

Incremental Syntactic Planning across Clauses

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Abstract

Language production research has focused on planning at the lexical and syntactic levels. Consequently, little is known about speakers' strategies for distributing information across multiple utterances. We present evidence that (a) the overall amount of information in an intended message affects how speakers distribute that information *across* clauses, and (b) speakers have relatively early access to (at least an estimate of) message complexity, specifically before word retrieval. The observed effect is unexpected for competing theories of sentence production based on availability or macro-propositional accounts. We discuss these findings in an information theoretic context coupled with a sketch of a model of limited resources at the level of macro-propositional planning.

Keywords: macro-propositional planning; syntactic planning; information theory; language production

Introduction

In order to communicate successfully, speakers need to translate an intended message into an orderly stream of articulations. In doing so, they make choices between different ways to convey the same message at the phonological, lexical, and syntactic levels. Phonological choices are evident in instances when speakers elongate vowels of articles depending on the givenness of the noun that follows (Arnold, Fagnano, & Tanenhaus, 2003; Fox Tree & Clark, 1997). Lexical choices include which verb to use, whether to use a pronoun or a noun, and whether to include optional function words (e.g. the relativizer 'that', Ferreira & Dell, 2000; Jaeger, 2006; Levy & Jaeger, 2006). Among the possible syntactic choices, speakers can realize transitive sentences in the active or passive (J. K. Bock & Warren, 1985; Prat-Sala & Branigan, 2000); they can choose between different orders for the post-verbal arguments of ditransitive predicates (Givon, 1984); they can order coordination conjuncts differently (Levelt & Maassen, 1981); they can include optional instruments (Dell & Brown, 1991), and so on. One principle that seems to account for many of a speaker's choices in production at different levels of linguistic planning is the preference for choosing structures based on the ready availability of upcoming material for pronunciation (J. K. Bock & Warren, 1985; K. Bock, 1987; Ferreira & Dell, 2000; Race & MacDonald, 2003).

While speakers' choices at or below the clausal level have been extensively studied, less research has been done on syntactic planning beyond the clause level (but see, e.g. Dell & Brown, 1991; Levelt & Maassen, 1981). To the best of our knowledge only a handful of controlled psycholinguistic

studies have investigated how speakers structure their utterances beyond the clause level — despite the fact that linguistic theory relies heavily on notions such as discourse structure, information packaging, and information flow (see e.g. Lambrecht, 1994; Schiffrin, 2003, among many others).

The present study looks at how the complexity of themes and goals affects the number of utterances/clauses speakers use when giving instructions. In particular we hypothesize that speakers prefer to distribute more complex realizations of thematic roles across two clauses instead of one. We show how different measures of complexity such as description length, information content and givenness affect speech act planning. First, we present two previous studies that focused on production above the clausal level. Then we present the Fruit Carts corpus which we used to investigate our hypothesis. Finally, we analyze data from the Fruit Carts corpus using logit mixed-effects models, and discuss the relevance of our findings to different theories of production planning.

Previous Studies at the Clausal Level

In the limited literature on language production above the clause level, Levelt and Maassen (1981) and Dell and Brown (1991) demonstrate that the choice of syntactic frame depends on lexical access effects (availability) and the listener's inferences and knowledge of the scene. Levelt and Maassen (1981) had subjects describe scenes in which two objects (e.g. a cross and a star or a cross and a triangle) were moving up. In that context, speakers have a choice between two ways of packaging the description of the scene they are observing. Both (1), where the entire description is packed into one clause, and (2), where the description is split up across two clauses, are perfectly fine descriptions.

Speakers were instructed to use easy versus difficult labels for certain objects on the screen. For instance, objects such as cross, star and diamond were labeled with their natural names in Dutch ("kruis", "ster", "ruit"), while other objects had more difficult unnatural labels (or allonyms): a circle ("cirkel") is labeled as coin ("munt"), a pentagon ("vijfhoek") labeled as kite ("vlieger"), a triangle ("driehoek") is labeled as tent ("tent"), and so on. By having speakers use less common labels in some of their referring expressions, an effect of availability is created. Interestingly, speakers had a preference for the bi-clausal variant (2) (Levelt & Maassen, 1981), when the second object had a label that was harder to produce, compared to when it was easier to produce.

