

How mechanistic can accounts of interaction be?

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Abstract

Ever since dialogue modelling first developed relative to broadly Gricean assumptions about utterance interpretation (Clark, 1996), it has been questioned whether the full complexity of higher-order intention computation is made use of in everyday conversation. In this paper, building on the DS account of *split utterances*, we further probe the necessity of full-intention recognition/formation: we do so by exploring the extent to which the interactive coordination of dialogue exchange can be seen as emergent from mechanisms of language processing, without either needing representation by interlocutors of each other's mental states, or fully developed intentions as regards messages to be conveyed (even in e.g. clarifications and completions when the content of the utterance is in doubt).

1 Introduction

The pioneering work of H. Clark (Clark, 1996) initiated a broadly Gricean program for dialogue modelling, in which coordination in dialogue is said to be achieved by establishing recognition of speaker-intentions relative to what each party takes to be their mutually held beliefs (*common ground*). However, computational models in this vein have very largely been developed without explicit high-order meta-representations of other parties' beliefs or intentions, except where dealing with highly complex dialogue domains (e.g. non-cooperative negotiation (Traum et al., 2008)) or phenomena (e.g. collaborative completions (Poesio and Rieser, to appear)). With concepts such as *dialogue gameboard*, *QUD*, (Ginzburg, 1995; Larsson, 2002) and *settledness* (Asher and Gillies, 2004) largely replacing intention recognition, it is arguable that the Gricean assumptions underpinning communication should be re-considered. A parallel weakening has been taking place within another major pragmatic paradigm, that of (Sperber and Wilson, 1986). The relevance-theoretic

view is that the content of an utterance is established by a hearer relative to what the speaker could have intended (relative also to a concept of mutual manifestness of background assumptions). However, (Breheny, 2006) argued that children in the initial stages of language acquisition communicate relative to a weaker 'naive-optimism' view in which some context-established interpretation is simply presumed to match the speaker's intention, only coming to communicate in the full sense substantially later (see (Tomasello, 2008) for a Gricean variant of this view).

With this weakening across all pragmatic models of the status of recognition of other interlocutor's intentions,¹ for at least some cases of communication, in this paper we set out the groundwork for an interactive model of communication using *Dynamic Syntax* (DS: Cann et al. (2005)), and examine its application to the tightly interactive dialogue phenomena that arise in cases of continuative/clarificatory/reformulatory splits among speakers. In this model, each party to the dialogue interprets the signals they receive, or plans the signals they send, egocentrically relative to their own context, without explicit (meta-)representation of the other party's knowledge/beliefs/intentions. Nevertheless, the effect of coordinated communication is achieved by relying on ongoing feedback between parties and the goal-directed action-based architecture of the grammar.

Our claim is that communication involves taking risks: in all cases where a single agent's system fails to fully determine choices to be made (either in parsing or production), the eventual choice may happen to be right, and might or might not get acknowledgement; it may be wrong and potentially get corrected, thereafter establishing explicit coordination with respect to some subpart of the communication; or, in recognition of the non-determinism, the agent may set out a sub-routine of clarification thereby delegating the choice of construal to the interlocutor before proceeding. Otherwise, a wrong choice which is uncorrected

¹see also (Kecskes and Mey, 2008)

might threaten the viability of the exchange. Success in communication thus involves clarification/correction/extension/reformulation etc (“repair strategies”) as essential subparts of the exchange. When modelled non-incrementally, such strategies might lead to the impression of non-monotonic repair and the need to revise established context. But pursued incrementally within a goal-directed architecture, these do not constitute communication breakdown and repair, but the normal mechanism of hypothesised update, context selection, and confirmation. By building on the assumption that successful communication may crucially involve subtasks of repair (see also (Ginzburg, forthcoming)), the mechanisms for informational update that underpin interaction can be defined without any reliance on (meta-) representing contents of the interlocutors’ mental states.

