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AUTHOR   Clifton, Charles, Jr.; Frazier, Lyn
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ABSTRACT
        This report describes part of a longer study on
sentence comprehension. The long range goal is to identify distinct
levels of processing in terms of the types of linguistic and
extralinguistic information each level uses. The focus of this part
of the study is sentences with filler-gap relations, such as, "This
is the girl the teacher wanted to talk to" and "This is the girl the
teacher wanted to talk." Forty-eight sentences were constructed
modelled on these two examples. The sentences, intermingled with
other sentences of varying structures, were presented on a
computer-controlled video display to 48 college-student subjects who
were instructed to indicate whether or not they thought they
understood each sentence, on the basis of an intuitive decision.
Another experiment was conducted with sentences in which the verbs
prevented possible ambiguity, in order to determine whether or not
other information is used in initial comprehension. It was found that
readers initially fill a gap in a sentence with the most salient
possible filler, and that this strategy is followed even when
semantic control information about a verb seems to prohibit it.
(AMH)

COMPREHENDING SENTENCES WITH MULTIPLE FILLER-GAP DEPENDENCIES*

Charles Clifton, Jr.   and   Lyn Frazier
Dept. of Psychology   Dept. of Linguistics
Univ. of Massachusetts   Univ. of Massachusetts

Theories of sentence comprehension come in two principal varieties. Theories of one variety, which can be termed "interactive", emphasize, in their extreme version, the grand complexity of sentence comprehension. They view a reader or listener as using a wide variety of types of information in a largely unstructured, unconstrained way. One reason to believe such theories is the fact that people identify words very rapidly when they occur in meaningful sentence contexts.

The other type of theory can be called "autonomous". These theories attempt to analyze the process of sentence comprehension into simpler component processes. They claim that possibilities for interaction among these simpler processes are severely constrained in their extreme versions. They claim that the components are distinct processing levels, in that they are ordered in terms of when they are initiated and in that they apply different computational strategies to different types of information. These theories attempt to capture whatever simple order exists in a complex process.

My colleague Lyn Frazier and I are conducting research which we hope will tease apart distinct and separable levels of processing in the domain of sentence comprehension. Our goal is to identify distinct levels of processing involves the types of linguistics and extralinguistic information each level uses. We have focused upon a class of sentence constructions that are of special interest in both linguistics and psycholinguistics, sentences with long-distance dependencies between their elements. Our initial focus has been upon sentences with filler-gap relations. Consider sentence 1A, in panel 1 of the handout. The verb "to talk" in this sentence seems to be missing a subject, and the preposition "to" is missing an object. We refer to the positions of these missing elements as "gaps", following Chomsky's analysis of such sentences. Each gap has a "filler". In the illustration, we have connected each gap to its appropriate filler. Presumably, a person reading or hearing the sentence must do the same.

The experiment I will report r ay studied the way in wr ch .... assi n ... lers to gaps, and attempted to identify both the strateg readers follo ... aking ... e -gap assignments, a. the types of information they u in app ng ... strategy.

We contra ed the compreher .. of sentenc similar s ...ence 1A with comprehensi n of sentences 1B 2A. Note that ... se sentences ... identical ... to the last ... rd. They are temporaril ambiguous up to this point, anc ... air amb ... ity lies in which ... ler shoul... be assigned to ... gap before th verb "to tal... . Many people ... tu tively find ... entence a little harde ... to understand than Sentence 1A. ... e purp se of ... riment ... to demonstrate tha this is in fact the case. Le... ... ... the e eriment, ...hen go on to interpret t is finding, among others.

We con ... ted 3 sentences modelled on E ampled 1A 2A. ur a tual sentences were more c ... , and Examples 1B and 2B are actual in ...nces ... sen ence we ...ed. We wrote ... fferent forms of each sentence, inc ... forms s ... 1B and 2B. We pre ted ... se sentences, intermingled with oth ... nces of vary ng stru ... es, on a compu r-co ... led video display, with the very ... instru .. on to our 4 c llege- student ...je... s that they were to press one button as qu ly ... poss le if ... ey thought they u... .te the sentence, and another if they fo ... onfus ng. We empha ... ed to our su ... ts ... t they should make quick, intuitive dec s on... Because of pil ... research, we used mode f presentation in which each word was pre ... ed separately, fo ... 50 msec, and instructed ... subjects to respond very quickly afte ... the la word of the sentence. We measured th ime subjects took to make a respon e th ... cated that the comprehended the sentence, ... we measured the probability that they nad ... se rther than the response indicat ng that they were confused. Note that, in th ... ... comparisons, all our sentences ... ed with the same last few words, so that we cann t at ibute any reaction time results v et to differences in word reading time.