1. **NP Conjunction** with easy labels:

The cross and the star went up

2. **Sentence Conjunction** with difficult label on second position:

The cross went up and the tent went up

This tendency is strikingly similar to speakers' preference for producing accessible elements earlier in a sentence, as predicted by availability-based production (see above). Lev-elt and Maassen conclude that once a speaker starts the utterance "the cross ..." difficulty in lexical access for the second item causes the speaker to select a syntactic frame that will delay the utterance of that item. The speaker then finishes the first clause as "the cross went up ..." and continues with a conjoined clause. This change in syntactic frame allows more time for the speaker to continue with a less disfluent production while the label for the second object is searched.

Dell and Brown (1991) elicited productions by presenting speakers with pictures of two people in which one person was about to attack the other. Their sentences are similar to (3).

3. The robber stabbed the man:

- (a) [end of utterance]
- (b) ...with the knife.
- (c) ...He used an icepick.

They argued that typical instruments such as a knife are more likely to be present in the macro-proposition (message level), and thus tend to appear in the same clause as the verb. Less typical instruments such as an ice pick may be added later in the production process in a separate phrase or clause, as an *embellishment* to the message (3.c).

We will see in later sections that these accounts do not explain the data we present in this paper, and how information theoretical and limited resource accounts provide a better model of how speakers realize a message in speech.

The Fruit Carts Corpus

To test our hypothesis, we used the Fruit Carts Corpus (Aist et al., 2007; Gómez Gallo et al., 2007) which consists of digital videos of 104 dialogues. Thirteen participants each directed another person in eight different referential description tasks. These interactions ranged from four to eight minutes in duration. The number of utterances in each scenario ranges from 20 to more than 100.

The corpus domain was designed to elicit complex referring expressions and object manipulations in unrestricted natural language (Aist et al., 2007). In the experiment, a person is given a map that needs to be reproduced on a computer screen (Figure 1). The map and the screen have the same objects, but in different positions. The speaker gives instructions to a listener/enactor to manipulate the objects according to the reference map. Using the mouse, the enactor can move, rotate or paint any object on the computer screen. Utterances 4 and 5 show a typical interaction in the corpus.

We explore the question of when and why speakers prefer to split up utterances. In particular, we hypothesize that there is a correlation between the description length of the thematic roles and the complexity of the syntactic structure. We investigate speakers' requests that an object be moved from one

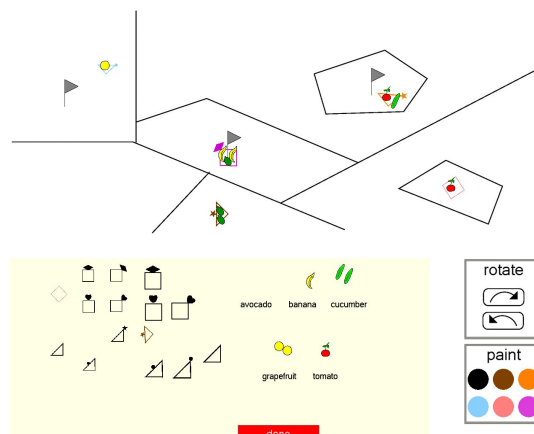


Figure 1: Fruit Carts Map: Speaker instructs listener to move, rotate and paint objects on the screen.

location to another. These requests can be performed in one of two ways: a simple request to move the object, using an implicit SELECT (e.g. Mono-clausal realization: *move X to Y* (4)), or, alternatively, a more complex request that the listener first SELECT the object, and then MOVE it (e.g. Bi-clausal realization: *take X, move it to Y* (5)). We hypothesize that the longer the description of the object, the more likely it is that a speaker will break the request into two parts.

