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Original Research

From medical research to educational practices: brain-based learning in developing English-speaking skills among medical students

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Abstract

Background: Recent advances in cognitive neuroscience have provided inspiring opportunities for the current understanding of the language-learning process and its neurological underpinnings. To date, several brain studies investigating the structure and functions of the language-learning process have provided reasonable explanations for biological aspects of language acquisition in addition to behavioral elucidations. Brain-related studies can provide valuable learning information for teachers to apply in classrooms. Accordingly, the current study investigated the impact of brain-based language instruction on medical students' English-speaking skills.

Methods: A quantitative quasi-experimental approach with a control group, using a pre-test/post-test format with a four-month follow-up in brain-based language instruction, was used for this study. To test the hypotheses underpinning this research, 64 medical students (40 women and 24 men) in a required course in general English in the Department of Foreign Languages at the Islamic Azad University of Kerman participated in this study during the 2021-2022 academic year. Pre- and post-tests of speaking skills were administered to ascertain differences in participants from the beginning to the end of the study.

Results: Analysis revealed that the experimental group, who received treatment in the form of a brain-based teaching approach, improved considerably in their speaking skill from the pre-test to the post-test ($P<0.01$). Although the control group improved from the pre-test to the post-test, the improvement was not significant, nor was it as large as the progress in the experimental group.

Conclusion: In brief, a collaboration between medicine and education elevates both fields of study and illuminates the process of language learning regarding the structural and functional operation of the brain. Findings around the new trend of brain network connectivity have paved the way for educational curricula to use teaching methods, materials, and tasks compatible with cognitive brain functions, potentially fostering learners in general and medical students in particular to reap the result.

Introduction

Immordino-Yang et al[1] identified three components for the brain's overall development: cognitive opportunities, social relations, and affective experiences. Based on such brain-based insights, educational practitioners and policymakers have developed basic principles that enable optimal learning, particularly in language learning. Research probing the neurocognitive basis of adult language learning, and the way it proceeds in mind, can provide insights into the intricacies of this process and may contribute to scholars and practitioners educating learners in acquiring a new language.[2] Different methods, from traditional psycholinguistic methods to pre-neuroimaging, neuroimaging, and, more recently, molecular genetic investigations, have been developed and employed to investigate the brain and its language-specific mental operations.[3] Regarding the language learning process, brain-based studies have the potential to provide valuable insights into studying the increasingly important acquisition of second languages (L2) in today's globalized world. People aspire to high proficiency levels in the second language of this ability's essential role in their social, economic, and personal lives. Given this significance, the acquisition of a second language can be

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varied according to the rate and efficiency of achievements and fulfillment. Understanding the factors affecting such variability contributes to describing the theoretical bases of second language acquisition (SLA) and – from an applied perspective – to improving both learning and instruction outcomes.[4]

Additionally, it has been shown that language is governed by coordinated activity in various brain regions.[5] Insights into brain connectivity, both in terms of the brain's structural and functional networks, continue to advance the understanding of the neural foundations of human communication. Such developmental brain research highlights a paradigm shift from focusing on local function and mental processing of brain regions to focusing on interrelationships between brain areas and networks of connectivity among them. Even a simple task does not yield the activation of a single area; rather, it is the holistic outcome of the activation of overlapping sets of brain areas, as described by scholars and neurologists such as Ganis, Thompson.[6] Several studies suggested that L2 experience actually changes the language and cognitive control functional networks and brain structures.[7-10] Briefly, for educational purposes, areas of brain language activities can be traced and reinforced by developing and practicing related tasks.

Since brain research emphasizes the key role of socialization and experience in shaping cognitive development[11-13] and regarding the fact mentioned by Hari and Kujala[14] that humans and their brains and minds are shaped and normally function in continuous interaction with other people, as well as from the standpoint of cognitive science, which stresses that learning a second language is also experience-based; thus, developing a second language learning model drawing from brain research findings with a focus on social brain and language socialization is a legitimate approach to attain optimal speaking skills in a target language.

