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Commentary

Effects of syntactic features on sentence–picture matching in Broca's aphasics: A reply to Drai and Grodzinksy (2005)

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Abstract

We reanalyzed the data in Drai and Grodzinksy (2005), considering individual patients' responses to different sentence types to be non-independent events. The analyses revealed effects of two of the three factors identified by Drai and Grodzinsky—constituent movement and passive mood. The result is inconsistent with the trace deletion hypothesis; we conclude that features of syntactic structure other than constituent movement are relevant to understanding performance variation in patients with Broca's aphasia.
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Drai and Grodzinksy (2005) continue the discussion of the statistical analysis of performances of Broca's in sentence–picture matching with semantically reversible sentences. The issue is important to questions about the nature of the comprehension deficit in these patients and potentially to the neural location of certain operations involved in sentence comprehension.

To set the issue in perspective, it has been known since Caramazza and Zurif (1976) that many Broca's aphasics perform at chance on sentence–picture matching when presented with sentences that are syntactically complex in some way. The "trace deletion hypothesis (TDH)" (e.g., Grodzinsky, 2000) maintains that the critical feature of sentence structure that engenders chance performance is the presence of what is sometimes called a "moved constituent." According to the TDH, Broca's aphasics will perform at chance on such sentences and not on sentences with other grammatical features. An oft-repeated argument against this hypothesis is that not all Broca's aphasics show chance performance on sentences with moved constituents, in particular, passive sentences (e.g., Berndt, Mitchum, & Haendiges, 1996). Drai and Grodzinksy (1999) countered this argument by suggesting that the distribution of percent correct scores of a set of Broca's aphasics culled from the literature on passives approximated a normal distribution, implying that individual patients in this set whose performances were above chance occurred at a rate consistent with a random process superimposed on the deficit described by the TDH. Caramazza, Capitani, Rey, and Berndt (2001) countered along several lines. The arguments

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they articulated that are relevant[1] are that (1) Drai and Grodzinksy (1999) had not shown that the distribution of performance in the patients they selected on passives was normally distributed, just that a second superimposed Gaussian curve did not lead to a better fit to the distribution; (2) that there were too many cases in the right tail of the distribution of scores in Drai and Grodzinksy's (1999) data set for the data to be normally distributed; and (3) that Drai and Grodzinksy (1999) did not take into consideration the number of trials contributing to each patient's performance, potentially leading to significant distortions of the estimate that any individual patient performed above chance (see Caplan, 2001a; Drai, Grodzinsky, & Zurif, 2001 for further discussion).

Drai and Grodzinksy (2005) approached the question of variation in the performance of Broca's aphasics on different sentence types in two new ways.

First, after selecting a group of Broca's aphasics, Drai and Grodzinsky calculated and displayed confidence intervals for each patient's performance on sentences with and without "movement," with and without differences in "mood" (passive morphology), and with and without center-embedded relative clauses ("complexity"). They noted that "visual inspection can verify that the Complexity contrast... discerns no structure; Movement, however, yields a highly significant contrast..." and "the Mood contrast discerns no structure, while the Movement contrast does." However, the confidence intervals were not analyzed statistically and serve illustrative purposes only (Drai, personal communication, 2004).

Second, Drai and Grodzinsky fit the distribution of the proportion of correct responses for different types of sentences in each patient to a Beta function, which incorporates information on the number of trials, and compared the Beta function parameters that yielded the best fits to performances of sentences with and without movement, changes in mood, and complexity. Drai and Grodnisky found that the Beta curves for sentences with and without movement differed and those for sentence types that differed in other ways did not. They therefore concluded that "Broca's aphasia leads to a robust cross-linguistic ***Movement*** deficit, cutting across other elements that have been thought to generate comprehension difficulties (***Mood***, ***Complexity***)." They say in their Abstract that the results are in line with the Trace Deletion Hypothesis.