2 Split Utterances

Switching of roles between speaking and hearing, across and within sentential structures, is characteristic of dialogue. People show a surprising facility to switch between speaker and hearer roles even mid-utterance:

- (1) Daughter: Oh here dad, a good way to get those corners out
Dad: is to stick yer finger inside.
Daughter: well, that’s one way. [from Lerner (1991)]
- (2) A: They X-rayed me, and took a urine sample, took a blood sample. Er, the doctor
B: Chorlton?
A: Chorlton, mhm, he examined me, erm, he, he said now they were on about a slight [shadow] on my heart. [BNC: KPY 1005-1008]
- (3) A: Are you left or
B: Right-handed.

The challenge of modelling such phenomena has recently been taken up by (Poesio and Rieser, to appear) (*P&R* henceforth) for German, defining a admirably fine-grained neo-Gricean model of dialogue interactivity that builds on an LTAG grammar base. Their primary aim is to model *completions*, as in (1) and (3), with take-over by the hearer because the remainder of the utterance is taken to be understood or inferable from mutual knowledge. Their account hinges on two main areas: the assumption of recognition of interlocutors’ intentions according to shared joint plans, and the use of incremental grammatical processing

based on LTAG. However, their account relies on the assumption of a string-based level of syntactic analysis, for it is this which provides the top-down, predictive element allowing the incremental integration of such continuations. The question we address here is whether the more parsimonious DS model, dispensing with an autonomous string-based syntax, can provide the required *predictivity* (for this psycholinguistic notion, see Sturt and Crocker (1996)); and indeed, besides its greater economy in representational levels, such a model seems better suited to capturing such phenomena since there are cases which show that such splits do NOT involve interlocutors intending to say the same string of words/sentence:

- (4) with smoke coming from the kitchen:
A: Have you burnt the
B buns. Very thoroughly.
A: But did you
B: burn myself? No. Luckily.

The explanation for B’s continuation in the fourth turn of (4) cannot be string-based as then *myself* would not be locally bound (its antecedent is *you*). Moreover, in LTAG, words are defined in terms of syntactic/semantic pairings, relative to a given head, with adjuncts as a means of splitting these. However, as (1)-(4) indicate, utterance take-over can take place at any point in a sequence of words with or without a head having occurred prior to the split. Many split utterances are not joint sentential constructions; and, they couldn’t be because, as (2)-(4) show, even the function of the utterance can alter in the switch of roles, with fragments playing multiple roles at the same time (in (3): question/completion/acknowledgment/answer). If the grammar necessarily induces fine-grained speech act representations such multifunctionality cannot be captured except as a case of ambiguity or by positing hidden constituent reconstruction.

The setting for the P&R analysis is one in which participants are assigned a collaborative task with a specific joint goal, so joint intentionality is fixed in advance and hence anticipatory computation of interlocutor’s intentions can be defined. However, (Mills and Gregoromichelaki, in prep) argue that, even in such task-specific situations, joint intentionality is not guaranteed but rather has to evolve as a result of routinisation. In accordance with this, as (1) shows, in ordinary conversation, there is no guarantee that there is a plan genuinely shared, or that the way the shared utterance evolves is what either party had in mind to say at

the outset, indeed obviously not, as otherwise such exchanges would appear otiose. Instead utterances are shaped incrementally and “opportunisticly” according to feedback by the interlocutor (Clark, 1996). And, as in (2), clarification can occur well before the completion of the utterance, which then absorbs both contributions. Grammatical integration of such joint contributions must therefore be flexible enough to allow such switches, with fragment resolutions occurring incrementally before computation of intentions at the pragmatic level is even possible.

The P&R account marks a significant advance in the analysis of such phenomena as it employs a dynamic view of the grammar in their analysis. But, as we saw above, the phenomenon is more general than just *completions/extensions*, the primary target of the P&R account. Nevertheless, given the observations above, dialogue exchanges involving incremental split utterances of any type are even harder to model adopting any other static grammatical framework. First of all, in such frameworks it is usually the sentence/proposition that is the unit of syntactic/semantic analysis, and, in the absence of an incremental/parsing perspective, elliptical phenomena/fragments are defined (following Dalrymple et al. (1991)) as associated with an abstraction operation over contextually provided propositional content to yield appropriate functors to apply to the fragment. But this problematically increases parsing uncertainty, since multiple options of appropriate “antecedents” for elliptical fragments become available (one for each available abstract). In consequence, to resolve such exploding ambiguities, the parsing mechanism has to appeal to general pragmatic mechanisms having to do with recognizing the speaker’s intention in order to select a single appropriate interpretation. The conundrum that opens up is that intention recognition, on which all such successful contextual resolution will have to be based, is inapplicable in such sub-sentential split utterances, in all but the most task-specific domains. In principle, attribution to any party of recognition of the speaker’s intention to convey some specific propositional content is unavailable until the appropriate propositional formula is established, so recognition of fully propositional intentions cannot be the basis on which incrementally established joint utterances are based. Moreover, from a generation point of view, relative to orthodox grammar-producer assumptions, the fact

