REVIEW OF INTERNATIONAL GEOGRAPHICAL EDUCATION

ISSN: 2146-0353 ● © RIGEO ● 11(5), SPRING, 2021

www.rigeo.org

Research Article

An objective tool for classification of language deficits in adults

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Abstract

Aphasia is a language impairment associated with difficulty in production or comprehension of speech. Post stroke rehabilitation plays a vital role in recovery of these individuals and has been repeatedly suggested that immediate intervention should be initiated as soon as possible after the occurrence of stroke. The results of standardised assessment are often used as a basis for therapy and help in planning treatment goals and individualizing intervention. Variability being a hallmark of aphasic syndromes there is a need of objectivity in routine aphasic evaluation. Selecting domains and controlling parameter that needs to be worked upon for rehabilitation is still challenging for novice therapists. Artificial Neural Networks have been found to be very effective in various fields. The aim of the present study was to build an objective tool that provides assistive objective evaluation along with confidence index on aphasic individuals and possible rehabilitation domains. The study was carried out in two phases i.e. Phase I included the development of the tool using MATLAB software and Phase II of the study testing of the developed tool. As a part of training of ANN, profiles of 49 participants diagnosed with aphasia was loaded onto MATLAB software. Phase II aimed at assessing the efficacy of ANN. Cases diagnosed through subjective assessment was cross verified with the developed tool. Results on Cohen's Kappa evaluation revealed an overall 0.916, indicating a positive agreement between the developed objective tool and traditional subjective evaluation. Hence this tool can help guide novice clinicians in decision making as well as planning appropriate intervention strategies

Keywords

Language; Aphasia; MATLAB; ACI; Confidence; Assessment

To cite this article: Issa S, H.; Ahmed, H. R.: Alwan, E, E, Mutahar, A, A, Bajiri, M, E, and Abhishek B.P (2021) an objective tool for classification of language deficits in adults. *Review of International Geographical Education (RIGEO), 11*(5), 4237-4246. doi: 10.48047/rigeo.11.05.305

Submitted: 11-10-2020 ● **Revised:** 14-12-2020 ● **Accepted:** 16-02-2021

Introduction

According to Horton et al. (2021), a person is considered to have aphasia, when s/he has a language impairment associated with difficulty in production or comprehension of speech with or without impaired reading and writing abilities. Aphasia is generally caused due to an injury to the brain. A common cause of aphasia includes stroke, road traffic accidents, head injuries, brain tumors, infections etc (Jenkins & Birkett-Swan, 2010). Prevalence rate of stroke in individuals aged above 65 ranges from 46-73 per 1000 persons. Aphasia can be noted in at least 30% of the stroke survivors (Pendlebury & Rothwell, 2009). Aphasia may expand the boundaries of a speech and language impairment and may affect the overall communicational skills.

The impact of aphasia on caregivers has been widely documented across literature (Evans, Hendricks, Haselkorn, Bishop, & Baldwin, 1992). Post stroke rehabilitation plays a vital role in recovery of these individuals and has been repeatedly suggested that immediate intervention should be initiated as soon as possible after the occurrence of stroke. The symptoms in aphasia can be heterogeneous, thus the classification of aphasia into sub variants would be essential. Classification of aphasia and its symptoms has been given great importance right from its early inception by Broca on his patient Mr. Tan (1861) as "a loss of the ability to co-ordinate the movements associated with articulated speech". Similar grouping of aphasia based on symptoms exhibited by PWA (persons with aphasia) can be seen across the literature (Ardila, 2010; Gaybullaevna, 2021; Geschwind, 1965; Goodglass, Kaplan, Weintraub, & Ackerman, 1976; Kozhokaru, Samoylov, Shmyrev, Poluektov, & Orlova, 2021; Luria, 1964; Marie, 1906; Park, 2021; Sekhon, Oates, Kneebone, & Rose, 2021; Wernicke, 1970). Recent classification system of Boston classification system (Liu et al., 2021) is one among the currently accepted classification systems. According to Liu et al. (2021) aphasia can be classified based on characteristics of verbal expression (non-fluent or fluent).

