Complexity in Output Systems: Evidence from Behavioral Hybrids

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The speech errors known as synonymic intrusions (e.g., 'sotally,' an inadvertent combination of initial word 'solely' and sequel word 'totally' in 'He was *sotally* responsible for that') suggest that two or more words can be simultaneously activated, competing for the same position in a sentence. Statistical analysis of 257 such intrusions showed that the intruding word (or phrase) was simpler than the initial one at the segment, syllabic, lexical, and at two syntactic levels. A hierarchic model for the serial production of speech, and more generally, for the study of other motor systems, is proposed.

Speech errors place strong constraints on theories of speech production, since an adequate model of normal speech must also allow for those errors, as does the actual speech-production system. Conversely, an adequate explanation of speech errors must incorporate the general principles of normal speech production, in the sense that an explanation of the backfiring of an automobile engine must incorporate the general principles of internal combustion. The present study explores some of the implications of this metatheory for theories of speech production as well as other motor systems.

Our more specific goal was to infer the nature of the speech-production system that generates the speech errors known as synonymic intrusions. Synonymic intrusions represent a class of behavioral hybrids that occur whenever a speaker begins with one expression (defined as the initial phrase or word) and inadvertently continues with another expression having roughly equivalent meaning. The intruding constituent is defined as the sequel phrase or word.

Consider the synonymic intrusion 'I am together,' an inadvertent combination of 'I am with you' (initial phrase) and 'We are together' (sequel phrase). What must be explained in such combinations is why the initial phrase stops where it does. One might suggest that the speaker is switching his message or revising his meaning when he makes such errors. But the fact that the initial and sequel phrases are synonymic, or semantically

American Journal of Psychology
1973, Vol. 86, No. 4, pp. 785–806

equivalent, goes against this somewhat elegant hypothesis. Rather, our data suggest a 'cross-talk' or parallel-processing explanation of these errors, with general implications for theories of speech production and other motor systems as well. We will argue that the reason for cross-talk, the intrusion of one motor program on another, simultaneously activated motor program, lies in the relative complexity of the operations underlying the production of these programs.

METHOD

— Data — Our data consisted of 257 synonymic intrusions published in German by Meringer and Mayer (1895) and Meringer (1908). Of these, 124 were synonymic intrusions within phrases, intrusions of the sort described in the introduction. The remaining 133 were synonymic intrusions within words, intrusions such as 'yawn,' an inadvertent combination of 'yard' (initial word) and 'lawn' (sequel word) in the context 'I'm putting in a *yawn*' (reported by Hockett, 1967).

Meringer's general methods of data collection are outlined in detail in MacKay (1970). Interrogation of the speaker served to determine the initial and sequel phrases. The component words of these initial and sequel phrases made up the corpus, which for the most part consisted of common German words that would be highly familiar to the individuals making the errors (mainly professors and their wives).

For Meringer, synonymic intrusions represented a subclass of a more general class of speech errors known as 'contaminations.' Contaminations were defined for all cases where two constructions, sentences or words, occurred to the speaker simultaneously, and he fused them. Not all contaminations involved words or phrases with the same meaning. Inadvertent production of a word read or heard earlier was also classed as a contamination. But the general characteristic of contaminations was that the speaker did not intend to say both words or phrases either simultaneously or in sequence, but only one of them. Meringer noted that synonymic intrusions were the most frequent type of contamination and argued that they may explain in part how new words are formed in the evolution of languages (e.g., the word 'smash' evolved as a combination of the already established words 'smack' and 'mash').

As already indicated, the present paper considers Meringer's synonymic intrusions only, so a note on the concept of synonymy is in order. The concept has aroused considerable debate in linguistics. Two words are said to be in *formal synonymy* only if they are interchangeably defined or have the same dictionary definitions, or only if they have exactly the same meaning or sense in all possible sentential contexts. It is even suggested that two words can be formally synonymous only if they can replace each other in all contexts without the slightest change in cognitive or emotional import. However, there are reasonable grounds for suggesting that formal synonymy in any of these senses constitutes a null set (Lyons, 1968).

In any case, the notion of *psychological synonymy* seems much more useful for studies in psycholinguistics. We define psychological synonymy for all cases where two words or phrases are interchangeable or have the same sense in any one particular context. Thus, for example, the words 'solely' and 'totally' have different dictionary definitions, have different senses in various sentential contexts, and by themselves carry different cognitive or emotional connotations. They are clearly not formally synonymous. But in the particular context 'He was solely (totally) responsible for that,' they can be defined as psychologically synonymous.

