A Brain Mapping Approach to Inspect the Underlying Neural Correlates upon Perceiving Persian Metaphors

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Abstract

Metaphors are frequently used in our daily life communications to comprehend and convey abstract concepts. Different neuroimaging studies also show a wide neural connection to metaphor perception. This study used a brain mapping setup (quantitative electroencephalography) to examine large-scale brain networks in participants when they were submitted to non-metaphorical sentences as compared to creative and conventional metaphorical phrases. To this end, 20 healthy right-handed individuals with Persian as their mother-tongue language consented to participate in the above language task. Having evaluated the functional connectivity across key cortical hubs, no significant or predominant role of the right hemisphere was observed upon comprehension of the conventional and creative metaphorical phrases. Rather, a wide interhemispheric functional connectivity is proposed to play a key part in the above task. Further understanding about the neural networks involved in the semantic processing of metaphors may potentially open new avenues to neural modulation in patients who find it challenging to comprehend figurative language or abstract metaphorical meanings (e.g. schizophrenics).

Keywords: Metaphors, Creativity, Semantic processing, Figurative language, qEEG, Networks

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1. Introduction

Figurative language is an important component in our daily conversation appearing in different forms such as metaphor, idiom and sarcasm, and adding efficacy and richness to the language. When someone says “life is a journey”, we rapidly understand that the meaning will not be taken word-by-word, otherwise it will not convey the idea correctly (Carroll, 1999). The contemporary theory of metaphor (Lakoff, 1993; Lakoff & Johnson, 1980) claims that such expressions possess both a surface and conceptual realization through which the meaning revolves around a conceptual mapping between “life” and “journey”. According to the same theory, conceptual metaphors seem to play a key part in conveying abstract meanings into concrete concepts at cognitive level.

Some earlier investigations (Glucksberg, 2003; Glucksberg, Gildea, & Bookin, 1982; Grice, 1975) substantiated both literal and figurative meanings in figurative language comprehension where both meanings can be taken serially or in parallel. Researchers have long been interested in the neural and cognitive aspect of figurative language comprehension, namely metaphors (Beaty, Silvia, & Benedek, 2017; Mashal, Faust, Hendler, & Jung-Beeman, 2007; Rapp, Leube, Erb, Grodd, & Kircher, 2004; Schmidt & Seger, 2009). Despite such a large body of evidence in the literature, little is known about the mechanisms behind figurative language comprehension.

Though loads of studies in the nineteenth-century associated left hemisphere with basic language functions, such as production and comprehension, others suggested some nodes in the right hemisphere for non-literal language processing. This has predominantly stemmed in neurological studies claiming that patients with right hemisphere injury are subject to some difficulties in non-literal language comprehension (Bottini et al., 1994; Brownell, Simpson, Bihrlé, Potter, & Gardner, 1990; Mashal, Faust, & Hendler, 2005; Pynte, Besson, Robichon, & Poli, 1996). Other investigations (Diaz & Eppes, 2018; Schmidt & Seger, 2009) claim that other than figurativeness, factors such as novelty and familiarity play a role in right hemisphere engagement. In the Graded Salience Hypothesis, Giora suggests that laterality of semantic processing is greatly influenced by meaning salience, indicating that highly salient metaphoric expressions are processed in the left hemisphere, while less salient ones undergo processing mainly on the right side (Giora, 1997, 1999, 2003). In the same vein, a study on nonliteral language perception, used the event-related potential (ERP) setup study to study neural network dynamics upon semantic processing of idioms (van Herten, et al., 2005). Their study demonstrated that semantic load is processed via the N400 ERP component during the perception of the metaphoric meaning of idioms vs. non-idioms. Moreover, the P600 component showed a higher peak in idiomatic than non-idiomatic phrases. Thus, despite the identical syntactic structures of either phrases, healthy brains were capably processing the figurative meaning of idioms while processing the syntactic information.

To date, cognitive neuroscience research is yet to highlight whether different types of metaphors (i.e., creative and conventional) may possibly be processed in the same way.

Consequently, a better understanding of the functional neuroanatomy involved in the process of semantic decoding of different types of metaphor is yet to be pursued.

What is important in the study of metaphor comprehension is to investigate how different brain regions get functionally connected in figurative language comprehension. Therefore, the present study aims to tackle this question through investigating neural correlates whereby metaphoric expressions are processed in the brain.

2. Methods

2.1. Participants

The study sample comprised 20 Persian speaking individuals with mean age of 25.4 (range: 22-32, SD = 2.92; 10 women, 10 men). All participants were right-handed (providing a mean result of 6.3 on the Edinburgh Handedness Inventory) and had normal or corrected-to-normal visual acuity. They revealed no neurological or psychiatric history had a within-normal range scores for Beck's Anxiety and Depression Inventories (BAI and BDI). They voluntarily took part in the experiment and were provided a written informed consent. The entire experiment was approved by the institutional ethical review board in terms of compliance with ethical codes.

