



MULTIPLE FEATURE MATCHING IN PRONOUN RESOLUTION: A NEW LOOK AT PARALLEL FUNCTION

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ABSTRACT

The goal of this paper is to examine various interpretations of the notion of 'parallel function' in pronoun assignment. The term usually denotes a strategy of assigning an ambiguous pronoun to an antecedent which has the same grammatical role (e.g., subject, object, etc.). However, I will show that the pronoun's grammatical and thematic roles both influence assignment; that differences in clausal attachment and global constituent structure can reduce the proportion of syntactically parallel assignment, consistent with a priming model of the comprehension of multiclausal sentences; and that subject pronouns are very strongly biased toward subject assignment because the preceding clause always has a parallel subject NP, and because assignment begins before information (either supporting or contradictory) about the pronoun's thematic role becomes available to the processor. Implications for AI and for language acquisition are also discussed.

INTRODUCTION

This paper proposes a feature-match model of the early (pre-semantic/pragmatic) stages of pronoun assignment. The model arises from the study of human processing of so-called 'parallel function' (PF) sentences (*John kicked Fred and [he /hé slapped Bill] [Bill slapped him/him.]*). In sentences like these, an unstressed pronoun is strongly biased toward the NP with the same grammatical function [1], and, conversely, a stressed pronoun is prohibited from having the parallel reading [2].

It has sometimes been suggested [3] that PF is merely a heuristic strategy which applies only in the absence of other linguistic or pragmatic cues. However, this does not accord with some simple observations about PF sentences. For example, in *John tickled Alice and then she poked Sue*, with the pronoun unstressed, there is a strong bias toward the anomalous reading (*she=John*). In other words, the gender cue fails to prevent the application of PF as one would expect it should if PF were merely a last-ditch heuristic. PF effects also resist pragmatic biases, as we see in *The musician gave the mechanic a CD and he gave the musician a wrench*. Again, PF applies in the face of contradictory information, and the sentence is anomalous without PF-blocking stress on the pronoun.

Psycholinguistic research suggests that automatic feature matching may be a central aspect of anaphora resolution. For example [4], assignment is faster when the pronoun and a nonantecedent are distinct in number or gender (*John left the party because Peter/Carol hit him.*). It seems that the nonantecedent cannot be rejected on syntactic grounds without also undergoing a redundant morphological feature check. Our preliminary observations about the obligatory nature of PF are therefore consistent with the idea that a pronoun's grammatical function is obligatorily checked against that of the candidate antecedents.

DEFINING PARALLELISM

There has been some interest within AI in

implementing PF effects [5,6,7,8], but little effort has been made to provide a model (or even a definition) that is explicit enough for the purposes of computational recognition. The first problem is that the term 'object pronoun' can be applied to the NP complement of a transitive verb, a dative verb, a preposition, and so on. Although these forms are all homophonous, it is not clear *a priori* whether that is sufficient for them to be treated as 'parallel' by the coreference processor. In a recent study of adults' resolution of nonsubject pronouns, Crawley et al. [3] did not control for these different types: inspection of the stimuli shows that about half their items had no NP in the preceding clause to match the pronoun's exact grammatical role (e.g., *Patricia gave Martha* (indirect object) *a present* and *Nicholas smiled at her* (prepositional object)). The finding of 60% subject assignment was interpreted as evidence against PF, but it suggests instead that the items with an exact match on grammatical role elicited the PF responses, and those with a feature mismatch elicited the nonparallel (SA) responses.

A second issue has to do with the fact that NP's can also vary in terms of their thematic roles. For example, in *Lauren liked David*, the verb assigns the Experiencer role to its subject and the Stimulus role to its object, while in *Lauren bored David*, these roles are reversed. Thus, a particular thematic role can be assigned to different grammatical positions, and NP's with different grammatical roles in different clauses may or may not have the same thematic role. In the Crawley et al. materials, the lack of control over grammatical roles often resulted in differences in the thematic roles as well, and this may have contributed further to the large proportion of subject assignment responses. In a related study, Stevenson et al. [9] report that pronoun assignment times and resolution preferences vary according to the thematic roles of the candidate antecedents, but since they did not control the thematic roles of the pronouns themselves, nothing can be said about the effects of thematic role parallelism.

