Title: Canonicity Effect on Sentence Processing of Persian-Speaking Broca’s Patients

Authors: Omid Azad¹,*

¹. Assistant Professor of Linguistics, Gonabad University, Gonabad, Iran.

*Corresponding Author: Email: oazad62@yahoo.com

To appear in: Basic and Clinical Neuroscience

Received date: 2020/07/27
Revised date: 2020/09/21
Accepted date: 2020/11/21

This is a “Just Accepted” manuscript, which has been examined by the peer-review process and has been accepted for publication. A “Just Accepted” manuscript is published online shortly after its acceptance, which is prior to technical editing and formatting and author proofing. Basic and Clinical Neuroscience provides “Just Accepted” as an optional and free service which allows authors to make their results available to the research community as soon as possible after acceptance. After a manuscript has been technically edited and formatted, it will be removed from the “Just Accepted” Web site and published as a published article. Please note that technical editing may introduce minor changes to the manuscript text and/or graphics which may affect the content, and all legal disclaimers that apply to the journal pertain.
Abstract:

This research with the aim of scrutinizing fundamental notions of mapping hypothesis tries to investigate the comprehension of diverse complex syntactic structures in four age, education and gender matched Persian-speaking Broca’s patients and eight matched healthy controls via conducting two tasks of syntactic comprehension and grammaticality judgment in which subjects’ comprehension of diverse complex structures were put into scrutiny. The structures being tested included subject – agentive, agentive passive, object experience, subject experience, subject cleft and object cleft constructions. Our results, while corroborating the predictions of mapping hypothesis, showed that in structures in which linguistic elements were substituted and dislocated out of their canonical syntactic positions, namely, agentive passive, subject - experiencer, object -experiencer and object- cleft constructions, Broca’s problems escalated. In contrast, in those structures whose constituent concatenations were aligned with canonical syntactic structures, namely subject agentive and cleft structures, patients had above chance performance. Ultimately, theoretical and clinical implications of the study were discussed.

Key Words: Mapping hypothesis, Broca, Object experience
1. Introduction

As of now, there have been lots of researches which attempted to scrutinize sentential parsing in Broca’s patients. Despite these abundant reviews of literature, there has still been some controversy regarding both the nature and extent of the deficit. To explain this type of controversy, some important theoretical accounts have emerged. Some interactive views of agrammatism proposed a constraint-satisfaction model of sentence processing expressing that once a required syntactic, semantic or morpho-syntactic condition is met, the person would commence automatically comprehending the sentence (Frazier, 1995; Grodzinsky & Finkel, 1998; Omazic, 2008; Seidenberg & MacDonald, 2001). For example, trade-off hypothesis proposes that in some syntactic structures, the parser doesn’t need to analyze the whole sentence from the first linguistic element to the last. For her, in as long as the intended processing requirement which could have allowed her either to judge accurately or comprehend plausibly is met suffices. As a result, holding a very general account of the nature of processing in Broca’s patients, they assign their deficit to the performance (Evans, Hula & Starns, 2019; Frazier & Friederici, 1991; Ferrill et al., 2012; Haarmann, 1993; Haarmann & Kolk, 1991; Kolk & Van Grunsven., 1985).

The second theoretical account unlike other views, trace deletion hypothesis, has held a very narrow and restrictive explanation on the nature of grammatical deficit in Broca’s aphasia. Attributing the nature of the deficit to the malfunction of grammatical module of the language and adopting some important theoretical notions from grammar and transformational theory of Noam Chomsky and more specifically his government and binding’s (GB) theory (Chomsky, 1992, 1993). Grodzinsky and his proponents have attempted to attribute Broca’s aphasics’ inappropriate performance to their incapability of co-indexing traces and their original positions in the sentence holding the longer the chain, the more problematic the sentence comprehension would become. As a matter of fact, they emphasize that these lexical nodes co-indexed with their antecedents are either governed or bound (Beretta & Munn, 1998; Grodzinsky, 1983, 1995, 2000; Grodzinsky, Shapiro & Swinney, 2000; Hickok., Zurif & Canseco-Gonzalez, 1993).
However, mapping hypothesis unlike the two former theories has proposed that neither a pure competence nor a sheer performance model of syntactic processing could plausibly justify Broca’s patients’ behaviors in different tasks. That is, this model analyzes individual’s parsing at two stages. At the first syntactic level, there seems to be no significant deficit in aphasics’ performance. However, at the second stage, subjects’ poor performance would evince while trying to assign semantic roles to the syntactic positions in the sentence. Henceforth, followers of this theory have claimed that their subjects would not have any problems in tasks entailing grammatical judgments of the sentences due to the involvement of less cognitive load. Yet, in tasks in which particular mapping is required for the plausible interpretation of the sentence, namely, sentence to picture matching task, their problems would emerge (Cho-Reyes & Thompson, 2012; Dragoy & Bastiaanse, 2010; Garraffa & Grillo, 2008; Linebarger, 1995; O’Grady & Lee, 2005; Piñango, 2000; Schwartz, Fink & Saffran, 1995; Schwartz., Linebarger & Saffran, 1985).

