Fluency Total: 32 points	Auditory Comprehension Total: 66 points	Repetition Total: 20 points.	Naming Total: 44 points	Total Score (162 points)
Very Severe	0-8	1-15	0-5	0-10	0-38
Severe	9-16	16-30	6-10	11-22	39-78
Moderate	17-24	31-45	11-15	23-33	79-117
Mild	25+	46+	16+	34+	118+

(AQ): Aphasia Quotient.

Table 3. Participants aphasia severity scores.

ID	Treatment Group	Speech Fluency	Auditory Comprehension	Repetition	Naming	Aphasia Severity (Total Score)	AQ Score Severity
K21	SLT+TMS	11	57	7	17	92	Moderate
K8	SLT+TMS	22	54	12	34	61	Severe
K11	SLT+TMS	13	40	14	16	73	Moderate
K22	SLT+TMS	19	58	16	24	116	Moderate
K13	SLT+TMS	19	58	14	21	112	Moderate
K17	SLT+TMS	14	46	16	20	96	Moderate
K9	SLT+TMS	10	30	10	23	73	Severe
K6	SLT+TMS	16	50	14	32	112	Moderate
K1	SLT+TMS	14	48	16	32	110	Moderate
K7	SLT+TMS	15	35	14	13	77	Severe
K4	SLT	9	12	15	8	44	Severe
K5	SLT	9	54	8	28	99	Moderate
K10	SLT	9	35	5	11	60	Severe
K14	SLT	15	58	11	18	102	Moderate
K20	SLT	15	60	10	19	104	Moderate
K23	SLT	14	44	9	17	84	Moderate
K24	SLT	17	46	10	15	88	Moderate
K25	SLT	9	37	10	8	64	Severe
K26	SLT	13	58	8	13	92	Moderate
K28	SLT	15	54	7	21	97	Moderate
K27	TMS	16	60	5	20	101	Moderate
K29	TMS	16	58	8	24	106	Moderate
K30	TMS	15	46	6	4	71	Severe
K32	TMS	13	47	5	24	89	Moderate
K36	TMS	10	40	8	19	77	Severe
K2	TMS	7	23	12	4	46	Severe
K3	TMS	8	13	8	5	39	Severe
K15	TMS	12	57	7	23	99	Moderate
K16	TMS	14	66	8	21	109	Moderate
K19	TMS	15	26	7	18	66	Severe
K34	Control	9	40	6	4	59	Severe
K40	Control	16	46	6	17	85	Moderate
K39	Control	12	56	10	13	91	Moderate
K37	Control	22	54	7	9	92	Moderate
K35	Control	22	49	8	10	89	Moderate
K38	Control	11	55	6	16	88	Moderate
K31	Control	12	56	6	12	86	Moderate
K33	Control	14	53	8	11	86	Moderate
K18	Control	10	33	10	12	65	Severe
K12	Control	6	22	6	11	45	Severe

(AQ): Aphasia Quotient.

Treatment data collection

Study data were collected in the first quarter of 2020. The treatment data collection process is outlined in Table 4. During therapy, a drawing/illustration what the word represents was first shown to the participant, and the participant was asked with a confrontation naming and was given 5 seconds to name it. Even if the participant correctly named the word shown to them, the relevant questions and their answers regarding the relevant features of the object were elicited. If the participant did not produce the word within the expected time or had difficulty in producing it, the participant was given a cue. A certain hierarchy was followed when giving cues. When the participant could not name the word (e.g., cat), verbal cues were given. In the original therapy, the phonemic first letter of the word (e.g., /k/) or the intonation of the word or the word itself (e.g., /cat/) was given as a cue.⁴⁸ The word naming and cueing process followed in the present study is shown in Fig. 3. For participants who could not name the word but made an effort to produce it, the first syllable of the word is imitated with the lips to help the patient recall and produce the word. The cue given at this stage is called lip forming. If the therapist was able to name the word, the therapist moved on to other related words, but if the participant was unable to name the word, the therapist moved on to the second phase. Where the first sound of the object was spoken aloud, followed by the first syllable and then the first syllable and the melody for the syllable. If the participant could name the word, the relevant questions were asked, but if the word could not be named, the clue in the third stage was given. In the last phase, the name of the word was told, and the participant was asked to repeat the name. After the participant's repetition, the other words were asked. The words grouped into five categories (20 objects) were practised for three sessions, whether the participant named them or not, following the process shown in Fig. 3. The category changes every three sessions.

Neuro navigation was used in the study, and the F8 region was determined by this method. TMS application to the motor cortex greater than the motor threshold may

cause muscle contraction and motor excitation potential (MEP). The motor threshold was determined by pulsing and thumb movement. The time between thumb movements can be recorded by TMS and is called conduction time.⁴⁹

The assessment instruments were applied as pre-tests at the beginning of the study, but three (BDS, TYM-TR, and EHPT) were only used as selection criteria. SQOAL-39, ADD, and T-RAT were repeated three times as pre-test, post-test, and follow-up. After pre-test measurements, Treatment I group received SLT, Treatment II group received TMS, Treatment III group received SLT and TMS consecutively, and no treatment was provided to the control group. Treatments took three weeks for fifteen therapy sessions. When the treatment phases were completed, the three measures were re-administrated a day after the end of the therapies. After a month with no treatments, the participants completed the instruments as a follow up.