The initial and sequel words and phrases in Meringer's corpus of synonymic intrusions were synonymous in this psychological rather than formal sense. Three types or classes of psychological synonymy were distinguished in the corpus: lexical synonymy, surface-structure synonymy, and deep-structure synonymy. These classes of synonymy are analogous in many respects to Chomsky's three types of ambiguity.[1] Lexical synonymy occurs when different words or lexical items have the same meaning in a given context (although possibly carrying slightly different connotations). For example, 'car' and 'automobile' are synonymous in the context 'The ______________ has a long history.' Surface-structure synonymy occurs when the same meaning can be expressed with alternate surface structures; for example, 'The boy whom the girl saw left' and 'The girl saw the boy who left.' Underlying-structure synonymy occurs when the same meaning can be expressed with base strings containing different elements. For example, 'It is hot' and 'It is not cold' are related in this way, since the base string for one construction contains the negative marker, while the other does not.

— Procedure — In this section we examine various methods used in the study of speech errors, with emphasis on pros and cons of the statistical methods used in the present study. Three procedures have been used to date. The most common approach is to develop a theory and then examine a corpus for examples that support (or refute) the theory (see Fromkin, 1971). The main problem with this method is that most variables influencing errors and their observation are neither known nor under control. These uncontrolled variables may in some instances neutralize or prove stronger than even a true underlying determinant of speech errors. This means that proof by example goes neither forward nor backward, since examples can virtually always be refuted with counterexamples. Of course, arguments arising from proof by example are usually considered settled if examples greatly outnumber counterexamples, but by this time the method has taken on the aspects of a statistical approach, albeit an inexact, unsystematic, and somewhat unprincipled one.

A second, related procedure is known as 'proof by imagination.' For example, Hockett (1967) viewed the ability to dream up semantic interpretations of intrusions such as 'yawn' as evidence for Freud's view of speech errors. Freud (and Hockett) contended that these synonymic intrusions reveal a disguised or hidden want, hope, fear, or intention of the speaker. Thus, the speaker combining 'lawn' and 'yard' as 'yawn' was revealing unconscious boredom with the ongoing conversation. A formally analogous 'proof' in chemistry would be that the property of drinkability explains why hydrogen and oxygen combine to form water. Of course, Freud's hypothesis is probably more difficult to test than this 'drinkability hypothesis' in that Freud's central terms (disguised wants, hopes, fears, intentions) cannot be operationally defined within his framework, since Freud felt that speakers were either unaware of their underlying wants, hopes, and so on, or were unwilling to report them accurately.

But the problem with proof by imagination seems quite distinct from the issue of operational definability. The problem is that any error can be interpreted in terms of some underlying property, wish, intention, or such, just as any dream can be associated with some sexual allusion. Indeed, proof by imagination cannot even be touched by counterexamples, since inability to dream up a semantic interpretation surely reflects only poverty of imagination. And counterproof by the lack of imagination is at least as inadequate as proof by imagination.

The third approach, based on statistical procedures, was adopted in the present study. The basic procedure in the statistical approach is to construct a null hypothesis, based on the frequency of a specific factor in error-free speech. Then statistical methods are used to determine whether this factor plays a significant role in the occurrence of the errors. Statistical analyses of speech errors are not without problems (see MacKay, 1972, for a discussion of some of them), but they are probably the only reasonable approach, since other methods avoid none of the problems of statistical procedures and introduce much more serious problems of their own.

A further difficulty with the statistical studies of speech errors is the 'correlational data problem.' Since analyses of speech errors involve correlational rather than experimental methods, causal interpretations are tricky. A correlation between two factors, A and B, allows three causal hypotheses: that A caused B, that B caused A, or that some third factor simultaneously caused both A and B.

However, in studies of speech errors, we can often determine the correct causal alternative by showing that only one of the causal hypotheses is reasonable. For instance, consider the fact that omitted phonemes usually precede or follow an identical phoneme in the word being produced, a statistically reliable 'context effect' (MacKay, 1969). This context effect represents a correlational finding — it does not per se indicate that repeated phonemes cause omissions or increase the probability of omissions. But this is the only reasonable alternative, since an omission cannot possibly influence what phonemes compose a word, and it is difficult to imagine a third factor that could simultaneously cause both an omission and the phoneme structure of the word the omission occurs in. The correlational data problem, like other problems in the statistical analysis of speech errors, therefore seems solvable in principle.

MAIN RESULTS

We found determinants of synonymic intrusions at five linguistic levels. These were the segment level, the syllabic level, and the lexical level (all involving intrusions within words), and two syntactic levels, the surface-syntax level and the underlying-syntax level (both involving intrusions within phrases).

