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Game Theory and the control of empty categories in grammar

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1. Introduction

Grammatical theory has advanced to the point where the mechanics of the interface (Chomsky 2010) between grammar and other capacities of mind has become a fundamental question that reaches to the heart of how grammar itself is represented.[1] Do we have predispositions about social relations that reach into grammar? It is obvious that there is utility in having pronouns (*I*, *you*), for instance, which capture Point of View biases of Speaker and Hearer, and implicatures which refer to an unspoken Common Ground. We can ask whether social interfaces affect grammatical *operations* as well.

Game theory has become an ingredient in reasoning about many domains of human interaction. It is commonly shown that rational negotiation often leads to a cooperative result (Straffin 1993; see p. 75 for *indefinite iteration*). The approach within linguistics has usually been to establish competitions among grammars or speakers or ways of modeling language change.

We argue instead that the logic of game theory projects a social interface onto the mechanical interpretation of empty categories. One property of speech is its speed which reflects a property found across grammar: encapsulation. Words are often encapsulations of complex objects: a *contract*, *marriage*, *election*, *triple lutz*, etc. They stand for concepts which one does not want to rehearse or disassemble during conversation (election = people go to precincts to cast ballots to choose a representative), and therefore we prefer the shorthand of a single word, rather than the full thought.
A singularly important product of game theory is a notion of cooperation, which we discuss below. It is a product of a complex negotiation which can be encapsulated in a single word. The concept of cooperation may already be built into our biology so that

1. We thank the audience at the ZAS Workshop on Game Theory and linguistics, where Tim Roeper presented this work, for comments, and the audience at a colloquium in Cologne where Tom Roeper presented some of this work. In addition we thank Patrick Brandt, Danny Green, Insa Gülzow, Lila Gleitman, Terry Langendoen, Luisa Marti, and Aynat Rubinstein for helpful conversations along the way.

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we can use it in other modules of mind. We argue that the theory of control, allowing empty categories for previously mentioned participants, also can involve the particular social arrangement we have mentioned, namely *cooperation*.

This argument fits the hypothesis that Jan Koster (2010) has articulated: complex aspects of culture, even particular cultures, can be encoded in words and, he suggests, in deeper aspects of grammar as well. We argue that cooperation reflects an encapsulated output of iterated Prisoner's Dilemma negotiations, which we will now illustrate.

2. Game Theory

The process that produces a cooperative equilibrium in an iterated Prisoner's Dilemma (see note)[2] depends on an indefinite number of future iterations. If players know which iteration will be their last one, they no longer have an incentive to cooperate because they do not need to fear retaliation. If it is a foregone conclusion that both sides will not cooperate in the last iteration, then neither side will have any incentive to cooperate in the penultimate iteration. The extension of this logic is that if the last iteration is known, there will not be an incentive to cooperate on the first iteration. However, if the number of future iterations is indefinite then both players will always fear retaliation on their next iteration, and have incentive to cooperate on the current one. The complexity and indefinite length of the process that produces a cooperative equilibrium makes it a natural candidate for encapsulation. In other words, the mind can encapsulate this knowledge and apply it in any situation. The encapsulated form is, we argue, available for the linguistic interface and has an impact on Control Theory.

2. The Prisoner's Dilemma is a classic problem in game theory in which two players are separated and offered two choices: cooperate or defect. The players' choices produce one of four outcomes for each player, with "1" being the best outcome either player can hope for, and "4" being the worst. It is summarized by the following matrix:

(1,4) means it's the best outcome for A and 4th best for B.	Player B Cooperates	Player B Defects
Player A Cooperates	(2,2)	(4,1)
Player A Defects	(1,4)	(3,3)

The paradox of the game is that if a player defects, he/she will have a better outcome no matter what the other player does, but if both players defect they will be worse off than if they both cooperate. The reason that players cooperate is to encourage the other player to cooperate in future rounds.

