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Semantic anomaly judgement in individuals with probable Alzheimer's disease

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Abstract

Background—Research has shown that individuals with probable Alzheimer's disease (PrAD) show impaired semantic knowledge of nouns. More specifically, while they demonstrate preserved superordinate category information, information regarding specific semantic attributes associated with subordinates appears to be disrupted. Results of some recent studies suggest that PrAD participants may also be impaired in processing semantic information associated with verbs.

Aims—Provided that a parallel exists between PrAD participants' noun and verb impairment, it is plausible that the semantic deficits observed in the breakdown of their noun lexicon may also exist in their knowledge of verb-related information. This experiment examined PrAD participants' knowledge of the semantic restrictions associated with the complements of verbs.

Methods & Procedures—Fourteen PrAD participants were asked to judge the semantic plausibility of 44 auditorily presented sentences. To examine their knowledge of the selection restriction of verbs, each verb was paired with two plausible complements that fully met the restriction, an implausible complement that violated the specific attributes required but belonged to the correct semantic category, and an implausible complement that violated the semantic category requirement.

Outcomes & Results—Results showed that PrAD participants' errors were primarily on anomalous sentences that contained implausible complements that belonged to the correct semantic category.

Conclusions—This finding confirms our hypothesis and suggests that a parallel pattern exists in PrAD participants' breakdown in noun and verb knowledge.

Research has shown that individuals with probable Alzheimer's disease (PrAD)[1] show impaired semantic knowledge about nouns (e.g., Chan, Butters, & Salmon, 1997;Hodges, Salmon, & Butters, 1991,1992;Martin & Fedio, 1983;Monsch et al., 1994;Smith, Murdoch, & Chenery, 1989). Despite their noun impairments, however, there is substantial evidence indicating the preservation of superordinate category information in individuals with Alzheimer's disease (AD): they often provide superordinate category names instead of specific exemplar labels in naming and category fluency tasks (e.g., Hodges et al.,

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[1]This term refers to individuals with dementia in whom all other causes of dementia, such as vascular dementia, infectious diseases, psychiatric disorders (e.g., primary depression or psychosis), encephalopathy, or other neurological conditions that may have affected cognitive functioning, are explicitly ruled out, per NINCDS-ADRDA criteria (McKhann et al., 1984).

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1991;Martin & Fedio, 1983), show preserved superordinate knowledge on sorting and definition tasks (Hodges et al., 1991), and answer probe questions concerning superordinate category with high accuracy (e.g., Chertkow, Bub, & Seidenberg, 1989). There is equally compelling evidence suggesting that information regarding the specific semantic attributes associated with a concept has been lost or disrupted: AD patients tend to make many coordinate errors (i.e., the responses from the same semantic category as the target, such as *lettuce* for *asparagus*) on naming tasks (Bayles & Tomoeda, 1983), have difficulties ranking the semantic attributes associated with concepts (e.g., Grober, Buschke, Kawas, & Fuld, 1985), and demonstrate difficulties in answering probe questions regarding perceptual and functional attributes of an object (e.g., Chertkow et al., 1989).

These patterns of performance suggest that at least some AD patients' semantic impairment is characterised by the progressive degradation or loss of specific, detailed semantic features associated with a concept, while category information is often preserved. Accordingly, some researchers have described AD patients' semantic impairment as showing a "bottom-up" breakdown pattern, with accompanying difficulty in differentiating meaning between within-category items, because they have an incomplete set of semantic features associated with individual exemplars (Hodges, Salmon, & Butters, 1992; Martin & Fedio, 1983; Smith et al., 1989).