This research, being the first in Persian context, tries to investigate the performance of Persian-speaking Broca’s patients within the framework of mapping hypothesis. Our motives for conducting this research are multifold.

First, having considered the existing controversy in the literature regarding the nature of deficit, this study attempts to analyze Broca’s performance on sentence parsing within the framework of mapping hypothesis and in doing so, it aims at testifying the validity of the predictions of the aforementioned model.

Second, unlike most former researchers (Byng, 1988; Caplan et al., 2007; Meyer & Thompson, 2012; Wassenaar & Hagoort, 2007) adopting some methodological changes, this study has combined two different grammatical judgment and sentence to picture matching tasks to increase the validity of the research and testify more efficiently the predictions of mapping hypothesis given its proposed double stage syntactic semantic model.
Third, it’s noteworthy to mention, as of now although there have been only a few researches in Persian context analyzing the performance of Broca’s aphasics in sentence comprehension (Mehriet et al., 2016; Nilipour, 2000; Raghibdoust, 1999), they have neither attempted to utilize mapping hypothesis for the justification of subjects’ performance nor did they combine diverse tasks for the explanation of their subjects’ comprehension (Salehnejad & Shekaramiz, 2016; Shiani et al., 2019) casting doubt on the validity of their research. Given these considerations, the necessity of conducting this research in Persian setting seems compulsory and essential to depict a more realistic picture of the nature of grammatical deficits in these patients.

Fourth, this study also tried to investigate the probable impact of language typology via testifying subjects’ performance on syntactic structures of Persian which are mainly different from those of European languages. That is, in Persian as a so-called SOV language, the dependent constituent precedes the verb in contrast with languages like English in which the reverse concatenation pattern is the case. Moreover, Unlike English and most European languages, bearing fixed syntactic structures, Persian has a rather floating structure meaning under certain circumstances for pragmatic and discoursal implications, the aforementioned SOV canonical order might change and other alternative category arrangement might be employed by the speakers (Karimi, 2003, 2008). It could be predicted that variations in syntactic arrangements of the linguistic elements might unconsciously affect Broca’s patients’ performance even in tasks in which canonical syntactic structures of Persian have been utilized for the purpose of analyzing aphasics’ comprehension. The significance of this typological difference would become more prominent, more specifically, in the mapping hypothesis as it is more vividly in this theory that the specific arrangement of linguistic elements would play a crucial role in subjects’ interpretation and its disruption would culminate in misinterpretation of the sentence.

And ultimately, regarding the scope of Broca’s aphasics in Iran suffering comprehension problems which would distort their interaction with healthy subjects, this research, having scrutinized the extent and nature of grammatical deficit in patients, attempted to provide some linguistic clues for the speech therapists or neuropsychologists whereby they could propose more effective styles of communication
for the caregivers or patients’ relatives whereby they could more efficiently negotiate and interact with their patients and thereafter via designing a much more satisfactory style of living, boost their life expectancy.

2. Method

2.1. Subjects

Having analyzed the neuropsychological profile of each of patients and reviewed their medical records as exhibited by CT scan, EEG and other neuropsychological tests, four age, education and age matched aphasics and eight healthy individuals as our control group were recruited. Also, their auditory, tactile and visual fields were reported to be normal. None of them were ambidextrous nor were they left-handed nor did their family background exhibited possessing these properties. Noteworthy to say, written consent proving patients’ satisfaction to participate in the tasks were taken. In table 1, the lesion descriptions of each patient have been presented. Concerning our selected sample, it should be asserted that they were all male having the age range of 51 to 64. Moreover, for their educational background, they had achieved at least diploma.