On a randomly selected one-third of the trials when subjects indicated that they understood a sentence, we presented a question about the sentence. In the case of interest we asked of Examples 1B and 2B, "Who would sing those songs?" We recorded and scored the answers.

Our measures of comprehension judgments indicated that sentences like 2 were indeed harder to understand than sentences like 1. As indicated in Panel B, the sentence without a preposition took about 100 msec longer to understand, and subjects reported understanding them 14% less frequently. Interestingly, questions about the two types of sentences were answered with equal accuracy.

We propose the following account of the differences we obtained. A reader, when he or she detects a gap in a sentence, initially chooses a possible filler from earlier in the sentence and assigns it to the gap. The filler chosen is the momentarily most salient one. Generally, this will be the most recent one, "the little child" in Examples 1B and 2B. The reader stays with this single initial assignment until contrary evidence arrives. In Example 1B, which we call a Recent Filler sentence, no contrary evidence arrives. The preposition "for" appears, and, since it is not followed by a noun phrase, it must have a gap after it. The head of the relative clause, "the woman," which must be assigned to some gap as a filler, is assigned to this gap after the preposition. In Example 2B, a Distant Filler sentence, contrary evidence does arrive. The sentence ends without assigning the obligatory filler "the woman" to any gap. Since it must be assigned to some gap, the reader must give up the original assignment of "the little child" to the gap before the verb, and assign "the woman" to this gap. This reanalysis process takes time, and is subject to error, resulting in the comprehension differences we obtained.

We have one piece of evidence that indicates subjects may choose the most salient filler to assign to a gap, not just the most recent. Half of our sentences had a relative pronoun present (parenthesized in Examples 1B and 2B), and half did not. Presence of a relative pronoun may serve to highlight the ﹍﹍ of the noun phrase which precedes it - "the woman" in our examples - as the ﹍ead of the relative clause, and thus make it more salient as a filler. In fact, including a relative pronoun decreased the difficulty of understanding Distant Filler sentences like Example 2B, but not Recent Filler sentences like Sentence 1B. These data can be seen in Panel C. We interpret them as indicating that the relative pronoun makes it more likely that the noun phrase to which it refers will be selected quickly as a filler.

So far, we have identified a strategy of assigning the most salient filler to a gap. Such a strategy, we claim, uses syntactic information, about the grammatical category to which words belong, about the phrase structure rules that apply to them, and, when the argument is worked through in detail, about their subcategorization frames. Is other information, such as semantic or pragmatic information, used in making this initial assignment?

Our experiment contained sentences like Examples 3A and 4A (3B and 4B are actual sentences from the experiment). These are just like our earlier sentences, except that the verb of the relative clause does not permit the possible ambiguity allowed by the earlier ones. The verbs of Examples 3 and 4 are specified for their semantic control information. Verbs like "started" and "decided" require that their own subject be the subject of their complement sentence; verbs like "forced" and "allowed" require that their object be the subject of their complement sentence. We refer to sentences with such verbs as "unambiguous," as contrasted with the temporarily ambiguous sentences of Examples 1 and 2.

If a reader could use the semant   control   ion present i Sentences
an 4 at the same time as th   nfo   on ab   matical categor   nd
    structure information,   r   uld   mistaken assignment of
    recent filler to the   in   Instead, the reader
     initially make the correc   ss ni   case, the difficul y we
     or Sentence 2B, as compa   to Sen   uld disappear n the com-
      so of Sentences 4B anc 3B.

There may, on the other har   e tw c m   istinct levels of processing
involved in the assignment of fi   rs to ga s.   comprehension time measure
 ay ta the products of an early l el w   u   ly syntactic and lexical
category information, not semantic ntrol   f   on, to make initial filler-
gap assignments. If so, the diffe nce   fou   ween our Recent Filler and
Distant Filler sentences would be mainta   the face of superficially
helpful semantic control information. Semantic c   rol information would have
no effect at all at the early leve of ^{processing} b   would be used only at some
more advanced level of processin .

