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Research Article

Investigating the Impact of Semantic Operations on Persian-Speaking Aphasics: Further Evidence on the Localization View

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ABSTRACT

Introduction: Broca and Wernicke's patients perform satisfactorily regarding the processing of canonical syntactic structures, as maintained by previous studies; however, there has been a gap in the literature because no particular research has yet investigated the performance of these patients in the Persian circumstances once they were required to analyze sentences which would demand extra-semantic processing. This study clarifies the role of two critical semantic operations demanding extra-semantic processing at the sentential level: Aspectual coercion. It complements to provide some evidence on the localist view of the brain. Our rationale for selecting these operations was their pure semantic nature, not relying on morphosyntactic properties.

Materials and Methods: Having recruited two age- and education-matched Broca, two Wernicke, and four healthy controls, we conducted a semantic judgment task in which the participants were asked to express their correct semantic judgment in the two coercion and two normal conditions.

Results: Our results showed an approximately above-chance performance of the Broca group for all conditions; however, in the Wernicke group, the same result was not observed due to their poor performance in coercion conditions, though in ordinary sentences, they performed much better.

Conclusion: Our findings, along with similar off-line and imaging studies, corroborate the view of localism, based on which Wernicke's area is mainly responsible for the primary semantic operations while Broca's area predominantly takes over syntactic parsing.

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Introduction

The particular interaction of syntactic and semantic components of the language plays a vital role in the accurate semantic composition of the sentence. In other words, to process a sentence easily, one must use both syntactic and semantic information. Particular canonical arrangements of the words in a sentence would contribute to and facilitate their accurate parsing. In situations where these canonical word orders are disrupted, leading to non-canonical structures, the effects of these semantic facilitations were not observed. Canonical word order denotes a situation in which primary syntactic categories like subjects and objects match their default semantic roles like agents and patients at the sentential level. For instance, by default, the syntactic position of the subject is usually occupied by the semantic role of the agent. Accordingly, in the sentence, "Ali ate the apple," the subject "Ali" bears the semantic part of the agent, and the object "the apple" bears the semantic role of the patient. Evidence emphasizing individuals' intact performance in canonical word order and their poor performance in atypical word orders were observed in healthy subjects [1-5] and aphasic patients [6-10].

Yet, regarding aphasics, a caveat should be considered here. Although purely syntactic explanations have been utilized to explain the malfunction of aphasics, there have been some dissociations between the performance of Broca and Wernicke's patients in syntactic tasks. That is, the severity of syntactic parsing concerning atypical and non-canonical constructions was more vivid in the case of Broca's patients. The results of neuropsychological tests have also corroborated this dissociation in aphasics' performance. While in Broca's aphasia, left hemisphere lesions, including Brodmann areas 44 and 45, are involved, in Wernicke's aphasia, Sylvian fissure, and superior temporal gyrus play significant roles [11-15].

In light of diverse syntactic models and their neuropsychological counterparts, the localism view of the brain could still be reliable. However, are syntactic composition models elaborated in different theoretical frameworks like mapping theory [16-19] or trace-deletion hypothesis [6, 20-24], the sole plausible and reliable ones explaining accurate semantic parsing in healthy individuals and inaccurate semantic composition in brain-damaged patients, namely, aphasics? The inevitable secondary question automatically raised here is whether Broca and Wernicke's aphasics would perform similarly.

Although, via presenting reliable evidence conducting off-line and online tasks, previous scholars corroborated their theoretical frameworks, the scrutiny of some specific types of sentences could still cast doubt on the accuracy of any syntax-based theory of language. Following this theoretical challenge launched initially by Pinango and Zurif, we hypothesized that resorting to some extra-semantic features in specific situations could play a facilitative role in the accurate interpretation of the sentences for which providing syntactic-based explanations, including a dependency relation, trace deletion hypothesis or mapping hypothesis, would be insufficient [25].

