Research Paper: Comparative Effectiveness of Semantic Feature Analysis (SFA) and Phonological Components Analysis (PCA) for Anomia Treatment in Persian Speaking Patients With Aphasia

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ABSTRACT

Objectives: Anomia is one of the most common and persistent symptoms of aphasia. Although treatments of anomia usually focus on semantic and/or phonological levels, which both have been demonstrated to be effective, the relationship between the underlying functional deficit in naming and response to a particular treatment approach remains unclear. The aim of this study was to determine the relationship between the effects of specific treatments (Semantic feature Analysis and Phonological Components Analysis) and their underlying functional deficit patterns within the framework of a cognitive processing model.

Methods: In an ABCB reversal control task design, four participants with aphasia were selected according to the criteria based on using a cognitive model of lexical processing. Each patient received two types of treatment. In SFA, features semantically associated to the target words were elicited from the patient, whereas in PCA treatment, the phonological components of the target words were the focus of treatment. Naming accuracy scores obtained in pre-treatment baseline phase were compared to post-treatment accuracy scores. Here, both item-specific effects and generalization of untrained items were analyzed.

Results: Both SFA and PCA treatments have the potential to improve naming ability in participants; however, the treatment approach that corresponds exactly to the underlying deficit causing failure in word retrieval is more effective.

Discussion: While PCA is more effective for participants with phonological impairments, SFA is more effective for participants with semantic impairments. Therefore, a direct relationship between underlying functional deficit and response to specific treatment was established for all participants.

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1. Introduction

Anomia, known as an impairment in word retrieval, is one of the most common and persistent symptoms of aphasia [1].While normal people are easily able to find an appropriate word for an object, action, idea, etc., it may be so laborious for aphasic patients, and they fail to accomplish that. Failure in retrieving the target words compensates communication during verbal interactions. Thus, anomia has been the topic of research in the field of aphasia in an attempt to elucidate its nature and also to develop treatments to reduce its effects.

There are several cognitive models of lexical processing which can explain different patterns of anomic errors. The Dell, Schwartz, Martin, Saffran, Gagnon Model (DSMSG), which is based on Dell's two-step interactive activation model, has been aimed to explain the distribution of errors produced by aphasic patients during picture naming tasks. This model hypothesizes that normal lexical processing involves spreading activation through a lexical network, which in turn, allows for mapping between the conceptual representation of an object (the picture) and the phonological form of its name. Activation cascades down to three layers of nodes, which are associated with semantic features, words, and phonemes, via excitatory connections. While top-down connections run from meanings to words and words to phonemes, there is also bottom-up connections, moving in the reverse direction, providing the model with excitatory feedback and turning it into an interactive system [2].

So far, two versions of the DSMSG model have been proposed. In the original version of the model, i.e. weigh-decay model, there are two basic value parameters: 'p' and 'q'. Parameter 'p' represents the overall connection weight between the layers of the lexical network and monitors the extent of activation spreading through the layers by their connective strength. Parameter 'q' denotes the rate of activation decay. According to this model, different types of brain damage are associated with a decrease in connective strength and an increase in the decay rate.

The new version is semantic– phonological, which explains naming errors made by aphasic patients more clearly and also more consistent with other data and theories in psycholinguistics and cognitive neuropsychology. The latter version suggests that reducing normal parameters of connections between semantic and lexical nodes (semantic weights) results in semantic errors and reduction of normal parameters of connections between lexical and phonological nodes (phonological weights) causes phonological retrieval deficits and non-word utterances [2].

The precise characteristics of functional nature of naming impairments help clinicians with choosing a suitable type of treatment. For example, semantic naming errors may be the result of impaired access to semantic representations or difficulty in the representation of themselves. In contrast, phonological errors may arise from impaired access to the phonological representation, or difficulty in presenting themselves [3]. Therefore, it seems that semantic-based treatment specifically targets on strengthening representations at the level of the word meaning and phonological-based treatment aims at enhancing representations at the level of the word form. Some studies have shown that semantic tasks are effective for patients with semantic impairments, and phonological tasks are effective for those with phonological impairments [4, 5].

One of the techniques that focus on semantic impairments is Semantic Feature Analysis (SFA). SFA helps patients with describing the semantic features which activate the most distinguishing features of the semantic system for a target concept [6]. According to the spreading activation theory, increased activation of semantic features about target concept is presumed to increase the probability that the target word will be activated beyond a minimum threshold level required for correct word production [7]. This technique is the most common semantic-based treatment procedure that was originally developed to treat patients with traumatic brain injury [8, 9].