The segment level

Our dependent variable at the segment level was the break in the synonymic intrusion — the last point at which the initial word left off and the sequel word began. For example, in Hockett's 'yawn' the break follows the 'y' in the initial word 'yard' and follows the 'l' in the sequel word 'lawn.'[2] Our independent variable was the voicing of the postbreak segments, in this case, of the consonants immediately after the break in initial and sequel words. We chose voicing as the distinctive feature for this analysis, since it was the only feature represented identically in all feature systems.

Our null hypothesis was the relative frequency of voiced and unvoiced consonants in spoken German (from Meier, 1964). Under this null hypothesis, 44% of the postbreak consonants in the initial and sequel words should have been unvoiced by chance. The data failed to support this chance hypothesis (see Table 1). Postbreak consonants in the sequel word were unvoiced significantly more often than chance expectation [$\chi^2(1) = 8.50, p < .001$].[3] Moreover, the postbreak consonant was unvoiced in the sequel word more often than in the initial word. More specifically, when a postbreak consonant in the initial word was voiced, it was voiced in the sequel word only 20% of the time and unvoiced 80% of the time. But when the postbreak consonant in the initial word was unvoiced, it was voiced in the sequel word about 50% of the time and unvoiced 50% of the time, an outcome not differing from chance [$\chi^2(1) = 1.01, p > .30$].

The syllabic level

We noted that the postbreak syllable in sequel words was usually stressed, as if stress were promoting the intrusion of the sequel word. An example is the intrusion '*an*be-*trifft*,' a combination of '*an*belangt' and 'be-*trifft*' (stressed syllables italicized), where the postbreak syllable is stressed in the sequel word but unstressed in the initial word. To determine whether this was true in general, we examined the cases where breaks occurred at a syllable juncture in the multisyllabic words of the

Table 1. The role of voicing of postbreak consonants in initial and sequel words of synonymic intrusions; data in percentages voiced or unvoiced

Postbreak consonants in initial words	Postbreak consonants in sequel words	
	Voiced	Unvoiced
Voiced (58%)	20	80
Unvoiced (42%)	50	50
Chance	56	44

corpus ($N = 80$). Our dependent variable was the stress of the postbreak syllables in these synonymic intrusions. Following Wahrig (1966), we marked only one syllable as stressed in each initial and sequel word, since one syllable in German words receives decidedly more stress than all the others.

The data showed that postbreak syllables were stressed more often in sequel than in initial words (see Table 2). Chance expectation, also shown in Table 2, reflects how often syllables in the same average syllabic position in the multisyllabic words of the corpus were stressed. Postbreak syllables in sequel words were stressed significantly more often than chance expectation [$\chi^2(1) = 4.12$, $p < .05$]. A similar analysis showed that postbreak syllables were stressed significantly less often in initial than in sequel words [$\chi^2(1) = 3.94$, $p < .05$].

Table 2. The role of stress in synonymic intrusions with breaks within and between syllables; data in percentages stressed

	Between-syllable breaks		
	Prebreak syllable	Postbreak syllable	Within-syllable breaks
Initial word	42	30	59
Sequel word	41	57	70
Chance	40	32	36

An analogous but unreliable effect of stress was found with breaks inside syllables ($N = 53$). In initial words, 59% of the breaks occupied a stressed syllable, as compared to 70% in sequel words (see Table 2). This difference is in the same direction as the effect of stress reported above, although it failed to reach statistical significance [$\chi^2(1) = 3.52$, $p < .10$).

The lexical level

We examined two variables in the synonymic intrusions at this level: word length and word frequency. Initial words were usually longer than sequel words, using either the segment (consonant or vowel) or the syllable as measures of length. The data for number of segments are shown in Table 3. About 12% of the initial and sequel words were the same length, about 62% of the initial words were longer than the sequel words, and 26% shorter, a difference significant at the .05 level using a two-tailed sign test with the intrusions as the unit of analysis.

Since word length usually varies with word frequency (Zipf, 1949),

Table 3. The role of length (number of segments) of initial and sequel words in synonymic intrusions; data in percentages of times the initial word was longer than, shorter than, or of the same length as the sequel word