The theoretical perspective of this study frames an inquiry into the implementation of a derived brain-based model into classroom instruction to foster speaking ability with English as the target language. The study is based on a contemporary understanding of brain network connectivity using graph theory, which has recently shed light on the human connectome (i.e., mapping the connectivity patterns of the human brain).[15-17] According to Sporns et al,[18] the human connectome is a map of the brain's neuronal, anatomical, and functional connections that result in a connection matrix or network. Connectome theory, which applies graph theory to substantiate developed cortical and subcortical networks, is emerging to study how human cognitive activities relate to the topologies of neural networks.[19]

According to Immordino-Yang et al,[1] three brain networks play a significant role in brain development. The default mode network is responsible for making meaning, retention, and reflection, the Salience network is responsible for affective mode and relations, and the executive control network is responsible for flexible attention and task productivity. Their findings and several other neuroimaging studies support the hypothesis that a significant portion of mental capacity, including aiding attention, cognitive reflection, and subjective appraisal, requires cooperation and coordination of these triple networks. Thus, functional connectivity of the brain and the exigency of social interactions, emotive experiences, and cognitive supplements are highlighted for improving the state of mind to maximize the prospect of learning. The connectedness of these three networks was provided sought through the mediation of graph theory in the study based on connectome theory. It was used as a model to presume that teaching speaking skills require the activation of the three networks to be effective and retained. As a result, the current research attempts to explicate a relationship between cognitive neuroscience research approaches and the pedagogy of language studies to link applied knowledge to theoretical expertise.

The exigency of language learning for medical students and researchers is seen not only in academic studies and dissemination of their research work[20] but also in their global communication. It is irrefutable that the level of medical English used in academic investigations, reference books, and field reports has become increasingly advanced. The English language plays a significant role in most scientific, technological, and academic information in the medical community. A lack of English communication ability can thwart a country from supplying requisite people with described meanings attached to a person by self and others.[21] As a significant goal of neuroeducation, the synergy of language instruction and brain function has the pedagogical potential to transform conventional language instruction into immersive learning (i.e., the feeling of being physically present and performing real-world tasks), thereby hopefully promoting authentic interactions that mirror spontaneous, unrehearsed communication in real-world tasks.[22,23] Accordingly, the current study examined the effectiveness of brain-based language instruction on the development of English-speaking ability among medical students.

Materials and Methods

To test the hypotheses underpinning this quantitative quasi-experimental research, 64 medical students (40 women and 24 men) in a required course in general English in the Department of Foreign Languages at the Islamic Azad University of Kerman participated in this study during the 2021-2022 academic year. To ensure those study participants were generally at the same level of English proficiency, potential participants took the Longman Placement Test (LPT) before starting the project. The LPT is a criterion-referenced measure developed by Pearson Longman ELT. The test consists of 100 multiple-choice questions and has a time limit of 50 minutes. It places students into the following categories: 00-20 Below Elementary, 21-35 Elementary, 36-60 Pre-intermediate, 61-85 Intermediate, and 86-100 Upper Intermediate. According to the placement test results, 75.5% of potential study participants were intermediate English learners, and 24.5% were upper-intermediate English learners. The upper-intermediate students were excluded from the analysis, leaving 64 intermediate participants who had never received any brain-based learning instruction. The participants ranged in age from 23 to 34 (M = 28.08, SD = 3.53). Ethical approval for this study was obtained from university administrators. Student participation was voluntary, and they received no remuneration. Clearly, students could withdraw from the study at any stage with no consequences. Pseudonyms were used to ensure confidentiality and anonymity. Data were not shared with anyone, including university administrators.

A speaking pre-test was performed at the beginning of the study to ascertain whether participants were at comparable levels. The test content focused on topics covered in class, and the language was as defined in the syllabus at this level and did not include new items. The questions were descriptive so that the students' world knowledge would not be involved in answering the questions. The questions in the pre-test and post-test were different to rule out repetition effects. Two raters agreed on the questions for the pre-test and post-test before the start of the program. A standardized framework for oral assessment was used to ensure the same procedure was followed in both classes. This procedure was used for the pre-test and the post-test. The assessment was adapted from Cambridge speaking assessment rubrics measuring the participants' speaking knowledge (grammatical resource, lexical resource, & pronunciation) and speaking skills (discourse management, interactive communication, & global achievement). Each student was assessed individually in a 15-minute interview using the Speak Now Testing Program:

- Interview questions (a list of teacher-led interview questions)
- Role-play cards (cards for students to role-play situations in pairs)
- Presentation topics (lists of ideas for students to prepare and deliver short oral presentations related to the unit topics)

A post-test was conducted to measure the change in each learner's English-speaking development at the end of the implementation period. The post-test was a mixture of topics covered during this period.