2.2. Stimuli and task

Experimental stimuli included three types of phrases i.e. literal, conventional and creative metaphorical. Given the paucity of already validated comparative testing method on non-metaphorical, creative and conventional phrases in Persian language, trials were investigator designed. As such, phrases were chosen from the study toolbox by Moloodi 2015 in which phrases were categorized according to generativity of metaphorical expressions. In that sense, 40 non-metaphorical phrases (e.g., "the kettle was exploded of heat") and 40 metaphorical phrases, 20 of which were relevant conventional (e.g. "he was exploded of heat") and 20 creative metaphors (e.g. "glasses were full of happiness wine") were randomly presented. In order to assign the timing of each block, 20 subjects, other than the main participants, were asked to "see", "read" and "comprehend" the phrases displayed on the screen and do some imagination (where applicable) and then, press next when they are done. Time to be taken for reading phrases by each subject was measured (mean of 7 seconds). Blocks were separated by 3 seconds of rest block (where subjects were asked to fixate on a haircross in the middle of the screen). The whole task began with 3-minute default and ended by a 3-minute baseline block.

2.3. Procedure

Prior to each experiment, subjects were informed about the state, process and goals of the research and voluntarily participated in the task. At first, before the task, all subjects were examined for their handedness by online Edinburgh Handedness Inventory and were all right-handed (with a mean of 6.3). Then, their cognitive agility and possible state of mental fatigue was tested using the flicker-fusion test as a surrogate marker. In Flicker

Fusion examination subjects who scored <36 were considered lacking attention and mentally fatigued hence were asked to take the test in another date where they acquired a more favorable vigilance score. During the qEEG data acquisition and the language task, subjects kept a one-meter distance, and sat before the screen at eye level in a comfortable sitting position. They were asked not to move and try to have the least blinking possible. Having passed 50% of the trials, including default and non-metaphorical phrases (which lasted 9 minutes and 20 seconds in sum), participants were allowed for a short 3-minute rest and then continued the second half. At the end, after having the task done, Flicker Fusion test was repeated to ensure any mental fatigue potentially induced by the task.

2.4. EEG recording

Brain activity was recorded using a 19 channel qEEG hardware device (Mitsar, model: Mitsar-EEG-10/70-201). Bandpass filters were set between 0.3 and 70 Hz. The bandwidths were grouped according to the following divisions: Delta: 0-4 Hz, Theta: 4-8 Hz, Alpha: 8-13 Hz, Beta1: 13-32 Hz, Beta2: 32-64 Hz. A fitted electro-Cap was used for each participant and electrodes were positioned at 19 locations on the scalp according to the standard 10/20 system with ground references linked on ears. Participants were asked to show up with clean scalp and hair. The forehead and earlobes were cleaned and scrubbed by Nuprep gel and all 19 electrodes were filled with electro-gel. The impedance was kept below 10 Ω across electrodes. EEG signals were preprocessed and processed by WinEEG [v. 2.127.98 (06.2018)].

Figure 1. Experimental Design. For each task, the sentence appeared in black in the center of a white screen for 7 seconds, followed by a 3-second wash-out (a white screen with a black plus sign in the center). The total of 80 sentences were randomly assigned and the number of conventional metaphors were equivalent to non-metaphorical sentences.

2.5. Data analysis

To quantitatively analyze the preprocessed EEG data, Neuroguide software (Applied Neuroscience Inc. USA, 2018) was used. In this way, the whole experiment was stratified into five different tasks (default, task1, task2, task3 and baseline) as per the main timing frames. Other than WinEEG preprocessing for possible artifacts, distorted signals following blinking, involuntary muscle contraction and other possible noises were visually detected and removed. Regions of interest were isolated as per the language network cortical hubs in the left hemisphere and their homologous pairs on the right side according to the previous studies. For each task, ROIs (F3, F4, T3, T4, F7, F8, T5, T6) were observed two-by-two in frequency bands of Alpha, Beta and Beta1 (i.e. for default, F3-F4 were checked in all three frequency bands). Data was then analyzed by One-way Repeated Measure Analysis of Variance (ANOVA) in SPSS. First, all ROIs and all tasks were considered separately in Alpha, then Beta and at last Beta1, and then in each bandwidth, tasks were compared two-by-two to see if there was any difference in absolute power measures.

Figure 2. Bitemporal relatively-symmetric CSD gain and coherence z-scores in Alpha and Beta1 bands upon creative metaphor comprehension task suggesting no hemispheric specialization (A-B). While earlier studies were proposing right hemisphere predominance both on ERP (N400 and P600 components) and qEEG absolute power, the present report was in line with more recent investigations such as the ERP/EEG study by van Herten et al. showing almost no laterality in alpha and beta power spectra. According to van Herten et al. there has been marginally no difference in source localization of ERP components which is in agreement with sensory-motor rhythm (SMR) CSD distribution upon metaphoric vs. syntactic language tasks as shown in our investigation (A,B & C). The down-right panel shows no hemispheric predominance in N400 and P600 ERP components upon semantic processing of metaphorical statement (D, van Herten et al. adapted with permission CC license). Taken together There seem to be no hemispheric predominance in the brain upon semantic processing of metaphorical phrases, rather, an interhemispheric functional connectivity is proposed to play a more significant role here.