The second approach assumes total independence of all data points. Drai and Grodzinsky fit a Beta curve to the distribution of proportion correct responses to a given sentence type in all relevant patients, and then fit another Beta curve to the distribution of proportion correct responses of a group of patients to another sentence type, ignoring the fact that, in most cases, the same patients have been tested on both sentence types.

Ignoring the within-subjects nature of the experimental design used in the cited studies discards a great deal of information that is relevant to the questions under investigation. For instance, it ignores the fact that patients vary in overall severity, so that good scores on one sentence type are associated with good scores on other sentence types. For instance, Pearson's r for the correlation of percent correct on relative clauses with and without movement in English patients tested on both structures is .45 ($p < .05$); for non-English speaking patients tested on active and passive sentences without moved constituents, Pearson's $r = .75$ ($p < .01$).[2] This might not affect the analysis if the same patients' performances were used to generate Beta models for each sentence type in each comparison, but in some analyses patients contribute data to only one sentence type. For instance, Drai and Grodzinsky's Fig. 4D depicts different Beta functions for monoclausal sentences that differ in movement but not in mood, but many more patients contribute to the data points for the [− movement] sentences than to those for the [+ movement] sentences (as seen in their Fig. 4B). If these patients are ones whose performance is overall very good, their performances on [+ movement] sentences might also be good, resulting in a quite different Beta curve, perhaps one that looks much more like the one that fits the [− movement] sentence data. The lack of independence makes comparisons between the beta functions for different sentence types difficult to interpret in terms of conventional statistical practices in the field. We re-analyzed the data in Drai and Grodzinsky's data set in two ways that considered performances on different sentence types in individual patients to be non-independent events.[3]

[1] Caramazza et al. (2001) also raised questions about patient selection, leading to discussion of both the criteria by which patients who are Broca's aphasics might become eligible to be included in sets of patients in whom the TDH and other related hypotheses can be tested and the justification for restricting for patient selection to this or any other clinically defined group. See also Badecker and Caramazza (1985), Berndt and Caramazza (1999), Caplan (1995), Zurif (1982), Zurif, Gardner, and Brownell (1989), Zurif and Pinango (1999), Caplan (2001a, 2001b), Caramazza et al. (2001), and Zurif (2001).

[2] We are grateful to Drai and Grodzinsky for providing us with their data set.

[3] Drai and Grodzinsky also treat performance on each token of each sentence type as an independent event. This assumption is universally made, but it is likely to be false as well. Statistical methods that test for and take into account non-independence of observations made on tokens of the same type in single subjects are complex and we have not tried to analyze the data provided by Drai and Grodzinsky using them.

Our approach is based on the familiar index of χ^2 based on 2×2 contingency tables.[4] For each patient, we examined a "pure" comparison such as that between active and passive mood constructions without movement. We calculated the number of trials for each sentence type and coded for each sentence type whether each token was responded to correctly or incorrectly. The resulting 2×2 contingency table supports calculation of a χ^2 value with 1 degree of freedom. This value incorporates information on the number of items of each sentence type administered to a patient, and includes the information that the observations on the two sentence types come from the same subject.

The results of this stage in our analysis are presented in Table 1. There are two features of the entries in Table 1 that we wish to note. The first is that a χ^2 of 0.000 indicates that a patient performed equally well on the two sentence types—a tie score. When a patient was at ceiling on both sentence types, we could not calculate a χ^2 value. There are two patients for whom this was the case. The second is that we added a minus sign to those χ^2 values that went in the unexpected direction: If a patient's performance was better on the more complex version of the sentence pair (i.e., on sentences with movement, passive mood marking, or center-embedding, compared to the corresponding sentences without these features), we changed the polarity of the χ^2 from positive to negative. This is crucial information to include, and is equivalent to including the +/− sign with a Pearson's *r* value.