The specific situations we proposed here, previously developed by the two researchers in English, include complement and aspectual coercion types. As with the former, we are considering a condition in which the particular properties of the noun phrase following the verb phrase, like its function and status, would constrain the plausible complements of the verbs. For example, in the Persian sentence "ʔu Az football lezzat bord," rendered in English as "He enjoyed soccer," the particular semantic property of "football" would constrain the plausible interpretation of "lezzat bord" or "enjoyed." Hence, concentrating on the complement structure of "enjoy," only activity should have taken place to make the sentence plausible, a hasty generalization discarded by the noun phrase "football." However, as this example shows, the noun phrase restricts the activity that could be performed by "enjoy," that is, soccer. Therefore, the action "lezzat bordan az football" would be automatically recovered by the listener. In Pustejovsky's terminology, this unique property of a noun phrase capable of amalgamating with a particular activity or verb (if talking syntactically) is called the qulia structure [26]. This structure could overtly manifest in verbs like enjoy, try, etc.

On the other hand, in aspectual coercion, the aspectual properties of the verbs, whether the verb is telic (transient) or non-telic (non-transient), could contribute to the sentence processing only if there is a correspondence between the aspectual content of the verb and the following modifying phrase. Consequently, the sentence "Mina qaz ra kosht," rendered as "Mina killed the goose," is plausible in the sense that "Mina" (a Persian female name) did it once because "kill" is a transient or telic verb in English. However, if we had said, "Mina killed the goose until morning," our utterance was incorrect because the semantic content of the following adverbial phrase is incongruent with that of the preceding verb. "Killing" is a telic activity that could only be performed once.

However, in some instances, just relying on aspectual information of the verb might not be fruitful. For example, the plausible interpretation of the sentence, "Reza jumped until morning," depends on aspectual information and the presence of some extra-semantic information called by some scholars as "repetition function" [26-27] and "type-shifting" by others [28]. Scholars utilized these terminologies to indicate that the aspectual content of the verb is changed via the operation of specific extra-semantic content. Hence, neither the semantic framework of the verb phrase nor the following noun phrase would play a significant role here. The specific semantic constraint involved here is "iterability," meaning if the same action by a person could be performed upon the same person or object many times, our constraint will be met. Hence, obeying this constraint, "Reza jumped until morning" would be plausible, but "the boy killed the goose until morning" would be implausible because the same goose could not be killed many times.

Hence, considering our primary purpose, having reviewed some syntactic research emphasizing the double dissociation of the brain and different patterns of performance in Broca and Wernicke's patients, and also based on different neuropsychological testimony, this study aims to see whether performing a purely semantic-based off-line experiment could still shed light on the classical view of the brain. If so, we could predict that the performance of Broca and Wernicke's aphasics in two coercion constructions would differ. Therefore, in this study, we try to fill the gap in the literature by enumerating some constructions in which relying only on syntactic account or the idea of canonicity might not be helpful. Instead, in some circumstances, as elaborated, we need to utilize semantic or extra-semantic information to provide a more convincing explanation for processing coercion constructions. Accordingly, the necessity and rationale of this research were twofold. First, we aim to divulge whether a purely syntactic account could explain sentential parsing by aphasics. Second, we attempt to see whether Broca and Wernick's aphasics manifested the same processing behaviors regarding these sentences, shedding more light on the classical left and right brain dichotomy known as the localist view of the brain. As for the clinical implications of this research, understanding the linguistic behavior of aphasics in the accomplishment of diverse syntactic or semantic tasks could shed more light on the localized view of the brain, paving the way for a better diagnosis of linguistic malfunction in aphasics. In doing so, considering that all the above conditions were met, appropriate speech therapies for each type of aphasia could be performed, and aphasics' quality of life could be boosted, respectively.

Materials and Methods

The first experiment

Study subjects

Following the methodology of Pinango and Zurif, two Broca's, two Wernicke's, and four healthy age- and education-matched controls were chosen for the experiments. We utilized the convenient sampling method to select our participants. The inclusion criteria were the lack of addiction to alcohol or drugs and being monolingual (Persian as their mother tongue). None of the participants had visual or auditory deficits; therefore, they could easily perceive auditory or visual stimuli. Patients suffering from neuropsychological diseases, such as anxiety, depression, and cardiovascular diseases, were excluded from our sample. Furthermore, those suffering from neurodegenerative diseases like Alzheimer or Parkinson were also excluded. Meanwhile, written consent was taken to verify patients' satisfaction with participating in the study. The lesion site descriptions of each patient are presented in Table 1. To preserve ethical guidelines and confidentiality, we only mentioned the initial letters of our patients' first and last names. While the age range of Broca's patients varied from 58 to 79 years, the age range was between 54 to 67 years in Wernicke's patients. Regarding educational background, both groups had at least a diploma. The diagnostic test to assess aphasics was the Boston diagnostic aphasic examination (BDAE) [29]. Having translated and confirmed the test in Persian and testified its reliability and validity, this study utilized it to screen subjects' aphasia type. Moreover, the review of neuroradiology testified to our evaluation, demonstrating our binary classification was in line with the classical Broca and Wernicke types.