Our diagnostic tool for assessing aphasia’s type was Boston Diagnostic Aphasia Examination (Goodglass and Caplan, 1972). Having translated and confirmed the test in Persian testifying its reliability and validity, we utilized it to screen our subjects’ aphasia type. Furthermore, the review of neuroradiology of patients corroborates our evaluation demonstrating our classification was in line with the classical Broca’s type. As a matter of fact, the common characteristics of all the patients were their effortful, telegraphic and ungrammatical as well as their rather intact syntactic comprehension capabilities. This observation is not surprising given the fact that it has been scientifically proven that agrammatism is typically a syndrome of aphasia patients (Tesok & Code, 2008).

Noteworthy to mention, though lesion site description of each Broca’s patient has been presented, as Ingram asserted no designated and compartmentalized lesion site could culminate in agrammatism
and it has been scientifically attested that an interaction of cell assemblies are involved in this syndrome. So, the properties of agrammatism could well be defined via psycholinguistic tests rather than clinical observations (Ingram, 2007). Taken this important scientific consideration, we could understand more of the nature of agrammatism in Broca’s aphasia patients through conducting a syntactic comprehension test, and why administering such a test could be fruitful.

Table (1): The Lesion Site descriptions of Patients

<table>
<thead>
<tr>
<th>Name</th>
<th>Diagnosis (BDAE and clinical consensus)</th>
<th>Lesion Site Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS</td>
<td>Broca’s</td>
<td>MS is a male suffering a stroke in 1992. An MRI taken that year demonstrated a diffuse lesion site including posterior frontal lobe and perisylvian area</td>
</tr>
<tr>
<td>BR</td>
<td>Broca</td>
<td>BR is a male suffering a stroke due to a cardiovascular accident in 1995. The lesion site involved was inferior anterior parietal lobe</td>
</tr>
<tr>
<td>SP</td>
<td>Broca</td>
<td>SP is a male due to cardiovascular accident in 1999. A CT scan taken that year demonstrated lesions in Perisylvian area.</td>
</tr>
<tr>
<td>GL</td>
<td>Broca</td>
<td>GL is a male suffering an accident in 2001. The study of CT taken that year showed the involvement of lesion sites including left temporal lobe as well as perisylvian area.</td>
</tr>
</tbody>
</table>

2.2 Material and Procedure

Totally, a hundred and twenty sentences of six group types were presented to the subjects. The first type included those sentences in which the subject is regarded as the agent of the sentence (agentive type). For example, “Ali sib ra xord” rendered in English as “Ali ate the apple”. An important typological property worthy of consideration here is that Persian belongs to OV or head-final group of languages- unlike English categorized as a VO or head initial group of languages- meaning it is the
object which precedes the verb in the canonical syntactic structure. The second group of sentences included agentive passive structures in which it is the semantic role of patient or theme or logical object that occupies the initial subject position of the sentence and the original subject is moved to the preverbal position of the sentence “ketab (tavassote mard) neveʃte ʃod” rendered in English as “the book was written (by the man)”. As could be detected, in Persian unlike English, agentive by-phrase occurs in the pre-verbal position which could also be optionally deleted. The third group of sentences includes subject cleft constructions in which the main verb follows the subject observing the canonical syntactic structure. For example, “iniz doxtar bud ke sib ra xord” rendered in English as “It was this girl who ate the apple”. The fourth group includes object cleft structure in which unlike subject cleft, canonical linear syntactic structure is disrupted in a way that it is the object rather than the subject which occupies the initial position of the sentence. For example, “iniz pesar bud ke doxtar donbalesh kard” which is rendered in English as “It was the boy who the girl followed”. The fifth group includes subject experiencer type. Possessing psychological predicates, these sentences encompass those structures which - unlike the default syntactic structure in which it is common that the subject occupies the semantic role of agent- deviate from the norm in the way that the entity psychologically affected by a specific stimulus would occupy the subject position of the sentence. For example, “kudak az gorbe tarsid” rendered in English as “the baby feared the cat”. And finally, the last group includes object experiencer verbs. These structures, compared to the subject experience verbs, deviate even more from the canonical linear heuristics in the way that it is the less default and remote object in the syntactic structure which substitutes for the subject. For example, “mard zan ra tarsand” rendered in English as “The man frightened the woman”.