In the first analysis, we determined whether each patient performed better on one sentence type than another and compared the number of cases who performed one way or the other using a sign test (which discards ties). Because each patient was tested on the same number of sentences of each type and the number of responses to each stimulus was the same across sentence types, this approach is not affected by differences in the num-

[4] We have used χ^2 as our basic statistic because it is commonly used to analyze data in this literature. There are other possibilities based on the discussion in Hayes (1973) that also incorporate the number of items into the result. The definition of χ^2 is the sum of squared *z* scores, one for each degree of freedom. For our application, each patient yielded a χ^2 with 1 degree of freedom. It is worth noting that one can obtain a form of Pearson's *r* (the phi coefficient) by dividing the χ^2 value from a 2×2 contingency table by *N*, the number of items, and then taking the square root. Thus, the χ^2 value is algebraically the same as calculating a Pearson's *r* between *X* as the Sentence type variable coded using 1 s and 0 s, and correctness as the *Y* variable coded using 1 s for correct and 0 for incorrect responses, squaring the *r* value, and then multiplying by *N*. We could have calculated Pearson's *r*, which would yield positive or negative values depending on the direction of the effect. We would then multiply the *r* value by the square root of *N* to provide a *z* score. The distribution of *z* scores for a contrast could then be examined. This approach, and the one used, work best with larger number of items, but these approaches nonetheless provide useful indices of the strength of the effect for each individual patient.

Table 1
χ^2 values for individual contrasts for individual patients based on data from Drai and Grodzinksy (2005). Missing values reflect instances where performance was at ceiling

Patient	Type	Contrast	χ^2
EM(4)	Comp	ObjCE, ObjRB	0.53
ER(1)	Comp	ObjCE, ObjRB	0
LD(2)	Comp	ObjCE, ObjRB	−3.96
S1(YM)	Comp	ObjCE, ObjRB	−1.82
S2(GV)	Comp	ObjCE, ObjRB	0
S3(ER)	Comp	ObjCE, ObjRB	0
S4(JG)	Comp	ObjCE, ObjRB	−0.27
S5(AB)	Comp	ObjCE, ObjRB	0.2
EM(4)	Comp	SubjCE, Subj RB	0
ER(1)	Comp	SubjCE, Subj RB	0.78
LD(2)	Comp	SubjCE, Subj RB	0.78
S1(YM)	Comp	SubjCE, Subj RB	0.95
S2(GV)	Comp	SubjCE, Subj RB	−0.83
S3(ER)	Comp	SubjCE, Subj RB	−2.22
S4(JG)	Comp	SubjCE, Subj RB	0.39
S5(AB)	Comp	SubjCE, Subj RB	2.4
FCO	Mood	Active, Passive (+Mvmnt)	−8.286
FER	Mood	Active, Passive (+Mvmnt)	2.667
B	Mood	Active, Passive (−Mvmnt)	8.54
BA	Mood	Active, Passive (−Mvmnt)	3.13
DH	Mood	Active, Passive (−Mvmnt)	0.23
HV	Mood	Active, Passive (−Mvmnt)	0
JR	Mood	Active, Passive (−Mvmnt)	2.03
K	Mood	Active, Passive (−Mvmnt)	.
KOE	Mood	Active, Passive (−Mvmnt)	1.03
LA	Mood	Active, Passive (−Mvmnt)	1.11
M	Mood	Active, Passive (−Mvmnt)	5.16
MP	Mood	Active, Passive (−Mvmnt)	1.02
OO	Mood	Active, Passive (−Mvmnt)	0
PO	Mood	Active, Passive (−Mvmnt)	0
POE	Mood	Active, Passive (−Mvmnt)	.
RG	Mood	Active, Passive (−Mvmnt)	0.14
ROE	Mood	Active, Passive (−Mvmnt)	−0.11
ROO	Mood	Active, Passive (−Mvmnt)	9.23
S	Mood	Active, Passive (−Mvmnt)	8.21
WE	Mood	Active, Passive (−Mvmnt)	4.4
WR	Mood	Active, Passive (−Mvmnt)	3.22
AL	Mvment	Active, −/+Mvment	15
CO	Mvment	Active, −/+Mvment	8.29
DH	Mvment	Active, −/+Mvment	4.659
FER	Mvment	Active, −/+Mvment	−0.1254
GR	Mvment	Active, −/+Mvment	7.68
HV	Mvment	Active, −/+Mvment	2.4
HY	Mvment	Active, −/+Mvment	21.17
JJP	Mvment	Active, −/+Mvment	4.29
JR	Mvment	Active, −/+Mvment	2.03
KKM	Mvment	Active, −/+Mvment	3.58
KTS	Mvment	Active, −/+Mvment	2.85
LH	Mvment	Active, −/+Mvment	8.52
MP	Mvment	Active, −/+Mvment	1.02
RG	Mvment	Active, −/+Mvment	1.09
RN	Mvment	Active, −/+Mvment	13.02
SZ	Mvment	Active, −/+Mvment	5.93
WE	Mvment	Active, −/+Mvment	14.67
WR	Mvment	Active, −/+Mvment	3.22
B	Mvment	Passive, −/+Mvment	2.05
M	Mvment	Passive, −/+Mvment	11.6
S	Mvment	Passive, −/+Mvment	2.49
DH	Mvment	SubjCE, ObjCE	5.64
EM(4)	Mvment	SubjCE, ObjCE	2.5