Treatment I – SLT

Semantic Feature Analysis based SLT was structured. The words used in treatment were selected according to their frequency of use in everyday language. In her doctoral dissertation on verbal fluency, Tunçer (2011) listed the elicited concepts in various categories such as animals, vegetables and fruits, vehicles, clothes, body parts and furniture in her doctoral thesis study with in determined age groups. In the study, the word frequency tables reported in Tunçer's (2011) study were considered and words with high, medium and low frequency in daily language were used in Semantic Feature Analysis. Therefore, treatment materials including diagrams, related categories, and the responses were designed by using the words drawn from the study by Tunçer.⁵⁰ When selecting categories, the functionality and usage of the words in these categories in the daily lives of individuals with aphasia and their involvement in their vital needs were taken into consideration. Within the scope of the study, verbal fluency values were taken into consideration in the selection

Table 4. *Experimentation process.*

Group	Pre-test	Treatment (three weeks)	Post-test	1 month	Follow-up test
Treatment I	BDS, TYM-TR, EHPT, SAQOL-39 ADD, T-RAT	SLT	SAQOL-39 ADD T-RAT	No treatment	SAQOL-39 ADD T-RAT
Treatment II	BDS, TYM-TR, EHPT, SAQOL-39 ADD, T-RAT	TMS	SAQOL-39 ADD T-RAT	No treatment	SAQOL-39 ADD T-RAT
Treatment III	BDS, TYM-TR, EHPT, SAQOL-39 ADD, T-RAT	SLT + TMS	SAQOL-39 ADD T-RAT	No treatment	SAQOL-39 ADD T-RAT
Control	BDS, TYM-TR, EHPT, SAQOL-39 ADD, T-RAT	No treatment	SAQOL-39 ADD T-RAT	No treatment	SAQOL-39 ADD T-RAT

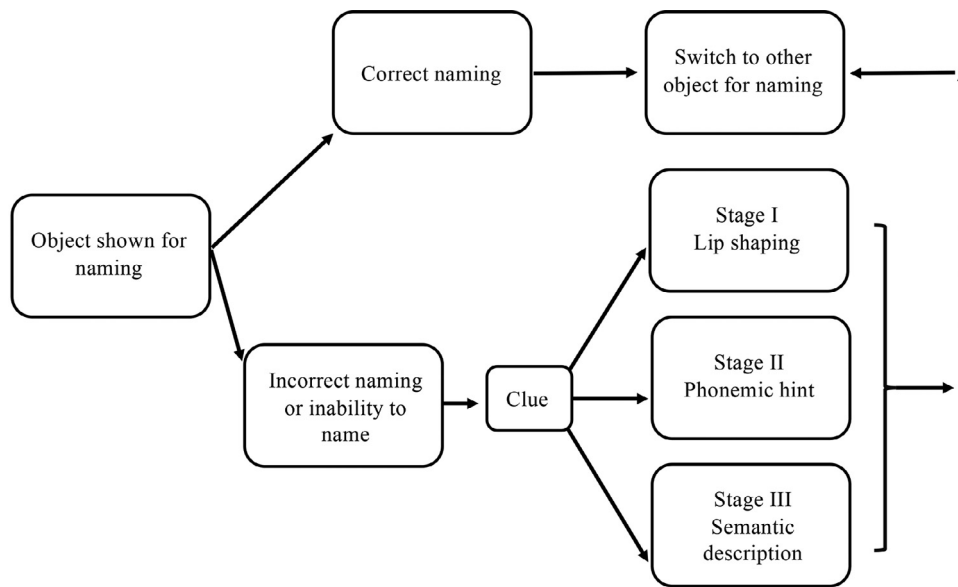


Fig. 3. Word naming and clue stages in SLT process.

of the words to be used in the Semantic Features Analysis. Verbal fluency is measured by the number of words that individuals produce in a certain period of time in accordance with the desired conditions.⁵⁰ Words with high verbal fluency have higher learnability. In addition, the more frequently a word is used in a language, the lower the activation threshold of that word and the easier it will be to recall.⁵¹

A diagram with the relevant picture for each word and worksheets with related categories and responses were used as practice materials. The clinical practice schedule in which Semantic Features Analysis was applied within

the scope of Speech and Language Therapy (SLT) and individually in terms of sessions for each participant; for each participant, it was carried out in a total of 5 sessions of 30 minutes each day from Monday to Friday. No applications were made on Saturday and Sunday. DCT practices continued in this way for three weeks. As a result, each participant in the intervention group participated in 15 sessions lasting 450 minutes in total.

The pictorial referents of the words used in the treatment sessions were taken from Shutterstock. Copyright costs were paid. The pictures were placed on white paper on with no distractions. During SLT treatment sessions,

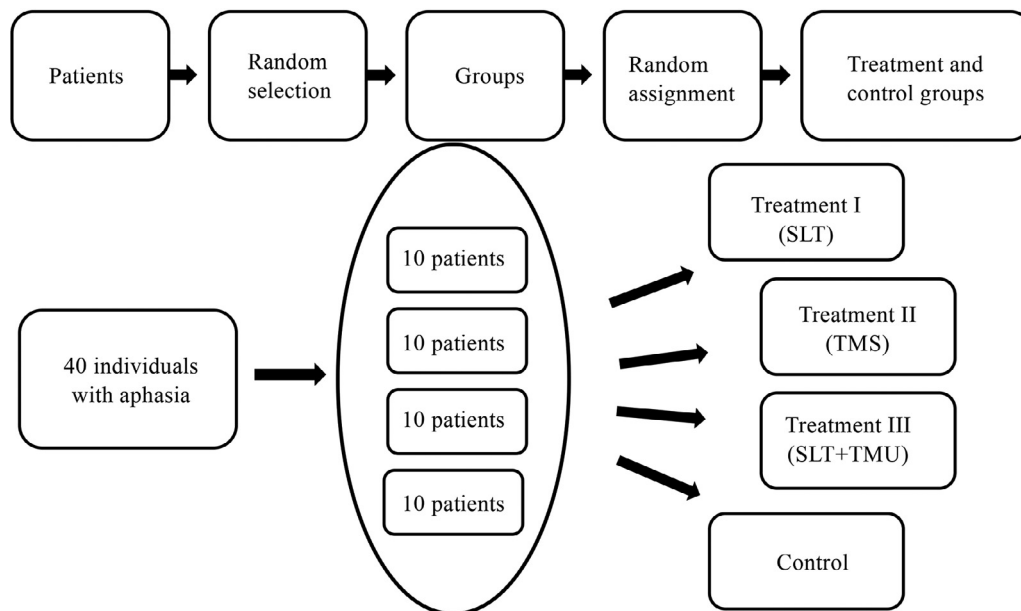


Fig. 4. Randomization of the participants.

each stimulus set was shown to each participant one at a time. Participants were asked "what is this picture?" and given up to five minutes to respond to the question. If participants were unable to name the picture spontaneously, they provided with cues relevant to the target word as needed. The therapist also followed all-therapy steps. Even if the patient is able to name pictures, studies have been carried out in our study to ask related questions and make naming other than the target word, in order to provide more verbal output with the activation of related semantic networks. SLT treatment took place over three weeks, and each of the 15 sessions lasted 30 minutes. The steps followed in the naming and cueing phase for the target words are shown in Fig. 3.