Word frequency	Word length		
	Initial word longer	Initial word shorter	Same length
Free to vary			
Data	62	26	12
Chance	44	44	12
Held constant			
Data	81	19	0
Chance	50	50	0

we next determined whether length had a separate effect when frequency was held constant. The frequency of the initial and sequel words was determined from Meier's (1964) count, the largest frequency count published to date in any language.[4] Initial and sequel words whose probabilities in German fell with $\pm .0000015$ were categorized as equally frequent, giving 21 cases in all. An analysis of these cases showed that length had an independent effect on synonymic intrusions. The initial word was longer than the sequel word in all but 4 of the 21 cases, an outcome reliable beyond the .02 level by a two-tailed sign test with the intrusions as the unit of analysis. Clearly, the effect of word length on synonymic intrusions cannot be explained in terms of word frequency. In fact, we failed to find an effect of word frequency even when word length was free to vary (see Table 4). In this analysis, initial words were less frequent than sequel words in 59% of the intrusions and more frequent in 41%, but this difference failed statistical significance at the .10 level using a two-tailed sign test with intrusions as the unit of analysis. And as might be expected, word frequency also had no effect when length was held constant. Initial and sequel words within ± 1 segment in length were counted as equally long, giving 36 cases in all. Sequel words were more frequent in only 19 of the 36 cases, an outcome nonsignificant at the .50 level (sign test). It seems that word frequency plays little or no role in the intrusion of sequel words.

The surface-structure level

Rules analogous to the phrase-structure rules of generative grammars served as the independent variable at the surface-structure level. For

Table 4. The role of frequency of initial and sequel words in synonymic intrusions; data in percentages of times the initial word was less frequent than, more frequent than, or of the same frequency as the sequel word

	Word frequency		
Word length	Initial word less frequent	Initial word more frequent	Same frequency
Free to vary			
Data	53	29	18
Chance	41	41	18
Held constant			
Data	53	47	0
Chance	50	50	0

example, we analyzed the initial and sequel phrases of synonymic intrusions such as 'I am together' into rules similar to those of Table 5. We then compared the complexity of the rules for generating the initial and sequel phrases of these intrusions ($N = 124$). The data are shown in Table 6. About 64% of the initial phrases involved more rules than their corresponding sequel phrases, whereas only 19% involved fewer, a difference significant beyond the .02 level using a two-tailed sign test with the intrusions as the unit of analysis. This finding suggests that the surface structure of sequel phrases was usually simpler than the surface structure of initial phrases.

Further analyses of the data led to qualifications and refinements of

Table 5. Phrase-structure operations for the expressions 'I am with you' (1–9) and 'We are together' (1a–6a); the symbol S stands for sentence, NP for noun phrase, VP for verb phrase, V for verb, P for preposition, A for adjective, Pn for pronoun, and PP for prepositional phrase; terminal elements at this level are presented in brackets and alternation rules by multiplication signs

'I am with you'	'We are together'
1. S→NP + VP	1a. S→NP + VP
2. NP→Pn × first person	2a. NP→Pn × first person × plural
3. Pn→['I']	3a. Pn→['We']
4. VP→V + PP	4a. VP→V × plural + A
5. V→['am']	5a. V→['are']
6. PP→P + NP	6a. A→['together']
7. P→['with']	
8. NP→P	
9. Pn→['you']	

Table 6. The role of complexity (number of phrase-structure rules) of initial and sequel phrases in synonymic intrusions; data in percentages of times the initial word was more complex than, less complex than, or of the same complexity as the sequel word

	Phrase complexity		
	Initial phrase more complex	Initial phrase less complex	Same complexity
Data	64	19	17
Chance	41.5	41.5	17

this finding. Two types of synonymic intrusions at the surface-structure level were noted, the distinction hinging on the form class (noun, preposition, participle, verb, or adjective) of the postbreak words. In 72% of the intrusions, the form class of the postbreak words was *identical.* An example is the intrusion 'you are true,' a concatenation of initial phrase 'You are correct' and sequel phrase 'That is true.' Here, the postbreak words in the initial phrase ('correct') and in the sequel phrase ('true') are both adjectives. For these cases, the postbreak word in the initial phrase was usually longer (in segments) than that in the initial phrase. Specifically, the initial word was longer in 54% of the examples and shorter in only 23%, a difference significant at the .001 level [$\chi^2(1) = 6.40$].

Moreover, the phrase-structure rules preceding the break in these cases (identical form class, postbreak words) were less complex for 73% of the sequel phrases and more complex for only 15%, a difference significant beyond the .01 level using a two-tailed sign test with the intrusions as the unit of analysis. However, there was no difference in complexity of the rules following the break in these intrusions [$p > .40$, same test].

In the remaining 28% of the synonymic intrusions at the surface-structure level, the form class of postbreak words in the initial and sequel phrases was *not identical.* These cases fell into four categories. One category ($N = 8$) might be described as 'impossible sentences' by analogy with the 'impossible figures' of Penrose and Penrose (1958). An example is 'I walked around the town I went,' a concatenation of initial phrase 'I walked around the town' and sequel phrase 'Around the town I went.' Intrusions of this sort were formed from an initial phrase with one word order and a sequel phrase with a different word order, the intrusion itself being an ungrammatical string whose constituents taken two at a time in sequence are grammatically permissible. These examples suggest the misapplication of a phrase-structure rule at an optional (permissible) point in the hierarchy.