SFA was applied to two patients suffering from traumatic brain injury. The result was increased production of semantic features for trained items, which was maintained after treatment, and generalization to untrained items [8]. Subsequently, this treatment method was administered to a mildly aphasic individual with word retrieval deficit [6]. The results indicated that confrontation naming on trained and untrained stimulus items was significantly improved. The results of this study have shown that SFA treatment is effective in improvement of naming deficits [10, 11]. A recent systematic review has also indicated that SFA was an effective treatment for improving confrontational naming in the majority of participants. However, limited generalization to untrained items and connected speech were reported in various studies [12].

Phonological Components Analysis (PCA) is a phonological approach for remediating naming deficits that are

similar in structure to SFA. PCA focuses on the phonological properties of words to facilitate processing at the level of the word form, and it was developed as a comparable phonological approach to SFA for contrasting the relative effects of each treatment on word retrieval deficits. To operationally specify the PCA treatment program and to investigate its efficacy, Leonard et al (2008) published a single-subject multiple-baseline study that used PCA treatment for ten individuals who had word retrieval deficit. Out of the total, seven individuals demonstrated significant improvement in naming treated items with longer-lasting effects and some generalization to untreated items [13].

The only study that compared SFA and PCA treatments is performed by Hees et al (2013) with 8 participants, each of which received both treatments. Most participants significantly improved in naming trained items at the end of phonological therapy, despite differences in their underlying impairments. In contrast, the semantic therapy was not beneficial for participants with primary semantic impairments [14]. Similar results with other treatment approaches have been found in several studies [15-18]. Such inconsistencies may relate to the type of functional deficit in naming processing. Weak activation at the semantic level will result in weak activation of semantic features representation or lexical representation.

It would remain unclear whether the reason for the weak lexical activation is a phonological impairment or a semantic one. Phonological tasks, hence, increased activation at the lexical level and the chance of retrieval of the phonological form will increase. As a result, phonological tasks might improve naming in individuals with semantic impairments, but this does not mean that they remediate the semantic impairment itself.

The primary objective of the present study, which has been conducted in the Persian language, was to provide more evidence regarding the selection of an appropriate treatment approach by a patient's underlying deficits within a cognitive processing model. Recent related findings are controversial and inconclusive in the sense that some studies have advocate selecting treatment approaches according to the underlying disorders and others have not reached to this conclusion. These contradictory findings may arise, in part, from the fact that patients who had been selected for these studies had both phonological and semantic disorders.

In this study, authors applied the DSMSG model for precise characterization of the functional nature of naming impairments. Participants with pure impairments at the semantic level or phonological level participated in the study to answer the following clinical question: For individuals with aphasia, what is the relationship between underlying functional deficit and responding to a particular treatment?

2. Methods

Participants

Patients who met all of the following criteria were included in this study: Speaking Persian as their first language, having adequate vision and hearing (with or without correction), absence of major psychiatric or neurologic comorbidities, severe apraxia or dysarthria, detection of left hemisphere cortical lesions on the basis of CT scan or MRI, and committing pure phonological or semantic errors rather than mixed ones. None of the participants received formal speech-language therapy at the time of the investigation. Four patients with aphasia

Table 1. Demographic information and lesion site for each participant

Sex	P1	P2	P3	P4
	Male	Female	Male	Male
Age (years)	61	52	45	47
Months post-onset stroke	24	17	67	15
Years of schooling	15	9	12	22
Type of aphasia	Broca	Broca	anomia	Broca
Lesion site	IFG, SMA, Insula, putamen	SMG, STG	ITG, MTG, STG	IFG, Insula

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IFG: Inferior Frontal Gyrus; SMA: Supplementary Motor Area; SMG: Supra-Marginal Gyrus; STG: Superior Temporal Gyrus; ITG: Inferior Temporal Gyrus; MTG: Middle Temporal Gyrus; STG: Superior Temporal Gyrus

resulting from left hemisphere stroke (one woman and three men) fulfilled these criteria.

They have been previously diagnosed with aphasia by their scores in Persian-WAB (P-WAB1) test [19]. Anomia was the main complaint of patients at the time of enrollment. Assessment and treatment sessions were conducted in an affiliated rehabilitation clinic of Isfahan University of Medical Sciences. All participants provided a written informed consent before starting the study. Demographic information and lesion site for each of the four participants are given in Table 1.