Treatment II – TMS

During this phase, 15 sessions of repeated Transcranial Magnetic Stimulation Therapy (rTMS) were applied. Magstim/Rapid 2 model 3012-00 rTMS device was used for stimulation. After determining the resting motor thresholds (rMT) of the participants, TMS was applied on the head area of the primary motor cortex in the unaffected right hemisphere, determined by neuro-navigation. rTMS application was followed for 20 minutes in the right inferior frontal gyrus (F8) at a magnitude of 1Hz and 1500 pulses with the motor threshold as 110% for 15 days (Fig. 5).

Treatment III – SLT+TMS

SLT and TMS were applied consecutively to Group 3. After each TMS session and SLT treatment started

immediately. Treatment consisted of 15 sessions of 30 minutes TMS + 30 minutes SLT. Applied rTMS parameters were the same as in TMS only.

Statistical analyses

The data were analyzed in two phases. In the first phase, data cleaning (mainly missing data and outliers) and parametric assumption tests were performed. No missing data or outliers were detected [Z-scores were between the ranges of [-3.29, +3.29].⁵² In the parametric assumption tests were not used since the number of the individuals in each group was lower than 30.⁵³ The normal distribution of the data was checked with the Kolmogorov-Smirnov test.⁵² Since the number of participants was fewer than 30 in each group, non-parametric tests were used. In multi-group comparison, ANOVA is used because our samples show a normal distribution. Consequently, the Friedman test was performed for comparing pre-test, post-test and follow-up comparison, while the Kruskal–Wallis test was performed for group (treatment –control) comparison. All analyses were run at 95% confidence interval, and η^2 was calculated for effect sizes.

Results

Demographic and neuropsychological characteristics of the participants are presented in Table 1. The treatment groups and the control group were equal in terms of sex, $\chi^2 = 1.125$, $p = 0.771$, age, $F = 0.418$, $p = 0.741$, level of education, $\chi^2 = 8.819$, $p = 0.455$, and Beck depression, $F = 1.688$, $p = 0.187$, but not TYM-TR, $F = 4.421$, $p = 0.01$.

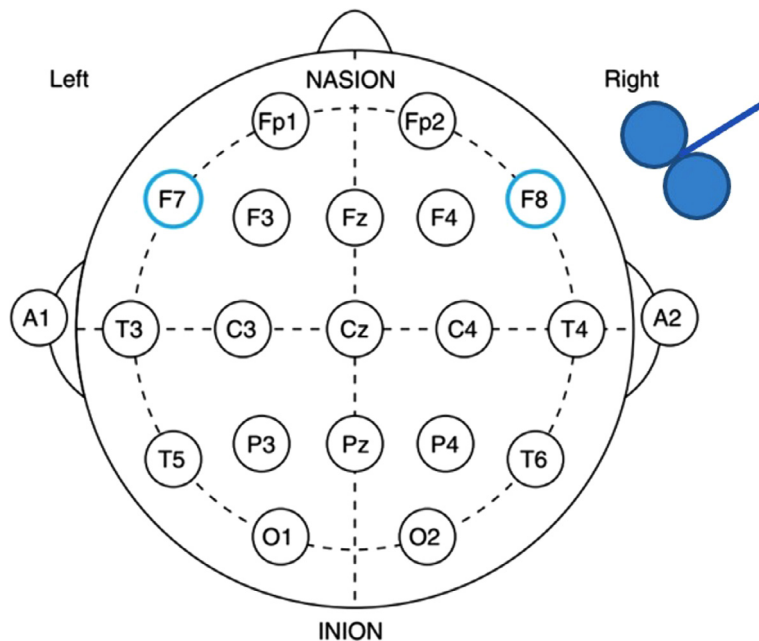


Fig. 5. TMS application area.

Table 5. Pre-test – post-test – follow-up test comparisons for treatment and control groups.