(*continued on next page*)

Table 1 (*continued*)

Patient	Type	Contrast	χ^2
ER(1)	Mvment	SubjCE, ObjCE	1.9
FC	Mvment	SubjCE, ObjCE	16.48
HV	Mvment	SubjCE, ObjCE	0.37
JR	Mvment	SubjCE, ObjCE	4.25
LD(2)	Mvment	SubjCE, ObjCE	3.96
MP	Mvment	SubjCE, ObjCE	0
RG	Mvment	SubjCE, ObjCE	3.77
s1(YM)	Mvment	SubjCE, ObjCE	0
S2(GV)	Mvment	SubjCE, ObjCE	1.82
S3(ER)	Mvment	SubjCE, ObjCE	5
S4(JG)	Mvment	SubjCE, ObjCE	0
S5(AB)	Mvment	SubjCE, ObjCE	0.8
WE	Mvment	SubjCE, ObjCE	6.84
WR	Mvment	SubjCE, ObjCE	0
AL	Mvment	SubjRB, ObjRB	7.92
EM(4)	Mvment	SubjRB, ObjRB	0.78
ER(1)	Mvment	SubjRB, ObjRB	4.8
GR	Mvment	SubjRB, ObjRB	6.65
HY	Mvment	SubjRB, ObjRB	13.87
LD(2)	Mvment	SubjRB, ObjRB	19.8
LH	Mvment	SubjRB, ObjRB	0.27
RN	Mvment	SubjRB, ObjRB	12.38
S1(YM)	Mvment	SubjRB, ObjRB	5.05
S2(GV)	Mvment	SubjRB, ObjRB	0.2
S3(ER)	Mvment	SubjRB, ObjRB	0.95
S4(JG)	Mvment	SubjRB, ObjRB	1.25
S5(AB)	Mvment	SubjRB, ObjRB	3.81
SZ	Mvment	SubjRB, ObjRB	5.93

Patient RD was omitted because the number of trials for each sentence type could not be determined from Drai and Grodzinsky's data.

ber of trials or response probabilities associated with different sentence types. We were careful to count each patient only once for each sign test to maintain the assumption of independence of observations. Satisfying this assumption is why we needed to use the more detailed taxonomy presented in the "Contrast" column in Table 1.

