PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Disorders of Sentence Production

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SUMMARY

Many processes contribute to the speech production system. Brain damage can lead to a wide variety of disorders of the spontaneous production of sentences. Different symptoms of a sentence construction disorder, such as agrammatic and paragrammatic speech errors, are briefly described. An explicit model of the grammatical processes is proposed, and it is shown how the symptoms can be explained in terms of selective impairments to components of the model. The construction of subject–verb agreement in speech is treated in detail.

1. INTRODUCTION

In ordinary conversation, or in delivering a talk, speakers utter around 120 words per minute: two words a second. When I was an undergraduate at Oxford, Isaiah Berlin lectured at double that rate, and Gilbert Ryle used to lecture at perhaps half that.

Each word the speaker utters has to be selected from a mental lexicon of between 50 000 and 150 000 words (depending on the speaker's level of education and on what counts as a word) (see Aitchison 1987). Each word is selected to express the speaker's exact current intention; it needs to occur in the right place in the current sentence; it should be the right grammatical category for its sentence location; and it must be equipped, where necessary, with the right grammatical inflections.

Two words a second is equivalent to 14 linguistically distinct speech sounds, called phonemes. The correct production of each phoneme requires that each of some 100 muscles involved receives an order 'to contract, relax, or maintain its tonus' (Lenneberg 1967, p. 92).

So the ordinary production of sentences is really an extraordinary achievement of decision-making, constraint-satisfaction and motor control. Most of the time it is accurate. It also seems effortless, although in fact the time needed to plan speech means that silent pauses make up *at least* a third of the total speaking time (Goldman-Eisler 1968; Butterworth 1980*a*), even for Isaiah Berlin (F. Goldman-Eisler, unpublished data).

Clearly, the planning and production of a well-formed sentence is the successful outcome of the coordination of a large number of *contributory processes*. In this paper, I will consider what happens when some of the processes that go into creating an appropriate well-formed sentence become disabled.

2. TYPES OF SENTENCE PRODUCTION DISORDER

(*a*) *'Speechlessness'*

When one or more of these contributory processes break down a complete 'system failure' has occasionally been observed, where the voluntary production of some sort of sentence has become impossible. The nineteenth century British neurologist, Hughlings Jackson (Jackson 1879) reported a patient who could say only 'pooh pooh'.

Howard & Orchard-Lisle (1984) have recently reported a patient who had but six phrases she could produce voluntarily:

(1) 'Yes', 'No', 'I understand', 'Cor blimey', 'Flippin' 'eck', and 'Sod it'.

From a set of 102 pictures of common objects, she was able to name only one. However, when the tester prompted her with the first sound – such as the /t/ in *tiger* – she was able to retrieve half of the correct picture names. This shows clearly that the impoverishment of her speech was not due to a difficulty in articulation *per se*.

Jackson classified patients unable to produce sentences *voluntarily* as 'speechless'; however, they were not therefore 'wordless'. This patient could, for example, understand many words she was unable to say, and could produce words with a prompt.

Examples of this kind of 'system failure' seem to be rare. It is far more usual for patients to manage some form of sentence production despite an impairment, even a severe impairment, to one or more of the component processes.

A traditional classification of aphasia distinguishes the clinical impression of fluent speech from the impression of hesitant speech. Some hesitant aphasic speakers may produce as few as 13 words per minute (Berndt 1987). Many hesitant aphasics may have well-preserved comprehension, while fluent speakers,

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especially with highly disordered speech, tend to have impaired comprehension.

(*b*) *Agrammatic speech*

In addition to their hesitancy, aphasics can show quite severe disorganization of sentence output, called 'agrammatism'. Its criterial features are usually given as the omission of grammatical inflections, omission of function words (prepositions, pronouns, auxiliaries, etc.) and short sentences with very simple structure (Berndt 1987; Schwartz 1987). The speech is often described as having a 'telegraphic' quality. It is *as if* there was a cost per word, so patients try to produce just those words that give the highest information yield, usually nouns.

The paradigmatic agrammatic speaker produces spontaneous output like (2) where the patient is describing a picture in which a man is emerging from a house with broken window, pointing an accusatory finger at a little girl: a boy, in baseball gear, is crouching behind a fence, out of sight.