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2.1 Encapsulated Game Theory and linguistic structure

Let us consider again where grammar and social assumptions may interact. We have not only the word Agent, but a morphological affix, *-er*, which can productively convert verbs into Agentive objects (*singer*, *sinner*, *winner*). Although they are a minimal marker for that property, they radically change the verbs to which they attach. The notions of *winner*, *loser*, *singer*, *doubter* all engage notions of agency in a non-uniform way although they are built on the same abstract notion of Agent. Thus a new computation requires the online integration of two encapsulated items, a root, and the flexible agentive affix. To win, lose, surrender or sing are all very different activities, with even different motives, but we use *-er* to capture an abstract notion of agency for all of them. The notion of Cooperation is, in a way, like the notion of Agency in *-er*: we have an abstract notion we can apply in many different situations. We will apply it inside grammar. Consider now the sharp contrast between these expressions:

(1) John and Bill agreed to disagree.

(2) *John and Bill disagree to agree.

Agree allows a controlled infinitive, while *disagree* blocks it. The only difference is that *agree* entails some cooperation and *disagree* does not.

We therefore argue that the PRO in the infinitive has to accommodate *cooperation* which we will formulate in those terms:

Hypothesis: The controlled empty category in infinitives is PROcooperative[3]

We leave unspecified whether this property should motivate the invention of a specific [+COOP] feature on the PRO or a more intricate interface mechanism. It stands however as a contrast in the class of empty categories where PROarb is another option. Exactly this option is present in a form which is acceptable:

(3) John and Bill disagreed about [PROarb agreeing].

While this allows *John and Bill* to be a choice for the subject of the noun *agreeing* one can imagine other subjects as well in this situation: John and Bill's relatives were arguing and while John thought they would eventually agree, Bill thought they never would. So the expression [Proarb agreeing] allows the relatives and not just John and Bill as subjects. Or PROarb can be an abstract reference where John and Bill disagree about the virtue of eventual agreement in political controversies.

3. For general background on control and suggestions of how verb semantics can play a licensing role, see Landau (2000), Wurmbrand (2002), Jackendoff (1987), Kawasaki (1989), Williams (1987, 1991).

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2.2 Cooperation and partial control

Our claim is that the infinitive selects for PROcooperative which is an encapsulated form of cooperation, derived from a complex process of negotiation Consider Partial Control (see Landau (2000), (2007) for extensive discussion):

(4) John proposed to meet at six.

(5) John refused to meet at six.

(6) *John rejected to meet at six.

These contexts are indeterminate: in (4) the meeters are John and others who are implicitly asked to agree to this, though we do not know who they are. The proposal in (4) presumes agreement, while in (5) we have an individual subject control which is automatically acceptable. In (6) however, we have a context where either cooperation or non-cooperation is a prerequisite, and the term *reject* entails non-cooperation with presumed others, and non-cooperation fails to fulfill PROcoop and therefore the sentence is ungrammatical. Note again that the nominal PROarb form works:

(7) John rejected meeting at six.

The contrast is easily repeated:

(8) John declined to meet at six

(9) *John derided to meet at six.

In (9) there is an implicit proposal by someone else with whom John not only disagrees but ridicules, while in (8) John alone acts though in a negative way.

It is sometimes suggested that some verbs simply lack an infinitival subcategorization [*reject to do], but we are arguing that this is not arbitrary and can have much deeper explanations – such as the relevance of game theory to all verbs which apparently allow partial control.

2.3 Cooperation and intentionality

Cooperation also entails joint action toward an intended goal which then becomes a further prerequisite to PROcoop control:

(10) *John and Mary smiled to agree to disagree.

(11) *They flirted to agree to disagree.

(12) *They saluted to agree to disagree.

In contrast again:

(13) They flirted with agreeing about disagreeing.

Note that if an explicit *in order to* is added then intended goal is added and the sentences become grammatical.

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(14) They smiled in order to agree to disagree.

(15) They flirted in order to agree to disagree.

(16) They saluted in order to agree to disagree.

Our claim is about a grammatical operation of binding. It is different from the fixed point interaction between mind and grammar which occurs when we insert a single word into a sentence, because control of PRO involves fixation of a binding relation between two NP's. Moreover it can involve Partial control where some bindees are implicit. The presence of Partial Control means that there are invisible cooperators that we imagine who are able to interact with a singular subject such that *John suggested to meet at six* is grammatical. Thus the idea continues to be present: the cooperation relation involves not just an empty PROcoop but how it is operationally connected to its (partly implicit) controllers in an online process.