that speakers are interrupted, with (possibly unintended) continuations of their utterances being provided instead, means that the original speaker’s plan to convey some full proposition will have to be abandoned mid-production, with some form of radical revision initiated in adopting the role of the parser. However, the seamlessness of such switches indicates no radical revision, and it is to be expected given the psycholinguistic evidence that speakers do not start articulating with fully formed propositional contents to convey already in mind (Levelt, 1989; Guhe, 2007).

Below we set out a model of parsing and production mechanisms that make it possible to show how, with speaker and hearer in principle using the same mechanisms for construal, equally incrementally applied, issues about interpretation choice and production decisions may be resolvable without reflections on the other party’s mental state but solely on the basis of feedback. As we shall see, what connects our diverse examples, and indeed underpins the smooth shift in the joint endeavour of conversation, lies in incremental, context-dependent processing and tight coordination between parsing and generation, essential ingredients of the DS dialogue model (Cann et al., 2005). Instead of data such as (1)-(4) being problematic for such an account, in fact, their extensive use illustrates the advantages of a DS account in its provision of restricted contextually salient structural frames within which fragment construal/generation take place. This results in effective narrowing down of the threatening multiplicity of interpretations by incrementally weeding out possibilities en route to some commonly shared understanding. Features like incrementality, predictivity/goal-directedness and context-dependent processing are, that is, built into the grammar architecture itself: each successive processing step relies on a grammatical apparatus which integrates lexical input with essential reference to the context in order to proceed. Such a view notably does not invoke high-level decisions about speaker/hearer intentions as part of the mechanism itself. That this is the right view to take is enhanced by the fact that, as all of (1)-(4) show, neither party in such role-exchanges can definitively know in advance what will emerge as the eventual joint proposition.

An additional puzzle for any common-ground/intention-based views is that both speakers and hearers may elect not to make use of

what is well established shared knowledge. On the one hand, in selecting an interpretation, a hearer may fail to check against consistency with what they believe the speaker could have intended (as in (5) where B construes the fragment in flagrant contradiction to what she knows A knows):

- (5) A: Why don't you have bean chili?
 B: Beef? You KNOW I'm a vegetarian
 [natural data]

On the other hand, speaker's choice of anaphoric expression, supposedly restricted to well-established shared knowledge, is commonly made in apparent neglect of their hearer:

- (6) A having read out newspaper headline about Brown and Obama, upon reading next headline provides as follow-on:
 A: They've received 10,000 emails.
 B: Brown and Obama?
 A: No, the Camerons. [natural data]

Given this type of example, checking in parsing or producing utterances that information is jointly held by the dialogue participants - the perceived *common ground* - can't be a necessary condition on such activities. Hence it is not intrinsic to utterance interpretation in virtue of which conversational dialogue takes place. So we turn to Dynamic Syntax (DS) to explore possible forms of correlation between parsing and generation as they take place in dialogue without reliance on any such construct.

3 Incrementality in Dynamic Syntax

DS is a procedure-oriented framework, involving incremental processing, i.e. strictly sequential, word-by-word interpretation of linguistic strings. The notion of incrementality in DS is closely related to another of its features, the *goal-directedness* of BOTH parsing and generation. At each stage of processing, *structural predictions* are triggered that could fulfill the goals compatible with the input, in an underspecified manner. For example, when a proper name like *Bob* is encountered sentence-initially in English, a semantic predicate node is predicted to follow ($?Ty(e \rightarrow t)$), amongst other possibilities.