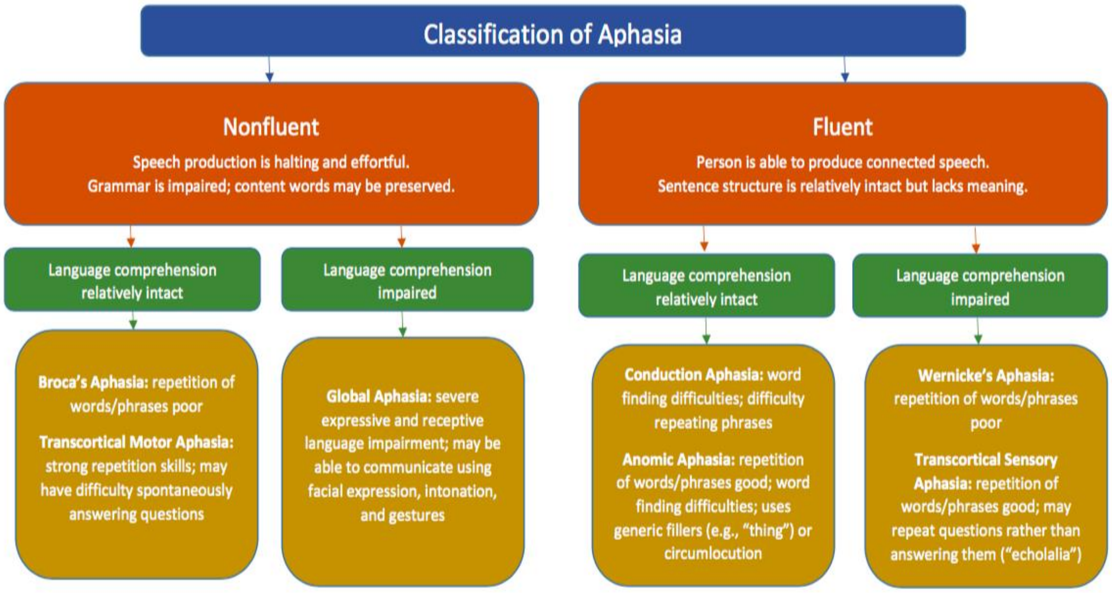

Figure 1: Pictorial representation of current aphasia classification system Liu et al. (2021).

Speech and language pathologists often give standardized aphasia test batteries or chosen subtests of standardized aphasia test batteries during clinical evaluations of people with aphasia (hence abbreviated PWAs) (hereafter abbreviated SLPs).The formal tests have a vital role in the diagnostic formulation of individuals and thereby gives information pertaining type/variant of aphasia and its severity. The formal evaluation may be used to get a comprehensive review of language strengths and weaknesses and is often repeated over time to monitor improvements. The findings are often utilized as a foundation for therapy, assisting in the formulation of therapeutic objectives and the individualization of intervention.

