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Research Paper: The Significance of Semantic Hierarchy and Canonicity in Sentence Comprehension: A Study of Persian-speaking Patients With Alzheimer's Disease

Omid Azad[1*]

1. Department of Linguistics, Faculty of Humanities, University of Gonabad, Gonabad, Khorasan Razavi, Iran.

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ABSTRACT

Introduction: A lot of research in diverse languages has tried to scrutinize the impact of canonicity upon the performance of patients with Alzheimer's disease. Regarding the gap in the Persian setting, this study tried to delve into the nature of this deficit in patients with Alzheimer.

Materials and Methods: This is a case series study, and our subjects included 2 Persian-speaking monolingual patients with Alzheimer and 5 healthy elderly individuals matched with each other according to parameters like educational degree, vernacular tongue, and homeland. The categories to be tested included subject agentive, subject experiencer, object experiencer, and object cleft constructions.

Results: The results of the sentence completion task demonstrated that problems would emerge when patients with Alzheimer try to comprehend the syntactic structures belonged to 2, 3, and 4 categories.

Conclusion: Our findings would demonstrate that patients with Alzheimer have many challenges when trying to map syntactic representation onto semantic realization. This type of deficit escalates when patients attempt to assign thematic roles to psychological predicates. As for the clinical implication of the research, it was recommended that the type of structures utilized by neuropsychiatrists for the communicative purpose be chosen from utterances that are in line with the mapping strategy.

Keywords: Alzheimer's disease, Psychological tests, Language tests

[*] **Corresponding Author:**
Omid Azad, PhD.
Address: *Department of Linguistics, Faculty of Humanities, University of Gonabad, Gonabad, Khorasan Razavi, Iran.*
Tel: *+98 (911) 3203468*
E-mail: *oazad62@yahoo.com*

1. Introduction

Alzheimer disease is one of the most prevalent types of cortical dementia progressively emerging after the age of 65. In this disease, cortical atrophy of the brain, particularly in the frontal, temporal, and parietal lobes, is observed. The third ventricle of the brain is enlarged [1], and the presence of extracellular amyloid, plaques, and intracellular tau encompassing neurofibrillary tangles in the brain is not an odd phenomenon [2]. The linguistic deficit is among the initial symptoms of dementia deteriorating as the disease progresses [3-6]. Moreover, the communicative capability of the patient would be disrupted in the early stage in a way that the patient would lose her ability to start communication and confront challenges in the comprehension of satire, irony, and indirect propositions [7, 8]. Also, at the syntactic level, the patient starts producing disconnected expressions, and the production of spontaneous utterances is regarded as the compensatory mechanism utilized by the patient. On the other hand, phonetic and semantic paraphasia, as well as neologism, are observed in patients [9].

Although the semantic deficit is among the symptoms of the first stage of the disease, the syntactic deficit is sometimes observed, too [9-13]. Some research concluded that patients' problems in sentential processing were due to the syntactic processing malfunction. For example, Small et al. researched 2000 subjects and asserted that the canonicity violation of the sentence was just due to the syntactic movement, not the intrinsic property of the predicate [12]. The same conclusion was corroborated by other researchers demonstrating that syntactic movement would play a crucial role in the violation of canonicity relations [14, 15]. Marková et al. asserted that syntactic complexity or deficit in the working memory or short-term memory do not play a significant role in the emergence of deficit in patients. However, patients' problems were related to the number of semantic prepositions employed in the sentence [16].

On the contrary, the Kempler et al. and Liu et al. results demonstrated that sentential comprehension deficit could be attributed to the working memory malfunction. The probable impact that syntactic processing might have been affected was not confirmed [17, 18]. In other studies, based on the similar performance of early and middle stage patients with Alzheimer in the comprehension of active and passive constructions, it was concluded that syntactic deficit is not responsible for patients' comprehension deficit yet damage to the executive system, as one of the most fundamental sections, plays a crucial role in patients' inappropriate comprehensive behavior [11, 19]. Meanwhile, Manouilidou et al. reported that the recruitment of some types of psychological predicates offended mapping relations between syntactic and semantic roles [20]. This general finding corroborated the particular semantic deficit of Alzheimer patients more carefully in the processing of semantic roles related to psychological predicates.