2. 1. Syntactic Comprehension task

For the purpose of evaluating our subjects’ performance on the syntactic comprehension test and their capability to assign thematic roles to the noun phrases, a figurine act-out task was administered based on which all subjects were expected to act out and sort a set of randomized toy figurines having heard a group of diverse sentences. Due to our patients’ requests, the testing sessions were conducted at their
homes. The subjects were told that they should manipulate the toy figurines in a way that the action or the state expressed by the verb could be easily detected.

For the purpose of subjects’ familiarity with the task, four practice trials were utilized initially. However, in case the subject demanded the experimenter to repeat the sentence, it was uttered for the second time. There was not particular time limit for the task until the experimenter was confident that the patient performed the task completely having understood the procedure. Noteworthy to mention is that all stimuli were presented to the patients in the same randomized order. Furthermore, following the procedure employed by Linebarger et al., (1983) and also for the purpose of minimizing the impact of prosodic and intonation properties on patients’ performance, all stimuli were uttered by the same experimenter observing approximately similar intonation pattern.

3. Results

3.1. Syntactic Comprehension Task

For the purpose of detecting a possible pattern in subjects’ performance as well as investigating whether canonicity impact could be observed in their linguistic behaviors, each individuals’ performance in diverse syntactic structures was reported.

In this respect, one-way repeated measures ANOVA for the six group types of sentences culminated in a main effect of sentence type, \( F(6, 38) = 33.95, P<.0001 \). The performance of our first subject on subject agent and subject cleft structures was ninety five and ninety one percent correct responses respectively, significantly above chance (subject agent: \( t(20) = 3.91, p = .0005 \); subject cleft: \( t(20) = 3.48, p = .001 \)). As for agentive passive and object cleft constructions, his performance was at chance with fifty percent correct responses (\( t(20) = 88, p = .31 \)) and forty eight percent correct responses (\( t(20) = 85, p = .33 \)) respectively. Yet, concerning both subject experience constructions (thirty percent correct responses, \( t(19) = -3.31, p = .817 \)) and object experiencer ones (twenty five percent correct responses, \( t(19) = -4.33, p = .818 \)), his performance was significantly below chance.
Subject two (BR) performed above chance at eighty six percent of the subject agentive constructions (t (20) = 2. 92, P=.005). Concerning his performance at subject cleft (eighty six percent correct responses), similar observation was made (t (20) = 2. 76, P= .005). As for agentive passive, he had at chance performance with sixty percent correct responses (t (20) = . 87, P=. 53). However, regarding object cleft constructions, he had below chance performance with forty seven percent correct responses (t (20) = 1. 43, P= .818). Ultimately, concerning psychological subject and object experiencer types, he had significantly below chance performance with twenty nine percent correct responses in the former (t(20)= -3. 32, P= .819) and twenty four percent correct responses in the latter (t(20)= - 4. 21, P= . 819). Subject three (SP) performed above chance in both subject agentive (eighty five percent correct responses, t (20) = 2. 55, P=. 014) and subject cleft constructions (eighty percent correct responses, t (20) = 2. 14, P= .022). Concerning agentive passives with fifty two percent correct responses (t(20)= . 97, P= .33) and object cleft constructions with forty one percent correct responses (t(20)= . 83, P=. 45), he had at chance performance. Yet, as with both types of psychological constructions he had below chance performance with thirty one percent correct responses (t (20) = 2.00, P=. 166) in subject experiencer structures and twenty two percent correct responses (t (20) = 2, 26, P=. 180) in object experiencer constructions. As for subject four (GL), again similar pattern was observed with subjects performing above chance at both subject agent with ninety one percent correct responses (t (20) = 3. 25, P=.0005) and subject cleft with eighty six percent correct responses (t (20) = 3. 18, P=. 0005). Although this subject had below chance performance in object cleft constructions (t (20) = 1. 30, P=. 250), in agentive passive constructions, his performance was at chance (t (20) =. 82, P=. 45). However, regarding both types of psychological predicate constructions, his performance was significantly below chance. That is, in subject experiencer constructions, he had twenty four percent correct responses (t (20) = -1. 46, p=. 824) and in object experience constructions, he had just nineteen percent correct responses (t (20) = - 1. 80, P=. 838).