It has shown that PrAD participants also have difficulties in processing the semantic information associated with verbs (e.g., Grossman, Mickanin, Onishi, & Hughes, 1996; Grossman, Mickanin, Onishi, Robinson, & D'Esposito, 1997; Grossman, Mickanin, Robinson, & D'Esposito, 1996; Kim & Thompson, in press). For example, Grossman et al. (1997) examined 16 PrAD participants' acquisition and mental representation of a novel verb ("wamble", which referred to the act of an animate entity returning to its home as in *The bees wamble to their hive.*) and their knowledge of known verbs, in order to evaluate the semantic and syntactic processing of verbs in these patients. PrAD participants' knowledge of the novel and known verbs was tested by sentence grammaticality judgement, picture identification, and thematic role judgement tasks. Violations of sentence grammaticality included that of the grammatical form class of the novel verb (e.g., *wamble* used as a noun instead of used as a verb, such as *Sally drives the wamble.*), that of the argument-taking properties (e.g., *The eagles wamble the nest.*), and that of the animacy of the agent (e.g., *Books wamble into the store.*). For the picture identification task, participants were asked whether the depicted scene correctly represented the meaning of the verb or not. Violations involved that of direction, goal, and nature of action associated with the target verb's meaning. For the thematic role judgement task, participants were required to judge whether the sentence was coherent or not. Incoherent sentences involved violations of the selection restrictions associated with the agent or the goal of the verb, or the direction of the motion. Selection restrictions refer to the semantic/pragmatic restrictions on the choice of expressions that can occupy a given sentence-position (e.g., the choice of a complement in the case of a verb), such as the restriction that the word *chairs* cannot occupy the subject position in the sentence *The _____ wambled to their table*, since a chair is an inanimate object that cannot return to its home.

Results showed that, compared to age- and education-matched healthy control participants, PrAD participants had more difficulties in learning the argument structure requirements of the novel verb. However, the PrAD participants did not show difficulties in learning the form class of the word, that is, learning that the novel word to which they were exposed as a verb and should be inserted in a verb slot. In addition, PrAD participants were poorer than control participants in learning the semantic aspects of the novel verb, in that they had difficulties in judging the violations of the restrictions on acceptable agents or paths

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associated with the verb. Grossman et al. also reported that some PrAD participants showed a similar deficit in understanding the selection restrictions associated with known verbs.

In a recent study, Kim and Thompson (in press) also found that semantic variables influence PrAD participants' use of verbs. Kim and Thompson examined 14 PrAD participants' retrieval of verbs associated with different amounts of semantic elaboration (i.e., semantically simple vs complex verbs such as *go* vs *run*). The decompositional view of verb representation adopted by theorists such as Jackendoff (1976, 1983) assumes that, at some level of semantic representation, rather than being indivisible units, verbs are composed of a number of primitive elements. For example, when the two verbs are decomposed, the representation for a more complex verb *run* naturally includes that of the simple verb *go* and further specifies the manner of the movement. Therefore, one could say that the verb *run* is semantically more complex than the verb *go.* Based on such distinctions, Kim and Thompson examined the influence of a verb's semantic complexity on verb retrieval in sentence completion and narrative tasks. Results showed that PrAD participants were generally better at retrieving semantically simple verbs than those with more elaborate semantic representations. Both healthy control participants and those with agrammatic aphasia showed a performance pattern opposite to that of PrAD participants, retrieving complex verbs better than simple verbs. These contrasting patterns of performance suggested that the reverse complexity effect observed in PrAD participants might result from the loss of semantic attributes associated with more complex verbs (i.e., verbs associated with more elaborate representations such as *scrub* in the pair *clean – scrub*), while the representation for simpler verbs might still be intact. This finding suggested that a "bottom-up" breakdown pattern may apply not only to PrAD participants' semantic knowledge of nouns but also to that of their verbs.

Building on earlier findings of Kim and Thompson (in press) and Grossman et al. (1997), this study was designed to examine PrAD participants' semantic knowledge of verbs by testing their performance on a semantic anomaly judgement task involving the violation of selection restrictions associated with verbs. As illustrated in the example given below, it is not usually the case that any expression, which belongs to the relevant category (e.g., noun class), can function as a complement of a particular verb. Rather, there are semantic and/or pragmatic restrictions on the choice of arguments that can co-occur with a predicate. Violation of the selection restriction associated with a verb's arguments makes sentences like (1)(c) and (1)(d) semantically incoherent or implausible as compared to (1)(a) and (1)(b).

(1)(a) The squirrel climbed up the tree.

(1)(b) The cat climbed up the tree.

(1)(c) The penguin climbed up the tree.

(1)(d) The chair climb up the tree.