3. Implicit objects

If our claim that game theory cooperation is relevant, then we might expect that it will affect other empty categories. There are well-known implied reciprocals which are often labeled *symmetrical* verbs. We argue that that they are *joint* but not necessarily *symmetrical* and fail as well to be *reciprocal* which, when explicit, means *distributed reciprocal*. We will argue that there is a distinct empty category for cooperative objects. Consider:

(17) John and Mary hugged/kissed/embraced/touched/snuggled.

(18) John and Mary meet.

(19) John and Mary make love.

(20) John and Mary compromise.

(21) John and Mary communicate.

and we find that the following cases are excluded:

(22) *John and Mary hit.

(23) *John and Mary avoid.

(24) *John and Mary surprise.

(25) *John and Mary abuse.

(26) *John and Mary ignore.

Both sets of verbs allow an explicit reciprocal:

(27) John and Mary kissed/embraced/hugged each other

(28) John and Mary avoided/abused/ignore each other.

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The reciprocal (*John and Mary kissed each other*) is not wrong for a joint reading, but it also allows a distributed reading:

(29) John kisses Mary and then Mary kissed John.

This is not equivalent to *they kissed* where exclusively a joint reading is called for and therefore we consider the term *symmetrical* to be slightly misleading. Most *joint* activities are not symmetrical, just as in

(30) John and Mary copulated.

(31) The quarterback and wide-receiver connected.

(32) The father and young son hugged.

(32) can be equivalent to:

(33) The father hugs the boy's head and the boy hugs the father's waist.

These cases where joint but non-symmetrical activity are found are arguably intransitive and their reciprocal potential is produced through an adjunct *with*-phrase.

(34) *John and Mary communicated each other.

(35) John and Mary communicated with each other.

(36) *The chemicals combined each other.

(37) The chemicals combined.

(38) The chemicals combined with each other.

which stand in contrast to cases which allow no *with*-phrase:

(39) *They kissed with each other.

We argue that the empty form has an invisible cooperative object with only a joint reading, that is not an intransitive to which one can add an adjunct (*with each other*).

(40) John and Mary kissed. [pro-cooperative]

3.1 Reflexives and empty cooperative objects

Now an important further contrast lies with reflexives, where a distributed reading is excluded for sentences like:

(41) John and Mary kissed themselves.

(41) means John kisses John and Mary kisses Mary, and neither kisses the other. Exactly the joint reading is available with the German monomorphemic reflexive:

(42) Hanns und Maria küssen sich.

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And in fact in German this reflexive is required and the empty object we find in English is impossible:

(43) *Hanns und Maria küssen.

This leads naturally to our hypothesis:

(44) The English form has a real empty category in the syntax that is the equivalent of *sich*.

Experimental work has been done with young children in German and English (Gülzow (2008), Gülzow, Roeper, and Green (in preparation)) where they are asked to interpret *they_kissed* and *they kissed each other* where three options exists: (1) John kisses John, Mary kisses Mary (himself and herself) (2) John kisses Mary and Mary kisses John and (3) they jointly *kiss*. The children show a preference for the joint over the distributed reading for these cases and the parallel cases with *sich* in German. Interestingly where there is deviation, children reliably prefer the *joint* readings, even for cases like:

(45) They kissed themselves.

If we return to our original verb we can see that the notion of *joint action* is implied with respect to objects as well, because inanimate subjects do not allow a missing object:

(46) John and Mary agreed.

(47) *Your ideas agreed.

(48) Your ideas agreed with each other.

(49) Your ideas are in agreement.

This view agrees with arguments from Everaert (1991) and Reinhard & Reuland (1993) who observe that the Germanic reflexive *sich* has lexical properties linked to specific verbs.[4]

3.2 Incorporation and evidence for an empty object

Roeper & Siegel (1978) argue that compounds are formed exclusively by incorporating the First Sister after the verb. So adjuncts are incorporable only if there is no noun in the object position:

(50) sounds beautiful ⇒ beautiful-sounding

4. we can get the distributed reading in German by adding selbst:

a.	Sie küssen sich	=/=	Sie küssen sich selbst
b.	they kiss reflex-coop		they kissed themselves

The non-joint complex reflexive sich selbst is equivalent to the English themselves.