(2) 'Like the door ... crash ... like, pants ... shirt ... shoes ... the boy ... the dress ... I dunno.' (Saffran *et al.* 1980, p. 223.)

This example shows all the criterial features. The length of phrases is very short, three words maximum; the syntactic structure is extremely simplified; mostly nouns, with very few function words, or inflections. However, there are some: *I* and *the*, plus two pluralizations.

In an important paper, Saffran *et al.* (1980) noted that some patients, usually classified as a agrammatic speakers, did not show all the criterial features. In particular, patients produced inflections and function words, yet showed abnormally simplified structures. Here are four patients trying describe a picture of a girl giving flowers to her teacher.

(3*a*) The young ... the girl ... the little girl is ... the flower
(3*b*) The girl is flower the woman
(3*c*) Girl is ... going to flowers
(3*d*) The girl is giving ... giving the teacher ... giving it teacher (Saffran *et al.* 1980, p. 228).

Other patients with relatively good grammatical morphology, but very simplified syntactic structures, have been reported by Berndt (1987).

Some patients omit main verbs (like Saffran *et al.*'s case in (2)), whereas others do not (e.g. Patient TF in Miceli *et al.* (1983)). There also seems to be some difference in the extent to which different categories of function words are omitted. (See Badecker & Caramazza (1985) for a discussion.)

Agrammatic speech manifests itself differently in different languages. In English, the omission of a verb inflection leaves a real word. For example, omitting the -ed from 'picked' would leave 'pick'. In Italian, on the other hand, the omission of an inflection would leave a non-word. For example, omitting -iamo from 'parliamo' (we speak) would leave 'parl', which is not a word. Agrammatic aphasics in Italian and other inflected languages do not omit verb inflections but often use the infinitive instead. Heilbronner (1906) (cited by Howard (1985)) noted this for German aphasics: 'Erst Morgen, Kaffee trinken' rather than the more usual, 'Ich trinke Kaffee'.

Given this mixture of symptoms, combined with striking individual differences, it is perhaps not surprising that attempts to offer a unified account for agrammatism have not been universally accepted. A recent review article noted that 14 different theories had been proposed to account for the agrammatism syndrome since the early 1970s (Niemi *et al.* 1993). These include the idea that there is loss of grammatical knowledge, or loss of a specialized vocabulary of function words and inflections, or that there is basically an articulatory or phonetic planning problem that makes continuous speech difficult (Kolk & Heeschen 1992) or affects the realization of particular parts of the speech plan (Kean 1979; Saffran *et al.* 1980).

Badecker & Caramazza (1985) have claimed that the original idea of agrammatism was not well motivated, because the criterial symptoms were not derived from a well-defined set of deficits and intact processes in what they call a 'computationally adequate' model of normal speech production.

(*c*) *Paragrammatic speech*

Fluent aphasic speech can also be disordered, though in a different way. Kleist (1916) noted that it was characterized by wrong inflections, rather than omission of inflections; wrong function words rather than omission of function words; and confused syntax rather than simplified syntax. He took this to be a syndrome separate from agrammatism and called it paragrammatism. The lesions responsible for paragrammatic speech are found in the posterior language regions, Wernicke's area; agrammatic speech is usually a consequence of damage to Broca's area in the frontal lobe.

Butterworth & Howard (1987) have analysed paragrammatic speech of five fluent patients, all of whom made substitution errors of grammatical elements, such as those in (4*a*, *b*). They might also affix an inflection in an illegal way, as in (4*c*):

(4*a*) He's went to picks the /dɪkɪz/. (Patient DJ) (past tense instead of participle; *s* on infinitive)
(4*b*) I was fed up *to* all of them. (KC)
(4*c*) Right and I wented with /ɪtʃ ʃɪtʃ/ (KP) (past tense formation error) (From Butterworth & Howard (1987).)

There were also many errors of sentence construction, such as sentences (5*a*, *b*).

(5*a*) Isn't look very dear, is it? (NS)
(5*b*) I'm very want it. (KC) (From Butterworth & Howard (1987).)

Although these patients made over six times as many paragrammatic errors as did our controls it is clear that there is much that is right with their speech. They all give the impression of good articulation, good prosody and a wide range of syntactic structures

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correctly produced, including correct production of quite complex forms. The examples in (6) give an idea of what they routinely achieved.