Dimension	Source of variance	Two-Way Repeated Measures ANOVA				
		Wilk's Λ	F	(df ₁ , df ₂)	p	Effect η^2
Speech Fluency	Main	Wilk's $\Lambda = 0.379$, $F(2, 35) = 28.643$; $p < 0.05$, partial $\eta^2 = 0.621$	34.894	(2, 6)	0.000*	0.492
	Interaction Between	Wilk's $\Lambda = 0.513$, $F(6, 70) = 4.620$; $p < 0.05$, partial $\eta^2 = 0.284$	6.534	(2, 6)	0.000*	0.353
				14.117	(3, 36)	0.000*
Auditory Comprehension	Main	Wilk's $\Lambda = 0.309$, $F(2, 35) = 39.107$; $p < 0.05$, partial $\eta^2 = 0.692$	47.287	(2, 6)	0.000*	0.568
	Interaction Between	Wilk's $\Lambda = 1.512$, $F(6, 70) = 4.620$; $p > 0.05$	1.713	(2, 6)	0.130	0.125
				1.082	(3, 36)	0.369
Repetition	Main	Wilk's $\Lambda = 0.583$, $F(2, 35) = 12.521$; $p < 0.05$, partial $\eta^2 = 0.417$	12.432	(2, 6)	0.000*	0.257
	Interaction Between	Wilk's $\Lambda = 0.782$, $F(6, 70) = 4.620$; $p > 0.05$	1.734	(2, 6)	0.125	0.126
				22.695	(3, 36)	0.000*
Naming	Main	Wilk's $\Lambda = 0.297$, $F(2, 35) = 41.373$; $p < 0.05$, partial $\eta^2 = 0.703$	60.476	(2, 6)	0.000*	0.627
	Interaction Between	Wilk's $\Lambda = 0.550$, $F(6, 70) = 4.067$; $p < 0.05$, partial $\eta^2 = 0.259$	6.534	(2, 6)	0.000*	0.353
				12.055	(3, 36)	0.000*
SAQOL – 39 – Physical	Main	Wilk's $\Lambda = 0.962$, $F(2, 35) = 0.962$; $p > 0.05$	0.735	(2, 6)	0.441	0.020
	Interaction Between	Wilk's $\Lambda = 0.719$, $F(6, 70) = 4.620$; $p > 0.05$	2.299	(2, 6)	0.068	0.161
				1.555	(3, 36)	0.217
SAQOL – 39 – Communication	Main	Wilk's $\Lambda = 0.125$, $F(2, 35) = 122.615$; $p < 0.05$, partial $\eta^2 = 0.875$	177.925	(2, 6)	0.000*	0.832
	Interaction Between	Wilk's $\Lambda = 0.431$, $F(6, 70) = 6.109$; $p < 0.05$, partial $\eta^2 = 0.344$	0.964	(2, 6)	0.424	0.074
				2.506	(3, 36)	0.074
SAQOL – 39 – Psychosocial	Main	Wilk's $\Lambda = 0.957$, $F(2, 35) = 0.792$; $p > 0.05$	1.170	(2, 6)	0.307	0.031
	Interaction Between	Wilk's $\Lambda = 0.780$, $F(6, 70) = 2.547$; $p < 0.05$, partial $\eta^2 = 0.117$	2.073	(2, 6)	0.088	0.147
				0.322	(3, 36)	0.809
SAQOL – 39 – Energy	Main	Wilk's $\Lambda = 0.998$, $F(2, 35) = 0.028$; $p > 0.05$	0.038	(2, 6)	0.962	0.001
	Interaction Between	Wilk's $\Lambda = 0.738$, $F(6, 70) = 1.912$; $p > 0.05$	2.081	(2, 6)	0.066	0.148
				0.564	3,36 [†]	0.642
Picture Naming Test – TR	Main	Wilk's $\Lambda = 0.192$, $F(2, 35) = 73.695$; $p < 0.05$, partial $\eta^2 = 0.808$	88.187	(2, 6)	0.000*	0.710
	Interaction Between	Wilk's $\Lambda = 0.270$, $F(6, 70) = 4.067$; $p < 0.05$, partial $\eta^2 = 0.481$	18.406	(2, 6)	0.000*	0.605
				3.421	(3, 36)	0.027

*p < 0.05.

Comparison of treatment groups with control group

To compare treatment groups with the control group in terms of study variables, 4 (groups) X 3 (measurement points) repeated measures ANOVA was conducted. Test results are shown in Table 5.

The main effect of treatment was significant for speech fluency [Wilk's $\Lambda = 0.379$, $F^{2,35} = 28.643$; $p < 0.05$, partial $\eta^2 = 0.621$], auditory comprehension [Wilk's $\Lambda = 0.309$, $F^{2,35} = 39.107$; $p < 0.05$, partial $\eta^2 = 0.692$], repetition [Wilk's $\Lambda = 0.583$, $F^{2,35} = 12.521$; $p < 0.05$, partial $\eta^2 = 0.417$], and naming [Wilk's $\Lambda = 0.297$, $F(2, 35) = 41.373$; $p < 0.05$, partial $\eta^2 = 0.703$]. Interaction effect of group and treatment was significant only for speech fluency [Wilk's $\Lambda = 0.513$, $F(6, 70) = 4.620$; $p < 0.05$, partial $\eta^2 = 0.284$] and naming [Wilk's $\Lambda = 0.550$, $F(6, 70) = 4.067$; $p < 0.05$, partial $\eta^2 = 0.259$]. Further analysis indicated that the treatment significantly increased the skills of participants in speech fluency [$F(6,72) = 6.534$; $p < 0.05$, partial $\eta^2 = 0.353$] and naming [$F(6,72) = 6.534$; $p < 0.05$, partial $\eta^2 = 0.353$] across groups. Pre-test, post-test and follow-up tests comparison for the treatment and control groups is shown in Fig. 6.

The main effect of treatment was significant only for communication [Wilk's $\Lambda = 0.125$, $F^{2,35} = 122.615$; $p < 0.05$, partial $\eta^2 = 0.875$] and the interaction effect of group and

treatment was significant only for communication [Wilk's $\Lambda = 0.431$, $F^{6,70} = 6.109$; $p < 0.05$, partial $\eta^2 = 0.344$] and psychosocial dimensions [Wilk's $\Lambda = 0.780$, $F^{6,70} = 2.547$; $p < 0.05$, partial $\eta^2 = 0.117$]. However, further analysis indicated that treatment did not significantly increase participants' quality of life across groups. The pre-test, post-test and follow-up test comparison on picture naming for the treatment and the control group is shown in Fig. 7.

The main effect of treatment [Wilk's $\Lambda = 0.192$, $F^{2,35} = 73.695$; $p < 0.05$, partial $\eta^2 = 0.808$] and interaction effect of group and treatment [Wilk's $\Lambda = 0.270$, $F^{6,70} = 4.067$; $p < 0.05$, partial $\eta^2 = 0.481$] were significant for picture naming. Further analysis indicated that treatment significantly increased participants' skills in picture naming [$F(6,72) = 18.406$; $p < 0.05$, partial $\eta^2 = 0.605$] across groups. The pre-test, post-test and follow-up test comparison on picture naming for the treatment and control groups is shown in Fig. 8.