A third factor that ought to be addressed is the degree of congruence between the structures of the two clauses. The principle seems to be that PF is weakened when the clauses differ in their global constituent structure. To test this, one can construct fully parallel sentences in which the PF interpretation is blocked by gender cues (leading to an anomalous interpretation), and then add extra constituents to one clause. If this kind of nonparallelism interferes with PF, assignment to the gender-appropriate NP should be less anomalous in the longer sentence, and this does appear to be the case: *?Fred tickled Sue and Jack poked him* vs. *Fred probably tickled Sue with that old feather duster, and Jack poked him*. A different aspect of global parallelism involves the structural relationship between the clauses. All of the examples cited so far have involved conjoined structures, but the effects of attachment differences become apparent when one compares nonparallel conjoined clauses like *The lawyer wouldn't tell Fred and he couldn't tell the judge*. with more ambiguous VP-attached complement structures like *The lawyer wouldn't tell Fred that / what he couldn't tell the judge*.

SYNTACTIC PRIMING

Why should factors other than the grammatical properties of the pronoun and the candidate antecedents themselves affect PF? One possibility is that priming between the first and second clause facilitates feature matching. Syntactic priming has been used to explain parallelism effects in sentence production [10]; for comprehension it guarantees that the representations of the two clauses will be at the same relatively superficial level, so that the mapping from one NP position to its counterpart in the preceding clause will be uncomplicated.

LEARNABILITY

The basic PF effects for conjoined sentences have been documented in children as young as 3 [11]. Such early acquisition would seem puzzling if PF had to be learned from exposure to positive evidence, especially in view of the existence of counterexamples made possible by differences in clause structure. But if, as I am suggesting, PF effects are simply a consequence of the architecture of a coreference processor that is based on feature-matching, early acquisition would be expected. Solan [12] presents some rather confusing evidence about the effects of syntactic parallelism and contrastive stress, finding that five-year-olds (but not older children) made nonparallel responses for unstressed pronouns, while treating stressed pronouns in an adult-like manner. However, this result contradicts Maratsos' finding that five-year-olds provided 93% parallel responses to similar items and all age groups, from 3 to 5, did better on unstressed than on stressed pronouns. Solan also found that children from 5 to 8 tended to match NP's according to thematic roles in sentences with an active and a passive clause, while adults had a less consistent pattern of results. However, this leaves many questions unanswered about the initial state of the coreference processor. Do younger children begin with syntactic role parallelism and later focus on semantic parallelism, as one might predict from my model? Or do they begin with semantic role matching and later acquire the more superficial syntactic matching strategy?

IMMEDIACY OF PROCESSING

Ehrlich & Rayner [13] have shown that eye movements during reading slow down during the fixation on which the pronoun is perceived, suggesting that pronoun assignment begins immediately. This feature of the anaphoric processor can be used to predict certain asymmetries in the processing of subject and nonsubject pronouns in SOV languages like English. The crucial point is that because a subject pronoun is perceived before the verb, resolution begins before the pronoun has been assigned a thematic role. On the other hand, a nonsubject pronoun comes after the verb, so that its antecedent search begins with all of the relevant information. Thus, if the feature hypothesis is correct, thematic role parallelism should have a stronger influence on nonsubject pronouns.

OBLIGATORY SUBJECTS

A different language-specific asymmetry between subject and object pronouns arises from the fact that subjects are obligatory in English tensed clauses. This means that a subject pronoun in a two-clause sentence will usually have a potential antecedent that is also a subject, whereas a nonsubject pronoun may have no syntactic analogue in the first clause.

Taken together, the obligatory subject and immediacy of processing principles can be used to predict

that in the absence of contradictory pragmatic or semantic cues, subject pronouns in two-clause sentences will almost always be resolved by PF, while nonsubject NP's should have more variable antecedent preferences.