(Goodglass et al., 1976).
The formal aphasia assessment's secondary objective is to ascertain the individual's present communicative, linguistic, and cognitive level. A formal assessment's purpose is to ascertain the existence, nature, and degree of the condition, as well as to map the language's strengths and weaknesses (Coppens, 2016). However, studies agree that assessing an individual's communicative competence simply via a formal aphasia evaluation is insufficient (Damico, Simmons-Mackie, & Wilson, 2006; Davis, 1985; Lesser & Milroy, 2014). Currently, we use a variety of standardised screening tests to assess aphasia, including the Aphasia Language Performance Scale (ALPS) developed by Ivanova et al. (2021), the Frenchay Aphasia Screening Test (FAST) developed by Enderby, Wood, Wade, and Hewer (1986), the Mississippi Aphasia Screening Test (MAST) developed by Nakase-Thompson (2004), and diagnostic tests such as the Minnesota Test for Differential Diagnosis of Aphasia; The Boston Diagnostic Aphasia Examination (BDAE)-Liu et al. (2021); Western Aphasia Battery (WAB)-Shewan and Kertesz (1980). In Indian scenario various adaptations of standardised test have been carried out, such as WAB in languages such as Kannada by Hwang, Na, and Pyun (2021); Telugu by (Faroqi-Shah, Shi, & Goodridge, 2021); Bedside Screening Test for Aphasics in Kannada by Kertesz (2020) and in Malayalam by Paplikar et al. (2020).
PWA's aphasic behaviors (verbal or nonverbal) may be noticeably different on the one hand, or overlapping on the other, to the point of misdiagnosis. Variability, which is a characteristic of aphasic disorders, is the main reason. Individual variations must thus be taken into consideration in order to avoid such mistakes. Every PWA has a distinct level of performance. This makes utilizing the existing subjective evaluation techniques to arrive at an accurate diagnosis very challenging. For instance, cases wherein the presentation of symptoms and designation of WAB doesn't match; example being, when seen based on experiences it will be conduction aphasia but WAB indicates anomic aphasia. Current standardised tests are highly subjective and little to no objectivity involved in them. With advent of technology in the field of communication disorders more and more tests are going digital to assist better service delivery for professionals. Once the evaluation is made there is no quantification of extent to which a condition might be possible using the present. Therefore there is a need for an objective tool that can assist professionals in classification of aphasic symptoms and provide an estimate on prognosis of an individual. This can also enable better measures in rehabilitation of Aphasia.
Although rehabilitation of individuals with aphasia has become more common, selecting domains and controlling parameter that needs to be worked upon for rehabilitation is still challenging for novice therapists. Therefore, it is necessary to develop a tool which not only helps in the diagnosis but also point towards an empirical approach, for predicting the possible domains to be worked upon during his/her rehabilitation. Application of Artificial Neural Networks (ANNs) have been widely studied in the last decades in various fields such as atmospheric sciences (Gardner & Dorling, 1998), energy system (Kalogirou, 1999, 2000), medicine (Agatonovic-Kustrin & Beresford, 2000; Baxt, 1995; RYDANT, Cusack, Smith, Shiplee, & Middlekauff, 2013; Wu et al., 1993) and ecological modelling (Lek & Guégan, 1999). Using weights manipulation a sensitivity analysis can evaluate the relations between the input and output variables in ANN (Garson, 1991). A recent study by Themistocleous et al. (2021) used ANN in automatic classification of primary progressive aphasia. Primary progressive aphasia was automatically classified into its variants (non fluent, semantic and logopenic) 85% of the times by the "system" hence the proponents suggest the utility of ANN in classification of aphasia. Therefore, we expected that aphasic symptoms can be explored by a successfully trained ANN model.

Need for the study

Rehabilitation begins with assessment and diagnosis. An accurate diagnosis points to the correct treatment for which one requires a proper assessment tool. Hence it is important to have standardized language tests to assess aphasia and its types. The standardised tests as stated in the above mentioned paragraphs is subjected to bias and variability and has to be cross verified with objective measures such as ANN

Aim

To develop an objective tool that provides assistive objective evaluation along with confidence index on aphasic individuals and possible rehabilitation domains.
To correlate the scores estimated by ANN with the subjective scores

Objectives

The objectives of the present study were (i) To build an objective tool to derive scores to classify and quantify aphasic symptoms. (ii) To check the accuracy of the developed tool through preliminary analysis.

Method

This study was conducted at premiere institute of Speech & Hearing, Mysuru after obtaining an ethical clearance from the Institutional review board for conducting research involving human subjects (Themistocleous et al., 2021). The study was carried out in two phases i.e. Phase I included the development of the tool using MATLAB version 8.5.0.197613 (Kim et al., 2021) software. In Phase II of the study, testing of the developed tool was carried out.

Phase I – Building and training the ANN

Participants included 49 people who had been diagnosed with aphasia. The participants' information was gathered retroactively. The sole criterion for inclusion was a language impairment; the length of time after a stroke and the severity of the disease were not taken into account. Participants and caregivers sign a permission form. The study's sole exclusion criteria were recognized neurodegenerative illnesses that were strongly linked to language difficulties or memory impairments, such as Alzheimer's disease or primary progressive aphasias.

Participants

Nineteen women and thirty men with aphasia took part in the study (Table 1). The PWAs ranged in age from 51 to 98 years old (with a mean of 67 years and a median of 64.5 years), and their aphasia was caused by an ischemic or hemorrhagic stroke. The duration of aphasia ranged from three months to ten years (with an average of 5.5 years, median 6 years).