In this example, the selection restriction on the arguments of the verb *climb* is that the agent-NP must be an animate entity that can grasp and pull itself up. The first implausible sentence (1)(c) contains an implausible agent *penguin,* which belongs to the same semantic category of animal as the plausible agents *squirrel* and *cat.* However, the sentence is anomalous, because, although a *penguin* has limbs, it cannot use them to either grasp or pull. The second type of violation (1)(d) is highly implausible because the agent *chair* is a piece of furniture, an inanimate object, which cannot climb a tree in any possible way. As illustrated in the example, in order to make a judgement on whether the noun complement in the sentence satisfies the selection restriction associated with the verb (i.e., semantic anomaly

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judgement), not only the appropriate semantic category of the complement but also the specific semantic features imposed on the noun complement need to be available.

Given the well-established breakdown pattern of PrAD participants' noun lexicon, if a parallel exists between their noun and verb impairment as postulated by Kim and Thompson (in press), it is plausible to hypothesise that their performance on a semantic anomaly judgement task such as the one described above may show the effect of superordinate category often observed in their noun impairment. For example, a PrAD participant may know that an animate noun belonging to the category of animal is required as an agent-NP for the verb *climb.* However, the more specific information that the agent should be able to grasp and pull itself up may not be available. In this case, he/she may quickly reject *chair* but accept *penguin* as a possible agent-NP of the sentence, since *penguin* satisfies the semantic category restriction. Therefore, this study aimed to test the hypothesis that PrAD participants may retain categorical information about the selection restriction associated with a given verb, but not the specific semantic attributes associated with the restriction via semantic anomaly judgement. A finding consistent with the hypothesis was expected to provide further evidence, although indirect, to Kim and Thompson's (in press) observation suggesting a "bottom-up" breakdown of the verb lexicon in PrAD.

METHOD

Participants

A total of 14 individuals with the diagnosis of probable Alzheimer's disease (PrAD) participated in the study. These individuals were recruited from the participant pool of the Clinical Core of the Northwestern Cognitive Neurology and Alzheimer's Disease Center and the Rush Alzheimer's Disease Center. All participants met NINCDS-ADRDA criteria (McKhann, Drachman, Folstein, Katzman, Price, & Stadian, 1984) for a primary diagnosis of probable Alzheimer's disease. All participants were native speakers of English with a minimum of 10 years of formal education. All passed a pure tone audiometric screening at 500, 1000, and 2000 Hz at 40 dB HL ANSI:1969, in at least one ear. All except one participant demonstrated visual acuity of at least 20/40 on the Snellen's chart. The participant who failed the Snellen test was able to describe pictures and name objects correctly.

Participants' demographic and selected neuropsychological data are presented in Table 1. Results of testing using the Mini-Mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975) indicated that ten participants were mildly impaired and four were severely impaired (mild: MMSE ≥ 18, severe: MMSE < 18) as classified based on the recommendation of Tombaugh and McIntyre (1992). Most participants evidenced impaired noun naming as shown by the results of the Boston Naming Test (BNT) (Kaplan, Goodglass, & Weintraub, 1983). Most participants were able to perceive gross visual distinctions as indicated by their performance on the CERAD Constructional Praxis test. All participants were community-dwelling at the time of testing.

Stimuli

A semantic anomaly judgement task was constructed to examine the ability to judge whether or not a sentence was semantically plausible, presumably based on whether a targeted noun complement in the sentence was acceptable. Originally, 15 verbs were selected in order to construct 60 sentences. Each verb was used four times, appearing twice in semantically plausible sentences, and twice in sentences that were implausible, due to violation of the selection restriction on the agent, theme, or goal-NP associated with the verb. The four sentences were created by taking a plausible sentence such as (2)(a) and replacing one of the

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arguments in each of the three following ways: with another plausible argument as in (2)(b), with an implausible argument that belonged to the same superordinate category as the original as in (2)(c), or with a highly implausible argument that belonged to an entirely different semantic category than the original as in (2)(d). Thus, there were an equal number of semantically plausible and anomalous sentences in the stimulus set, and the anomalous sentence set was equally subdivided into the sentences that met the category requirement of the associated selection restriction and those that did not. For example, the verb *knit* appeared four times, twice associated with a plausible theme and twice, associated with an implausible theme as in the following examples:

(2)(a) The mother knitted a *sweater*.