Procedure

Participants were divided into two groups based on their performance on the Persian Naming Test: lexical-semantic (n=2) and lexical-phonological (n=2). Naming errors were categorized according to the Philadelphia Naming Test [20]. A web-based semantic–phonological fitting formula was applied for the better determination of the level at which deficits occurred[1] [21].

This interactive activation model analyzes the patterns of aphasic errors by changing the normal parameters of semantic weights (i.e. connections between semantic and lexical nodes) or phonological weights (i.e. the connections between lexical and phonological nodes). The defective values of each parameter were calculated by the Web-based automated data fitting program in a way that the lowest values reveal the most impaired connections [22]. The lexical-semantic group (i.e. participants 1 and 2) made only semantic errors, and the lexical-phonological group (i.e. participants 3 and 4) committed only phonological errors while naming pictures presented to them.

Treatment design

An ABCB reversal control task design was used for the investigation of the specific effects of the two treatment methods on each participant [23]. The treatment period started with three baseline measurements, with a one-week interval between them. Participants named the set of 143 target pictures at each baseline session, which allowed to observe the changes overtime. To diminish the effect of fatigue, the pictures were randomly presented to the patients throughout the baseline sessions.

Pictures which had not been named correctly within 10s after the presentation in 2/3 of the sessions, were selected as subject-specific stimuli and subdivided into three training sets and three untraining sets. Each set contained 12 items. Although each participant had his/her own stimuli sets, investigators tried to match them as closely as possible according to the category, frequency, and number of syllables.

One week after the third baseline measurement, the treatment phase was started. Three phases of treatment, with 1-week intervals between each phase, were administered. Half of the participants (1, 4) began with PCA treatment followed by SFA treatment in the second phase, and again PCA treatment in the third phase. The other half (2, 3) started with SFA treatment, followed by PCA treatment and another SFA treatment phase. The subjects were allocated alternately to each of the two treatment sequences. Within each phase, seven separate 45-minute treatment sessions were conducted over two weeks. To assess item-specific treatment effects, all training items were probed immediately after each treatment session. To evaluate generalization effects, all untraining items were probed after each two treatment sessions.

Control task

Written sentence comprehension, which is also impaired in most of the people with aphasia, was selected as an unrelated task to dissociate specific treatment effects from non-specific improvement. It was conducted before and after the entire therapy.

Treatment

SFA was used as the semantic therapy task, in which participant needs to focus on the features associated with target words semantically using a chart of cue words (group, use, action, properties, location, and association) to increase the activation of semantic information required for word retrieval. PCA was used as the phonological therapy task. PCA therapy was modeled after SFA therapy, in which the focus is on the phonological components of the target word (first/last sound, number of syllables, first sound associate, and rhyme) rather than semantic features. The therapy tasks followed the same procedure as previous studies employing SFA and PCA [7, 11, 14].

Each picture was presented in the center of a chart, and the participant was asked to name it. Irrespective of his/her ability to name the picture, the participant was asked to identify the features of the item according to each cue word in the chart. Once the participants provided responses, the clinician wrote them on the chart into the relevant boxes. If a participant produced an incorrect re-

1. For further details, please refer to http://langprod.cogsci.uiuc.edu/cgi-bin/webfit.cgi

sponse or no response, the clinician provided a correct response both orally and in written form. After all the features were produced, the clinician asked the participant to name the item again. Regardless of correct/incorrect response, the clinician then reviewed all the features of the object and asked the participant to name the item once more. If the participant was still unable to provide a response spontaneously, the clinician provided a model for the participant to repeat it. Each session continued until all items from the treatment set were completed.

Data analysis techniques

Throughout the study, data were visually analyzed to inspect any occurrence of interactions between different intervention types [24]. The treatment effects were quantified using effect size estimation. The magnitude of treatment effects was determined by calculating the Percentage of Non-overlapping Data (PND). The criteria for interpreting the findings were as follows: <50% was considered as an unreliable treatment, 50%-70% was considered as questionable effectiveness, and >90% was considered as highly effective [25].

3. Results

The participants showed stable performance patterns in the unrelated control task. Also, baseline performance for 4 participants on trained and untrained lists was low and stable.