Table 1:
Summary of participants of Phase I

Type of aphasia	**Number (%) of participants**	**Gender**	
	(n = 49)	Male	Female
Brocas	15	9	6
Wernicke	6	2	4
Anomic	8	3	5
Conduction	4	1	3
Transcortical Sensory	3	2	1
Transcortical Motor	5	1	4
Global	10	7	3

None of the participants were able to return to their previous occupation after their stroke. Participants' written consent was obtained from all the care givers.

Procedure

Aphasic profiles of all the participants were loaded onto MATLAB software. Using the Artificial Neural Network toolkit a feed forward neural network was built. Optimal number error approach was used to specify the maximum number of training epochs, learning rates, number of nodes in a hidden layer. During the ANN's training phase, parameters such as the number of nodes were adjusted between 6 and 24, with learning rates ranging from 0.01 to 1.0 in increments of 0.05. The ANN was simulated using the variable of mean square error (MSE) between the observed data and the model output. To avoid over generalization of the trained neural network the data was divided into two set, first was for model training (80%) by computing the gradient and revise the network and the second was for model testing (20%) for model testing using error validation. Randomization of the model weights was done during the training process and was terminated when over fitting of the data was seen for validation set.

Phase II: Evaluating the efficacy of the ANN

The efficacy of ANN was determined by considering new cases. The diagnosis of the new cases was confirmed by experienced speech-language pathologists with 3-7 years of experience.20 Individuals who reported to a reputed speech and hearing institute with a suspected complaint of aphasia were evaluated by three SLPs (the first author and two other SLPs). Details of the SLP's are summarised in Table 2.All the SLP's were experienced in working with assessment and management of aphasia.

Table 2:
Summary of participants of Phase II

Details of SLP's	Years of experience
SLP 1	5
SLP 2	7
SLP	3

Further, using the developed ANN the evaluation was repeated. Subjective evaluations focused on obtaining information regarding diagnostic label, Confidence behind each diagnosis and highlight domains to be worked upon during rehabilitation. Objective evaluation revealed diagnostic information, Aphasia Confidence Index (ACI), Insight on domains to be worked upon for rehabilitation. The aphasic profiles obtained from both the methods of evaluations were further co-related to find agreement between both the ratings.

Results and Discussion

Phase I

An interactive ANN was built as the result of the phase I of this study. The ANN provided output highlighting three domains i.e. Classification of aphasic type (Brocas ,Wernicke, Anomic, Conduction, Transcortical Sensory, Transcortical Motor or Global aphasia), ACI and domains to be worked upon for rehabilitation.
ACI was a relative score that ranged between 0 to 1 and was distributed across all the aphasic variants. ACI provides a confidence behind each classification and also highlights the trend of recovery. To understand ACI easily look at the example provided. (Figure 2)