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(51) make a hat beautifully ⇒ hat-maker, *beautifully-maker

The passive, by moving the object, creates a new first sister *beautifully* which can incorporate:

(52) the hat was made beautifully ⇒ beautifully-made hat

We can now seek a parallel contrast. Note these differences:

(53) *quickly-kisser quickly-kissed

(54) *quickly-fighter quickly-fought

The question is whether there is an invisible *sich* after *kissing* which would block incorporation from (55) to (56):

(55) The boys were kissing [sich] quickly.

(56) the quickly-kissing boys

However (56) is not actually ungrammatical, but instead has a slightly different meaning. It does not mean that the boys kiss each other quickly, but kiss anybody quickly. This second reading is weakly available for (55) as well, which means that only the empty object generic form allows incorporation. If *sich* is present, then it is blocked as we predict:[5]

(57) the cousins [__] kissing [sich] quickly

←=====//====

On the other hand,.

(58) the quickly-kissed boys

(59) The boys were quickly-kissed.[6]

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5. The following contrast seems very real to us:

(i) The boys were kissing.
(ii) The boys were kissing quickly.

In (i) we only get the reciprocal sich reading, while in (ii) the generic reading seems weakly available. It is not clear to us why, without an adverb, the joint reading is forced.

6. Notice that seemingly similar cases are acceptable because adverbs can move throughout the sentence:

(i) The boys quickly were kissing.
(ii) The boys were quickly kissing,

So in (ii) there is a similar word order, but quickly is not incorporated.

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(59) implies exactly that they were specifically kissed, therefore no reciprocal is implied and the origin of the sentence is:

(60) Someone kissed the boys quickly.

All of this follows from the First Sister principle under the assumption that the hidden *sich* can be present and blocks incorporation, but the generic object is an intransitive reading (with the THEME present in the thematic structure, but not projected) and therefore does not block incorporation:

(61) They kiss quickly.

(62) [kiss {AGENT (they),THEME (generic object)}]

where we know that someone must be kissed, but nothing is projected onto the object position. In sum, we argue that incorporation respects the reality of the implicit pro-coop (*sich*) as an empty category in object position.

4. Counter-examples

Other kinds of productive morphology resist infinitives:

(63) *I discontinued to drive a car.

(64) *I restarted to sing.

(65) I started to sing again.

(66) I managed to buy a car.

(67) *I mismanaged to buy a car.

The restrictions are not specific to prefixes, since one can say (68) but not (69):

(68) I was disinclined to go.

(69) *I was dissuaded to go. (*compare:* I was dissuaded from going)

These cases are, interestingly, often not controlled by L2 users of English (who may say "I have stopped to sing") which also suggests that they involve subtle restrictions on how control works that may be language-particular.

One additional property some of these constructions may share is an aspectual bias toward completion (telicity) which interferes with the unbounded intentionality of the infinitive. We will not explore this murky area but just offer this contrast which provides a rough illustration:

(70) He replayed winning the game.

(71) *He replayed to win the game.

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(70) involves a known endpoint, a victory, and (71) is odd because the infinitive is unbounded and entails that the endpoint is unknown. Once again these examples pose interesting questions of a different stripe, but which still illustrate the notion that control can respond to much more than the co-indexation of subject and PRO.

4.1 Implicit dative empty categories

Implicit datives overlap in part with *sich*-reciprocal cases:

(72) This is troubling/inspiring.

where one can project:

(73) troubling (to me, to anyone)

(74) inspiring (to children)

These are just another kind of missing element that can participate in control:

(75) John yelled to open the window
= John yelled to someone for someone to open the window.

Generic sentences also might seem to be counter-examples:

(76) Girls fight.

which is ambiguous between *fight with each other* and *fight other people* as a characteristic of being girls. This is again the generic construction which we discussed above and argued does not involve an object-pro, such that it allows incorporation of an adverb (quickly-kissing boys).

However there are more straightforward counter-examples to our notion of cooperation:

(77) John and Bill fought/battled/bickered/quarreled.

Here the object is *sich*-reciprocal, not generic (John and Bill fight = fight each other), and we do not seem to have cooperation. Yet important subtle differences exist. Some of these forms appear to be intransitives as indicated by the fact that they receive reciprocality through adjuncts (78), not real objects (79):

(78) John and Bill quarreled/bickered *with each other*.

(79) *John and Bill bickered each other.

The other cases are interesting because they allow this addition as well:

(80) John and Bill fought with each other.

(81) John fought with Bill.

(82) John and Bill fought each other.