The project lasted four months, during which the students were exposed to a 3-hour training per week. Speak Now 4 (Oxford University Press) was selected as the textbook for the instruction content during this experiment for both groups. The Speak Now series focuses on oral communication skills. A conventional teaching approach was utilized through activities prescribed in the textbook and the course syllabus over the semester (16 sessions).

Before the beginning of the semester, a descriptive meta-analysis of the previous literature in neuroimaging, brain function, brain mapping, and neuroscience of language was conducted by searching databases including Science Direct, Scopus, Google Scholar, PsycINFO, PubMed, and SpringerLink. The structural and functional brain regions involved in language learning and cognitive functions were explored and classified under the major activities and functions of the three large-scale brain networks, as shown in Table 1. A computer model of brain network connectivity was created. Based on this, instruction processes and class activities were developed to capitalize on the unique features of brain function that are conducive to foreign language speaking ability. These features were also aligned with the underlying principles of a brain-based teaching approach that are beneficial for language acquisition, such as multimodality, creativity, flexibility, problem-solving, collaboration, enhanced input, spontaneous output, authenticity, and negotiation of meaning.[24,25] The textbook's instructional materials and class activities were oriented toward brain-based principles and activation of the three large-scale networks (salience, default mode, and executive control/central executive). The instruction and activities implemented for the

Table 1. The triple network areas of activity and functions

Salience network (SN)
Active: when there is a change in behavior, adapting and adjusting to new behavior (the parallel process of the brain)
Function: interaction and communication, being aware of self (emotion and positive affection are essential for pattern making, both conscious and unconscious processes of learning are possible)
Default mode network (DMN)
Active: when there is consistency in narratives, evaluating beliefs and self-esteem, thinking back memories, daydreaming, future imagination, and creativity and critical thinking (learning takes place through focused/peripheral attention)
Function: directed thinking or self-contemplation (search for meaning is innate and pattern-based)
Central executive network (EN)
Active: when there is an emotionally challenging task or cognitive complexity (challenge boosts learning while intimidation frustrates learning)
Function: making a decision, solving a problem, goal-directedness (detecting and developing parts and wholes is simultaneous), recognition, noticing, and retaining information in mind (learning entire physiology is involved in learning), different types of memory are engaged. Curbing emotions and processing information (the brain is exclusively unique).

experimental group were brain-based oriented regarding triple network connectivity and, more specifically, the 12 brain-based principles by Caine and Caine.[26]

Concerning the experimental group, the following classroom activities are some examples of the attempted activation of the three networks via tasks and activities:

1. Instructing new words (e.g., pass out, witness, turn out, standoffish, gregarious, awkward, claustrophobia, agoraphobia), students were asked to associate the new words with certain concepts depending on the theme of the terms. For example, if the lesson was about describing friends, the students were supposed to link the new words to an object (a good friend is like a blood pressure gauge, feel safe to be around in need); if it was about commenting to suggestions, they were asked to link a comment to color or mood (saying "I'm not sure that would work" is like crossing the adviser with a red truck); or describing a real/imaginary experience. This strategy continued every time they were taught a new lesson. The stranger the links, the funnier the class environment; therefore, students were more receptive to the rest of the lesson. This activity involves the activation of the three networks, where teacher/student interaction (SN), creative thinking, and self-generated thoughts (DMN) promote positive emotion (EN).
2. Following a pair-work exercise from the book, students were asked to think of real situations e.g., the last time they sympathized with a friend, and then to organize conversations based on their memories of past experiences utilizing language boosters (e.g., A: it bugs me when doctors ignore my details of pain complaints, B: yeah, I hear you). This activity involves the activation of the three networks as follows: goal-directed behavior (EN), social interaction (SN), and calling up personal memories (DMN).
3. In every session, depending on the situation or the lesson's difficulty level, students were offered three minutes of doing nothing except keeping silent and daydreaming (where they wish to be at the moment and what they wish to do). Then they were asked to voluntarily talk about what was crossing their mind. This task was changed to future thinking (students were asked to imagine themselves 10 or 20 years later from class time and report their future position to the class). This activity involves the activation of the three networks: emotionally and cognitively challenging tasks (EN), teacher/student interaction (SN), daydreaming, and envisioning the future (DMN).
4. To review the lesson, students were given 3 to 5 words or phrases from previous lessons (injury, affable, processed food, procrastinating) and were asked to make a connection between these and tell a story just offhand. Later they were asked to offer a few words or language boosters to their language partners so that the other had to improvise a meaningful but funny speech. This activity involves the activation of the three networks: peer interaction (SN), challenging tasks (EN), and creative thinking tasks (DMN).
5. Every four sessions, the students were asked to select a topic and converse with their native language pen pal on a site to which the related web was previously introduced to them. The students were asked to use as many words, expressions, and language boosters as possible that they had learned and to send a screenshot of their conversation to the instructor. Later they would receive feedback from their instructor. This activity involves the activation of the three networks: student/native speaker interaction via online chat (SN), regulating emotions (EN), and calling up learned materials; words and language boosters (DMN).
6. Classroom discussion: Emotionally challenging topics were selected to inspire speaking. For example, talking about phobias (EN); role play: partner, director, motivator, etc. (SN); expressing personal experiences and recalling instances of different types of phobias (DMN); and looking into the reasons for their phobias and thinking of solutions (EN).

The focus of these classroom activities was an attempt to activate and stimulate the cooperation of these three large-scale networks as in normal brain development from birth. The presumed hypothesis is a bottom-up process of tracing and bolstering neural connections and pathways to result in enhanced learning. In other words, what is practiced in this experimental study is a reverse process. Since previous neuroimaging studies have revealed areas of the triple network's functions under controlled activation of the related areas, here the study attempted to copy the brain map of functions to reinforce activities that trace neural connection pathways so that every attempt in the learning process will be a double internalization leading to enhanced learning.

Results

Before examining the research questions, the normality of the distribution of research variables was examined. There are several ways to check the normality of variables, and one is to obtain a value (statistic of skewness divided by standard error of skewness). If the result is less than (± 2.58), the data have a normal distribution[27]; therefore, as Table 2 shows, it can be concluded that the variables had a normal distribution at both times and for each group (control and experimental).

The results showed there was no significant difference ($P > 0.05$) in mean scores for speaking development at the pre-test for the control and experimental groups (Table 3). Results are considered significant at $P < 0.05$.

An independent t test showed a significant difference in mean scores for speaking development at the post-test for the control and experimental groups. The effect size was 1.32, and r was 0.55 (Table 4).

A paired sample *t* test analysis showed a significant difference in the mean scores for speaking development in the pre-test and post-test of the control group, with an increase in the post-test. The effect size was 0.97, and the *r* was 0.44 (Table 5).

The paired sample *t* test results in Table 6 showed a significant difference in the mean scores for speaking development from the pre-test to the post-test for the experimental group ($P=0.000$). The effect size was 3.14, and *r* was 0.84.

Discussion

Since neuroeducation focuses on the application of brain research and findings to instruction and learning, it is crucial to adopt compatible approaches to enhance and accelerate learning in general and skills in particular. In medical sciences, learning English, the global language of medical and scientific communication has long been considered a challenging task to prioritize. Moreover, mastering this skill is significant for those who call for international negotiation of medical sciences. Brain-based learning studies have generally been confined to theoretical investigations or laboratory circumstances. A recent trend in educational development derived from medical science has been applied in this study to develop the skill of English speaking among medical students. More specifically, the effect of activating three large-scale DMN, SN, and EN networks was investigated as a brain-based model of instruction in enhancing medical students' English-speaking skills. The purpose of the pattern was to strengthen connectivity and interaction within and between the networks by intentionally activating areas of desired functions. This model was advantageous in helping medical students learn English speaking skills in the experimental group. Thus, if researchers and teachers consider the instructional pattern as a cycle, illustrated in Figure 1, certain activities will cultivate interaction, and successful interaction induces positive emotions and thus creates a positive experience. This positive experience improves memory and moves learners toward an inclination to interact effectively, thus continuing the cycle. These activities are projections of the underlying functions of interdependent brain networks. This model has successfully and positively affected medical students' English-speaking skills. However, this does not imply a lack of network connectivity in the control group; rather, the difference lies in this brain-based model, which concentrates on a deliberate, systematic activation aimed at strengthening connections/neural pathways so that the desired change is planned and programmed following