Participant 1

Visual inspection of graphical data (Figure 1) revealed that both treatment approaches resulted in improvement of naming following therapy. However, the percentage of trained items which were named correctly following PCA compared to baseline scores was considerably more than the percentage of items which were named correctly following SFA. Compared to his performance during the baseline sessions (from 0 to 5.5%), his naming improved by an average of 7.4 items following PCA treatment phase (from 41.6% to 75%), and by 5.2 items following SFA treatment phase (from 41.6% to 50%), and by 10.5 items following completion of the second PCA treatment phase (from 75% to 100%). Furthermore, more generalization to untrained items occurred following the phonological approach. In fact, he named an equal number of untrained items correctly during the sessions following the semantic treatment (by an average of 2 items). However, his score improved by 4.6 items following the first PCA phase and by eight items following the second PCA phase (Figure 2).

Participant 2

She was able to name more trained and untrained items following both treatment approaches. Her naming ability had improved greatly from the baseline to the post-treatment sessions: by 0.97 items during baseline sessions (from 0 to 2.7%); 6.66 items following the first semantic treatment phase (from 41.6% to 75%); 10.66 items after the phonological treatment (from 75% to 100%); and 8.66 items following the second semantic treatment phase (from 50% to 91.6%) (Figure 3).Similarly, visual inspection of graphical data revealed considerable generalization to untrained items (Figure 4); compared to baseline (from 0 to 5.5%), the average number of the items she named had improved on average by 4.33 and 5.66 items following the semantic treatment phases, respectively, and by 6.99 items following the phonological approach.

Participant 3

He benefited equally from both treatment approaches even though generalization to untrained items was better following semantic treatment phases rather than following phonological treatment. Compared to his performance during the baseline sessions (from 0 to 5.5%),

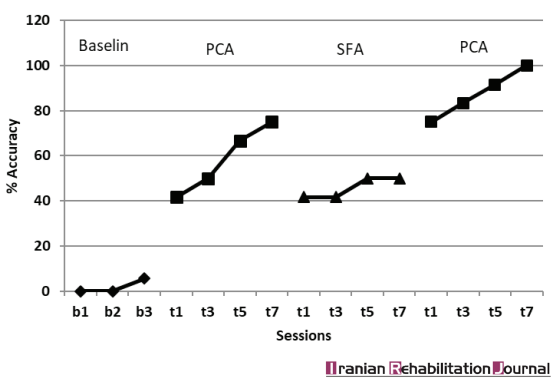

Figure 1. Naming accuracy data in trained items for participant 1

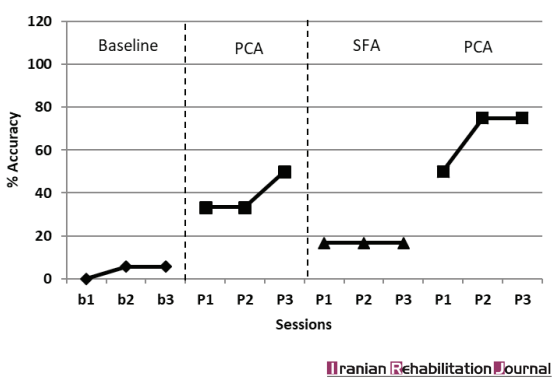

Figure 2. Naming accuracy data in untrained items for participant 1

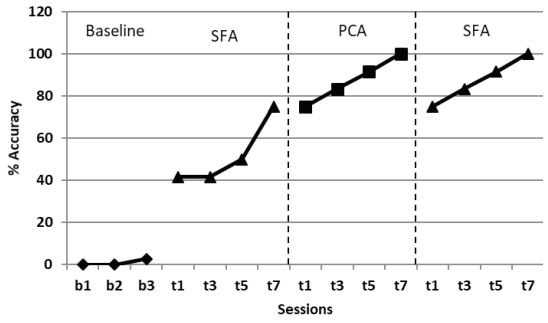

Figure 3. Naming accuracy data in trained iitems for participan 2

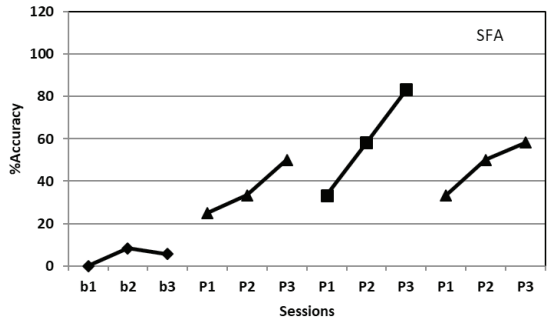

Figure 4. Naming accuracy data in untrained items for participant 2

his naming had improved by an average of 10.4 items following both SFA treatment phases, and by 9.1 items following completion of the PCA treatment phase (from 58.3% to 100%) (Figure 5). On average, he showed much generalization to untrained items following the semantic treatment phases with the average of 7 items (Figure 6); compared to baseline (from 0 to 5.5%), while only 3.3 items were named correctly following the phonological approach (from 25% to 33.3%).