In contrast with agrammatic Broca’s patients, regarding control group, one-way repeated measures ANOVA for the sentence types demonstrated no main effect of sentence type (F, 39) = . 87, P= 43).
As a matter of fact, they performed very well on all sentence types of subject agentive, agentive passive, object clefts, subject experiencer and object experiencer types with 98%, 96%, 93%, 94% and 90% correct responses respectively.

3. 2. Grammaticality Judgment Task

Subject 1 (MS) performed above chance in all constructions including subject agent with ninety six percent correct responses ($t(20) = 3.87, P= .005$), subject cleft with ninety two percent correct responses ($t(20) = 3.3.171, P=.005$), agentive passives with eighty eight percent correct responses ($t(20)= 3.26, P=.005$), object clefts with ninety one percent correct responses ($t(20)= 3.26, P=.005$), subject experiencer with eighty five percent correct responses ($t(20)= 2.78, P=.005$) and ultimately object experiencer with seventy five percent correct responses ($t(20)= 1.817, P= .005$).

Also, subject two (BR) performed above chance in all syntactic constructions with ninety one percent correct responses in subject agentive ($t(20)= 3.78; P= .005$), eighty nine percent correct responses in subject cleft ($t(20) = 3.68, P= .005$), agentive passives with eighty five percent correct responses ($t(20)= 2.87, P=.005$), object clefts with ninety three percent correct responses ($t(20)= 3.27$), subject experiencer with eighty percent correct responses ($t(20)= 2.71, P= .005$) and ultimately object experiencer with seventy one percent correct responses ($t(20)= 1.808, P= .005$).

Subject three (SP) had an intact performance on subject agent with ninety eight percent correct responses ($t(20)= 4.21, P= .005$), subject cleft with ninety five percent correct responses ($t(20) = 3.73, P= .005$), agentive passives with eighty nine percent correct responses ($t(t(20)= 2.92, P=.005$), object clefts with eighty five percent correct responses ($t(20)= 3.15), subject experiencer with eighty eight percent correct responses ($t(20)= 2.79, P=.005$) and ultimately object experiencer with seventy one percent correct responses, t(20)= 1.84, P=.005). Subject four (GL) performed above chance in subject agent with ninety two percent correct responses ($t(20)= 3.82, P=.005$), in subject clefts with eighty nine percent correct responses ($t(20)= 3.168, P=.005$), in agentive passives with eighty two percent correct responses ($t(20)= 3.166, P=.005$), in object cleft constructions with eighty seven
percent correct responses ($t(20) = 3.22$, $P = .005$), in subject experiencer constructions with seventy six percent correct responses ($t(20) = 1.88$, $P = .005$) and ultimately in object experiencer constructions with sixty eight percent correct responses ($t(20) = 1.79$, $P = .005$).

4. Discussion

As observed, while our patients performed above chance at both subject agentive and subject cleft constructions, in syntactic comprehension task, they performed very poorly on some constructions including agentive passives, object clefts, subject experiencer and object experiencer constructions. This inconsistency in subjects’ performance could be accounted in different ways.