Study materials

A total of 20 pairs of sentences composed of complement coercion types (ranging from 5 to 11 words) were created. The reliability and validity of which had already been verified. We used the Cronbach α to evaluate the internal consistency of the test. The statistical analysis results represented 0.93, proving the excellent consistency of the questions. Having asked a group of linguistics specialists about the content of the questions, we assessed the content validity of the test. The content validity index of 0.84 corroborated the excellent validity of the test and demonstrated its suitability with the research objectives. Each pair of sentences included a transparent sentence and its coercion type. For example, the transparent member of a pair was "ʔu football bazi

Table 1. Lesion site descriptions of patients

Name	Diagnosis (BDAE and Clinical Consensus)	Lesion Site Information
OR	Wernicke's	A male patient suffered from a stroke in 1990. That year, an MRI showed a diffuse lesion, including the posterior left temporal lobe and anterior occipital lobe.
BS	Wernicke's	A male suffered from a stroke due to an accident in 1992. The lesion sites involved included the angular gyrus and right lateral ventricle.
SA	Broca's	The patient was a male suffering from a stroke in 1995. That year, A CT scan indicated lesions in the left temporal lobe and inferior portion of BA 22.
TU	Broca's	A female patient suffered from an accident in 1994. A study of CT scans taken that year showed the involvement of lesion sites, including the inferior frontal gyrus and insular cortex area.

JMR

Abbreviations: BDAE: Boston diagnostic aphasic examination; MRI: Magnetic resonance imaging; CT: Computed tomography.

kardan ra shoru kard," rendered as "He began to play soccer." This sentence is transparent because the verbal complement of the verb phrase is explicitly asserted as "bazi kardan." As shown above, in Persian, because of its typological structure belonging to object-verb languages, the complement of the sentence occurs before the verb. On the other hand, the second member of the pair belonged to the complement coercion type of the sentence in which the verbal complement of the main verb, though not explicitly asserted, could be recovered by the listener via the general subcategorization information of the main verb as well as the specific semantic properties of the following noun phrase constraining the main verb's meaning. Thus, as an example of our second member of this experiment in the structure "ʔu football Ø ra ʃoru kard," rendered in English as "He began Ø soccer," the null category (Ø) demonstrated that this covert category, though deleted, could be recovered via the semantic content of the upcoming noun phrase. The second member was called coercion because it enforced only specific interpretations. To eliminate the influence of context or syntax on subjects' interpretation, none of the sentences contained any contextual or morpho-syntactic clues like plural markings "ha" and "an," which are equivalent to plural ending "s" in English.

Study procedure

The study was conducted in a quiet room with sufficient light to create a more comfortable and relaxed atmosphere for the participants. Having randomized and recorded the performance, a native speaker of Persian presented the stimuli to the subjects. Furthermore, for subjects' familiarity with the experiment, four separate training sentences were presented to the subjects. After presenting each sentence to the subjects, we utilized a grammaticality judgment task in which we asked our participants to judge the grammaticality of the sentences. The testing duration was about 1 h for each subject. Sitting on the table and looking at each linguistic stimulus printed on a sheet of paper, the participants were required to judge the grammaticality of the sentences. Meanwhile, when necessary, a rest break was utilized. During test sessions, our participants' physical and mental conditions were considered so as not to make them weary or put them under pressure.

The second experiment

Study material

In the second experiment, the same participants were presented with 14 pairs composed of aspectual coercion sentences, the reliability and validity of which had already been attested. Similar to the previous test, we used the Cronbach α to evaluate the test's internal consistency. The statistical analysis results represented 0.89, proving excellent consistency of the questions. Having asked a group of linguistics specialists about the content of the questions, we assessed the content validity of the test. The content validity index of 0.86 corroborated the excellent validity of the test and demonstrated its suitability with the research objectives. Furthermore, each pair of sentences was composed of two members. The first member belonged to the transparent group of sentences in which just relying upon the syntactic composition of the sentence was sufficient for the subject to judge its grammaticality. "Fatima qaz ra koʃt," rendered in English as "Fatima (a female name) killed the goose."