As of now, a lot of research studies in diverse languages have attempted to delve into the issue of the impact of canonicity of syntactic and semantic relations upon the performance of patients with Alzheimer and, more specifically, to scrutinize the nature of the verb deficit in these patients [16-25]. Yet, the nature of their linguistic deficit has remained unanswered. Following the related literature, this study attempted to scrutinize the special impact that canonicity might affect the performance of patients with Alzheimer in the Persian setting. Notably, we concentrated on the way thematic roles were assigned in four types of constructions. Henceforth, this study attempted to detect whether there is a comprehension deficit due to the violation of the mapping strategy between syntactic and semantic roles. Particularly, our research aimed at testifying the impact of the canonicity relations in the processing strategy of the patients when trying to comprehend simple canonical as well as complex syntactic structures.

According to the mainstream attitude in the generative approach, different aspects of syntax are deemed as the projection of lexical properties of words [21]. In Table 1, diverse thematic roles introduced by various researchers could be observed.

An important point worth mentioning about Table 1 is that despite the existence of numerous thematic roles, this diversity mainly relates to the thematic roles occupying the post-agent position. So, when an agent exists in a sentence, it would occupy the subject position, and when the agent is absent, two scenarios might occur. The first scenario takes place when the argument occurring after the agent in the canonical hierarchy fills the subject position, violating the canonical hierarchy of syntactic and semantic roles. This situation could be manifested in subject experiencer constructions. The second scenario takes place when the symmetric relation between the syntactic and semantic roles is violated. It is the theme that then occupies the initial position of the sentence in the hierarchy. For instance, the sentence "Ali feared Mina" represents the first scenario, and "Mehdi's behavior satisfied his dad" and "It was Mohammad who Ali

followed" exemplifies the second scenario. Concerning psychological predicates, it is noteworthy to mention that as stated by Manouilidou et al. in 2009 [20], a minimal pair of psychological predicates endowed with the same propositional content yet possessing different thematic role realization could be detected. For instance, the minimal pair of fear/frighten possesses the same propositional content of "fear" yet different from the viewpoint of a person affected by these emotional and psychological states. Accordingly, "Ali feared Reza" could be contrasted with "Reza frightened Ali".

In view of the above and because of the existing gap in the Persian setting, this study aimed to analyze the performance of Alzheimer patients in parsing specific syntactically complex structures disrupting canonicity and hierarchy orders and to compare their performance with that of healthy control participants. The importance of this study was that it aimed at scrutinizing the impact of canonicity and hierarchy in a language with some dramatically different typological characteristics. In other words, Persian as scrambling and floating language are endowed with some unique syntactic as well as semantic properties. Its investigation could shed light on the role of canonicity relations in the performance of Alzheimer patients. Taken all these considerations, we tried to investigate whether early-stage Alzheimer patients and healthy individuals perform equally in Persian syntactic structures disrupting canonicity/hierarchy relations. More specifically, and as our second question, we would scrutinize and determine whether parsing syntactically complex systems composed of psychological predicates differed among the participants of two groups of Alzheimer patients and healthy controls.

2. Materials and Methods

Study participants

In this research, we utilized a type of homogeneous purposive sampling to recruit our participants. So, our participants were selected according to the inclusion/exclusion criteria. It is worth mentioning that by conducting neuroimaging, laboratory, and neuroimaging tests, the neurologist had already classified the participants as mild Alzheimer patients. Also, no previous history of stroke, traumatic brain injury, and other neuropsychological diseases were reported. All of them were monolingual, with Persian being their native language.