Comparison of treatment groups across pre-test, post-test, and follow-up test

Participants' attainments from the pre-test to the follow-up test were assessed using the Friedman test, and comparison among the tests for each treatment group was

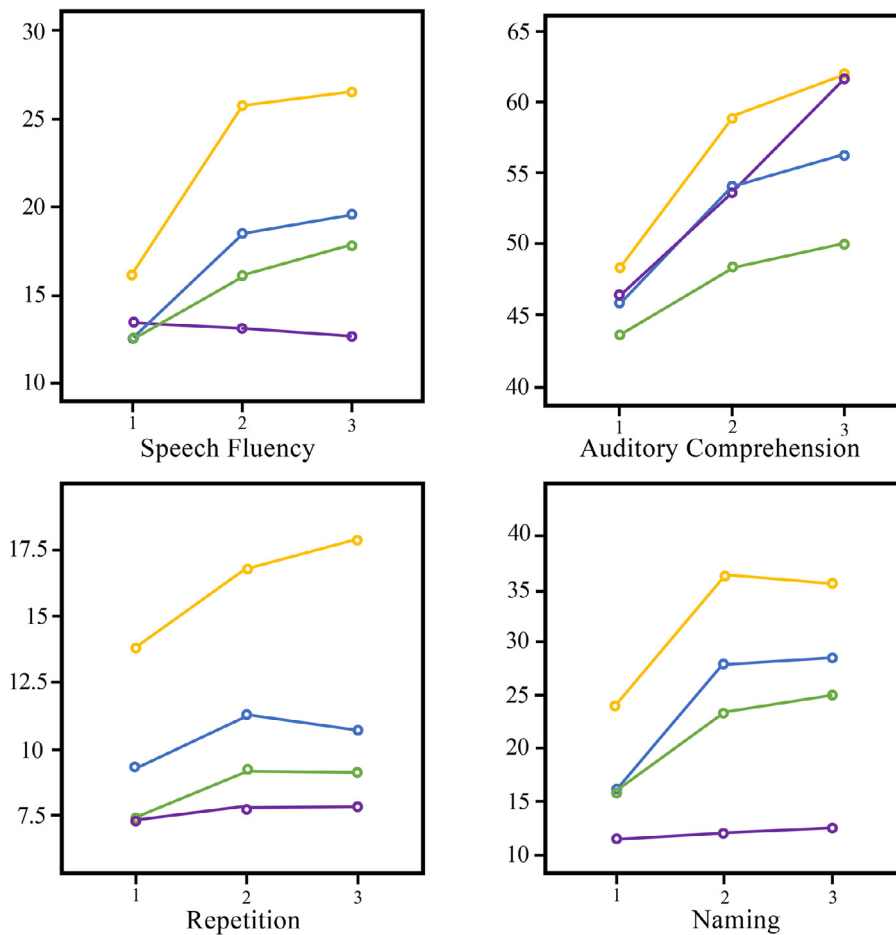


Fig. 6. Pre-test – post-test – follow-up test comparison for treatment and control groups for the dimensions of Aphasia Language Assessment Test (1, 2, 3 represents pre-test, post-test and follow-up test, respectively; yellow line represents Treatment 1, blue line represents Treatment 2, green line represents Treatment 3, and purple line represents Control group).

examined by performing Wilcoxon Sign Rank test. Test results are given in Table 6.

As for *Test of Language Assessment in Aphasia*, speech fluency of participants increased significantly from pre-test to post-test for SLT ($\chi^2=7.40$, $p<0.05$), TMS ($\chi^2=10.126$, $p<0.05$) and SLT + TMS ($\chi^2=16.889$, $p<0.05$) groups. Auditory comprehension of participants increased significantly in the pre-test to the post-test for SLT ($\chi^2=13.40$, $p<0.05$) and TMS ($\chi^2=7.267$, $p<0.05$), and the pre-test to the post-test and the post-test to the follow-up test for SLT + TMS ($\chi^2=18.571$, $p<0.05$) groups. Repetition skills of participants increased significantly from the pre-test to the post-test for the SLT+TMS ($\chi^2=14.824$, $p<0.05$) group. Naming skills of participants increased significantly from the pre-test to the post-test for SLT ($\chi^2=16.270$, $p<0.05$) and TMS ($\chi^2=16.00$, $p<0.05$) and SLT+TMS ($\chi^2=12.842$, $p<0.05$) groups. As for *Stroke and Aphasia Quality of Life Scale (SAQOL-39)*, no significant change was observed for the physical and psychosocial quality of life of participants in any of treatment groups. Communication quality of participants increased significantly from the pre-test to the post-test for SLT ($\chi^2=14.923$, $p<0.05$), TMS ($\chi^2=9.243$, $p<0.05$), and SLT+TMS ($\chi^2=15.436$, $p<0.05$) groups.

Energy quality of the participants decreased from the pre-test to the post-test only for the SLT+TMS ($\chi^2=8.688$, $p<0.05$) group. As for *Picture Naming Test*, the picture naming skill of participants increased from the pre-test to the post-test for SLT ($\chi^2=15.436$, $p<0.05$), TMS ($\chi^2=10.889$, $p<0.05$), and SLT+TMS ($\chi^2=15.20$, $p<0.05$) groups.

Discussion

In this study, the effect of SLT, TMS, and SLT+TMS on improving language skills, naming, and quality of life in individuals with Broca's aphasia was investigated by comparing their outcomes in language skills including speech fluency, auditory comprehension, repetition, and picture naming, as well as quality of life dimensions including physical, communication, psychosocial, and energy compared to the control group.

Language skills

Semantic Features Analysis is known to be effective in retrieving conceptual information by accessing semantic networks.⁵⁴ In therapies using this method, patients are