However, the second member of this pair belonged to the aspectual coercion type of sentence "Fatima ta sobh parid," rendered in English as "Fatima jumped until morning." As mentioned earlier, the verb "parid," ren-

dered as "jump" in English, is a telic or transient verb, meaning it could happen only once. However, the adverb phrase "ta sobh," rendered as "until morning" in English, highlights its durative content. Therefore, we have a type of "aspectual shifting," which would make its interpretation plausible. This operation, as mentioned earlier, is purely semantic.

Study procedure

Initially, similar to the first experiment, the stimuli were randomized by a native speaker of Persian. Furthermore, four separate tentative sentences were used for subjects' familiarity with the experiment's procedure. After presenting each sentence to the subjects, we used a semantic judgment task to ask our participants whether the action denoting that sentence occurred once or many times. Sitting on the table and looking at each linguistic stimulus printed on a sheet of paper, the participants were required to judge the frequency of occurrence of the action related to each sentence expressed by the examiner. Furthermore, utilizing gestures and hand movements, the examiner reinforced each alternative. Similar to the previous experiment, each individual was tested separately. Moreover, to eliminate the effect of morpho-syntactic parameters on subjects' comprehension, we did not utilize any morphological or syntactic hints in our experimental sentences. The testing session for each subject lasted about 1 h. When needed, a rest break was employed. The examiner recorded All tests' stimuli utilizing a Sony mono digital voice recorder in a sound-proof room with sufficient light at a sampling rate of 9 KHz and 10-bit quantization.

Study statistics

The chi-square (χ^2) statistic was utilized to measure the difference between the observed and expected performance of Broca and Wernicke's patients in each condition of coercion or complement. Although our sample size was small, we conducted a paired t-test since our within-pair correlation was high. We aimed to assess whether Wernicke and Broca's performance in each condition of the experiments was significant.

Results

The first experiment

Regarding the control group, they performed well in both conditions of this experiment, including transparency and coercion. However, as Table 2 indicates, a similar pattern was not observed regarding Broca and Wernicke's patients. To preserve ethical guidelines and confidentiality in our research, we mentioned only the initial letters of our patients' first and last names.

In other words, the patient's performance showed no significant difference for the two conditions ($X^2_{(transparent)}$=16.42, P<0.05 vs $X^2_{(coercion)}$=6.33, P<0.05). They understood transparent sentences significantly better than coercion ones (t (2)=8, P=0.08, one-tailed). On the contrary, Broca's patients perform above chance in either transparent (X^2=18.38, P<0.05) or coercion conditions (X^2=13.48, P<0.05). Furthermore, the comparative analysis of their performance in the two conditions revealed no significant difference (t (2)=2.12, P=0.08).

Table 2. Number and percentage of correct responses by aphasics

Aphasia Type	Patient	No. (%)	
		Transparent	Coercion
Broca	SA	17(85)	19(95)
	TU	17(85)	15(75)
	Mean	18(90)	16(80)
Wernicke	OR	17(85)	11(55)
	BS	19(95)	13(65)
	Mean	18(90)	12(60)

JMR

Table 3. Number and percentage of correct responses by aphasics

Aphasia Type	Patient	No. (%)	
		Transparent	Coercion
Broca	SA	14(100)	14(100)
	TU	12(85.71)	13(92.85)
	Mean	13(92.85)	13.5(96.42)
Wernicke	OR	11(78.57)	6(42.85)
	BS	12(85.71)	7(50)
	Mean	11.5(82.14)	6.5(46.42)

JMR

The second experiment

As observed in the first experiment, the normal control subjects performed flawlessly in the second experiment, showing no difficulty in both conditions. However, according to Table 3, a performance contrast between Broca and Wernicke's patients was observed. For confidentiality, only initial letters of our patients' names were reported.