Furthermore, the Persian version of the Western Aphasia Battery was used to neutralize any possibility of the patient's affliction with Aphasia [26]. Being a bedside type of the Western Aphasia Battery, this test could be considered a quick screening test for Persian-speaking Aphasia patients. This test's components include automatic speech, speech fluency, auditory comprehension, consecutive ordering, repletion, and naming. The maximum score of each subtest (component) is 10, and the patients' performance is calculated based on their raw scores to obtain a percentile aphasia quotient. Relying upon the results, we could determine the severity of the disease. Thus, those obtaining nine or more on the Persian version of the Western Aphasia Battery were chosen. The healthy elderly controls were also Persian monolinguals exhibiting no history of traumatic brain injury, neuropsychiatric or neuropsychological diseases. Moreover, they were not addicted to alcohol or drug of any kind. Those participants suffering from auditory or visual impairments were also excluded from the study.

Table 1. Thematic role hierarchy order extracted from Manouilidou et al. [20]

Authors	Diverse Thematic Roles
Fillmore (1968)	Theme<instrument<agent
Jackendoff (1972)	Theme<location<source<goal<agent
Givon (1984)	Instrument<location<patient<beneficiary<agent
Baker (1989)	Location/goal<patient<theme<instrument<agent
Grimshaw (1990)	Theme<location/source/goal<experiencer<agent
Van Valin (1990)	Patient<theme<location<experiencer<stimulus<agent
Jackendoff (1990)	Location/source/goal<theme<beneficiary/patient<agent

Table 2. Demographic information of the patients

Patients	H. G	F. B
Age (y)	86	80
Education	Bachelor of Arts	BA
Occupation	Retired employee	Retired employee
Disease duration	3 years	4 years
Type of disease	Alzheimer	Alzheimer
Drugs	Exelon, Citalopram, Lorazepam	Rivastigmine, Exelon
Lesion sites	Periventricular	Periventricular
Vernacular tongue	Persian	Persian

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To evaluate the participants' cognitive capability, the validated Persian version of the Clinical Dementia Rating (CDR) was employed by a geriatric specialist. CDR, as a reliable tool, could be well administered to designate the severity of Alzheimer's disease [27, 28]. Asking 75 questions in 6 different domains of memory, the orientation of time and space, problem-solving, judgment, social work, home, amusements, and ultimately, personal care, the specialist could more reliably score each area. Each domain's score ranged from 0 to 3. That is 0 for no impairment, 0.5 for questionable, 1 for mild, 2 for moderate, and 3 for severe impairments.

Consequently, in this study, those Alzheimer patients standing at the mild stage were chosen (CDR score=0.5). On the other hand, those healthy elderly controls endowed with standard cognitive capability (CDR score=0) were ultimately selected. Ultimately 2 early-stage Alzheimer patients and 5 healthy individuals meeting the abovementioned screening tools' criteria were selected for the final analysis.

In our research, we recruited one group of Alzheimer patients and one control group. The age range of Alzheimer patients was 80 to 87 years, with the Mean±SD age of 83±3 years all belonging to the early stage category. In Table 2, the patients' demographic information was presented. Our control group comprised 5 healthy elderly individuals with the age range of 74 to 85 years. These people who lived in Ekbatan District in Tehran City, Iran, approximately matched with Alzheimer patients, according to the criteria of age and education.

Study instruments

The diagnostic tool for evaluating Alzheimer patients' ability to process psychological predicates and detect the nature of verb deficit was the sentence completion task. Administered to 135 Persian-speaking individuals (76 to 87 years old), the syntactic comprehension task was normalized. Some of the essential psychometric characteristics of the syntactic task included the validity of the syntactic comprehension task (0.83) and the criterion validity (0.71). Furthermore, the task's internal consistency was 0.87, while the measurement index regarding time stability was 0.85. Each syntactic structure to be tested was composed of 14 sentential stimuli. Henceforth, a total of 42 stimuli were selected. The distribution of the stimuli was carried out randomly. In type 1 structure, the subject represented the semantic role of agent/Baqban alafha ra kand/. In type 2 structure, the semantic role of experiencer occupied the syntactic role of subject/ Ahmad az Mehdi tarsid/. In structure type 3, the subject represented the semantic role of theme, and the object represented the semantic role of experiencer /raftare Mehdi pedarash ra khoshnud kard/. In structure type 4, a kind of reversed thematic role could be detected. That is, the patient or theme was moved to the initial subject-agent default position of the sentence, for example, /in Mehdi bud ke Mina donbalesh kard.