(2)(b) The mother knitted *a sock.*

(2)(c) #The mother knitted *blue jeans.*

(2)(d) #The mother knitted *a closet.*

The first implausible sentence (2)(c) contains an implausible theme *blue jeans*, which is a within-category exemplar. While *blue jeans* is a member of the same semantic category as *sweater* and *sock*, namely that of clothing, it is implausible to *knit blue jeans* because the selection restriction associated with the meaning of the verb *knit* constrains the theme of the action to be something a person can create with knitting needles. The second violation is highly implausible, in that the theme *closet* in (2)(d) is a piece of furniture, which a person cannot knit in any plausible manner. Thus, the semantic implausibility of the second type of violation is highly implausible and anomalous.

All of the sentences were tested with healthy pilot participants prior to our collecting data with the PrAD participants. A total of 10 healthy elderly participants (9 female and 1 male; mean age = 69.7 years; mean years of education = 15.9 years) were recruited from the participant pool of the Clinical Core of the Northwestern Cognitive Neurology and Alzheimer's Disease Center. All pilot participants scored 27 and above on MMSE and showed a negative history of disease or disorder that might have affected their cognitive and/or language function. Only those quartets of sentences that showed 100% accuracy in judgement by pilot participants were included in the stimulus set. This testing eliminated four verbs, resulting in a total of 44 sentences (22 plausible and 22 anomalous; 11 anomalous sentences with correct category and 11 anomalous sentences with category violation), employing 11 verbs. There were one 1-place verb, three 2-place verbs, and seven 3-place verbs. Most anomalous sentences were created by a theme violation. However, three of the verbs were associated with a violation of the agent and one contained a violation of its goal. A complete listing of sentence stimuli is found in the Appendix.

Procedures

The procedures described were in accordance with the guidelines of the Northwestern University Institutional Review Board. All sentence stimuli were recorded by a native English speaker (with standard American dialect) and presented auditorily. Before the task, the following instructions were read by the examiner: "You are going to listen to some sentences. I want you to tell me if each sentence makes sense or not." After listening to each sentence, the participant pointed to one of the two cards on which the word "plausible" and "implausible" respectively was written. A smiling (for plausible) and a frowning face (for implausible) were also depicted on the cards. Four practice items—two plausible and two implausible—were presented. Some PrAD participants preferred to give the response verbally rather than pointing to the cards. A participant was judged to demonstrate an adequate understanding of the task when he or she answered correctly for at least three of the four practice items. All participants met the criteria during the practice trials.

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Appropriate feedback on a participant's response was provided during the practice trials. No feedback on participants' response was provided during the test. When requested, the sentence was repeated up to two times by replaying the recording. Participants were given 10 seconds to respond. If a participant could not decide whether the sentence was plausible or not, the trial was scored as incorrect. All responses were scored as correct or incorrect by the examiner. An independent judge, a graduate student in communication sciences and disorders, scored participant responses on-line as correct vs incorrect for at least 30% of experimental sessions. Point-to-point agreement between the scores of the primary examiner and the independent judge was 100%.

RESULTS AND DISCUSSION

Results showed that the PrAD participants demonstrated a high level of accuracy across all sentences tested (M = 93.8%). However, analysis of performance on anomalous vs non-anomalous sentences revealed that PrAD participants made more errors judging the plausibility of anomalous sentences (% error = 9.4%) than non-anomalous sentences (% error = 2.9%), although this difference only approached significance using a Wilcoxon signed ranks test, T^+ (N = 10) = 46, p = .064. Further, when performance patterns were analysed by anomaly type (e.g., within-category vs other-category substitutions) as shown in Table 2, the PrAD participants made significantly more errors on anomalous sentences that involved within-category substitutions of noun arguments (such as judging #*The mother knitted blue jeans.* as plausible; % error = 8.8%) than on anomalous sentences that involved other-category substitutions (such as judging #*The mother knitted a closet.* as plausible; % error = 0.6%), T^+ (N = 10) = 55, p = .002. This effect was prominent in that 93.1% of all errors on anomalous sentences (27/29) were on sentences involving within-category substitutions of a noun argument. This suggests that the PrAD participants did not have as much difficulty detecting an implausible noun argument belonging to an illegitimate semantic category as they did in detecting the anomaly created by within-category substitutions. This was exactly the pattern predicted, based on the semantic category effect assumption.