Another category ($N = 2$) of this second type of intrusion at the surface-structure level can be described as passive transforms, since these involved an interaction between active and passive syntactic constructions. An example is 'Me was asked by nobody,' which represents the concatenation of initial phrase 'Me nobody asked' (grammatical in German) and sequel phrase 'I was asked by nobody.'

A third category ($N = 7$) involved the addition rather than substitution of a constituent. An example is 'We must enter over into the order of the day,' a concatenation of 'We must step over to' and 'We must enter into.' As can be seen, the particle 'over' intruded from the sequel.

The remaining intrusions ($N = 16$) of this surface-structure type in which postbreak words were not of an identical form class seemed to represent a miscellaneous category. An example is 'I am together,' a concatenation of initial phrase 'I am with you' and sequel phrase 'We are together.' Here the initial postbreak word ('with') is a preposition, whereas the sequel postbreak word ('together') is an adjective. We examined the phrase-structure rules for the initial and sequel phrases in these intrusions and found that they did not differ in complexity [$p > .20$] using a two-tailed sign test with the intrusions as the unit of analysis. However, the initial phrase was more complex than the sequel phrase following the break and less complex preceding the break in all but two examples, an outcome exceeding chance expectation at the .02 level, two-tailed sign test.

The underlying-structure level

By Chomsky's (1965) definition of underlying structure, certain synonymic intrusions can be said to occur at the underlying-structure level. In Chomsky's framework, sentences can be synonymous in their semantic interpretation and at the same time contain different elements in their base or underlying structure. For example, 'The door isn't open' and 'The door is shut' require the same semantic interpretation although the base string for the first sentence contains the negative marker, while the other does not.

The class of synonymic intrusions known as negative transforms involved a concatenation of base strings that were marked and unmarked for negation in this way. An example is 'Don't be clever,' a concatenation of an affirmative construction, 'Be clever,' and a synonymic negative, 'Don't be stupid.' Eleven intrusions met the negative-transform criterion that one component phrase be positive and the other negative. These examples are interesting because they contradict the hypothesis that speech errors follow the surface characterization of a sentence (see Fromkin, 1971). Another interesting feature of negative transforms is that the initial phrase usually contains the negative marker. In all 11 of Meringer's examples, the initial phrase was negative whereas the sequel phrase was positive, an outcome exceeding chance expectation at the .001 level using a two-tailed sign test with intrusions as the unit of analysis.

SUBSIDIARY RESULTS

We noted three phenomena bearing no direct relation to the notion of complexity — the underlying theme of this paper. Because these phenomena seemed of interest in their own right, we record them here as subsidiary results.

Segment repetitions

Prebreak segments in initial and sequel words were often identical, as in the initial word 'k*l*ug' and the sequel word 'sch*l*au,' which combine to form the intrusion 'klau.'[5] Using Meier (1964), we calculated that two consonants taken at random from a frequency-ordered stock of German consonants will be identical about 4% of the time; this, then, was our null hypothesis. In the data, 54% of the prebreak consonants in initial and sequel words were identical, significantly more than the 4% expected by chance [$\chi^2(1) = 15.78$, $p < .001$].

On the surface, these data suggest that identical segments may contribute to the intrusion of a sequel word. However, this should not be taken as evidence for a chain-association model of speech production, since other segments in the initial and sequel word also tended to be identical. For example, in the intrusion 'hastlos,' a combination of 'hastig' and 'rastlos,' two ('a,' 's') out of three segments preceding the prebreak segment ('t') are identical, while zero out of one segment following the postbreak segment ('l') is identical. Of the segments preceding the prebreak segment that could have been identical, 55% were in fact identical. And of the segments following the postbreak segment that could have been identical, 59% were in fact identical.

The words combined in a synonymic intrusion were therefore similar in sound. Why this was so is not clear at present. It is not even clear that similarity of sound is an underlying determinant of synonymic intrusions.

For example, it could be that words similar in meaning just happen to be similar in sound as well. Further research is required to determine a null hypothesis for testing whether similarity of sound plays a determining role in synonymic intrusions. But this is not to say that phonological factors are unimportant in determining phoneme fusions for example (see discussion).

Discontinuous intrusions

Sometimes a synonymic intrusion began with elements from the initial word, continued with elements from the sequel word, and ended with elements from the initial word. An example is 'zeitaufraubend,' a discontinuous combination of 'zeitraubend' and 'aufregend.' These discontinuous intrusions were infrequent ($N = 8$) but are of interest because they are easy to explain in a parallel-processing model and difficult to explain in a serial or chain-association model.