4. **MOVE with an implicit SELECT (Mono-Clausal):**

Put [*theme*an apple] [*loc*directly inside the triangle]

5. **MOVE with an explicit SELECT (Bi-Clausal):**

(a) Take [*theme*the square with the heart on the corner]

(b) Move [*theme*it] [*loc*up into Forest Hills]

The objects and regions on the map were designed in such a way as to control the complexity of the language used in the commands. The objects were of contrasting sizes, colors, shapes and decorations. These geometrical figures elicit complex referring expressions such as "the big triangle with the heart on the hypotenuse". To obtain simple referring nouns, fruits were also used as referents, in sets of avocados, bananas, cucumbers, grapefruit and tomatoes. Hence, the speaker can say "a banana" to refer to any banana in the banana set. The regions on the map have landmarks such as flags that are used as orientation points by the speakers (e.g. "put it below the flag in Central Park").

Annotation

In this paper, we focus on MOVE actions. We determined whether speakers decided to express a MOVE request as mono versus bi-clausal realizations by manually labeling select and move actions in 1300 utterances from 10 subjects. Of these, 400 utterances are either mono or bi-clausal MOVE actions. The remaining are refinements or elaborations of some semantic role (e.g. theme or location). For instance, *more towards the right ... a bit more ... a bit more* is an elaboration of the location first introduced in (4). Elaborations by definition

follow a previously stated MOVE action and do not require a preceding SELECT action.

Annotation follows the scheme developed in (Gómez Gallo et al., 2007) to semantically label units comprising speech acts in the corpus. The thematic roles (e.g. theme, target location) were annotated along with theme givenness and location types. Givenness has four levels: new, given, implied and set-of (Prince, 1992). An object’s first mention is marked as new. Objects already in the discourse are marked as given. The implied label is used when an object is not directly present in the discourse but can be inferred possibly using world knowledge. Speakers sometimes refer to given objects collectively (e.g. *move X to Y, move Z to Y, now paint that set blue*). We used set-of to mark these cases.

The description length of themes and locations was also measured in terms of the number of characters and words, and whether disfluencies and pauses were present in the description¹. Wasow (1997) and Szmrecsanyi (2004) compared different measures of complexity (e.g. grammatical weight, syntactic complexity, cognitive complexity) and found that number of characters, words, and syntactic nodes are highly correlated in English. Furthermore, Szmrecsanyi (2004) shows that word counts are a “nearly-perfect proxy” for measuring complexity. In our data, too, word counts correlate strongly with other complexity measures, such as the character count, as shown in Figure 2.

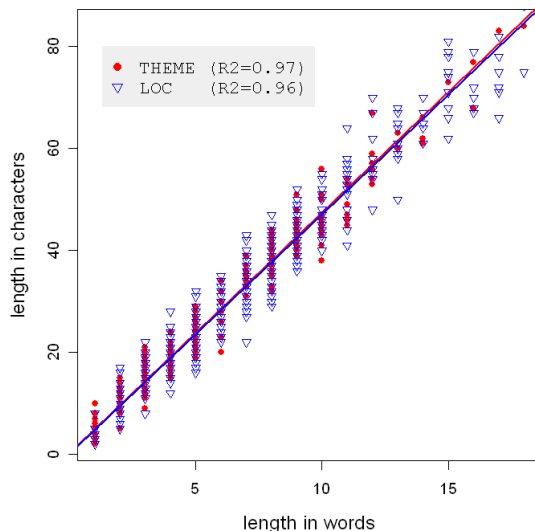


Figure 2: Correlation of thematic role description length measured in characters and words

In the following sections, we study the relationship between theme and location complexity, information density and the speakers’ choice of mono-clausal or bi-clausal realizations.

Effects of Theme and Location Complexity

We performed a mixed logit model analysis with the outcome variable of whether speakers realize the message with a mono-

¹Disfluencies such as repeated or aborted words did not count towards description length measures

or bi-clausal structure. The regression predictors were theme givenness, and three measures each of theme complexity and location complexity: log length in words, existence of pauses, existence of disfluencies.