First, it seems that in pro with the predictions of mapping hypothesis, in constructions where syntactic heuristics is observed, subjects would perform above chance (Berndt, Mitchum & Wayland, 1997; Kolk & Weijts, 1996), explaining their good performance in subject agentive and subject cleft constructions. In other words, these two structures should be regarded as canonical syntactic forms because in both the semantic role of agent was assigned or mapped to the syntactic role of subject facilitating subjects’ performance. In contrast, in all remaining constructions including subject experiencer, object experiencer, object cleft and agentive passive constructions, this canonicity impact was not observed in that the syntactic role of subject or thematic role hierarchy was violated culminating in subjects’ poor performance in syntactic comprehension task. In this respect, our results are in pro with those of other researchers who attributed Broca’s aphasics’ poor performance in syntactic comprehension task to the disruption in mapping capability of patients. Henceforth, our subjects’ performance could be explained well according to the predictions and framework of mapping hypothesis. For example, in object cleft constructions, the hierarchical syntactic-semantic taxonomy is violated in that it is the semantic role of object rather than subject which occupies the initial position of the sentence demonstrating the influential role of syntactic heuristics in subjects’ interpretations. Also, the semantic role of theme (patient) took over that of agent. As a matter of fact, as mentioned earlier, an important note regarding unique syntactic structure of Persian is that a pronominal clitic
could be attached to the verb bearing the same semantic role. Although, this property should have facilitated our Broca’s patients’ performance, surprisingly it did not have any influence on their comprehensive abilities. However, in agentive passive structures, again the linear concatenation of syntactic roles is disrupted in that it is the object occupying the initial subject position. Moreover, this time, our noun phrase would bear the semantic role of theme. Ultimately, psychological constructions violate canonical syntactic structures in that whether they assign the semantic role of experience to the subject (subject experiencer) or they attribute the semantic role of experiencer to the object (object experiencer). As Pinango (2000) asserted while these two predicates are psycholinguistically interesting, the latter is more attractive in that it places less-agent like semantic role (theme) in the subject position. In other words, the more remote semantic category in the canonical semantic hierarchy is promoted to the subject position, the more problems Broca’s patients would have comprehending the sentence. As a matter of fact, Broca’s patients’ poor comprehension in syntactically complex structures has already been corroborated in both processing (Friederici & Frazier 1992; Kolk, 1995; Wulfec, 1987; Wulfec, Bates & Capasso, 1990) as well as representational account of agrammatism (Bradley, Garrett & Zurif, 1980; Caplan, Hildebrandt & Marshal, 1988; Caramaza & Zurif, 1976).

Within the light of this research it should be highlighted that it is not merely the number of predicates in a sentence that would make it more complex but also the type of predicates (psychological & agentive) would play an outstanding role in its complexity. Moreover, subjects’ poor performance in the aforementioned structures demonstrate that semantic hierarchy violations and heuristics all by all could be envisaged as potential culprits for subjects’ poor performance.

Yet, regarding grammaticality judgment task as reported, all our patients performed above chance demonstrating their rather intact syntactic abilities. This finding is in pro with previous researches which already verified Broca’s patients’ rather intact performance in the aforementioned task (Linebarger et al., 1983; Linebarger, 1995; Wulfec et al., 1991) yet on par with other researches (Kolk & Weijts, 1996; Raghibdoust, 1999) emphasizing subjects’ poor performance on the task.
As a matter of fact, the pattern of dissociation in subjects’ performance- their intact performance on grammaticality judgment task Vs their poor performance on syntactic comprehension task- could be explained within the framework of mapping hypothesis more conveniently.

First, it seems at the first level of syntactic parsing, agrammatics perform very well justifying their rather intact performance on the grammaticality judgment task; however, it is at the second stage that their semantic representation problems emerge in that they are incapable of utilizing stored syntactic information to assign thematic roles to the syntactic categories explaining their poor performance on syntactic comprehension task (Linebarger, 1995). Henceforth, agrammatics’ difficulty lies in the specific designated deficit impeding them to assign thematic roles properly to their appropriate positions in the syntactic nodes (Ingram, 2007).

As our ultimate comment, it should be emphasized that in order to detect the possible patterns of syntactic comprehension in agrammatics, more comprehensive researches with a much larger sample in diverse languages utilizing diverse tasks and methodologies should be conducted. Moreover, socio-demographic as well as psychological characteristics of patients should also be constrained. Meeting all these variables in various researches, we could more scientifically and systematically underpin the nature of their syntactic knowledge.

This dissociation between our subjects’ performance on grammaticality judgment and syntactic comprehension tasks has already been attested in diverse studies (Wulfeck, 1987; Wulfeck et al., 1991). As a matter of fact, this incongruence between subjects’ performance in diverse tasks could be attributed to the recruitment of distinctive processing mechanisms activated at different levels of linguistic processing (Grodzinsky, 1983; Wulfeck, 1987).