Multiple interactions

Synonymic intrusions sometimes involved more than two output programs. For example, Meringer showed that the intrusion 'kein menschlicher Fuss' represented the interaction of three underlying determinants that might be translated 'no person,' 'no mortal,' and 'no mortal foot.' Similarly, he was able to trace the intrusion 'bromen' to the three interacting determinants 'Böhmen,' 'Prag,' and 'Krone.' Such errors suggest that the semantic component in speech production can simultaneously address or call upon at least three output programs. This being the case, it seems plausible to assume that in normal, error-free speech the planning mechanism may prime or partially activate many more phonetic representations than are finally produced.

DISCUSSION

Wilhelm Wundt proposed one of the first theories of synonymic intrusions, based on an analogy from the field of attention. According to Wundt (1897), a sequel word intrudes into ongoing behavior in much the same way that an extraneous stimulus intrudes into the ongoing perceptual processing of external events, the extraneous stimulus producing a diversion from ongoing perceptual processes and the sequel word a diversion from ongoing output processes. The diversion in both cases reflects a voluntary switch from one program or channel to the other.

This 'switching hypothesis' has pervaded virtually every theory of synonymic intrusions since Wundt. But problems with the serial-processing assumption are easy to find and difficult to solve. We have already noted that discontinuous intrusions and multiple interactions favor a parallel rather than sequential process. The fact that intrusions virtually never include the beginning of the sequel word or phrase, but start in the middle, also favors a parallel-processing model. Another problem for the switching hypothesis is the phenomenon of phoneme fusion, demonstrated and discussed by MacKay (1972). Phoneme fusions are novel segments that share some but not all features of the postbreak segment in the initial word, and some but not all features of the postbreak segment of the sequel word. For example, in 'cagsi,' a combination of 'cab' and 'taski,' the postbreak phonemes have fused: the 'b' of 'cab' and the 'k' of 'taksi' have concatenated to give 'g.' Such examples are easy to explain in parallel-processing models but pose a problem for switching models.[6]

This is not to say that Wundt's switching model should be completely abandoned, even though we found no unambiguous evidence in its favor. It is possible that switching plays a role in some intrusions but not in others. Switching and parallel processing may even combine as determinants of synonymic intrusions. Speech errors are conditioned by a host of quite heterogeneous factors, a fact which further undermines the method of proof by example and makes speech errors a special case of Feynman's (1965) observation that "nature seems to be so designed that . . . things in the real world appear to be a kind of complicated accidental result of a lot of laws."

Synonymic intrusions are indeed the complicated results of a lot of laws operating at virtually every level of speech production. But for the most part, our data seem to fit an apparently simple model, the cross-talk hypothesis.

Under the cross-talk hypothesis, synonymic intrusions occur when the semantic component calls up or simultaneously activates two or more output programs. That is, the coding operations for producing the initial and sequel phrases (or words) are simultaneously activated and the phrase readied for production soonest gets produced. The sequel phrase intrudes because at some point it is simpler and is thus readied for production sooner than the initial phrase. Its simplicity (or time to organize a program) depends on the number of underlying coding operations. The detailed operation of these coding procedures entails a model of the mechanisms underlying the production of speech and renders the cross-talk hypothesis more complicated than it first appeared. We examine some of the mechanisms suggested by our data below.

At the segment level, we found that postbreak consonants in within-word intrusions were usually unvoiced. Under the cross-talk hypothesis, this finding can be explained in terms of phonemic simplicity as defined in theories of phonological markedness. In these theories, a consonant marked for voicing (e.g., 'b') involves at least one more coding operation than an unmarked one (e.g., 'p'). Adding this voicing operation to an unvoiced, prototype consonant takes time, which may well explain why unvoiced consonants tended to intrude on voiced consonants in our data. Our findings therefore support one aspect of the as yet incomplete theory of phonological complexity.

The role of syllabic stress in within-word intrusions can be similarly explained. Our data showed that stressed syllables intruded on unstressed ones with greater than chance probability. Under the cross-talk hypothesis, this finding suggests that stressed syllables are organized for production faster than unstressed syllables, an assumption supported in several experimental studies (MacKay, 1971). This assumption is also consistent with current linguistic theories. For example, in Chomsky and Halle's (1968) grammar of phonology, stressed syllables are simpler than unstressed syllables: several operations on an underlying stressed syllable are required to form an unstressed one. These additional operations would presumably take time, which may explain the intrusion of stressed syllables in our data. This aspect of the Chomsky-Halle model is therefore consistent with our present results, although other explanations are possible.