Participant 4

He benefited from both treatment approaches even though generalization to untrained items was noted only following the semantic approach. Compared to his performance during the baseline sessions (no items named correctly), his naming improved by an average of 7.99 items following PCA treatment (from 50% to 83.3%), by 10.66 items following SFA treatment (from 75% to 100%), and by 9.32 items following completion of the second treatment PCA (from 66.6% to 91.6%) (Figure 7). On average, he named relatively an equal number of untrained pictures correctly during the baseline sessions and in probes following both phonologic treatment phases. However, his score improved by 8.5 items following the semantic treatment (Figure 8).

Effect size measures supported visual analysis. PND scores for both treatment approaches were >90% across conditions in four participants. According to Scruggs et al. (1987), this level of PND suggests that both treatments were "highly effective".

4. Discussion

In a single subject study with four aphasic participants, a phonologically-based and a semantically-based treatment task of anomia were compared in a reversal control task design. In this study, semantic–phonological processing model was used as the theoretical framework for investigating processes that underlie naming. Only participants with either semantic or phonological deficit (excluding mixed deficits) who had word-retrieval impairment participated in the study. Accordingly, the subjects were classified into two subgroups, "semantic impairment", and "phonological impairment". It was expected that the participants with "semantic impairment" show an advantage of the semantic over the phonological treatment, whereas the participants with "phonological impairment" showed the reverse pattern [5, 22]. All four participants benefited from both treatment approaches; although, the percentage of correct responses and generalization to untrained items were of different degrees.

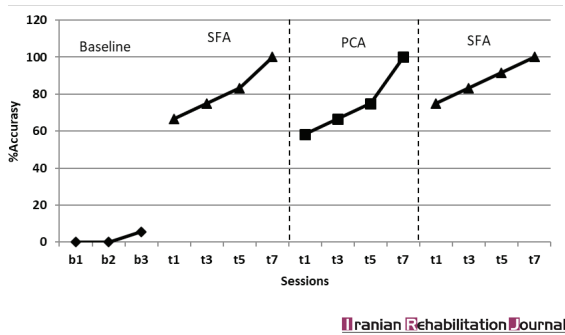

Figure 5. Naming accuracy data in trained iitems for participan 3

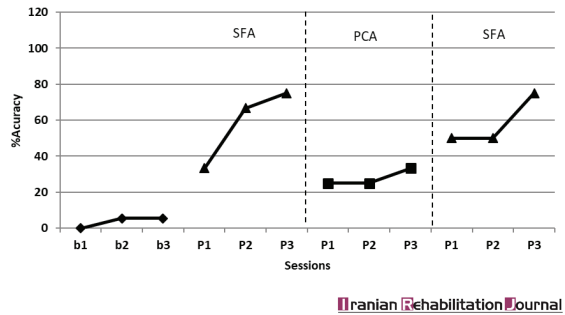

Figure 6. Naming accuracy data in untrained items for participant 3

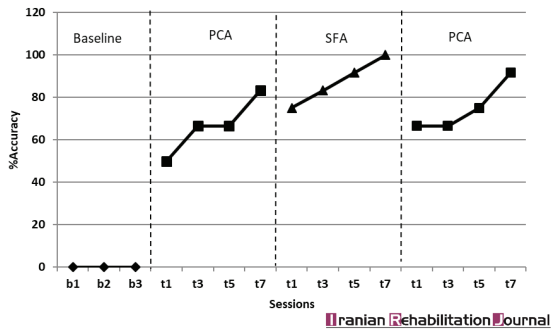

Figure 7. Naming accuracy data in trained iitems for participan 4

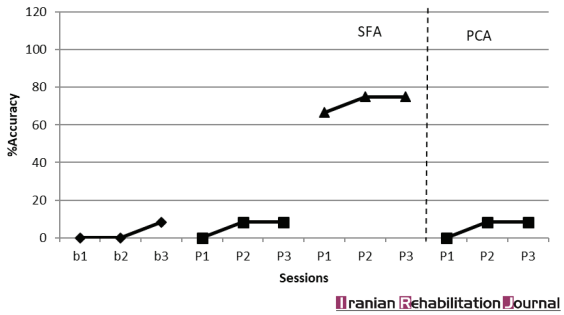

Figure 8. Naming accuracy data in untrained items for participant 4

Participants 1 and 2 whose pre-treatment assessments showed phonological impairments displayed approximately similar treatment effects. Although they showed improvements in naming accuracy for both treatment approaches, PCA treatment tends to have superior performance. It seems that both participants show the similar pattern of performance– for both treatment approaches, naming accuracy was better for PCA items in comparison to SFA items.