By way of rehearsing DS devices, let us look at some formal details with an example, *Bob saw Mary*. The 'complete' semantic representation tree resulting after full processing of this sentence is shown in Fig 1 below. A DS tree is

binary and formally encoded with the tree logic *LOFT* (Blackburn and Meyer-Viol, 1994). It carries annotations at every node which represent semantic formulae with their type information (e.g. ' $Ty(x)$ ') based on a combination of the epsilon and lambda calculi:

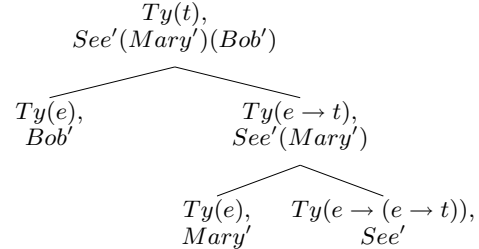


Figure 1: A DS complete tree

Such complete trees are constructed, starting from a radically underspecified goal, the *axiom*, the leftmost minimal tree in the illustration provided by Fig 2. Going through *monotonic updates* of partial or *structurally underspecified* trees, complete trees are eventually constructed. Crucial for expressing the goal-directedness are *requirements*, i.e. unrealized but expected node/tree specifications, indicated by '?' in front of annotations. The axiom says that a proposition (of type t , $Ty(t)$) is expected to be constructed. Furthermore, the *pointer* notated with ' \diamond ' indicates the 'current' node in processing, namely the one to be processed next, and governs word order.

Updates are carried out by means of applying *actions* of two types. *Computational actions* govern general tree-constructional processes, such as moving the pointer, introducing and updating nodes, compiling interpretation for all non-terminal nodes. In Fig 2, the update of 1 to 2 is executed via computational actions expanding the axiom to the subject and predicate nodes, requiring the former to be processed next (given the position of the pointer). Construction of only weakly specified tree relations (*unfixed nodes*) can also be induced, characterized only as dominance by some current node, with subsequent update required. Individual lexical items also provide procedures for building structure in the form of *lexical actions*, inducing both nodes and annotations. In the update from 2 to 3, the set of lexical actions for the word *see* is applied, yielding the predicate subtree and its annotations. Unlike conventional bottom-up parsing, the DS model takes the parser/generator to entertain some predicted goal(s) (*requirements*) to be reached eventually at any stage of processing. Thus *partial trees*

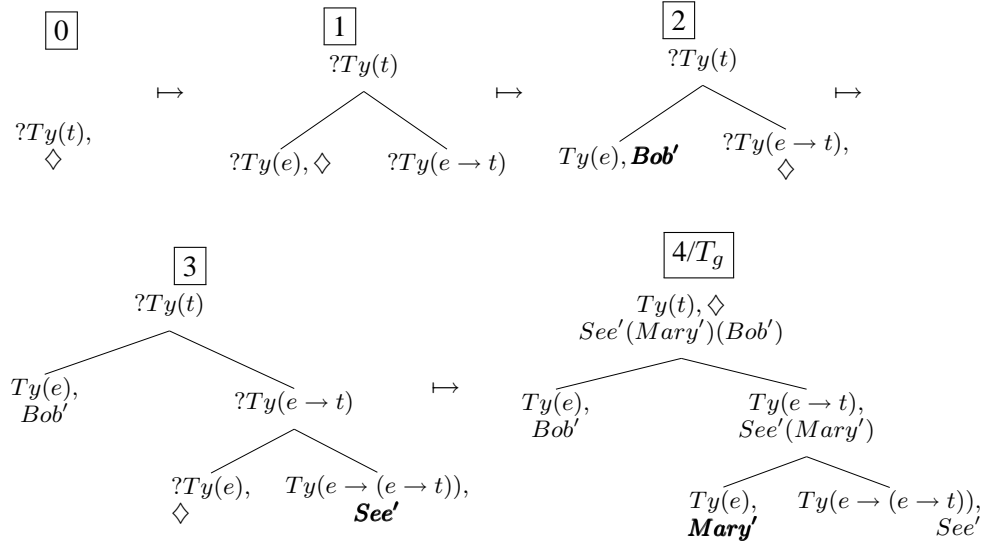


Figure 2: Monotonic tree growth in DS

grow incrementally, driven by procedures associated with particular words as they are encountered.