Consider now the effect of word length on within-word intrusions, the fact that sequel words tended to be shorter than initial words in our data.[7] This word-length phenomenon might be explained in terms of an internal monitor which notes that a longer program is being produced and decides to switch to the shorter program for reasons of economy or laziness. However, monitoring explanations generate serious problems and in any case do not explain why the sequel word begins where it does unless they incorporate all of the principles of the following cross-talk explanation.

To illustrate the detailed mechanics of this explanation, consider the intrusion 'klau,' an inadvertent combination of initial word 'klug' (clever) and sequel word 'schlau' (clever). Under the cross-talk hypothesis, the semantic component simultaneously activates two hierarchies of coding operations for 'klug' (1–8 in Table 7) and 'schlau' (1a–6a in Table 7). Note that the two sets of coding operations in Table 7 (after MacKay, 1972) are equally complex up to rule 5 — the recoding rule for the vocalic group. But the vocalic group of 'schlau' involves fewer coding operations and is therefore readied for production sooner than the vocalic group of

Table 7. Recoding rules at the syllable level for the initial word 'klug' (1-8) and the sequel word 'schlau' (1a-6a); the symbol Sy stands for syllable, ICG for initial consonant group, VG for vocalic group, C for consonant, VN for vowel nucleus, and FCG for final consonant group; terminal elements are presented in brackets

'Klug'	'Schlau'
1. $Sy \rightarrow ICG + VG$	1a. $Sy \rightarrow ICG + VG$
2. $ICG \rightarrow C_1 + C_2$	2a. $ICG \rightarrow C_1 + C_2$
3. $C_1 \rightarrow$ ['k']	3a. $C_1 \rightarrow$ ['sch']
4. $C_2 \rightarrow$ ['l']	4a. $C_2 \rightarrow$ ['l']
5. $VG \rightarrow VN + FCG$	5a. $VG \rightarrow VN$
6. $VN \rightarrow$ ['u']	6a. $VN \rightarrow$ ['au']
7. $FCG \rightarrow C_1$	
8. $C_1 \rightarrow$ ['g']	

'klug,' explaining the intrusion of 'au,' the general form of the intrusion 'klau,' and the effect of word length in our data.

This interpretation is relevant to Zipf's (1949) law. If the planning mechanism for speech production calls upon more items than are finally produced in normal, error-free speech, then shorter words, being organized for production sooner, will usually be produced. From this it follows that shorter words will be more frequent in a language than longer words — which, of course, is Zipf's law. There are undoubtedly other determinants of this law (e.g., a tendency to shorten or abbreviate frequently used words, perhaps in accordance with Zipf's 'laziness principle,' although laziness at a purely articulatory or phonetic level seems unlikely). The Zipf curve, like other natural phenomena, probably reflects the joint operation of several heterogeneous principles, a complicated accidental result of a lot of laws rather than a single law.

Consider now the role of word frequency in our data on within-word intrusions. Pairs of initial and sequel words in our corpus were relatively similar in frequency. The Spearman rank correlation between the frequencies of initial and sequel words in our corpus was .48 [$p < .001$]. However, this should not be taken as support for Oldfield's (1966) theory that word finding begins by specifying the frequency class of a word. One might just as readily say that the first decision in naming or word production concerns word length, since the length of initial and sequel words is even more highly correlated [$r = .61$, $p < .001$]. In fact, one might argue that the correlation of word frequencies is due to word length (see the correlational data problem). Indeed, the fact that word frequency had no effect on our results suggests that frequency should be considered a secondary or derived variable in models of complexity. Our data do not support Greenberg's (1966) hypothesis that word frequency plays a direct role in linguistic complexity.

We can turn now to the surface syntax of within-phrase synonymic intrusions. Our data suggested that two sorts of mechanism play a role at this surface-structure level. Consider first the cases where the postbreak words differed in form class, as in 'I am together,' a combination of initial phrase 'I am with you' and sequel phrase 'We are together.' What must be explained in such intrusions is why the sequel phrase is usually simpler, after the break, than the initial phrase. To illustrate the form of our explanation, we will examine the example above in detail.

According to the cross-talk hypothesis, coding operations for producing 'I am with you' and 'We are together' are basically similar to phrase-structure rules (see Table 5) except that the symbols stand for complex semantic ideas, the symbol S, for example, being equivalent to Wundt's (1897) *Gesamtvorstellung* — a simultaneous representation of the overall idea or proposition of the sentence. The arrows in our rules stand for 'is analyzed or recoded as.' For the sentence 'I am with you' the *Gesamtvorstellung,* S, is analyzed into the subunits NP + VP, which are themselves syntactic (and semantic) complexes. This recoding process then operates on the leftmost subunit until a terminal unit (represented in brackets in Table 5) is generated. Whereupon the next unexpanded unit is analyzed until all of the constituents of S have been recoded as lexical markers.