(6) My father, he is the biggest envelope ever worked in Ipswich. He strikes every competition and constitution that's going. He's got everybody situated and they've got to talk to him. (Intact: left dislocation; superlative clause formation; subject relative clause; infinitival phrase; anaphors; main-clause co-ordination; verb inflections) (Patient NS)
(From Butterworth & Howard (1987), p. 23.)

Although they make more inflectional errors than normal, control of verbal inflections is generally well preserved: they make only about five inflectional errors per thousand words. Even on neologisms, the inflections are usually correct, as in (7).

(7) She /wiksəz/ a /.en/ from me.

This patient, KC, managed to produce correctly 45 out of 46 obligatory inflections on neologisms.

Although these patients made vastly more errors than normals, they nevertheless used more correct than incorrect forms; there did not seem to be any particular type of construction that was most likely to lead to error. This supports the idea that the grammatical knowledge underlying the sentence production system in these patients is intact.

Moreover, it was found that these types of sentence production error could be found also in the slips of the tongue of normal speakers. Like normal slips of the tongue, the errors seem to result from transient failures to control the system. By control in this context implies four distinct components: (i) an instruction to initiate an action by a contributory process; (ii) transfer of information from other processes that the determine the operation of the contributory process; (iii) a check that the output of the process is correct and appropriate; (iv) an instruction to terminate the operation of a contributory process.

One kind of control failure is where the speaker produces more than one candidate output plan for the next sentence: malfunction of control process 4. The speaker may then to try to blend them together†. This is what we think has happened in the examples (5). The patients blended together two candidate outputs, in the same way that Fay (1982) has shown that blends occur in normal slips of the tongue. This may have happened as in (8). The words actually uttered are capitalized.

(8*a*) ISN'T VERY DEAR, IS IT?
Doesn't LOOK VERY DEAR, does it?
(8*b*) I'M VERY keen on IT
I WANT IT
(From Butterworth & Howard (1987).)

† Following Fay (1982), three restrictions were imposed on what would count as a blend: (i) the two putative sentences are near-synonyms; (ii) they share words in the environment of the substitution; and (iii) the resultant string cannot be explained by the substitution or omission of a single word.

If these patients make several attempts to convey the same message, it would not be surprising if they make more of these blending errors. The relation between sequential alternatives and blending comes out clearly in the following example, where the blend is sandwiched between the two alternatives.

(9) I'm naughty there. I'm still naughty wrong, very naughty. I'm wrong.
(Patient KC. Butterworth & Howard (1987), p. 34.)

These paragrammatic patients also made omission errors usually ascribed to agrammatic patients: omissions of function words (10*a*, *b*), and omissions of inflections (10*b*, *c*).

(10*a*) __ Boy and the wife. (Patent DJ)
(10*b*) Thank you very much for allow __ me __ see you. (KC)
(10*c*) and he go __ and set __ on. (NS)

In these patients, omissions have natural control explanations: omission of function words could be due to a failure to initiate retrieval of the required element. There is no need for function words to be permanently lost or damaged. Inflectional omissions in English could be due to selection of the wrong part of the verb, but another suggestion is offered below.

Although the agrammatic patients also omit these elements, it does not follow that they omit them for the same reason.

4. DISORDERS OF SUBJECT–VERB AGREEMENT (SVA)

Inflectional errors, as we have seen, have been key indicators of underlying disorders: omissions indicating agrammatism, and substitutions indicating paragrammatism. However, a simple count of substitution or omission errors on verbs, for example, is insufficient to provide a diagnosis of functional deficit. It is easy to see that failure to produce the correct *inflection on a verb* can have a variety of causes, because getting the correct inflection requires that satisfaction of several distinct conditions. So SVA errors may be due to failure to satisfy any one or more of these conditions.

(*a*) *Minimal list of conditions that need to be satisfied to get subject–verb agreement right*

(i) Correct NP as subject; (ii) correct Verb as target; (iii) correct agreement features on NP (number, person, gender); (iv) same features on Subject and Verb; (v) correct form of the N (e.g. plural intended and plural produced); and (vi) correct conjugation of Verb; (e.g. concordant number, person and gender features with subject, and right tense and aspect from conceptual representation, etc.).