Moreover, we assessed our subjects' performance conducting the forced-choice task. In doing so, the first choice denoted the correct answer, the second choice, i.e., the distractor choice, represented the reversed thematic roles utilized in type two and three structures. The third choice represented the alternative whose selection made the sentence ill-formed. Ultimately, the last option

Table 3. The performance of the control group

The Correct Responses of The Control Group	The Verb Encompassing Subject Agent Role Type (1)	The Verb Encompassing Subject Experiencer Role Type (2)	The Verb Encompassing Object Experiencer Role Type (3)	Object Clefts Type (4)
Mean of correct responses	13	12	11	10
Percentage of correct responses and standard deviation (Mean±SD)	98.6±1.400%	94.2±5.800%	89.6±1.400%	71.42±1.350%

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denoted the alternative, whose selection made the sentence grammatically as well as semantically ill-formed. The distribution of choices was conducted in a randomized manner. The task was carried out in a special room of the Iranian Alzheimer's Association Complex. The sheet distribution was performed separately. The time needed to perform the task was 30 minutes. Concerning the control group, the task was performed in Khane Salamat, belonging to Tehran municipality. Concerning Alzheimer patients, because of their poor eyesight, all sheets were distributed separately, and all the questions were read for them. All the subjects were exposed to a sentence in which, in the verbal position, there was a blank /Pedare Mehdi az ʔu ……/. Afterward, the subjects were required to fill in the blank with one of the verbal alternatives. Before the task started, a warm-up session with two stimuli was performed, and all the subjects were told that they could ask any type of questions related to the task.

Furthermore, to investigate the impact of canonicity on our subjects' comprehension of a syntactically complex structure, object clefts, a figurine-act task was designed. Conducted on 120 matched number of Persian-speaking 76 to 87 years old individuals, the figurine act task was normalized. Some of the essential psychometric characteristics of the figurine-act task included the validity (0.91) of the figurine-act task and its criterion validity (0.78). Further, the internal consistency of the task was 0.75, while the measurement index regarding time stability was 0.90. Henceforth, a total of 14 stimuli were selected based on which our participants were required to demonstrate their understanding of semantic roles throughout the manipulation of some toys referring to diverse entities. For example, concerning the sentence of /in Mehdi bud ke Mina donbalesh kard/, the participant was required to manipulate the figurine toy of the woman before the woman toy. In other words, if she were capable of manipulating and organizing the toys in the reversed order, she would perform inappropriately as an essential signal that she had not grasped semantic roles.

3. Results

Understanding the nature of syntactic deficit in three structures entails analyzing subjects' performance in

Table 4. The performance of the experimental group

Alzheimer' Patients	Correct Responses	The Verb Encompassing Subject Agent Role Type (1)	The Verb Encompassing Subject Experiencer Type (2)	The Verb Encompassing Object Experiencer Role Type (3)	Object Clefts Type (4)
H. G	Number of correct responses	12	9	6	6
	Correct response percentage	86%	68%	42.85%	42.85%
F. B	Number of correct responses	13	10	5	7
	Correct response percentage	93%	75%	35.71%	46%
-	Mean correct responses of patients	12.5	9.5	7.5	6.5
	Mean percentage of correct responses	89.28%	67.85%	39.28%	46.42%

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Table 5. The number of patients' errors in each structure