(83) John fought Bill.

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In (80), (81) and (83) we have individual, reciprocal action which can in fact be one-sided:

(84) John fought with Bill, but Bill did not fight back.

(85) John fought Bill, but Bill did not fight back.

This does not hold for:

(86) *John and Bill fought, but Bill did not fight back.

The ancient Greeks regarded fighting in warfare as a cooperative activity which could only be undertaken jointly. Cases like *John and Bill fought* fit the joint form, while *John fought Bill* show that there is a non-joint form.

This reveals again how *encapsulation* works. For instance, when nominalization occurs, creating a noun from a verb, it encapsulates the meaning but it can alter it as well. A word like *the decision* refers to the outcome of a process and the process itself is no longer visible. Similarly when *encapsulation* of game theory occurs and we have a form like PROcoop to capture *cooperation*, a *joint* interpretation arises in which the suggested symmetry of reasoning is no longer present. If people cooperate, they may all do so in different ways. Formal and informal accounts of these verbs (Langendoen 2003; Gleitman et al. 1996; Rubinstein 2009; Partee 2008) often refer to them as *symmetrical verbs*, which perhaps can be taken either as just a label or an actual description. As we have argued, if symmetry is seen as a description, it is not completely faithful to the *joint* meaning we have seen.

4.2 Game Theory application

Let us re-examine how the game theory calculus applies. Consider the earlier example:

(18) John and Mary meet.

For two acquaintances, John and Mary, to meet one another implies an initial commitment from both sides to be with each other during a certain period of time (except for an accidental meeting). This involves cooperation because at the appointed time, both John and Mary must stop doing whatever they are doing at that time to fulfill their commitment to meet each other. Of course, it is within either party's power to simply decide to renege on their commitment and do something else. However, if John were to do so, he runs the risk of being unable to get Mary to meet with him in the future, or if Mary does agree to meet John in the future, she may feel less obligated to actually fulfill that commitment. John and Mary's commitment to meet one another is binding because they may have an ongoing relationship of indefinite length. It is a decision-making process that can be modeled by an indefinitely iterated Prisoner's Dilemma. We argue that the cooperative equilibrium that emerges from that is part of what is encapsulated by *meet* in the above example.

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Now let us consider the example:

(87) John and Bill fight.

It is harder to see fighting as an example of cooperation, but it is easy to understand as part of an ongoing interaction between two people. In the moment of fighting, by far the easiest and simplest thing for either party would be to simply disengage and hope to never interact with the other person again. The decision to engage in the unpleasantness of fighting one another requires a certain level of cooperation on both sides.

Encapsulated concepts have a specific origin but apply very generally and can even apply in paradoxical or contradictory circumstances. So although fighting may seem very different from meeting, it cannot occur in this sich-reciprocal form, unless both parties willingly participate. While it is impossible to know the future factors each side implicitly takes into account, we recognize that the sentence *they fight* has the same cooperative grammar that *they meet* does. In effect, both parties think that there are future eventualities to consider that makes them willing to be participants, even if we do not know what those considerations are. In this way, fighting could be modeled by an indefinitely iterated game similar to a Prisoner's Dilemma.

To summarize we can use *fight* in three ways. It is cooperative with a generic object unspecified in:

(88) John and Bill fought for their country. = together

(89) John and Bill fought. = fight *sich* = agree to fight

(90) John fought with Bill. = no necessary cooperation

So we argue that some form of cooperation on social norms is required for (89). Consider a case where this requirement fails and the sentence becomes ungrammatical (under the reasonable assumption that the verb "to nuke" implies no future relations):

(91) ?*The Soviet Union and the USA nuked over territory.

The sentence is ungrammatical because it implies some cooperation, but if it has an explicit reciprocal it becomes acceptable and implies no cooperation:

(92) The Soviet Union and the USA *nuked each other* over territory.

It is exactly the *sich*-reciprocal empty object that is unavailable.

5. Conclusion

We have labored to show that subtle facts about the system of control in English respond to the notion of cooperation. In the spirit of building interfaces we have

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drawn a parallel to the way in which cooperation arises in other social domains where it has been studied. In this case game theory.

We end with this observation: the root word *infinite* within the term *infinitive* matches game theory's requirement of indefinite iteration to produce a cooperative outcome in a Prisoner's Dilemma game.

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