Within the category of mood effects there were two comparisons. For active and passive sentences without movement, 13 patients performed better on sentences marked for mood than on sentences not marked for mood and one showed the opposite pattern ($p = .002$). For active and passive sentences with movement, one patient performed better on sentences marked for mood and one patient showed the opposite pattern. There were two sentence type comparisons within the category of complexity effects. For sentences containing subject relative clauses, six patients performed better on right branching (simple) sentences than on center-embedded (complex) sentences and two showed the opposite pattern ($p = .289$).[5] For sentences containing object relative clauses, three patients performed better on simple sentences and two performed better on complex sentences. Finally, for the effect of movement there were four comparisons. For passive sentences, three patients performed better on sentences without moved constituents than on sentences with moved constituents and 0 showed the opposite pattern. For Active sentences, 17 patients performed better on sentences without moved constituents and 0 showed the opposite pattern ($p < .001$). For center-embedded sentences, 13 patients performed better on sentences without moved constituents and 0 patients showed the opposite pattern ($p < .001$). Finally, for right-branching sentences, 15 patients performed better on sentences without moved constituents and 0 patients showed the opposite pattern ($p < .001$).

The sign test takes into account the performance of each patient on different sentence types, but does not make use of the number of items on which each patient was tested. In the second approach, we also took into account the number of observations made in each patient by considering the size of the χ^2 statistic for each patient as well as the direction of the effect. We compared the χ^2 statistic for each patient's performance on sentence types that are relevant to comparisons of interest against chance performance. In the typical application of χ^2 statistics, the average "chance" performance is 1.0 for a 1 degree of freedom test (Hayes, 1973). However, because we used a minus sign to reflect effects in the unexpected direction, the "chance" performance on average would be 0.00. We tested whether the average χ^2 value for a single comparison type was reliably greater than 0.00 using a single sample *t* test. Again, as discussed above for the application of the sign test, we used each patient only once for each *t* test in order to maintain the independence of observations. We recognize that the distribution of $+/- \chi^2$ values will not be normal, but the *t* test is robust with respect to violations of this assumption.

The distribution of χ^2 values for the three contrasts of interest is shown in Fig. 1 and the resulting statistical measures in Table 2. The movement factor is highly significant. The results for the other two contrasts reveal a complexity to the patterns of performance that is not visible in the analysis of Beta curve fits reported by Drai and Grodzinsky.

The "complexity" factor is not significant, for sentences either with or without movement. This is likely to be due to the fact that the presence of a center-embedded relative clause triggers many processes that have contradictory effects on performance. Center-embedded relatives have higher syntactic storage and integration costs than right branching relatives (Gibson, 1998), but are easier to process in other ways. Restrictive relative clauses implicate a contrast set, and this background information is comprehended more easily early in a sentence, leading to shorter reading times for cen-

[5] Patient RD was included in the sign test because proportion correct was available but not in the calculation of χ^2 because number of observations for each sentence type was not (see legend to Table 2).