To rule out any complexity effect due to the use of verbs with different argument structure and different types of semantic violations, we performed a series of pair-wise comparisons of accuracy, using the proportion of errors across verb types (1-, 2-, and 3-place verbs) and violation types (agent, goal, and theme). The Wilcoxon signed ranks statistic was used to determine if the participants consistently made errors on one stimulus type as compared to another. None of these comparisons was statistically significant (with p-values ranging from .23 to .84). Therefore, we concluded that there was no effect based on the linguistic complexity of the stimulus sentences.

The semantic category effect interpretation is based on the assumption that PrAD participants may retain the knowledge of the semantic category requirements of the NP associated with a verb (via selection restriction) while more specific information on the acceptable exemplars in the category may not be available. This would result in difficulty in judging whether a particular exemplar in the relevant category is a legitimate NP that satisfies the selection restriction associated with the target verb. For example, PrAD participants may know that the verb *knit* requires an item of clothing as its object-NP. Thus, they are likely to correctly judge the sentence, #*The mother knitted a closet.*, as anomalous. However, degradation or loss of semantic information associated with the verb *knit* may cause them to fail to recognise that *blue jeans* is not an acceptable exemplar, although it satisfies the semantic category requirements, and thus, incorrectly judge #*The mother knitted blue jeans as* plausible. The findings of the present study are consistent with the interpretation that complete semantic information associated with the selection restrictions

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holding between the verb and its arguments is not available to some PrAD participants whereas semantic category information is preserved.

While a breakdown in the semantic knowledge of nouns may contribute to some degree (given PrAD participants' well-known disruption of the noun lexicon), the loss of semantic features associated with verbs appears to influence PrAD participants' semantic anomaly judgement as well. This interpretation supports the results of Kim and Thompson (in press) who found that PrAD participants show difficulties retrieving verbs with more complex semantic representations than simpler representations in a sentence completion task. In a hierarchical model of the semantic representation of verbs in the tradition of a decompositional view of verb meaning (e.g., Jackendoff, 1976, 1983; Schank, 1973), simpler verbs could be compared to superordinate category words and more complex verbs to subordinate-level words. Therefore, the difficulties seen in the PrAD participants included in this study in retrieving complex verbs as compared to simpler verbs appeared to support the interpretation that category information is preserved but information regarding specific items within the category is not available.

While the present findings support a bottom-up breakdown of the verb lexicon in PrAD, one limitation of this study concerned the number of stimuli, which resulted from balancing our stimuli. Future research could increase the number of stimuli by focusing only on within-category anomalies. It would also be interesting to examine how normal participants rate the subtlety of within-category substitutions, both to control the stimuli and to investigate this effect more carefully. In addition, future research examining PrAD participants' knowledge of the semantic features of verbs, along with a naming task involving the same target verbs, may provide further evidence supporting the "bottom-up breakdown'' hypothesis. PrAD participants' knowledge of not only the target verbs but also noun complements used to develop questions should be examined in order to tease apart the effect of semantic impairments in the word categories studied.

CONCLUSION

The semantic category effect observed in this study, considered together with the results of Kim and Thompson (in press), suggest that individuals with PrAD evidence deficits concerned with the semantic features in their verb lexicon. It is interesting that nouns and verbs show parallel breakdowns in PrAD, in that category information and labels are better preserved while subordinate exemplar labels and associated information are often unavailable in both word categories. If nouns and verbs are hypothesised to be stored in the same semantic system, such parallel breakdown patterns may naturally be expected. However, it has been hypothesised by many that nouns and verbs are stored separately with respect to both the organisation of the lexical-semantic system (e.g., Caramazza & Hillis, 1991) and neuroanatomic substrate (e.g., Damasio & Tranel, 1993). The differences in their taxonomic organisation discussed by some (e.g., Huttenlocher & Lui, 1979) also seem to support such a distinction between nouns and verbs.