Results

Speakers are more likely to produce a bi-clausal plan with longer themes ($e^{\beta} = 1.31, p < 0.0001$) and marginally so with longer locations ($e^{\beta} = 0.39, p = 0.085$). Similarly, new themes lead to a higher likelihood of bi-clausal realizations ($e^{\beta} = 1.6, p < 0.0001$) as well as disfluent locations ($e^{\beta} = 0.29, p < 0.05$). Speakers were less likely to produce bi-clausal realizations with disfluent themes ($e^{\beta} = -0.62, p < 0.005$).

Discussion

We found significant theme complexity effects and marginal effects of location complexity, as well as significant givenness and disfluencies effects. We briefly discuss two potential issues with the current results.

Givenness Effect In addition to an effect of theme complexity in terms of the number of words, we also find that the givenness of the theme’s referent influences speakers’ choice of a bi-clausal plan. The inclusion of givenness as a factor and its independent effect is crucial since it rules out a potential confound.

Without controlling for givenness, the observed correlation between object length and message structure could have been an artifact of information-structure constraints. It is well known that repeated reference to the same referent correlates with shorter expressions for that referent (Ariel, 2001, e.g.). Thus it could be the case that the shorter object descriptions in our sample are descriptions of objects that have been mentioned before in the discourse, while the longer descriptions may be mostly first-time mentions. The observed effect may then be due to a preference on the part of speakers to introduce new objects via a SELECT request, thereby directing their interlocutors’ attention to the relevant object before more detailed requests are uttered. However, the effect of theme complexity remains highly significant above and beyond givenness (and the effects are not confounded by collinearity).

Furthermore, under the assumption that new themes are less accessible and have more information, we predicted that bi-clausal plans would be more likely with new themes, even if they were short. This hypothesis was confirmed since new themes were positively correlated with bi-clausal plan. This suggests that even at the early message level, speakers were aware that they might have to elaborate on the object to be moved, and therefore chose to dedicate a clause to the SELECT action.

Disfluency Effect A bi-clausal realization is more likely when locations contain disfluencies and less likely when themes do. The presence of disfluencies shows a higher degree of production difficulty possibly due to accessibility. Therefore we expect to have a bi-clausal plan in these cases. The fact that disfluent theme is correlated in the opposite direction to the message structure is unexpected and requires further investigation.

Information Density of Semantic Roles

So far we have measured theme and location description lengths with different units (e.g. characters, words). These measures aim to quantify the propositional complexity of themes and locations. Information content can also give us insight into the 'heaviness' of such semantic roles. In fact, information content and length measures are highly correlated in our dataset, although not as strongly as the different length measures discussed above, as shown in Figure 3 (see below how information content was calculated). This raises the question of whether the observed effects are driven by some limit on the amount of information speakers prefer to put in a clause rather than a limit in terms of words, syllables, or other length-based complexity measures.

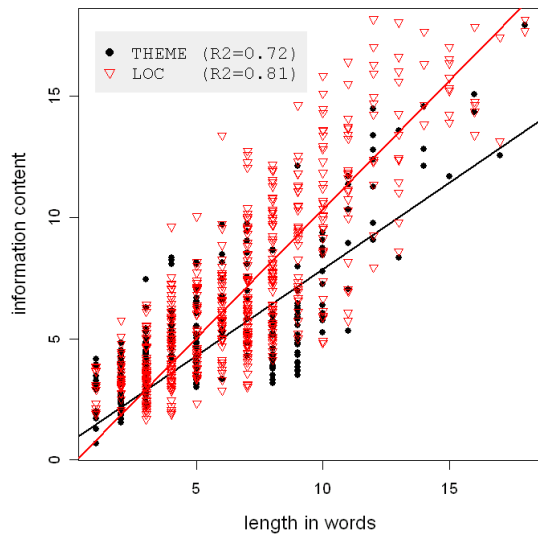


Figure 3: Correlation of information density and length in words for theme and location.