EVIDENCE FOR THE MODEL

Most adult research on PF effects has been limited to subject pronouns in subordinate clauses [14,15,16,17]. This is problematic because PF and SA are indistinguishable for subject pronouns, and because no attempt has been made to control for clausal attachment. In Smyth (1991) [18] I presented data to support several of the hypotheses discussed above. In one of the experiments, three types of sentences were presented to subjects for written antecedent selections: Type I had fully parallel structure, Type II had different grammatical roles for nonsubjects in the two clauses, and Type III had fully parallel structure except for the addition of an adjunct to one clause. As expected, subject pronouns did not differ significantly across types (for the grammatical role condition, this is because every subject pronoun had a potential subject antecedent), but the nonsubject pronouns had significantly fewer PF responses in the two nonparallel conditions. The lack of effect of adjunct asymmetry on subject pronouns can be explained by the immediacy of processing principle, since subject pronoun assignment begins before the structure of the second clause is known.

Another study used sentences in which the second clause was attached within the VP of the first clause, as in "John told Fred that Sue liked him" or "John told Fred that he bored Sue". In this case, SA was always the preferred strategy, accounting for 83% of responses for subject pronouns and 62% for nonsubjects. On the other hand, this difference was significant, indicating a much-weakened PF effect.

EXPERIMENT

The present experiment was designed to test my claims regarding the effects of both syntactic and thematic roles, including subject/object asymmetries. One innovation was to include a 1-5 rating scale on which subjects indicated their confidence in each pronoun assignment. The efficacy of this method was then tested by comparing analyses of the simple resolution scores with analyses using combined recognition-assignment scores obtained by assigning the positive value of the subject's rating to subject assignments, and the negative value to object assignments.

Subjects: 24 members of the University of Toronto community participated.

Materials: The stimuli consisted of 24 sentences with two clauses conjoined by 'and'. Each clause consisted of a subject NP, an Experiencer verb, and a direct object NP. The verbs differed in argument structure: half assigned Experiencer to the subject and Stimulus to the object (the 'like' type), and half assigned Stimulus to the subject and Experiencer to the object (the 'bore' type). Half the sentences had verbs with the same argument structure in both clauses, while half had verbs with opposite argument structure. Within each set, half had a subject-Experiencer verb in the first clause, while half began with an object-Experiencer verb. Finally, there were equal numbers of sentences with subject and object pronouns. There were also eight distractor sentences in which the pronoun could be resolved by gender cues and 24 additional pronoun-assignment sentences from a different study. The sentences were recorded with the pronouns unstressed and a falling contour in each clause. There was a pause of

five seconds between items, and a 10 second break after each set of eight items. Examples of the main types are given below:

Parallel thematic roles

Subject pronoun

Tim liked Harvey and he worshipped Sandra.

Object pronoun

Fran accepted Olivia and Simon resented her.

Nonparallel thematic roles

Subject pronoun

Mike enjoyed Jethro and he infuriated Helen.

Object pronoun

Jim adored Benjamin and Debbie scared him.

Procedure: Subjects listened to a tape of the sentences recorded in random order. They were instructed to listen to each sentence, imagine the situation it described, decide on an antecedent for the pronoun, circle the appropriate name on the page, and indicate their confidence in this judgment on a scale of 1 to 5. The response sheets contained a content cue from each sentence, followed by the two names from the first clause in the order in which they appeared in the stimulus sentence, and the rating scale. A practice set of eight items was included in the instruction phase.

Results: The data were scored in three different ways. In the first analysis, the dependent measure was the proportion of subject assignment without regard to confidence scores. The design was an analysis of variance with three factors: Thematic Role Parallelism, Pronoun Position, and Clause Order. The main effect of Pronoun Position was significant ($F(1, 184) = 445.04, p < .0001$; $F(1, 24) = 198.90, p < .0001$). Subject pronouns received more subject assignment than object pronouns. The interaction between Thematic Role Parallelism and Pronoun Position was also significant ($F(1, 184) = 18.97, p < .0001$; $F(1, 24) = 7.70, p < .01$). Simple effects tests showed that the effect of Thematic Role Parallelism was significant only for object pronouns ($p < .0001$), but that the pronoun position effect held for both parallel and nonparallel thematic role sequences. The means for this interaction are shown in Table 1.

Table 1: Mean proportion of subject assignment.