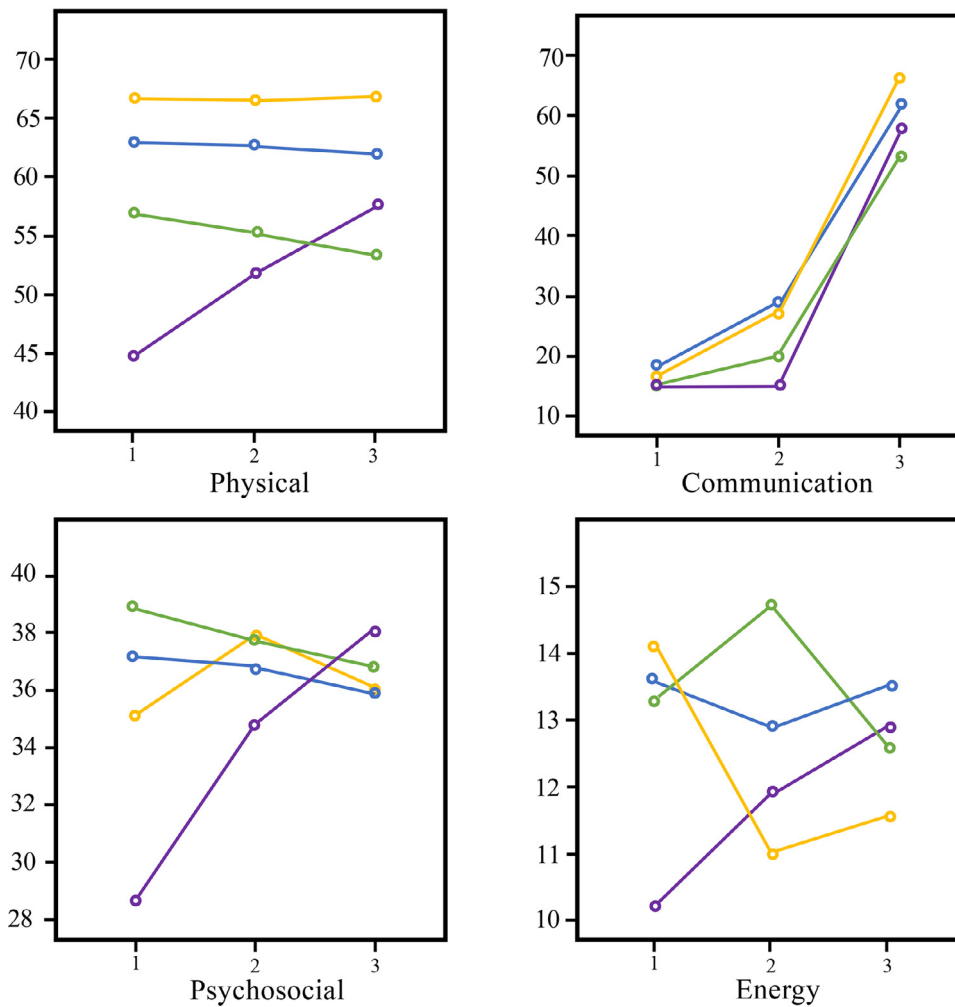


Fig. 7. Pre-test – post-test – follow-up test comparison for treatment and control groups for the dimensions of Stroke and Aphasia Quality of Life Scale (SAQOL-39) (1, 2, 3 represents pre-test, post-test and follow-up test, respectively; yellow line represents Treatment 1, blue line represents Treatment 2, green line represents Treatment 3 and purple line represents Control group).

asked to produce words that are semantically related to the target word. By activating the semantic network surrounding the target word, the probability of naming this word increases.²⁸ Several studies of individuals with aphasia using Semantic Features Analysis as an experimental intervention show that this method is generally promising and helps many individuals with aphasia to recall the target word and semantic concepts.⁵⁵ The method is effective not only in naming but also in speech production, sentence organization, and dialogue skills. In another study, it was demonstrated through experimental applications that SFA can be used as a functional therapy tool that facilitates naming and connected speech.²⁴

Participants' gains in speech fluency, auditory comprehension, repetition, and naming improved from pre-test to post-test, and their outcomes retained from the post-test to the follow-up test compared to the control group. Significant changes were observed in all treatment groups for speech fluency, auditory comprehension, and naming, but only in the SLT+TMS group for repetition. When

comparison was made among the four groups in terms of language skills, the greatest change was observed in the group in which SLT and TMS were applied together. These findings are parallel with the current literature on aphasia.⁵⁶

Treatment with SLT significantly contributed to participants' development of speech fluency, auditory comprehension, and naming. Several experimental studies with different treatment intervals examined the effect of SLT on the improvement of language skills of individuals with aphasia. In parallel with the present study, SLT was found to be effective in the improvement of language skills of individuals with aphasia (e.g., speech fluency,⁵⁷⁻⁵⁹ and naming.⁶⁰ SFA, especially, activating the semantic network through an organized approach, facilitates the recall or production of words in individuals with aphasia. The process is important in the effective use of language and speaking skills. The effectiveness of SLT was revealed in the meta-analysis of a published study in the literature;⁶⁰ in which there was a direct relationship between the

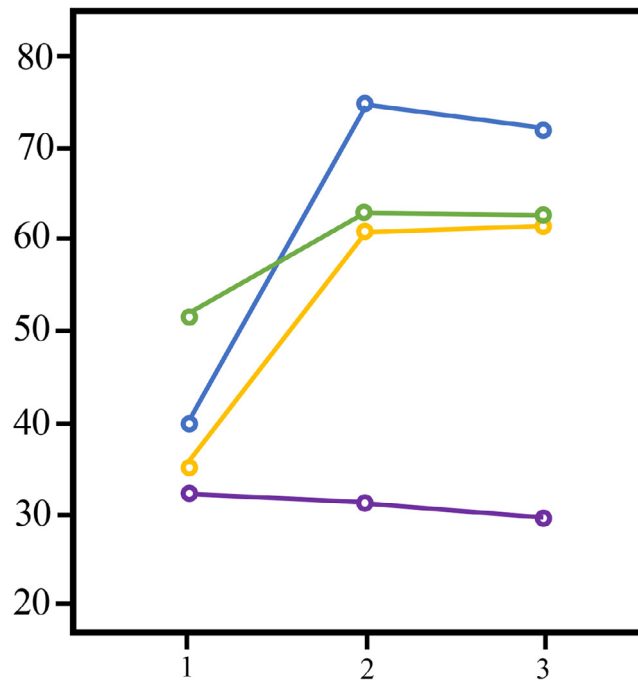


Fig. 8. Pre-test – post-test – follow-up test comparison for treatment and control group for Picture Naming Test – Turkish (1, 2, 3 represents pre-test, post-test and follow-up test, respectively; yellow line represents Treatment 1, blue line represents Treatment 2, green line represents Treatment 3 and purple line represents Control group).

Table 6. Comparison of pre-test – post-test – follow-up test results of treatment groups using Friedman’s test.