Hale (2001) and Levy (2006) show that comprehension difficulty of a word is positively correlated with its information content or surprisal. Other studies of language production have shown that production planning is sensitive to the amount of information being processed and that speakers structure their utterances such that information is distributed relatively uniformly across the utterance as it unfolds over time (Genzel & Charniak, 2002; Jaeger, 2006; Levy & Jaeger, 2006).

This principle of Uniform Information Density (UID) (Jaeger, 2006; Levy & Jaeger, 2006) both minimizes comprehension complexity and maximizes information transfer (Levy & Jaeger, 2006). Indeed, several recent studies have provided evidence that information density influences production at many levels of linguistics representation (Bell et al., 2003; Frank & Jaeger, 2008; Jaeger, 2006).

UID makes predictions about how much information speakers convey per unit of time. However, without further assumptions, it does not make predictions as to how much information speakers prefer to pack into a clause. Although the above-mentioned work examines only single clauses, we can use their approach to extend UID beyond the clause level.

We predict that speakers will prefer to distribute high information thematic roles across several clauses. Therefore we measured the information content of both themes and locations in order to study their effect on speech act structure. Information content of an event is defined as the negative log-probability of such an event (or $\log \frac{1}{P(event)}$). In our case, the event is the sequence of words (w_1, w_2, \dots, w_n) that instantiate the theme or location expression. Thus we compute $-\log P(w_1, w_2, \dots, w_n)$ by estimating the word sequence probability using backoff trigram language models trained on the Fruit Cart corpus. The training was done on all extracted semantic roles and the Good-Turing discounting smoothing technique was applied. Once we compute the information content (equation 1) per semantic role, we can find its information density by dividing by its description length.

$$-\log P(w_1, w_2, \dots, w_n) = -\log P(w_1) - \log P(w_1|w_2) + \sum_{i=3}^n -\log P(w_i|w_{i-1}, w_{i-2}) \quad (1)$$

Analysis of Information Density Effect

We use a logit mixed model with random subjects effects. The modeled outcome variable was whether speakers realize the message with a mono or bi-clausal structure. The regression predictors were five measures of theme and location: log length in words, information density, existence of pauses, existence of disfluencies, and theme givenness. We excluded sentences that deal with MOVE elaborations since these do not require a preceding SELECT clause.

Results

Speakers were more likely to realize their message in a bi-clausal manner when the themes had longer descriptions, higher information density and were newly introduced in the discourse ($e^{\beta} = 2.01$, $p < 0.000$; $e^{\beta} = 1.6$, $p < 0.003$; $e^{\beta} = 1.8$, $p < 0.0002$).

Description length and information density of location did not come out as significant predictors in the analysis, nor did the presence of pauses in either theme or location. The effects of disfluencies in theme and location descriptions are both significant, though in opposite directions ($e^{\beta} = -0.79$, $p < 0.005$; $e^{\beta} = 0.64$, $p < 0.007$). A bi-clausal plan is less likely with a disfluent theme description, the contrary is true for disfluent location description.

General Discussion

A bi-clausal realization is most likely when the theme is longer with higher information density. Our results suggest that information density plays a role in predicting the message structure beyond the degree of complexity. Speakers were more likely to have a separate clause to select a theme when the theme had higher information density. We tested collinearity effects between information density and complexity and, although they are very correlated (.84), the correlation is not as high as other measures of length measures of complexity (.96). This may be a consequence of the way we are estimating the probabilities for information content

computation. We plan to improve these calculations by using better models that include structural and information cues. Location effects do not turn out to be significant in either description length complexity or information density.