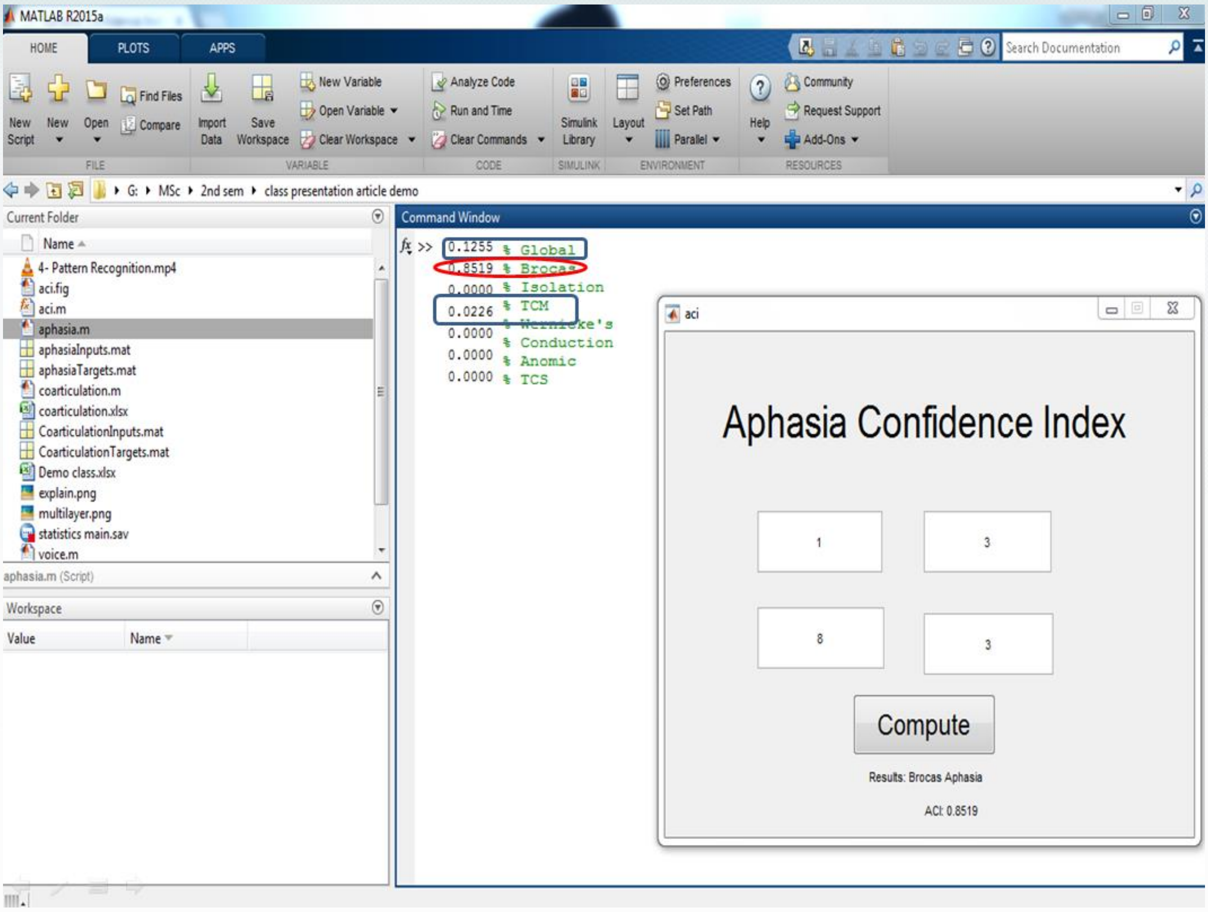

Figure 2: Mr.Y was found to have an ACI of 0.8519 in Brocas Aphasia variant, 0.1255 in global variant and 0.0226 in TCM variant. Based on the cognitive communicative variables of Mr. Y he was classified as having Brocas aphasia. Further it can be predicted that the individual recovered from a global variant of aphasia and still has reminiscence of certain features of global aphasia but the 0.0226 speculates that Mr.Y is slowly progressing into the TCM type. Aphasic symptom estimates of repetition (R), spontaneous speech (SS), auditory comprehension (AC), naming (N) and visuo-spatial & constructional skills (VC) were acquired using Western Aphasia Battery (WAB). Individual values of R, SS, AC, N and VC were estimated for all the participants and corresponding diagnostic label and possible rehabilitative domains were summed up as well. It is well known that cognitive-communicative variable such as repetition, spontaneous speech, auditory comprehension, naming and visuospatial & constructional skills influence aphasiac population. Thus to obtain aphasic label and streamline rehabilitation process it is essential to consider cognitive-communicative variables as inputs. Typically a ANN model is made by using nonlinear combinations of input variables (Bishop, 1995; Joshi & Sukumar, 2021; Zhu et al., 2021). ANN used in the present study was a feed forward network and a linear activation of the output node in MATLAB. Training was implemented using back-propagation algorithm (Figure 3).
Therefore a dataset for the entire set of participants made up of 49 records were used to develop the tool. The ANN model was developed to formulate the aphasic symptom and predict the domains to be worked upon during rehabilitation.