Dimension	Treatments	Pretest (1)	Post-test (2)	Follow up test (3)	Friedman’s Test		Wilcoxon sign rank test for comparison
		$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$	χ^2	p	
Speech Fluency	Treatment 1 (SLT)	12.50±3.17	18.50±7.26	19.60±5.96	7.40	0.025*	2>1, 3>1
	Treatment 2 (TMS)	12.60±3.27	16.10±3.47	17.80±5.69	10.129	0.006*	2>1, 3>1
	Treatment 3 (SLT + TMS)	16.20±3.58	25.70±3.43	26.60±4.11	16.889	0.000*	2>1, 3>1
Auditory Comprehension	Treatment 1 (SLT)	45.80±14.80	54.00±12.88	56.20±11.83	13.40	0.001*	2>1, 3>1
	Treatment 2 (TMS)	43.60±17.82	48.40±16.09	50.00±18.03	7.267	0.026*	2>1, 3>1
	Treatment 3 (SLT + TMS)	48.30±8.68	58.90±5.54	61.90±3.78	18.571	0.000*	2>1, 3>1, 3>2
Repetition	Treatment 1 (SLT)	9.30±2.66	11.3±3.43	10.70±4.24	5.515	0.063	-
	Treatment 2 (TMS)	7.40±2.01	9.20±3.85	9.10±3.38	3.938	0.140	-
	Treatment 3 (SLT + TMS)	13.80±2.93	16.80±3.39	17.90±2.46	14.824	0.001*	2>1, 3>1
Naming	Treatment 1 (SLT)	15.80±6.19	27.90±8.11	28.50±7.41	16.270	0.000*	2>1, 3>1
	Treatment 2 (TMS)	16.20±8.43	23.40±11.23	25.00±13.32	16.00	0.000*	2>1, 3>1
	Treatment 3 (SLT + TMS)	24.00±7.63	36.20±9.82	35.50±8.63	12.842	0.002**	2>1, 3>1
SAQOL – 39 Physical	Treatment 1 (SLT)	63.00±18.99	62.70±19.60	61.90±22.19	0.514	0.773	-
	Treatment 2 (TMS)	56.90±21.59	55.20±21.95	53.40±23.45	0.242	0.886	-
	Treatment 3 (SLT + TMS)	66.80±11.68	66.50±16.10	66.90±16.41	0.200	0.905	-
SAQOL – 39 Communication	Treatment 1 (SLT)	18.10±3.31	28.90±3.28	26.90±2.46	14.923	0.001*	2>1, 3>1
	Treatment 2 (TMS)	15.10±5.40	20.10±3.14	20.70±3.49	9.243	0.010*	2>1, 3>1
	Treatment 3 (SLT + TMS)	16.70±3.46	27.30±5.22	28.70±3.30	15.436	0.000*	2>1, 3>1
SAQOL – 39 Psychosocial	Treatment 1 (SLT)	37.20±9.99	36.80±9.70	35.90±12.29	2.053	0.358	-
	Treatment 2 (TMS)	38.90±9.78	37.70±9.34	36.80±10.07	0.424	0.809	-
	Treatment 3 (SLT + TMS)	35.20±4.96	37.90±11.83	36.20±13.66	0.051	0.975	-
SAQOL – 39 Energy	Treatment 1 (SLT)	13.60±5.25	12.90±5.08	13.50±5.14	0.839	0.657	-
	Treatment 2 (TMS)	13.30±4.32	14.70±7.0	12.60±4.45	1.448	0.485	-
	Treatment 3 (SLT + TMS)	14.10±3.84	11.10±4.80	11.60±3.89	8.688	0.013*	1>2, 1>3
Picture Naming Test - TR	Treatment 1 (SLT)	39.90±21.65	74.60±24.98	71.90±25.83	15.436	0.000*	2>1, 3>1
	Treatment 2 (TMS)	51.60±33.28	62.80±38.49	62.60±37.71	10.889	0.004*	2>1, 3>1
	Treatment 3 (SLT + TMS)	35.20±17.22	60.70±20.02	61.60±17.30	15.20	0.001*	2>1, 3>1

*p<0.05.

amount of therapy and the development of the individual with words, and the success level could reach up to 52% after 15 sessions of treatment.

The treatment with TMS significantly improved participants' speech fluency, auditory comprehension, and naming; the participants' gain was found to be sustained in scores in the follow-up test. Similarly, Rubi-Fessen et al.⁶¹ reported positive effects of TMS application on the improvement of language skills and functional communication of individuals in aphasia therapy. When the dominant hemisphere of the tongue is damaged, the inhibition of the right hemisphere is weakened and its excitability is increased. This in turn increases inhibition in the left hemisphere and causes a further decrease in the damaged left hemisphere. This also reduces the excitability of the left hemisphere. Studies have shown that TMS can restore the physiologic equilibrium state of both hemispheres by adjusting the stimulation parameters. Low-frequency TMS (≤ 1 Hz) is commonly used to reduce cortical excitability,⁶² while high-frequency TMS (≥ 5 Hz) is applied to facilitate the neural activation.⁶³ Therefore, the left hemisphere can be stimulated a high rate or the right hemisphere can be inhibited at low frequency by using TMS. Both forms of application may help to improve language function.^{64,65} There are many studies confirming that people suffering from aphasia can be treated more effectively with repeated low-frequency application of TMS to the right hemisphere.^{62,64} As a result of meta-analysis studies, there are generalizations that the studies were mostly conducted on the right pars triangularis region and the results were mostly based on visual naming skills.⁶³ For example, when 1 Hz rTMS was applied to the Broca area in the right hemisphere for 10 sessions, an increase in naming skills was observed in individuals with aphasia.³¹ It was observed in neuroimaging studies that individuals with chronic Broca's aphasia have much higher activation in the right Broca area and right presilvian areas during speech production. It is thought that this may lead to maladaptive results. Low-frequency rTMS application may cause an inhibitory effect on the area of interest and reactivate the area in the left hemisphere;⁶⁶ the study is based on this assumption. In another study conducted on thirty participants, the effectiveness of rTMS application on the right hemisphere was examined. In this randomized, sham and controlled study, stimulation was applied to the inferior right frontal gyrus (BA45) region at 1 Hz for 20 min in 10 sessions for 10 days. A similar application was performed over the vertex region with 15 participants who were allocated as a sham group. The participants in the study group showed significant improvement in all of their speech and communication skills.³² There are many other successful examples of the rTMS low frequency application used in the study. The results of these studies recorded positive progress in language skills such as comprehension, naming, and

repetition with rTMS low frequency application to the undamaged area.^{35-37,67} In this context, the study reveals similar results to the literature.