Early Commitment to a Plan

Speakers seem to have early access to an approximate measure of the complexity of the theme. This approximation is available not only before they decide on the linear order of the argument expressions, but also before they choose the verb and the syntactic structure (in whichever order this happens). In our database, speakers used the verb ‘take’ over 70% of the time when they described a SELECT action, but never when they described a MOVE action. On the other hand, the three verbs that together made up over 95% of all MOVE descriptions (‘move’, ‘put’, and ‘be’), were seldom used in SELECT actions (less than 10%), even though - as one of our reviewers pointed out- this would have been possible (e.g. “Next move the banana. Put it into Central Park.”). This strongly suggests that speakers have already committed to a specific clausal structure when they choose the verb. Given that the verb is the first word in the sentences in our corpus in 54% of all utterances, and given that additional analyses found that the effect of theme description complexity also holds for only verb-initial cases, this means that speakers have access to some estimate of theme complexity very early during sentence planning. There is no need for the complexity measure to be as detailed as the number of words that the speaker is eventually going to use to refer to the thematic roles. Speakers may have access to some heuristic estimate of the complexity of yet-to-be-lexically-planned thematic roles. For example, speakers might know that a referent will have to be elaborated on, or that they have not yet established a shared label referring to the argument.

Availability and Dell-Brown Accounts and Description Length Effect

We are aware of only two competing theories that address inter-clausal material. Firstly, availability-based approaches are very successful at predicting how intra-clausal material is processed (J. K. Bock & Warren, 1985; Ferreira & Dell, 2000) and also extend to some earlier findings on production beyond the sentence level (Levelt & Maassen, 1981). On their view, the readiness of upcoming material affects the production plan as a way to delay the production of the non available material.

However, this does not explain the theme effect present in our data. Theme is most commonly placed in second position in both mono and bi-clausal plans. This means that choosing “take X ... move it to Y” does not actually provide the speaker with any more time than “move X to Y” for the theme to become available.

Secondly, Dell and Brown (1991)’s macro-proposition approach does not account for our results either. According to their findings, speakers included embellishments (utterance 3.c) when either the instrument was not part of the initially intended macro-proposition or when it could not be inferred by the listener. This extra-clausal material exists as part of a post-production reasoning stage (i.e. as an afterthought).

However, in our study the speaker commits to a message

structure at an early stage, not as a post-production inference. Additionally, in the Fruit Cart corpus mono-clausal MOVE could not be later converted to a bi-clausal SELECT+MOVE through the addition of a second clause. This is because the SELECT always comes first.

Conclusions

Our findings argue that there is a limit on how much information speakers can or prefer to pack into one clause, and that, at least in this context, the point at which speakers decide to split the message into two clauses occurs before the onset of the first utterance. An upper limit on the information conveyed per clause explains why speakers dedicate a separate clause to complex themes (utterance 5.a).

More generally, we hypothesize that there is a per-clause information content limit on what can be put into the memory component in a sentence planning system. This content limit affects the planning of intended messages in terms of the choice of a mono or bi-clausal utterance.

If speakers limit the information conveyed per clause, both higher theme and location complexity should correlate with a higher likelihood of splitting the message into two clauses. However, we only found clear effects of theme complexity. The lack of an effect of location complexity may be a spurious null effect. As discussed above, speakers in the Fruit Cart corpus elaborate extensively on the location, which makes it hard to distinguish between the complexity of the original message and the complexity of elaboration that speakers provide after they see that further clarification is necessary. We therefore plan to conduct further tests on another corpus that is currently being developed by Cook, Jaeger, and Tanenhaus (2008). Cook et al. elicited ditransitive structures using scenes in which one person gives an object to a second person. As in the data discussed above, speakers have a choice between a single- or multi-clausal plan (e.g. “Simon showed a hat to the girl” vs “Simon has a hat. He showed it to the girl with the striped shirt”).

We also plan to explore the effects of working memory on mono- versus bi-clausal choices. Slevc (2007) shows how higher loads can affect availability effects, where availability is measured by the information status of verb arguments. For instance, we can explore how an increased cognitive load affects the explicit mention of themes in mono versus bi-clausal realizations.

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