Satisfying some of these conditions is by no mean a computationally trivial matter. For example, getting the correct subject NP causes problems where there is a complex NP containing two candidates for subject-

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hood. Consider the sentence. 'The readiness of our conventional forces are at an all-time low'. The speaker seemed to take *forces* instead of *readiness* as the subject. This is a common error called 'proximity concord' by Quirk *et al.* (1972). It can be experimentally induced, as will be seen.

Of course, a list of conditions does not entail that each condition corresponds to a separate process. A computationally adequate model of the speech production system is needed which specifies how the speaker manages to satisfy at least these conditions. The models that have been used to explain grammatical disturbances (see, for example, Dell (1986); Garrett (1980)) may be able to differentiate in a general way inflectional processes from lexical processes, but they have little to say about the satisfaction of these conditions.

Incremental Procedural Grammar (IPG) is a model where the processes of agreement are spelled out in detail. This model has been implemented by Kempen & Hoenkamp (1987), and by De Smedt (1990), who uses feature unification instead of copying. Many linguists have argued that feature unification not only has attractive computational features, but also provides a better linguistic account of agreement phenomena (Barlow 1988; Pollard & Sag 1988).

The key properties of IPG are as follows. (i) Phrases can be output as they are constructed, not when the whole sentence has been formulated. (ii) There are two stages of word retrieval: abstract 'lemmas' retrieved from the 'semantic lexicon' (Butterworth 1980*b*), which supplies the relevant grammatical information about the word to be produced; and a stage when the pronunciation is retrieved from what I have called a lexicon of phonological word forms. (iii) Lemmas activate 'category procedures' that construct fragments of structure. (iv) These are combined by using 'functional procedures'. The sentence fragment 'the road is . . . ' would be constructed roughly as shown in figures 1–3. It is easy to see the ways in which SVA could fail in a model like this: (i) wrong agreement features on NP; (ii) correct features on NP not transmitted to V; (iii) incorrect selection of phonological form N: 'roads' instead of 'road'; and (iv) incorrect selection of phonological form of V: 'are' instead of 'is'.

(*b*) *Explanation of agrammatic speech symptoms*

It is also quite easy to see how one might account for *some* of the agrammatic symptoms mentioned earlier.

1. *Preserved inflections* and function words but reduced structure (as in (3) above) can be explained as an impairment to functional procedures for combining phrases.

2. In addition, *lack of inflections* can be interpreted as a failure to use agreement features. Suppose that in the absence of the relevant agreement features, lexical selection takes the *default* option; this might vary from language to language. In English it would be, perhaps, the most frequent form, i.e. without the *s*. By contrast, in German it might be the infinitive.

3. *Anomalous constituent ordering.* Constituent order is handled by De Smedt as a separate procedure (rather as the linguists Gazdar & Pullum (1981) proposed separating rules characterizing the 'immediate dominance; of elements in a constituent from rules about their 'linear precedence'). Constituent misordering could therefore be due to a separate deficit of these ordering procedures.

4. Reduction of certain lexical categories – such as pronouns or verbs – may be an additional deficit.

I must make it clear that I do not propose to add to the long list of explanations of agrammatism. I just want to show how a detailed model can suggest explanations of specific disorders.

Paragrammatic errors of SVA may be due to faulty *transmission* of agreement information from the NP procedure to the VP procedure, or from the conceptual representation. Note that faulty transmission is a proposed control malfunction, as I have already mentioned.

(*c*) *Subject–verb agreement in the model*

A key novel element in the model is its treatment of agreement features. Agreement is usually considered a purely syntactic process that copies features from a source or controller, like a subject NP, onto a target such as a verb. In de Smedt's version of the model, features on the subject and verb are unified, not copied, as was shown above. One might extend the range of feature types to include referential or semantic features, as well as purely syntactic ones. The importance of this can be seen in the following phrases:

(11*a*) the road to the islands
(11*b*) the label on the bottles

Most people interpret 11*a* to refer to just one road, whereas they interpret 11*b* to refer to several labels, one for each of several bottles. The difference in interpretation is called 'distributivity'; it has to do with the assigned scope of the implicit quantifiers in the phrases.