Individual DS trees consist of predicates and their arguments. Complex structures are obtained via a general tree-adjunction operation licensing the construction of LINKed trees, pairs of trees where sharing of information occurs. The assumption in the construction of such LINKed structures is that at any arbitrary stage of development, some type-complete subtree may constitute the context for the subsequent parsing of the following string as an adjunct structure candidate for incorporation into the primary tree, hence the obligatory sharing of information in the resulting semantic representation.

Appositional structure, as in *A consultant, a friend of Jo's, left*, can then be established by defining a LINK transition as in Fig 3 from a node of type e in which a preliminary epsilon term² has been constructed (with all terminal nodes decorated but nonterminals not fully compiled) onto a LINKed tree introduced with a requirement to develop a term using that very same variable. A twinned evaluation rule then combines the restrictors of two such paired terms to yield a composite term (unlike the P&R account, this does not involve ambiguity of the head NP according to whether a second or subsequent NP follows). The fact that the first term has not been completed is no more than the term-analogue of the delaying tactic

²Epsilon terms, like $\epsilon, x, Consultant'(x)$, stand for witnesses of existentially quantified formulae in the epsilon calculus and represent the semantic content of indefinites. Defined relative to the equivalence $\psi(\epsilon, x, \psi(x)) = \exists x\psi(x)$, their defining property is their reflection of their containing environment, and accordingly they are particularly well-suited to expressing the growth of terms secured by such appositional devices.

made available by expletive pronouns, extraposition etc, whereby a parse can proceed from some type specification of a node but without completing (*evaluating*) its formula. This strategy allows term modification when the pointer returns from its sister node immediately prior to compiling the decorations of its mother (as in *A man has won, someone you know*). Should this sequence of transitions be adopted by the hearer, in the absence of any such end-placed modification, it would constitute motivation for asking for clarification to enable a complete parse.

Such LINKed trees and their development set the scene for a general characterisation of context. *Context* in DS is defined as the storage of *parse states*, i.e., the storing of partial tree, word sequence parsed to date, plus the actions used in building up the partial tree. All fragments illustrated above are processed by means of either extending the current tree, or by constructing LINKed structures with transfer of information among them so that one tree provides the context for another. Such fragments are licensed as well-formed by the grammar only relative to such contexts (Gargett et al., 2008; Kempson et al., 2009).

4 Parsing/Generation Coordination

This architecture allows a dialogue model in which generation and parsing function in parallel, following exactly the same procedure in the same order. Fig 2 also displays the generation steps 0 to 4 of *Bob saw Mary*, for generation of this utterance follows precisely the same actions and trees from left to right as in parsing, although the complete tree is available as a *goal tree* from the start (hence the labelling of the complete tree as T_g):

Having parsed *a friend of Jo's* in *A consultant*, *a friend of Jo's*, left:

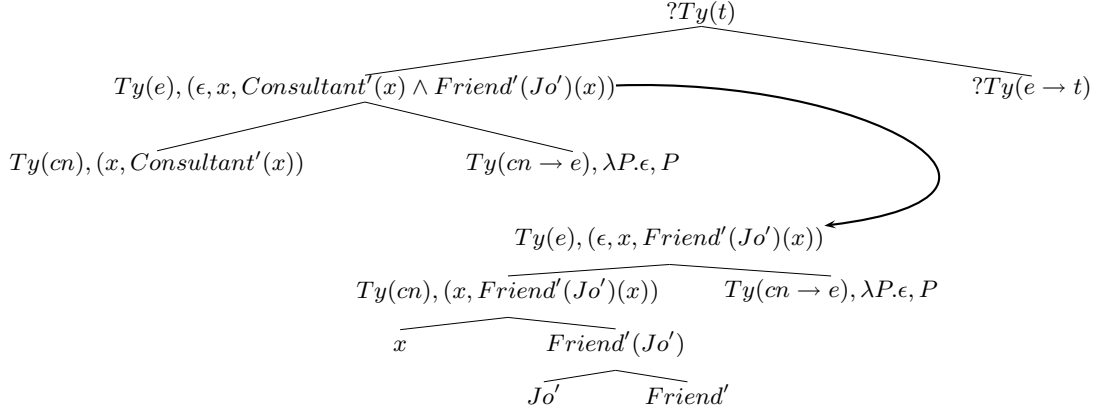


Figure 3: Apposition in DS

in this case the eventual message is known by the speaker, though of course not by the hearer. What generation involves in addition to parse steps is reference to T_g to check whether each intended generation step (1, 2, 3, 4) is consistent with it. That is, a *subsumption* check is carried out as to whether the current parse tree is monotonically extendible to T_g . The trees 1-3 are licensed because each of these subsumes T_g in this sense. Each time then the generator applies a lexical action, it is licensed to produce the word that carries that action only under successful subsumption check: at step 3, for example, the generator processes the lexical action which results in the annotation ‘*See*’, and upon success and subsumption of T_g license to generate the word *see* ensues.

For processing split utterances, two more consequences are pertinent. First, there is nothing to prevent speakers initially having only a partial structure to convey, i.e. T_g may be a *partial* tree: this is unproblematic, as all that is required by the formalism is monotonicity of tree growth, and the subsumption check is equally well defined over partial trees. Second, the goal tree T_g may change during generation of an utterance, as long as this change involves monotonic extension; and continuations/reformulations/extensions across speakers is straightforwardly modelled in DS by appending a LINKed structure annotated with added material to be conveyed (preserving monotonicity) as in single speaker utterances:

- (7) A friend is arriving, with my brother, maybe with a new partner.

Such a model under which the speaker and hearer essentially follow the same sets of actions, each incrementally updating their semantic representations, allows the hearer to mirror the same series of partial trees as the producer, albeit not

knowing in advance the content of the unspecified nodes. Furthermore, not only can the same sets of actions be used for both processes, but also a large part of the parsing and generation algorithms is shared. And both parties may engage with partial tree representations. Even the concept of *goal tree*, T_g , may be shared between speaker and hearer, in so far as the hearer may have richer expectations relative to which the speaker’s input is processed, as in the processing of a clarification question. Conversely, the speaker may have only a partial tree as T_g , relative to which they are seeking clarification.

In general, as no intervening level of syntactic structure over the string is ever computed, the parsing/generation tasks are more economic in terms of representations. Additionally, the top-down architecture in combination with partiality allows the framework to be (strategically) more radically incremental in terms of interleaving planning and production than is possible within other frameworks. And there is evidence that such incrementality increases efficiency (Fernanda and Swets (2002):77).

4.1 Split utterances in Dynamic Syntax

Split utterances follow as an immediate consequence of these assumptions. For dialogues (1)-(4), A reaches a partial tree of what she has uttered through successive updates, while B as the hearer, follows the same updates to reach the same representation of what he has heard: they both apply the same tree-construction mechanism which is none other than their effectively shared grammar³. This provides B with the ability at any stage to become the speaker, interrupting to continue A’s utterance, repair, ask for clarification, reformulate,

³A completely identical grammar is, of course, an idealisation but one that is harmless for current purposes.

or provide a correction, as and when necessary. According to our model of dialogue, repeating or extending a constituent of A's utterance by B is licensed only if B, the hearer now turned speaker, entertains a message to be conveyed (a new T_g) that matches or extends in a monotonic fashion the parse tree of what he has heard. This message (tree) may of course be partial, as in (2), where B is adding a clarificational LINKed structure to a still-partially parsed antecedent. Importantly, in DS, both A and B can now re-use the already constructed (partial) parse tree in their immediate context as a point from which to begin parsing and generation, rather than having to rebuild an entirely novel tree or subtree. In this sense, the most recent parse tree constitutes the most immediately available local "antecedent" for fragment resolution, for both speaker and hearer, hence no separate computation or definition of *salience* or speaker intention by the hearer is necessary for fragment construal.