In fact, the inferiority of stant   ller s ntences remained when we
tested unambiguous sentences. T   ita from our unambiguous sentences closely
mirror the data from our ambiguc   entences. No interaction or main effect
involving whether a sentence per .   a temporary ambiguity in filler-gap
assignments approached statistic s nificance. We take this to indicate that
semantic control information is n   ed it the early level of sentence compre-
hension that our comprehension react -time increase taps. This level presumably
uses only more purely syntactic information, anc operates prior to any level at
which semantic control information bou a verb can be used.

We do have   idence that semantic control informat   s used at some later
point of proces   g.   One kind of evidence   from ir   tive judgments of
sentence   pre   ion difficulty. Almost   ur subj   ntuitively   dge
sentences like   be harder to comprehe   n the r   ng sentences.
Certainly, 4B ir   ively seems eas   r tha   We thi   t these intu   ons
tap only levels   processing that p duce   ningful se   interpretat   ns
of sentences. U   biguous Distant F   ences like   easy, because
the semantic con   ol information blc   rroneous se   nterpretation
that would trigge   the intuition of   een misled.   m   ig   us Distant
Filler sentences, like 2B, are open   n erroneous seman c interpretation,
and hence seem confusing. However,   r   rehension react   ime measure taps
an early, pre-sem   tic, level of p   s   t which all D   Filler sentences
share a source of   ifficulty.

    The other t   of evidence we   e t at semantic cont   information is
use at a later p int in processin   me   from our questio   nswering data.
There was no diffe rence in the acc   cy wi h which questio   about Recent Filler
and Distant Fille sentences were   wered.   However, sema tic control information
did have an effec .   Subjects answe ed questions about ser ences with unambiguous
verbs more accu a ly than questions about sentences whose verbs permitted a
temporary ambigui y, 84% vs. 72%.   Semantic control information may be used in
assigning meaningful interpretations to sentences after an initial structural
analysis is assigned to them. The semantic support a verb with unambiguous
semantic control properties gives to a correct structural analysis may make a
sentence with an unambiguous verb easier to remember.

    Let me sum up. We found that readers initially fill a gap in a sentence
with the most salient possible filler. We further found that they follow this
strategy even when semantic control information about a verb seems to prohibit

We found, however, that semantic control information affected intuitions sentence difficulty, and the accuracy with which questions about sentences uld be answered. We concluded that our sentence comprehension measures pped an early level of sentence processing which uses syntactic but not mantic control information, while the latter type of information is used later processing. We intend to continue this research by identifying other levels processing that occur as distinct, analyzable components of sentence compre- nsion, and by characterizing each level of processing in terms of the types of nguistic and extra-linguistic information it uses.

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Charles Clifton,   and   Lyn Frazier
Dept. of Psychol[...]   Dept. of Linguistics
Uni[...] of Massachusetts

PANEL A: ILLUSTRATIVE SENTENCES

1a. This is the girl$_i$ the teacher$_j$ wanted _____ [...] [...]k to _____$_i$.

2a. This is the girl$_i$ the teacher$_j$ wanted _____ [...] [...]lk.

3a. This is the girl$_i$ the teacher$_j$ decided _____ [...] talk to _____$_i$.

4a. This is the girl$_i$ the teacher$_j$ allowed _____ [...] talk.

PANEL B: EXPERIMENTAL SENTENCES AND DATA

Sentence Type	Example Sentence	Comprehension RT	% comprehension response	% correct question answer
1b. AMBIGUOUS RECENT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ begged _____$_j$ to si[...] those stupid French songs for _____$_i$ la[...] Christmas.	1073	77%	72%
2b. AMBIGUOUS DISTANT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ begged _____$_i$ to sing those stupid French songs last Christmas.	1174	63%	71%
3b. UNAMBIGUOUS RECENT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ started _____$_j$ to sing those stupid French songs for _____$_i$ last Christmas.	1068	78%	83%
4b. UNAMBIGUOUS DISTANT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ forced _____$_j$ to sing those stupid French songs last Christmas.	1155	69%	84%

PANEL C: EFFECT OF RELATIVE PRONOUN (Comprehension time, msec)

Type of Sentence	Ambiguous Control Verbs		Unambiguous Control Verbs	
	Relative Pronoun Absent	Relative Pronoun Present	Relative Pronoun Absent	Relative Pronoun Present
Recent Filler (1,3)	1077	1069	1042	1094
[...] Filler (2,4)	1228	1120	1170	1141