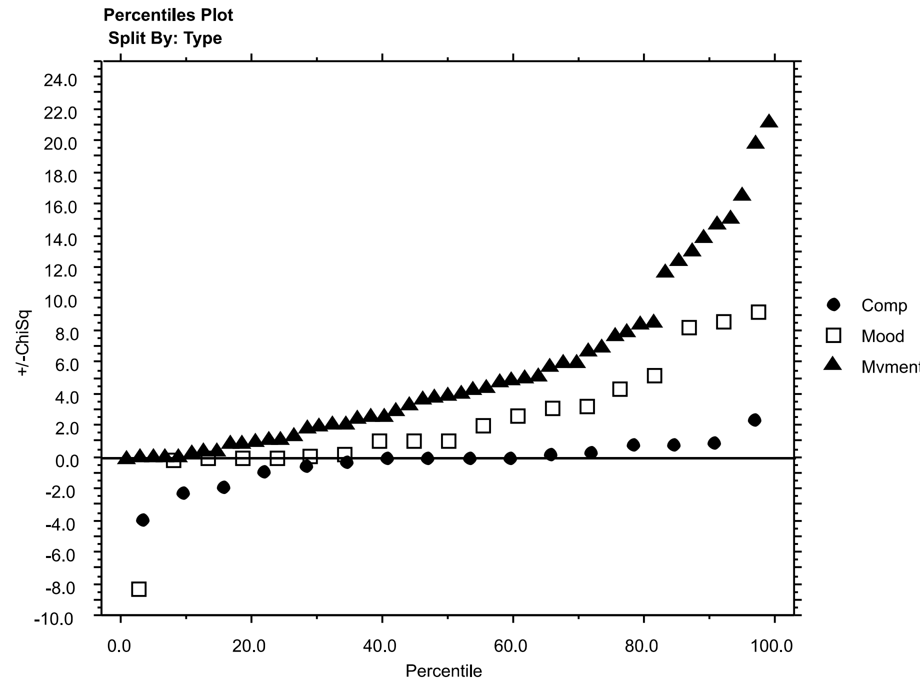

Fig. 1. Percentile plot of χ^2 values for the effects of movement, complexity, and mood.

Table 2
χ^2 values for effects of movement controlled for complexity (bi-clausal sentences), complexity controlled for movement, mood controlled for movement, and mood overall

Type	Comparison	Mean χ^2	*DF*	*t* value	*p* value
Movement	SubjCE, ObjCE	3.3	15	3.2	<.01
	SubjRB, ObjRB	6.0	13	3.8	<.01
Complexity	SubjCE, Subj RB	0.28	7	0.6	ns
	ObjCE, Obj RB	−0.7	7	−1.3	ns
Mood	Active, Passive (−Movement)	2.8	16	3.6	<.01
	Active, Passive (+Movement)	−2.8	1	−0.5	ns
	Overall	2.2	18	2.4	.02

No subject appears twice in the calculation of any *t* value.

ter-embedded than right branching relative clauses (Gibson, Desmet, Grodner, Watson, & Ko, in press). In addition, a heuristic strategy that assigns the sentence-initial noun phrase the thematic role of agent of all verbs (Capan & Hildebrandt, 1988; Caplan, Baker, & Dehaut, 1985) would lead to better performance on center-embedded than on right branching structures.

The "mood" factor is significant when all cases are considered together, contra Drai and Grodzinsky. However, inspection of Fig. 1 suggests a more complicated picture. There is one Spanish patient who performed better on sentences with passive markers than those without passive markers, and whose χ^2 value was very high (the extreme negative value in Fig. 1). This patient, and one other Spanish case, were tested on sentences in which there was constituent movement in both the active and passive sentences; that is, the active sentences in these studies contained scrambled noun phrases in which thematic roles occurred in non-canonical order and were indicated by declensional markings on noun phrases and the passives were ones in which thematic roles occurred in non-canonical order and were indicated by passive morphology. These two patients performed in opposite directions, one performing above chance on scrambled case-marked actives and at chance on passives and the other (the one with the very high negative χ^2 value) performing above chance on passives and below chance on scrambled case-marked actives. What appears to be occurring is a double dissociation in the ability to utilize the cues of declension and passive marking to establish thematic roles in the presence of non-canonical thematic role order. Eighteen of the 19 patients who were tested on sentences in which there was no movement in either the active or the passive versions (three English patients, nine Dutch patients, and seven German patients) performed at the same level or better on active than on passive sentences. This result was highly significant by *t* test, as shown in Table 2. The data indicate that mood affects performance in sentences with canonical thematic role order, but thematic role assignment is determined by the ability to base thematic role assignment on particular morphological features when patients have to assign thematic roles in non-canonical orders.

In summary, an analysis of the data culled from the literature by Drai and Grodzinsky that incorporates the fact that observations were made on the same patients reveals that two of the three factors identified by

Drai and Grodzinsky exert significant effects on performance. The effect of syntactic movement is robust. The effect of mood is found overall, but seems to exert discernable effects on accuracy of thematic role assignment only in sentences with canonical word order. There is no effect of complexity, probably because center embedding creates complexity at certain levels of processing and simplifies processing in other ways. The results are not consistent with the trace deletion hypothesis, which postulates an effect of constituent movement *alone* in Broca's aphasia. Rather, the performance of Broca's aphasics appears to be influenced by many aspects of sentence structure, which affect multiple types of psycholinguistic operations.

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