If nouns and verbs are not stored together, as suggested by many, one needs to postulate a mechanism that can explain the seemingly parallel breakdown in the noun and verb lexicons in the semantic system of PrAD participants. One possibility is that semantic systems or networks are organised hierarchically not only logically but also physiologically (or neuroanatomically). In other words, the hierarchical organisation of a semantic network may be served by hierarchically organised neural circuitry. Under such an assumption, the physiological progression of Alzheimer's disease may have a directly measurable impact on the network, showing the early loss of exemplar information across syntactic category (i.e., both nouns and verbs) and better preserved category information. This, then, will lead to the

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bottom-up breakdown pattern in both word categories. This explanation is speculative since the present study was not designed to study the neural organisation of the verb lexicon. Future research using a neural network approach (such as neural network lesion studies) might provide further insight into and support for the mechanism affecting such a breakdown pattern across word categories.

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APPENDIX. SENTENCE STIMULI USED IN SEMANTIC ANOMALY JUDGEMENT TASK

Violation of selection restrictions associated with theme-NP

1 fry

The man fried the hamburger.

The man fried the eggs.

#The man fried the salad.

#The man fried the trumpet.

2 pour

The father poured the water.

The father poured the juice.

#The father poured the watermelon.

#The father poured the truck.

3 read

The lady read the newspaper.

The lady read the magazine.

#The lady read the picture.

#The lady read the grass.

4 sweep

The mother swept the floor.

The mother swept the garage.

#The mother swept the toilet.

#The mother swept the ocean.

5 knit

The mother knitted a sweater.

The mother knitted a sock.

#The mother knitted blue jeans.

#The mother knitted a closet.

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6 bake

The chef baked a pie.

The chef baked a cake.

#The chef baked the ice.

#The chef baked the table.

7 boil

The woman boiled the eggs.

The woman boiled the water.

#The woman boiled the toast.

#The woman boiled the lamp.

Violation of selection restrictions associated with agent-NP

8 swim

The man swam toward the island.

The dog swam toward the island.

#The sparrow swam toward the island.

#The car swam toward the island.

9 climb

The squirrel climbed up the tree.

The cat climbed up the tree.

#The penguin climbed up the tree.

#The chair climbed up the tree.

10 build

The eagle built a nest.

The swallow built a nest.

#The butterfly built a nest.

#The cucumber built a nest.

Violation of selection restrictions associated with goal-NP

11 give

The farmer gave the carrot to the child.

The farmer gave the carrot to the horse.

#The farmer gave the carrot to the fish.

#The farmer gave the carrot to the desk.

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TABLE 1

Demographic and selected neuropsychological data of the PrAD participants

Subject	Sex	Age	Education	MMSE*	BNT	Category fluency	Letter fluency	Construction[a]
SG	M	84	13	26	59	17	59	10
AB	F	67	12	24	43*	8*	30	8*
NT	F	77	14	23	58	15	26	8
BM	M	53	13	23	52	11	14*	10
RM	F	75	12	20	28*	5*	14	10
EN	F	84	10	19	39	11	24	7
ABj	F	85	12	19	33*	8*	20	7
AR	F	85	12	19	21*	9	15	9
MD	F	87	10	19	35*	8	22	8
JS	F	78	14	18	15*	7*	14	9
MB	F	83	16	17	15*	9*	32	10
DS	M	75	14	16	40*	6*	15*	9
MH	M	64	14	15	20*	2*	26	9*
JW	F	81	12	13	14*	0*	4*	9
Mean		77	12.7					

[a]Total possible score is 11.

*Indicates impaired performance (all subjects were impaired on the MMSE).

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TABLE 2

Proportion of errors by type of sentence and violation

Non-anomalous sentences	9/308 = 2.9%
Anomalous sentences	29/308 = 9.4%
Within-category violation	27/308 = 8.8%
Other-category violation	2/308 = 0.6%

There were a total of 308 anomalous and 308 non-anomalous sentence trials across all participants.