3. Results

When comparing the task outcome in “default” vs. “task1”, T3, T4, F8, T6 cortical regions (at least partly implicated in the process of language comprehension) showed a higher Alpha band absolute power. A similar comparison was done in Beta band showing an intensified current source density (CSD) in T5, F3, F8, T4, T6 cortical areas. With regard to the Beta1 bandwidth, only F3, T4, T6 were found to demonstrate a notable CSD gain. Later in our analyses, “task1” and “task2” states were compared in terms of Alpha band CSD whereby T4, T6, T5 Alpha power notably declined while subjects were submitted to emotionally-loaded metaphorical statements. Meanwhile, a similar comparison in Beta and Beta1 bands revealed no statistically significant difference. Finally, “task2” vs. “task3” comparison showed a notable CSD gain in T3, T4, T5, T6 in Alpha and Beta-1 bands with no significant interhemispheric amplitude asymmetry.

Multivariate Tests ^c						
Effect		Value	F	Hypothesis df	Error df	Sig.
Task	Pillai's Trace	.069	2.021 ^a	4.000	109.000	.097
	Wilks' Lambda	.931	2.021 ^a	4.000	109.000	.097
	Hotelling's Trace	.074	2.021 ^a	4.000	109.000	.097
	Roy's Largest Root	.074	2.021 ^a	4.000	109.000	.097
Task * Region	Pillai's Trace	.222	.938	28.000	448.000	.559
	Wilks' Lambda	.794	.930	28.000	394.427	.570
	Hotelling's Trace	.240	.922	28.000	430.000	.582
	Roy's Largest Root	.106	1.703 ^b	7.000	112.000	.115
a. Exact statistic b. The statistic is an upper bound on F that yields a lower bound on the significance level. c. Design: Intercept + Region Within Subjects Design: Task						

Table 1. Statistical outcome from one-way repeated measure ANOVA test. The table summarizes the comparative alpha band CSD gain across regions and tasks.

Multivariate Tests ^c						
Effect		Value	F	Hypothesis df	Error df	Sig.
Task	Pillai's Trace	.075	2.206 ^a	4.000	109.000	.073
	Wilks' Lambda	.925	2.206 ^a	4.000	109.000	.073
	Hotelling's Trace	.081	2.206 ^a	4.000	109.000	.073
	Roy's Largest Root	.081	2.206 ^a	4.000	109.000	.073
Task * Region	Pillai's Trace	.216	.915	28.000	448.000	.594
	Wilks' Lambda	.796	.920	28.000	394.427	.586
	Hotelling's Trace	.241	.925	28.000	430.000	.578
	Roy's Largest Root	.125	2.001 ^b	7.000	112.000	.061

a. Exact statistic
b. The statistic is an upper bound on F that yields a lower bound on the significance level.
c. Design: Intercept + Region
Within Subjects Design: Task

Table 1. Statistical outcome from one-way repeated measure ANOVA test. The table summarizes the comparative beta band CSD gain across regions and tasks.

4. Discussion

Back in several years, a plethora of research (Rapp, Mutschler, & Erb, 2012) elaborated on the neural network upon literal and non-literal tasks. Indeed, over 35 studies were collectively evaluated in a meta-analysis corroborating the finding that one of the two hemispheres is predominantly responsible for the non-literal language comprehension, among which 149 cortical hubs (32%) were in right hemisphere. Other investigators (Schmidt & Seger, 2009) believed that principles as how abstract, familiar or unfamiliar and difficult a sentence can be, would affect the region of the network in the brain and claim right hemisphere is involved only when metaphorical and non-metaphorical sentences are shown in contrast to each other.

Finally, though researchers have been studying such a phenomenon since long, there is no clear-cut answer to the question of “where non-literal sentences get processed in the brain”. Over an above, none of the two hemispheres are known to predominate for the comprehension of metaphorical sentences. This has been in line with what we reported in the present investigation.

There are several limitations to the current study. Overall, figurativeness and familiarity in Persian language is so delicate in which it was, in some cases, difficult to recognize a conventional metaphor from the novel ones. Additionally, the lack a standard language test in which metaphors were clearly mentioned obliged us to create one. Not only that, but for a number of participants, some phrases were not enough comprehensive and they were not sure about which one to consider. Also, some reported that the test was tedious.

5. Conclusion

This study did not support the Graded Salience Hypothesis (GSH) and the significant role of right hemisphere upon processing novel and creative metaphorical phrases (Mashal et al., 2007; Rapp et al., 2004; Yang, Edens, Simpson, & Krawczyk, 2009). According to our findings, no meaningful difference was noted in regions involved in conventional and creative metaphor comprehension. This has been in agreement with what reported by Beaty and colleagues (Beaty et al., 2017). According to the findings from the study by Beaty et al., and that of the present work, homologous regions in left and right hemisphere are proposed to be functionally inter-digitated to form a wider network employed upon comprehension of these two types of metaphors. Further insights into the above question may offer novel perspectives for neuromodulation in patients with abstract thinking and predicaments in understanding metaphorical phrases (e.g. schizophrenics).

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