Such results suggest that although PCA and SFA treatments may both be effective for individuals with phonological impairments, PCA was much more effective. This finding is in line with previous studies which found phonological treatment beneficial for participants with phonological impairments. For example, Miceli et al. (1996) used a lexical–semantic processing model for investigating two participants with selective damage to the phonological output lexicon and reported improvements in naming for both participants following phonological treatment with long-lasting effects. Similarly, other studies also reported that treatment outcomes are maintained after the completion of phonological therapy, highlighting that phonologically-based treatment can yield long-term results [5, 23, 24].

Participants 3 and 4, whose pre-treatment assessments showed semantic impairments, displayed considerable improvement for both treatment sets immediately after treatment. However, differences were found regarding generalization of treatment. The third participant was able to name more untrained items following the semantic treatment program compared to the phonological program. Generalization to untrained items occurred only after semantic treatment program for the fourth patient.

Such results supported the idea in which targeting the underlying deficit directly is a better treatment. This hypothesis was proved to be true in a study conducted by Nettleton et al. In this study, six aphasic patients with naming deficits were selected according to the criteria of a cognitive neuropsychological naming model to evaluate the relationship between the type of treatment and the underlying naming deficit. Four patients received model-appropriate treatments: two of them who had phonological deficits received phonological treatment, and the other two patients with semantic deficits received semantic treatment. The remaining two patients whose deficits were at the phonological mounting level received an inappropriate program, that is, semantic treatment.

The results of the study indicated that 3 out of 4 patients are receiving model-appropriate treatments improved in their naming abilities while those 2 patients provided with model-inappropriate treatment showed no improvement [5]. One of the limitations of this study was that each patient was planned to receive only one treatment, so it is not clear whether the patients in the model-inappropriate group improved in naming if they received the appropriate treatment. Another study, in which each patient received both treatments, showed that the semantic therapy was not beneficial for participants with primary semantic impairments [14].

Although both SFA and PCA tasks showed to improve naming ability in participants, effects of those items which were trained using treatment approach targeting underlying deficit were great. As mentioned earlier SFA treatment primarily focuses on semantics impairments, and PCA treatment focuses on phonological impairments. However, both treatments use picture naming task which involves semantic and phonological processing [2, 25]. Thus, while SFA is supposed to focus on semantic features of target stimuli, it includes word production, and as a result, it may facilitate phonological processing. Likewise, although PCA strengthens structural features by encouraging patients to analyze the phonological structure of target words, recognizing and naming pictures presented to them may enhance semantic processing.

Finally, participants with phonological impairment showed considerable generalization to untrained items following PCA treatment unlike those participants with a semantic impairment who showed generalization following SFA treatment. It is argued that two treatment approaches which targeted two presumed underlying impairments- SFA for strengthening semantic representations and PCA for strengthening word form- were more successful than those that were not impairment-based. It proves that cognitive diagnosis provides a suitable way to select the kind of treatment.

Because DSMSG model makes it possible to distinguish different stages of word retrieval process, it can be used as a useful framework for classifying the naming difficulties encountered by aphasic individuals by processing dysfunctions. Having such approach may bring more benefits to the anomic patient than simply classifying their errors. With the help of DSMSG model, therapists are able to differentiate among different naming difficulties according to the dysfunctional processes and consequently to plan treatment programs that specifically target them.

5. Conclusion

This primary finding supports the hypothesis in which phonological-based and semantic-based treatment tasks target phonological and semantic processing directly. The phonological-based therapy is more effective for participants with predominantly phonological impairments; on the other hand, the semantic-based therapy is more effective for participants with predominantly semantic impairments consistent with works proving the same results [24, 26, 27]. A cognitive model of the lexical processing system is also proved to be a practical framework for designing a treatment program because it determines possible underlying functional deficits, allowing therapists to hypothesize the nature of the underlying deficit in the patient.

It is necessary to assert that the small sample of subjects in the current study (4 participants) may limit the generalization of the obtained results to a larger group of patients with aphasia. However, results of this study can be regarded as a starting point for future research in this area.

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Conflict of Interest

The authors declared that there is no conflicts of interest.

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