Like 'The readiness of our conventional forces are at an all time low', these phrases contain two NPs with competing number features, and are therefore likely to lead to agreement error. Bock & Miller (1991) have used phrases like this in a sentence completion task. Subjects are asked to repeat the phrase and then finish the sentence any way they like. They found that subjects produced more errors when the two noun phrases were *mismatched* for number.

Now if the process of determining the agreement features on the Verb uses information from the conceptual representation, then perhaps, there would be fewer errors for 11*a*, which is semantically and referentially singular. However, Bock & Miller (1991) found that speakers of (American) English made the same number of errors in completing the two types of phrase. This is what one would expect if

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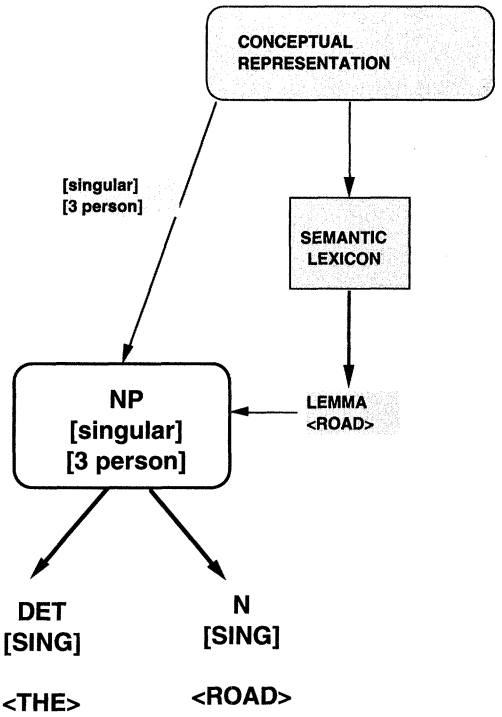

Figure 1. The construction of the NP from the sentence fragment 'the road is . . . '. Stage 1 is marked by shaded areas, and shows the use of semantic information to retrieve the lemma, ⟨road⟩, from the semantic lexicon. Conceptual information about person and number is made available to the NP procedure. Stage 2 – without shading – is the construction of the NP by the NP category procedure, making use of grammatical information from the lemma and agreement features [singular] [3rd person] from the conceptual representation. The resulting fragment would carry the agreement features for subsequent processing. Stage 3 – not depicted – would retrieve the pronunciations /ðə/ and /rəud/ for the lemmas ⟨the⟩ and ⟨road⟩.

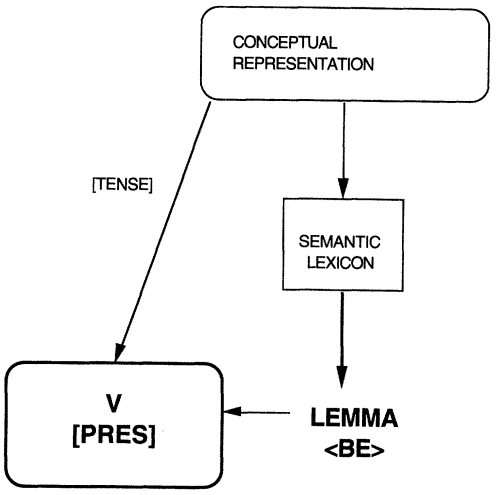

Figure 2. The Verb procedure is initiated by the retrieval of the verb lemma ⟨be⟩. Tense – or some more abstract temporal information – is made available from the conceptual representation. In this instance, the tense is the feature [present].