Variables	Errors	Reverse Thematic Role	Semantically Anomalous	Syntactically Anomalous	Total
Subject agent structure (type 1)	Number of errors of H. G	1	0	0	
	Number of errors of F. B	1	0	1	
	Number of errors	2	0	1	3
	Mean percentage of errors	7.14%	0	3.57%	10.71%
Subject experiencer structure (type 2)	number of errors by H. G	3	1	1	
	Number of errors by F. B	2	1	1	
	Number of errors	5	2	2	9
	Mean percentage of errors	17.85%	7.14%	7.14%	32.13%
Object-experiencer (type 3)	Number of errors by H. G	5	1	2	
	Number of errors by F. B	6	1	2	
	Number of errors	11	2	4	17
	Mean percentage of errors	39.28%	7.14%	14.28%	60.71%

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these structures. In Table 3, the mean and percentage of correct responses of these groups were presented.

As Table 3 presents, the control group had significantly above chance performance in all constructions, including the subject agent ($t=4.987>2.17$, $P=0<0.05$), object experiencer ($t=3.787>3.27$, $P=0<0.05$), subject agent ($t=5.876>2.25$, $P=0<0.005$), and object cleft constructions ($t=4.998>2.17$, $P=0<0.005$). In Table 4, the performance of Alzheimer patients in each predicate type was presented.

As Table 4 demonstrates, although the Alzheimer group had above chance performance in the subject agent ($t=4.187>2.17$, $P=0<0.005$) and subject experiencer constructions ($t=3.286>2.47$, $P=0<0.005$), they demonstrated below chance performance in the object experiencer ($t=1.32<2.14$, $P=0.0817$), and object cleft constructions ($t=1.42<2.27$, $P=0.000$).

Moreover, a comparative analysis of the results of both groups in the different types of constructions corroborated that while there was not a significant difference between Alzheimer groups' performance and the performance of healthy controls in the subject agent (type 1) ($P=0.865>0.05$) and subject experiencer (type 2) ($P=0.751>0.05$), the two groups' performance in the object-experiencer constructions (type 3) ($P=0.0017<0.005$) and object clefts (type 4) ($P=0.0026<0.005$) were significantly different. Ultimately, to detect the nature of Alzheimer patients' deficit concerning the comprehension of psychological predicates, the type of error each patient committed in the structures of type 1, 2, and 3 were taken into account. In Table 5, the number of patients' errors in each abovementioned syntactic structures was presented.

As Table 5 shows, the average percentage of errors committed by our participants in the reversed thematic role alternative was significantly higher than their mean percentage of errors in the syntactically and semantically anomalous alternatives ($P=0.000<0.05$).

4. Discussion

In the current study, we tried to scrutinize and compare the performance of patients with Alzheimer and their healthy counterparts in the processing of 4 types of syntactic structures and their ability to assign thematic roles. The research results corroborated that Alzheimer patients would suffer more challenges in comprehending those structures whose argument realizations are not in line with the thematic role hierarchy. Proof to this claim comes from our patients' outstanding challenges in the parsing of type 3 (object experiencer) and type 4 (object cleft) constructions. Concerning the control group, it should be asserted that they were endowed with an intact performance in all structures, including the subject agent

(type 1), subject experiencer (type 2), object experiencer (type 3), and object cleft (type 4) constructions.

Moreover, the inter-group comparison showed that although the performance of the control group in the subject agent (type one 1) and subject experiencer (type 2) structures was approximately the same as Alzheimer patients' performance, these two group's performance in type 3 (object experiencer) and 4 (object cleft) structures was significantly different. The observed difference between Alzheimer patients and healthy controls in the parsing of object experiencer and object cleft constructions could be attributed to the former group's failure to map semantic roles onto syntactic roles accurately once the thematic role hierarchy/ordering is disrupted. So, as demonstrated in Table 1, regarding subject agent construction, as both syntactic/semantic role mapping and hierarchy are observed, our patients did not divulge in any problems. Consequently, in both groups of Alzheimer patients and healthy controls, the subject agent construction (type 1) was the most comfortable type to interpret. As with respect to the subject experiencer construction, notwithstanding, the syntactic/semantic mapping is violated, the semantic role hierarchy/ordering is still preserved, facilitating its parsing for Alzheimer patients.