Phase II

In Phase II of the study, Cohen's Kappa evaluation was executed to check the agreement between the developed ANN to that of SLP's evaluation. An overall Kappa coefficient of 0.916 with the p value of <0.05 was found indicating a positive agreement between both the ratings. The agreement was found to be homogenous across all aphasic variants. Further aphasiac confidence index of the developed tool provided additional guidance regarding the domains to be worked upon in each individual such as naming, repetition, auditory comprehension, reading and writing etc, Thereby streamlining the intervention protocol.

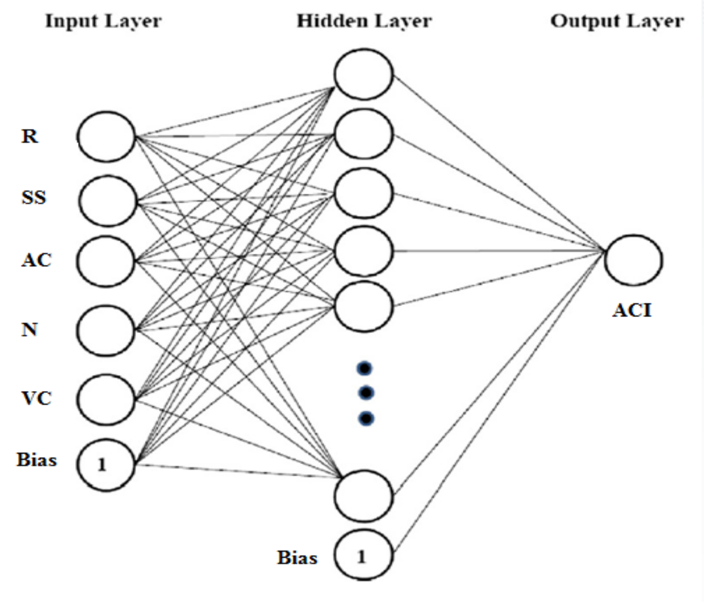

Figure 3: A representation of a feed forward ANN.

In this study, an objective tool was build which estimates diagnostic information, aphasia confidence index as well as guidelines for rehabilitation domains. Based on the findings of the preliminary analysis, it can be speculated that the developed tool provides objectivity to the traditional diagnostic formulation of aphasic symptoms. By using the developed tool, it is possible to classify and quantify aphasia using the aphasia confidence index. It also hints on suitable domains to be worked upon for individual patient hence tailor making the intervention protocol. By using the developed tool the issue of subjectivity using the standardised evaluation protocols can be addressed i.e. it has the potential to overcome variability in results in terms of testing carried out by examiners with differential experience in the assessment of PWA. The issue of poor tester-retest reliability can be one of the major breakthrough solutions that this particular tool has to offer due to its objectivity in processing data.

Limitations and future research

One limitation of this study is the small sample size. By using a convenience sampling this study ignored an aphasic variant group of isolation aphasia. No attempt was made to control for participant ethnicity, gender, or age. The study failed to consider factors such as comorbid conditions, Post-onset duration etc. As the study is first of its kind to talk about aphasia confidence index its difficult to draw comparisons' between previous studies. However it can be speculated that the results of the present study are promising and requires replication on a larger population by considering other parameters. Finally, the topic of Aphasia Confidence Index can broaden our understanding of aphasia and its symptomatology and guide many students and professionals who are new to aphasia.

Conclusion

The present study aimed to build an objective tool that assists professionals in deriving a confidence index along with classification of various aphasiac symptoms. The present study was a first of its kind to derive a confidence index that could highlight on the recovery period of aphasiac symptoms and thereby guide in choosing appropriate intervention strategies.

Results of the present study have revealed good agreement between the traditional standardized test scores and the results of the developed tool. The premise for these findings was nonlinearity and the generalization of the ANN in the training phase. This tool can help guide novice clinicians in decision making as well as planning appropriate intervention strategies. Further studies are required to evaluate its effectiveness on a larger audience and make this tool a universal tool. Hence making it to be an easy to use assistive tool that guides professionals in the complex task of diagnosis and intervention planning of aphasic population.

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Acknowledgements

The authors would like to thank the Director, AIISH, Mysuru for permitting to carry out this research study & Special thanks to Head of Department of Speech Language Sciences for providing necessary support.

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