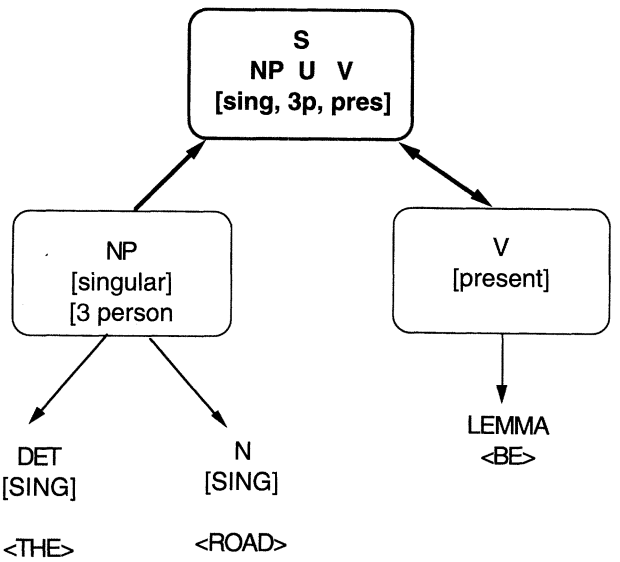

Figure 3. A functional procedure combines the NP and the V, assigning the function subject of the V to the NP. This procedure will unify the features [singular] [3rd person] and [present] to fully define the conjugation of the verb ⟨be⟩. A later stage will retrieve the pronunciation /ɪz/ from the phonological lexicon. Note that word order, strictly speaking, is not defined by this functional procedure. See text for comment.

agreement features on the verb were derived solely from the NP.

However, Gabriella Vigliocco, a graduate student at the University of Trieste, Carlo Semenza & I have found that Italian speakers (Vigliocco *et al.* 1994*a*) and also Spanish speakers (G. Vigliocco, B. Butterworth & M. F. Garrett, unpublished results) make significantly fewer errors when the phrase is normally interpreted to denote a single object. That is, the Verb procedure does seem to recruit semantic information in the construction of subject–verb agreement, at least for Italian and Spanish speakers. Why is there this language difference?

In English, indicative sentences always have subjects, and these are produced before the verb. The verb conjugation can thus be controlled by the number features on the subject noun. Italian and Spanish, on the other hand, both allow sentences in which the subject can follow the verb or in which there is no subject at all: they are pro-drop or null subject languages. In terms of our lemma-driven model, the conjugation of the verb will have to be computed before the agreement features on the subject NP have been determined. The verb procedure will need to make reference to the conceptual representation to get the features right.

In the production of the Italian sentence, 'è lunga' – 'it's long' – there is no subject; and in 'è lunga (la strada verso le isole)' the subject occurs after the verb. Both forms are entirely normal in Italian. The processing question is this: where are the agreement features going to come from? They cannot come from the subject Noun, because it has not been constructed. Of course, it is possible to postulate that dummy subjects are always created with just those features necessary to get the right conjugation, and for no other reason (except to preserve the theory). However, an alternative is to derive them directly from the conceptual representation.

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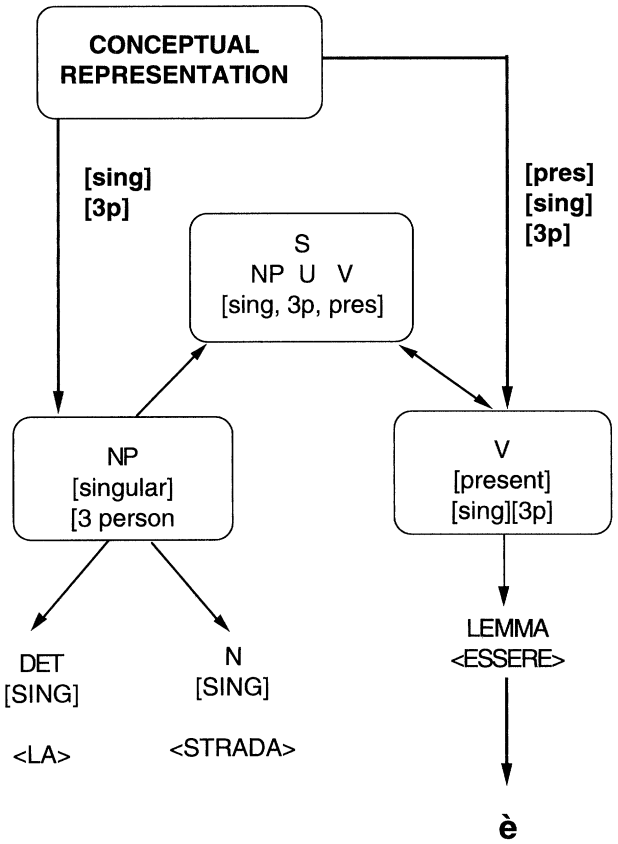

Figure 4. This is a partial model of subject–verb agreement construction for the sentence fragment 'la strada è . . .' or 'è la strada . . . '. Agreement features [singular] and [3rd person] are made available from the conceptual representation to both the V procedure and the NP procedure. The unification yields the projection of both sets of features.

