

A Linear-time Model of Language Production: some psychological implications (extended abstract)

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Traditional psycholinguistic studies of language production, using evidence from naturally occurring errors in speech [1][2] and from real-time studies of hesitations and reaction time [3][4] have resulted in models of the levels at which different linguistic units are represented and the constraints on their scope. This kind of evidence by itself, however, can tell us nothing about the character of the process that manipulates these units, as there are many *a priori* alternative computational devices that are equally capable of implementing the observed behavior. It will be the thesis of this paper that if principled, non-trivial models of the language production process are to be constructed, they must be informed by computationally motivated constraints. In particular, the design underlying the linguistic component I have developed ("MUMBLE"--previously reported in [5][6]) is being investigated as a candidate set of such constraints.

Any computational theory of production that is to be interesting as a psycholinguistic model must meet certain minimal criteria:

- (1) Producing utterances incrementally, in their normal left-to-right order, and with a well-defined "point-of-no-return" since words once said can not be invisibly taken back;
- (2) Making the transition from the non-linguistic "message"-level representation to the utterance via a linguistically structured buffer of only limited size: people are not capable of linguistic precognition and can

readily "talk themselves into a corner"²

- (3) Grammatical robustness: people make very few grammatical errors as compared with lexical selection or planning errors ("false starts") [7].

Theories which incorporate these properties as an inevitable consequence of independently motivated structural properties will be more highly valued than those which only stipulate them.

The design incorporated in MUMBLE has all of these properties; they follow from two key intertwined stipulations--hypotheses--motivated by intrinsic differences in the kinds of decisions made during language production and by the need for an efficient representation of the information on which the decisions depend (see [8] for elaboration).

- (1) The execution time of the process is *linear in the number of elements in the input message*, i.e. the realization decision for each element is made only once and may not be revised.
- (2) The representation for pending realization decisions and planned linguistic actions (the results of earlier decisions) is a surface-level syntactic phrase structure augmented by explicit labelings for its constituent positions (hereafter referred to as *the tree*).³ This working-structure is used simultaneously for control (determining what action to take next), for specifying constraints (what choices of actions are

2. In addition, one inescapable conclusion of the research on speech-errors is that the linguistic representation(s) used during the production process must be capable of representing positions independently of the units (lexical or phonetic) that occupy them. This is a serious problem for ATN-based theories of production since they have no representation for linguistic structures that is independent from their representation of the state of the process.

3. The leaves of this tree initially contain to-be-realized message elements. These are replaced by syntactic/lexical structures as the tree is refined in a top-down, left-to-right traversal. Words are produced as they are reached at (new) leaves, and grammatical actions are taken as directed by the annotation on the traversed regions.

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ruled out because of earlier decisions), for the representation of linguistic context, and for the implementation of actions motivated only by grammatical convention (e.g. agreement, word-order within the clause, morphological specializations; see [6]).

The requirement of linear time rules out any decision-making techniques that would require arbitrary scanning of either message or tree. Its corollary, "indelibility",⁴ requires that message be realized incrementally according to the relative importance of the speaker's intentions. The paper will discuss how as a consequence of these properties decision-making is forced to take place within a kind of *blinders*: restrictions on the information available for decision-making and on the possibilities for monitoring and for invisible self-repair, all describable in terms of the usual linguistic vocabulary. A further consequence is the adoption of a "lexicalist" position on transformations (see [9]), i.e. once a syntactic construction has been instantiated in the tree, the relative position of its constituents cannot be modified; therefore any "transformations" that apply must do so at the moment the construction is instantiated and on the basis of only the information available at that time. This is because the tree is not buffer of objects, but a program of scheduled events.

Noticed regularities in speech-errors have counter-parts in MUMBLE's design⁵ which, to the extent that it is independently motivated, may provide an explanation for them. One example is the

4. I.e. decisions are not subject to backup--"they are written in indelible ink". This is also a property of Marcus's "deterministic" parser. It is intriguing to speculate that indelibility may be a key characteristic of psychologically plausible performance theories of natural language.

5. MUMBLE produces texts, not speech. Consequently it has no knowledge of syllable structure or intonation and can make no specific contributions to the explanation of errors at that level.

phenomena of *combined-form errors*: word-exchange errors where functional morphemes such as plural or tense are "stranded" at their original positions, e.g.

"My *locals* are more *variable* than that."
Intended: "...variables are more local"

"Why don't we go to the 24hr. Star Marked and you can see my friend *checking cashes*."
Intended: "...cashing checks."

One of the things to be explained about these errors is why the two classes of morphemes are distinguished--why does the "exchanging mechanism" effect the one and not the other? The form of the answer to this question is generally agreed upon: two independent representations are being manipulated and the mechanism applies to only one of them. MUMBLE already employs two representations of roughly the correct distribution, namely the phrase structure tree (defining positions and grammatical properties) and the message (whose elements occupy the positions and prompt the selection of words). By incorporating specific evidence from speech-errors into MUMBLE's framework (such as whether the quantifier *all* participates in exchanges), it is possible to perform synthetic experiments to explore the impact of such a hypothesis on other aspects of the design. The interaction with psycholinguistics thus becomes a two-way street.

The full paper⁶ will develop the notion of a linear-time production process: how it is accomplished and the specific limitations that it imposes, and will explore its implications as a potential explanation for certain classes of speech-errors, certain hesitation and self-correction data, and certain linguistic constraints.

6. Regretably, the completion of this paper has been delayed in order for the author to give priority to his dissertation.

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