	Pronoun Position	
	Subject	Object
Parallel Thematic Role	.95	.19
Nonparallel Role	.90	.39

The second analysis had the same design, but the dependent measure was the combined assignment-confidence score described above. The same factors were significant as in the first analysis: Pronoun Position ($F(1, 184) = 471.94, p < .0001$; $F(1, 24) = 202.62, p < .0001$), with more subject assignment for subject pronouns, and the interaction between Thematic Role Parallelism and Pronoun Position ($F(1, 184) = 28.04, p < .0001$; $F(1, 24) = 12.096, p < .002$). See Table 2 for the means within this interaction.

Table 2: Mean assignment-confidence scores.

	Pronoun Position	
	Subject	Object
Parallel Thematic Role	4.16	-2.71
Nonparallel Role	3.40	-0.78

All four relevant comparisons are significant (p ranges from .02 to .0001); the reason for the interaction is that when the thematic roles clash there is significantly less SA for subject pronouns and significantly more SA for object pronouns. In other words, a pronoun was more likely to be construed as coreferential with a syntactically nonparallel NP when that NP matched the pronoun in thematic role.

Finally, the confidence scores were analyzed without regard to the direction of resolution. The main effect of Pronoun Position was significant ($F(1, 184) = 16.98, p < .0001$; $F(1, 24) = 40.30, p < .0001$); confidence scores were consistently higher for subject than for object pronouns. The main effect of Thematic Role Parallelism ($F(1, 184) = 15.44, p < .0001$; $F(1, 24) = 37.57, p < .0001$) was also significant; confidence scores were higher for sentences with parallel thematic roles in the same syntactic position than for sentences with nonparallel thematic roles. Finally, the interaction between Thematic Role Parallelism and Clause Order was significant ($F(1, 184) = 5.74, p < .02$; $F(1, 24) = 15.52, p < .001$). Simple effects tests showed that differences in confidence scores for thematically parallel vs. nonparallel cases held only for subject-Experiencer verbs, with means of 4.38 vs. 3.66 for parallel and nonparallel thematic roles respectively. However, for object-Experiencer verbs confidence scores did not differ significantly (4.12 vs. 3.96).

Discussion This experiment lends further support to the model of pronoun assignment described above. First, it shows that both the syntactic and thematic roles of NP's affect pronoun assignment. There was a clear tendency for subject pronouns to go with subject antecedents and for objects to go with objects, but the opposite pattern appeared most often when the syntactically nonparallel NP had the same thematic role as the pronoun. Secondly, the results confirm the immediacy of processing hypothesis, since thematic roles carry much less weight in the resolution of subject pronouns. In the simple assignment scores, subject pronouns were unaffected by a thematic role mismatch with the preceding subject NP, while object pronouns were attracted toward the thematically matching antecedent. Third, these results also demonstrate the value of using confidence ratings as a measure of ambiguity in a pronoun assignment task. The difference between thematically parallel and nonparallel cases was not significant in terms of the outcome of assignment -- subject pronouns were almost always assigned to a preceding subject NP in both conditions -- but this same comparison was significant when confidence scores were taken into account. In other words, subject assignment is *always* highly favoured for subject pronouns, as predicted by the immediacy of processing hypothesis, but even for subject pronouns a thematic role clash does lead to lower confidence ratings.

Finally, the fact that confidence scores were uniformly lower for nonsubject pronouns follows from joint consideration of syntactic role parallelism, the immediacy

principle and the assumption that SA is the default strategy for pronoun assignment. All three of these factors promote assignment of subject pronouns to subject antecedents.

GENERAL DISCUSSION

The extended parallel function hypothesis is a much richer source of information about pronoun assignment than had been previously suspected. Taken together, the results of the experiments discussed above make it possible to formulate a coherent model of assignment based on the assumption that the earliest stage of pronoun assignment is a search for an antecedent with the same syntactic role as the pronoun. If no such NP is available, or if there are differences in the constituent structure or attachment sites of the two clauses, the probability increases that the default strategy of subject assignment will apply instead, and SA will always apply more often to subject pronouns because of the grammatical role match. Mismatches on thematic role attract responses away from the syntactically parallel antecedent and toward the thematically parallel NP, but only for object pronouns, as predicted by the immediacy of processing principle. For subject pronouns, thematic role clashes have no effect on the outcome of assignment, but do reduce confidence that the pronoun has been resolved in the way the speaker intended.

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