To generalize this finding, so that both NP and V procedures can derive the agreement features from the conceptual representation independently, we offer an account for Italian as shown in figure 4. There is no evidence that English requires this additional route from conceptual representation to verb procedure.

(*d*) *Subject–verb agreement in two contrasting aphasic patients*

Now if speakers of Italian do refer to the conceptual representation when using their Verb-constructing procedure, then the selective breakdown of this process would provide evidence that our view of normal processing is correct. We have recently had the opportunity to study two *Italian* patients to whom we could administer these sentence completion tasks (Vigliocco *et al.* 1994*b*).

MM was a woman 65 years old, a largely recovered conduction aphasic patient. At the time of testing her spontaneous speech production was fluent and mildly paragrammatic including 21 agreement errors of all kinds in a sample of about 400 words.

PF, a woman 25 years old, presented with agrammatic speech: the omission of most bound morphemes, omissions of the main verb (28/102 indentifiable finite clauses) and the use of the infinitival form of verbs where the finite form would be normal (21/102). However, the majority of verbs were correct (53/102). She produced, in spontaneous speech, four agreement errors.

Table 1. *Scores from two aphasic patients, MM and PF, on the tests of Miceli* et al. *(1991)*

(Grammatical performance in MM and PF (number correct/number of tests); data from Vigliocco *et al.* (1994*b*).)

test	MM	PF
grammaticality judgments		
auditory presentation	46/48	37/48
visual presentation	22/24	16/24
repetition		
phrases	7/7	5/7
sentences	11/13	11/13
comprehension: auditory presentation		
active sentences	27/30	30/30
passive sentences	25/30	25/30
comprehension: visual presentation		
active sentences	29/30	29/30
passive sentences	26/30	28/30

Table 2. *Subject–verb agreement experiment 1*

(Data are sentence completion scores (percentages correct in parentheses). Distributivity was not tested.)

	MM	PF	Normals
correct responses	161 (63)	162 (63)	2271 (89)
agreement errors	60 (23)	57 (22)	81 (3)
repetition errors	26 (10)	7 (3)	128 (5)
miscellaneous responses	9 (4)	30 (12)	80 (3)
number mismatch vs. match	35 vs. 18*[a]	36 vs. 11*	*

[a] Asterisk indicates significant difference in number of errors.

Both patients had good comprehension, and despite differences in their speech, seemed similar in their general linguistic competencies (table 1). In our first sentence completion experiment, they both had very similar error rates, and both showed similar normal sensitivity to number mismatching in the subject NP (table 2). They are certainly both worse than normals in this task; and this similarity in their performance would usually be taken to indicate the same deficit.

In our second experiment (table 3) we systematically varied distributivity. PF shows normal sensitivity to the semantic factor of number of tokens, whereas MM does

Table 3. *Subject–verb agreement in experiment 2*

(Data are percentages of agreement errors in sentence completion, where distributivity is tested.)

	single token	multiple token	error rate
patient MM	48.3	51.7	48.4
patient PF	18.8	81.2	25.0
normal controls	23.0	77.7	3.2

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not. In this task, conceptual information seems to help PF suppress erroneous responses in the single token condition. However, MM seems unable to make use of conceptual information in the normal way: in this patient there is a failure of the *control process* that transfers information from the conceptual representation.

These data are therefore consistent with the claim that for Italian speakers there is an additional process in the construction of verb phrases that utilizes *conceptual information* about number agreement features, and not just information from the head of the subject NP. This raises the possibility that person and gender features may be derived in the same way. The more general implication of the cross-linguistic findings, and the selective deficit reported here, is that agreement in some languages may not be a purely syntactic process.

5. CONCLUSION

We have seen that there are a wide variety of ways in which the complex processes underlying sentence production can break down, ranging from speechlessness, through agrammatic and paragrammatic speech, to very specific impairments of the subject–verb agreement processes. A detailed model of incremental sentence construction, combined with separate 'control' processes for its component procedures, provides a useful framework for explaining the range of disorders of sentence production.

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