Table 2. Normality of research variable distribution

Variable	Group	Time	Statistic of skewness	Standard error of skewness	$\frac{\text{Statistic of Skewness}}{\text{Std. Error of Skewness}}$
Speaking development	Control	Pre-test	-0.28	0.41	0.68
		Post-test	-0.42	0.41	1.02
	Experimental	Pre-test	0.23	0.41	0.56
		Post-test	-0.11	0.41	0.27

Table 3. Independent sample *t* test of research variable (pre-test)

Variable	Group	N	Mean	Standard deviation	*t* test	*df*	*P* value
Speaking development	Control	32	13.96	1.42	0.22	61.98	0.830
	Experimental	32	13.94	1.45			

Table 4. Independent sample *t* test of research variable (post-test)

Variable	Group	N	Mean	Standard deviation	*t* test	*df*	*P* value	Effect size
Speaking development	Control	32	15.75	2.16	-5.09	46.77	0.000	0.55
	Experimental	32	18.02	1.13				

Table 5. Paired sample *t* test of research variable (control group)

Variable	Group	N	Mean	Standard deviation	*t* test	*df*	*P* value	Effect size
Speaking development	Pre-test	32	13.96	1.42	-6.70	31	0.000	0.44
	Posttest	32	15.75	2.16				

Table 6. Paired sample *t* test of research variable (experimental group)

Variable	N	Mean	Standard deviation	*t* test	*df*	*P* value	Effect size	N
Speaking development	Pre-test	32	13.94	1.45	-18.10	31	0.000	0.84
	Posttest	32	18.02	1.13				

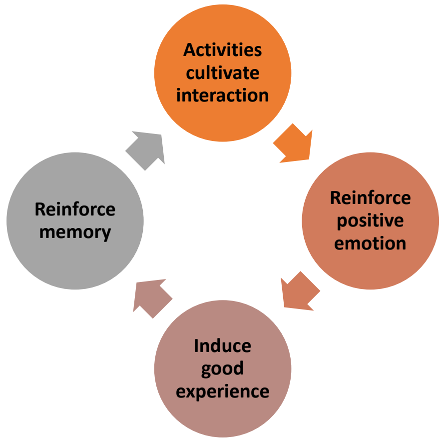

Figure 1. Systematic brain-based model of instruction including factors as projections of underlying functions of interdependent triple networks.

early childhood brain development.

Since the experimental group received brain-based instruction in a manner in which every task and activity was followed within the framework cycle, which is a practical manifestation of the activation of the triple network, the resulting speaking post-test revealed that the experimental learning group benefited from better speaking features such as fluency, accuracy, pronunciation, expressiveness, discourse management, and communicative interactions. The control group, which received only a conventional method of instruction (presenting new words with their synonym/definition, doing vocabulary exercises in the textbook, listening to conversations, highlighting grammatical points, and recreating a similar conversation), also improved their English-speaking skills. However, they did not improve as significantly as the experimental group. The evaluation of the speaking skill of both groups conducted according to Cambridge speaking assessment rubrics showed an outperformance of the experimental group. Under attempted controlled conditions, this result could be firmly attributed to the intervention of a brain-based model of instruction.

Brain-based learning/instruction is an umbrella term encompassing a range of principles, strategies, techniques, and programs based on the brain map of development and learning. Regarding the activities implemented in the intervention program, this study is similar to several studies that inquired about the effect of brain-based teaching on different learning skills. Parallel to Alizadeh Oghyanous,[28] who studied the positive impact of three techniques of brain-based instruction (relaxed alertness, orchestrated immersion, and active processing) with EFL learners' self-efficacy, the activities implemented regular assessment through tests, encouraging feedback, and breathing exercises oriented toward developing a good state of mind ready for enhanced learning. Along the same line, this study is similar to Khalil et al,[29] probing the positive effect of brain-based strategies such as cooperative learning, discussion, brainstorming, mind mapping, and setting up a caring and supportive environment for EFL learners' critical writing. Similarly, improved critical writing in the experimental group of this study was attributed to brain-based instruction focused on considering the quality of brain development for learning skills.