Furthermore, to demonstrate the nature of the verb deficit in Alzheimer patients, subjects' performance in the three types of structures was compared. As observed in Table 5, although the analysis of the errors committed by the subjects indicated they exhibited more errors in the type 1 structure (subject agent), in type 2 (subject experiencer) and 3 (object experiencer) structures, the majority of errors belonged to the reversed thematic roles. The interpretation of this finding is that our patients can understand the core meaning of psychological predicates because they rarely chose syntactically and semantically anomalous sentences. Consequently, our patients did not suffer any problems comprehending predicates, but their particular problem was related to the thematic role assignment. Particularly, whenever the inappropriate thematic role assignment creates non-canonical thematic ordering, their problems exacerbate. Proof of this claim is our participants' similarly poor performance in object cleft constructions. Thus, when syntactic constituents are moved from their canonical positions to atypical positions, as observed in object clefts, the facilitative effect of canonicity would collapse, paving the way for participants' poor performance [18, 20]. Generally, our findings are consistent with previous research results highlighting the appropriate performance of patients in the comprehension of agent type predicates and emphasizing English-speaking Alzheimer patients' problems in the comprehension of object experiencer psychological predicates [17-25].

However, in contrast with previous research results in the other languages [20, 21], our Alzheimer group performed very well in the parsing of subject experiencer constructions. The crucial explanation of this observation in the Persian setting lies in the predominant role of thematic mapping in the comprehension of diverse syntactic structures. In other words, even though in the subject experiencer construction, the hierarchy of syntactic and semantic roles are violated, as shown in Table 1 of the introduction, this construction still commits to the mapping principle hence culminating in fewer challenges for our patients. The second argumentation could be assigned to the different typological characteristics of Persian, as stated in the introduction. Enjoying unique semantic and syntactic features, Persian constructions are represented differently from other Indo-European languages. Henceforth, it is sufficient for the Persian speakers to parse diverse constructions in as much as the ordering or hierarchy of syntactic/semantic roles are not violated. As the number of propositions employed in these four types of syntactic structures was similar, those accounts [16] regarding the number of semantic propositions responsible for the patients' poor performance should be discarded.

5. Conclusion

The bottom line of this research is that Alzheimer patients' inability to process psychological predicates on the one hand and their challenges to appropriately map syntactic and semantic representations of all structures except for the type 1 indicate the paramount role of thematic hierarchy in the argument realization. As within the clinical perspective, it could be recommended that the required communicative stimuli be selected from those structures in which the mapping rule is observed. In other words, speech therapists and neuropsychologists should avoid syntactic structures violating thematic hierarchy. Because, as it was divulged in this research, the processing of these types of structures would be challenging for patients suffering from brain atrophy, more specifically Alzheimer patients. In this regard, parsing psychological predicates and utterances violating the canonicity principle would be more problematic for these patients. Upon these observations and considering how significant and essential utilizing such a speech strategy might be in improving the quality of life of neuropsychiatric diseases like Alzheimer patients via easing their mutual communi-

cations with healthy individuals, conducting these types of studies could be very informative.

However, an important caveat should be considered here. Our research was performed with small sample size and specific method. Nevertheless, to gain more insight into the importance of canonical semantic roles and hierarchy/ordering, it is necessary to conduct more research in diverse languages with different typological characteristics and utilizing various methodologies. At that moment, we could more frankly judge to what extent thematic hierarchy could affect the comprehension of those patients who have Alzheimer's disease.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles were considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them.

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Authors' contributions

The author conducted all sections of the research.

Conflict of interest

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