As we saw, the hearer B may respond to what he built up in interpretation, anticipating the verbal completion as in (1)-(3). This is facilitated by the general predictivity/goal-directedness of the DS architecture since the parser is always predicting top-down goals (*requirements*) to be achieved in the next steps. Such goals are what drives the search of the lexicon (lexical access) in generation so a hearer who shifts to successful lexicon search before processing the anticipated lexical input provided by the speaker can become the generator and take over. In (3), B is, indeed, using such anticipation as, simultaneously, at least a completion of A's utterance, an acknowledgment of his understanding of the question and of his taking it up, and as a direct form of reply. Any framework that relies on complete determination of the speaker's intention in order to resolve such fragments does not allow for such multiple functionality. Instead, such fragments would have to be characterized as multiply ambiguous requiring the parser to select interpretations among a set of pre-defined options (but cf Ginzburg (forthcmg):Ch 3 for arguments in favour of this approach). Even if pre-determination of such options were feasible, such a stance once more increases parsing uncertainty at the choice points so that inferential pragmatic mechanisms (appealing to deciphering speakers' intentions with reference to common ground) have to be invoked to select the appropriate update rules that should or should not apply at this juncture.

5 Summary Evaluation

With grammar mechanisms defined as inducing tree growth and used incrementally in both parsing and generation, the availability of these derivations from within the grammar shows how the core dialogue activities can take place without any other-party representation at all.⁴ This then results in a view of communication that is not grounded in recognizing speaker's intentions, hence can be displayed by both young children and adults equally. The two crucial properties are the intrinsic predictivity/goal-directedness in the formulation of the DS, and the fact that both parsing and production can have arbitrary partial goals, so that, in effect, both interlocutors are able to be building structures in tandem. Because of the assumed partiality of goal trees, speakers do not have to be modelled as having fully formed messages to convey at the beginning of the generation task but can instead be viewed as relying on feedback to shape their utterance. As goal trees are expanded incrementally, completions by the other party can be monotonically accommodated even though they might not represent what the speaker would have uttered if not interrupted: as long as what emerges as the eventual joint content is some compatible extension of the original speaker's goal tree, it may be accepted as sufficient for the purposes to hand. Hence "repair" phenomena naturally emerge as "coordination devices" (Clark, 1996), devices exploiting mutually salient contexts for achieving coordination enhancement. And such jointly constructed content through cycles of "miscommunication" and "repair" is more securely coordinated (see e.g. Healey (2008)) and thus can form the basis of what each party considers shared cognitive context.

It might appear that the analysis faces the familiar exponential explosion of interpretations requiring the computation by the hearer of speaker intentions on the basis of common ground, albeit at a sub-propositional level. However, on the incremental processing view developed here, on the one hand, such speaker intentions are not available at the relevant juncture and, on the other hand, speaker intentions might not have even been formed given the partiality of the goal trees. But with feedback able to be provided/accommodated at any (sub-propositional) stage, the potential exponential explosion of interpretations can be kept firmly in check: structurally, such fragmental

⁴Note that we are not claiming that they necessarily do.

feedback can be integrated in the current partial tree representation directly (given the position of the pointer) so there is no structural ambiguity multiplication. What is notable is that for any one such intermediate check point, matching use of tree-construction processes by the parser and generator means that consistency checking can remain internal to each interlocutor's system. The fact of their mirroring each other results in their being at the same point of tree-growth and this provides a shared basis for understanding without explicit modelling of each other's information state. Even repairs may be processed relative to each interlocutor's own set of trees (background knowledge) and with no thought of what the other might have in mind. This is compatible with a mechanistic view of dialogue processing (Pickering and Garrod, 2004), though without invoking *priming*.

Of course, DS being a grammar formalism, an account of all facets of dialogue including its non-monotonic aspects is not within its remit. Nevertheless, the account provided does not preclude the representation of "intentions" as explicitly expressed and manipulated (in the form of adjoined LINKed structures), derived through the mechanisms mentioned in P&R or alternative routinisation accounts (Mills and Gregoromichelaki, in prep). Yet the dual applicability of the mechanisms, defined identically for both parsing and (tactical) generation, enables us to see how apparently shared contents can be incrementally and egocentrically derived, all context-based selections being based on the individual's own context as far as fragment resolution is concerned. Where uncertainty arises, the context-dependent repair mechanisms can take over. This, in its turn, makes possible an account of how hearers may construct interpretations that are transparently inconsistent with what both interlocutors know ((5)-(6)). Hence we suggest, contra (Tomasello, 2008), that we need to be exploring accounts of human communication as an activity involving emergent agent coordination without any required high-level mind-reading.

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