As shown in Table 3, Broca's performance was above chance. This result was observed in the transparent condition and the coercion one. In contrast, Wernicke's patients observed this above-chance performance when they tried to execute transparent condition. On the other hand, when trying to execute coercion-type sentences, these patients demonstrated chance performance. A paired t-test conducted to assess Wernicke and Broca's performance in each condition indicated only in Wernicke's group, the difference in the performance of subjects in both conditions was significant ($t(2)=7.58$, $P=0.008$, one-tailed). Furthermore, Wernicke's group demonstrated at-chance performance on coercion condition ($X^2=0.27$, $P>0.05$]. In contrast, the analysis showed Broca's patients' above-chance performance for both conditions, either transparent ($X^2=10$, $P<0.05$) or coercion ($X^2=8.51$, $P<0.05$). Also, their performance in these two conditions was not different ($t(2)=-0.41$, $P=0.51$, one-tailed).

Discussion

Our findings demonstrated that relying on syntactic accounts, like canonicity or trace-deletion theory, could not explain the linguistic behaviors of aphasics. Instead, in some circumstances, resorting to a semantic account represented in coercion constructions or extra-semantic information is the more optimal solution to explain phasic's processing of semantically entailed constructions. Regarding semantically induced constructions, our findings highlighted that Broca's aphasics do not demonstrate significant problems in both conditions. Therefore, their performance on both conditions of each experiment was approximately the same. On the contrary, though Wernicke's patients did not manifest any problems understanding single-word meanings, executing extra-semantic information in each coercion sentence exhibited significant problems.

The significant difference in the performance of the two different types of aphasics, Broca's and Wernicke's, shed light on the critical neuropsychological fact that the crucial area for the appropriate execution of coercion types of sentences is Wernicke's area. Thus, the left posterior cortical region or Wernicke's area is primarily involved for these complex semantic operations to take place more vividly. On the other hand, the left anterior cortical region or Broca's area does not play a significant role; hence, all these observations are in pro with the localist's view of the brain, asserting the left hemisphere manipulates semantic operations on the one hand and syntactic operations are integrated for the most part by the right hemisphere of the brain [30-33]. The malfunction of Broca's aphasics regarding the processing of Persian syntactic constructions, whose interpretation requires extra-semantic information on one hand, and the comparatively intact performance of Wernicke's aphasics in processing these constructions further corroborate the localized view of the brain. Henceforth, our findings could have major implications for speech therapists and clinicians to utilize appropriate therapies regarding the linguistic performance of each type of aphasia. More par-

ticularly, speech therapists could emphasize and recommend using syntactically cued constructions and oppose utilizing semantically induced structures for Wernicke's aphasics to boost their communicative competence.

Our research findings are in line with the results of Pinango and Zurif's study in English [26]. These researchers employing and executing these two types of semantic assessment tests showed that Wernicke's patients, unlike Broca's group, had many challenges comprehending coercion types of sentences. However, in our research, unlike the study conducted by the researchers above, a unified methodology was employed to assess aphasics' understanding of two semantically complex sentences. Moreover, in contrast to their study, in this research, we used both experiments in a single group to assess whether the same individuals would perform differently in diverse semantically complex structures. Nonetheless, our results corroborated their findings.

Furthermore, despite the typological difference between Persian as a subject-object-verb language and English as a subject-verb-object language, the results of the two researches were the same, discarding the possible hypothesis emphasizing the role of the typological characteristics of languages on patients' performance.

Conclusion

The parsing of aspectual coercion and complement types of sentences in the two groups of aphasic patients demonstrates that our brain is localized for linguistic performance. That is, while syntactic processing is supervised mainly by the left hemisphere, the right hemisphere manipulates the parsing of the semantic domain of the brain.

However, by no means least, there is an important caveat that should be considered seriously. In our study, similar to Pinango and Zurif's study, the utilized sample was small, which might have distorted the results. Therefore, to generalize our conclusion, it is essential to recruit a much larger sample with more subjects participating to corroborate the localist's view of the brain in light of these semantically complex sentences. Meanwhile, regarding the probable influence of typological characteristics on subjects' performance, the diversity of the languages chosen in the upcoming research could also be illuminating.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article.

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Authors' contributions

Conceptualization, methodology, data collection, data analyzing: Omid Azad; Supervision, review, and final approval: Mousa Ghonchepour.

Conflict of interest

The authors declared no conflict of interest.

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