Furthermore, the findings of the current study support Kaufman et al[30] confirming that principles such as creating specific patterns, using the brain's natural learning tendencies, and engaging in active participation are essential factors that contribute to better performance. Regarding the social brain, eliciting emotion, and developing thinking skills as effective determinants for brain-based language learning instruction, the empirical findings corroborate the principled findings by Hileman[31] and Tate,[32] who offered tips for engaging the brain and implementing strategies that potentiate brain-based learning. Our findings are also consistent with the connectome and graph theory emphasizing the integration of brain functions through joint actions of dispersed areas in the brain rather than as separate actions from different brain areas. Unlike the brain modularity paradigm, which addresses the independent operation of brain areas for processing and producing cognitive functions, the positive impact of brain-based instruction in the current study reconciles with brain network connectivity theory for overall brain development. Moreover, reinforced and directed cooperation of the triple network for better results in learning the skill are in line with the super learning hypothesis of Caligiore et al,[33] which found that cooperation and co-working of different learning mechanisms along several brain regions caused a boost to learn by focusing on the way the cerebellum, cortex, and basal ganglia might function interactively via a close connection between supervised, unsupervised and reinforced learning processes.

The developed model of a brain-based teaching approach emphasizing the activation of the triple network is a pedagogical and practical extension of Immordino-Yang et al,[1] where efficient educational curriculums improved learners' involvement and learning process via exerting opportunities to establish, enhance, and reinforce learning capabilities in culturally related, appropriate, and creative tasks. As presented in the planned activities for the experimental group, in every session, simultaneous activation of the three large-scale networks was deliberately exerted to achieve the desired learning skill. Hence, brain-based function tasks that can reasonably support and trigger these networks' activity and connectivity hopefully would have the potential to lead to learning desired skills to stabilize successful brain-based instructions and strategies.

However, what distinguishes this study from other brain-based learning/instruction investigations is that the simultaneous activation of three large-scale networks was an attempt to follow an instructional pattern systematically organized and practiced through related activities, strategies, and techniques.

Conclusion

As reviewed in this study, methods developed from cognitive neuroscience provide educators with effective tools to transfer meaningful content knowledge in medical education. Language training and tutorials, as a supplement to the understanding of functional brain connectivity, will enlighten our perception of the operating system and neural mechanisms of the brain that underpin language acquisition. The capacity of the human brain to learn and the influence of environmental incidents on its growth and evolution provide valuable opportunities for scholars in different fields. Using neuroimaging studies and techniques, researchers have traced changes in the brain, expanding our knowledge about how the brain operates. This study opens up further inquiry for those keen on integrating neuroimaging experiments with medical and educational policies. Collaboration between education and medicine benefits both fields of study considerably, in addition to comprehending the process of learning languages concerning mapping the structure and function of the brain.

In brief, looking into the brain network's structure and functions provides novel insights into the mechanics and state of language acquisition processing. Accordingly, this supplies language teaching and learning with operational pedagogies and curriculums for medical students. Designing compatible tasks and teaching materials that reinforce the activation of the three networks and related areas of cognitive function can facilitate, accelerate and enhance learning outcomes among medical students, including English speaking skills, fluency, self-investment, and fulfillment. Finally, a bottom-up approach could be implemented, given that neuroimaging methods and facilities can substantiate, track, and confirm the brain's functional and structural connectivity. Accordingly, individuals could maximize their own learning abilities by participating in directed brain-based interactive tasks.

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Author Contributions

Conceptualization: Farzaneh Iranmanesh.
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Ethical Approval

All the technical terms and concepts, as well as quotes, are referenced. This investigation was approved by the Islamic Azad University of Kerman branch with the ethical code No. 1400.17 948.

Competing Interests

The authors declare no conflict of interests.

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