We used inhibitory rTMS targeting the healthy hemisphere to restore this interhemispheric imbalance. Several studies confirmed that the application of repeated TMS at low frequency to the right hemisphere can effectively treat people with aphasia.^{31,37,63,64,68}

The combined treatment of SLT+TMS improved all dimensions of language skills of the participants. The dimension of repetition was improved significantly only by SLT+TMS treatment compared with the other treatments. The result is supported by the recent studies done by Seniow et al.⁶⁹ and Balossier et al.⁷⁰. A study by Georgiou et al.¹⁵ on participants with communication disorders suggests that TMS can facilitate recovery of language impairment in individuals with aphasia. Consecutive SLT and TMS applications provide double stimulation in individuals while trying to activate the functioning mechanism of the brain and support the rehabilitation process with linguistic stimulation.

Naming

Word production models assume that three basic cognitive functions are effective in the processes of word coding and naming visual perception, conceptual activation, and production dimensions.⁷¹ There is a system whose purpose is to select words from the mental dictionary that properly express the speaker's intention. There is another system that prepares expressive gestures for these selected words in the context of expression. At this point, providing clues is important in the activation of the process. Neurocognitive mechanisms similar to those of healthy individuals are activated in the process of responding to clues in the word production stage of individuals with aphasia.⁷²

The experimentation process indicated that participants' naming performance significantly increased from pre-test to post-test in all treatment groups. Also, patients naming performance was sustained even one month after treatments. These results are inconsistent with the results of previous studies.^{36,58,59,73} The literature revealed that TMS⁷⁴⁻⁷⁷ and SLT+TMS⁷⁸⁻⁸⁰ were successful for improving naming performance of individuals with aphasia. According to the results of the study, the increase in naming scores was higher in only SLT and SLT+TMS treatment groups compared to the other groups. The group in which SLT and TMS were applied consecutively achieved higher scores than the group in which only SLT was applied. This situation indicates that speech and language therapy have a positive effect on the increase in naming scores but naming performance may increase with the additional application of TMS. It can be interpreted that that application of TMS alone provides a partial increase.

Quality of life

Quality of life (QL) is defined as the individual's perception of their well-being.⁸¹ Individuals' difficulties in controlling their emotions, anxiety, loneliness, depression, irritability, and disappointment have recently been observed in studies conducted on individuals with aphasia.⁸² In a study comparing the psychological stress levels and quality of life of individuals with and without aphasia after stroke; they were followed for six months. Individuals with aphasia had increased psychological stress levels as their aphasia progressed and their psychological stress levels were higher than the individuals without aphasia.⁸³ It is stated that aphasia affects the quality of life of the individuals with all its dimensions. Any intervention is very important in increasing the individual's participation in life and gaining functionality.

In the consideration of the present study indicated that all treatments significantly improved participants' communication only, and the treatment of SLT+TMS significantly decreased participants' energy dimension of quality of life. As we explained in detail above, aphasia is the most important potential consequence of stroke and negatively affects the patient's life by causing emotional distress, depression, and social isolation due to loss of language functions. The health-related QL reflects the impact of a healthy state on a person's ability to lead a fulfilling life and encompasses an individual's satisfaction in the physical, functional, psychological, and social domains.⁸¹ The treatments impacted other quality of life dimensions, but pre-test, post-test and follow-up test differences were not statistically significant. Williamson et al.⁸⁴ found that there was no relationship between severity of aphasia and quality of life scale scores, and these results were valid regardless of age or time elapse after stroke. Most studies about rTMS used naming to measure efficacy; however, our study has a different perspective by comparing to the quality of life.

A recent review of the literature on the social participation levels of individuals with aphasia revealed that little is known on this subject.⁸⁵ To date, a few small studies have been reported on the subject; however, there have been studies focusing mostly on a relatively small population, case studies, or only social relations.^{5,86}

Improving communication in daily life is an important goal of intervention programs for people with acquired communication difficulties.⁸⁷ This result can be achieved by processing language and cognitive functions that support communication or by introducing compensatory strategies and changes to the environment that support communication. Over the past three decades, philosophical advances and routine clinical challenges in healthcare (e.g., limited generalization of some disorder-focused treatment, institutional constraints in service delivery) have encouraged clinicians and researchers to explore intervention programs aimed at direct communication.⁸⁸

Conclusion

It is very important in the management of the treatment process to reveal the effectiveness of the separate or combined applications of SLT and TMS in restoring language skills, naming performance, and social participation of individuals with chronic aphasia. SLT has provided gains in language skills and social life participation in these individuals. The use of SLT in combination with TMS increased the amount of gaining in these skills, and the use of TMS alone provided gains in naming performance. It is suggested that individuals with Broca's aphasia, even if they have chronic phase, should definitely need SLT, and the effectiveness of this therapy will be enhanced by TMS, which will contribute to the rehabilitation of communication.

Findings show that performing TMS and SLT, either separately or together, has a positive effect on various language skills in individuals with post-stroke aphasia. It was observed that both SLT and TMS methods applied together to individuals with Broca's aphasia were effective, and positive results were obtained from their application. The application of the methods both separately and together contributed positively to the participants gaining language skills.

Limitation

This study is limited due to only having 40 participants because of the limited research budget. Also, different types of aphasia were not included, and education level and pre-therapy history were not taken into account when determining the participants. The study was limited to individuals with long-term aphasia so that the gain obtained with the interventions could not be explained by the spontaneous recovery period. In addition, we tried to ensure homogeneity between participants in terms of aphasia severity, however no additional assessment of aphasia severity was used. Furthermore, no neuropsychological evaluations were made after the applications.

Declaration of Competing Interest

None.

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