Now, the expressions 'I am with you' and 'We are together' represent alternate expansions of the same *Gesamtvorstellung,* or semantic proposition. These coding operations proceed simultaneously, according to the cross-talk hypothesis, but at some point the coding operations for the sequel phrase reach the terminal level sooner than those for the initial phrase. In this example, the coding operations for the adjective 'together' reach the terminal level sooner than those for the prepositional phrase 'with you.' Note that unlike the monitoring theory, this hypothesis accounts for the exact location of breaks in initial and sequel phrases.

Explanation of the other class of intrusions at the surface-structure level requires a similar model. In these intrusions, the form class of the post-break words was identical, as in 'You are true,' a combination of initial phrase 'You are correct' and sequel phrase 'That is true.' Two aspects of these intrusions require explanation: why the sequel word was usually shorter than the initial word, and why the sequel phrase was usually less complex than the initial phrase prior to the break. Under the cross-talk hypothesis, the intrusions occur when the same underlying term is expanded in two different ways: for example, Adjective → 'correct,' and Adjective → 'true.' The sequel word intrudes both because it is simpler than the initial word (involves fewer coding operations at the phonological level) and because the coding operations for the prebreak sequence in the sequel phrase are simpler. Both factors allow the sequel word to be readied for production before the initial word, thereby explaining the intrusion under the cross-talk hypothesis.

A similar explanation holds for the addition of constituents, as in the intrusion 'We must enter over into the order of the day,' a concatenation of initial phrase 'We must enter into the order of the day' and sequel phrase 'We must step over to the order of the day.' The coding operations for these initial and sequel phrases are shown in Table 8. As can be seen there, the particle 'over' in the sequel phrase would be organized for production before the preposition 'into,' thereby explaining the form of this and similar intrusions under the cross-talk hypothesis. Discontinuous

Table 8. Recoding rules for 'zeitraubend' (1–4) and 'aufregend' (1a–4a) and for 'We must enter into' (1–9) and 'We must step over to' (1a–10a); the symbol W stands for word, NS for noun stem, V for verb, VS for verb stem, PPtR for past participle rule, Pr for particle, S for sentence, NP for noun phrase, VP for verb phrase, Pn for pronoun, Aux for auxiliary, PP for prepositional phrase, and P for preposition; terminal elements are presented in brackets

'Zeitraubend'	'Aufregend'
1. W → NS + V	1a. W → V
2. NS → ['zeit']	2a. V → Pr + VS × PPtR
3. V → VS × PPtR	3a. Pr → ['auf']
4. VS → 'raub' × PPtR → ['raubend']	4a. VS → 'reg' × PPtR → ['regend']
'We must enter into'	**'We must step over to'**
1. S → NP + VP	1a. S → NP + VP
2. NP → Pn × first person × plural	2a. NP → Pn × first person × plural
3. Pn → ['We']	3a. Pn → ['We']
4. VP → Aux + VP	4a. VP → Aux + VP
5. Aux → ['must']	5a. Aux → ['must']
6. VP → V × plural + PP	6a. VP → V + Pr + PP
7. V → ['enter']	7a. V → ['step']
8. PP → P + NP	8a. Pr → ['over']
9. P → ['into']	9a. PP → P + NP
	10a. P → ['to']

intrusions can be explained within the same framework. Consider the intrusion 'zeitaufraubend,' a combination of 'zeitraubend' and 'aufregend.' The recoding rules for these words also are shown in Table 8. As can be seen there, the recoding rule for the particle 'auf' is expanded before the rule for the past participle 'raubend' in 'zietraubend,' thereby explaining the discontinuous intrusion of 'auf' under the cross-talk hypothesis.

We come now to the negative transforms, cases where positive forms intruded on negative forms or vice versa. Freud (1901) argued that Meringer's negative transforms reflect the intrusion of an unconscious wish or intention that directly contradicts the speaker's conscious or expressed intention. But Freud's theory cannot be considered a viable explanation of these errors, since it fails to capture the fact that affirmatives always intruded on negatives and never vice versa in Meringer's corpus. However, this phenomenon can be readily explained in a cross-talk model. In models of syntactic complexity, affirmatives are simpler than negatives, which involve the addition of at least one cognitive operation to an affirmative base or prototype form (Greenberg, 1966). Under the cross-talk hypothesis, this extra operation takes time, allowing the intrusion of the positive form.

RELATED PHENOMENA

Synonymic intrusions closely resemble phenomena in other motor systems. We examine some of these analogous phenomena below.[8]

Homologous intrusions

MacKay and Soderberg (1971) demonstrated a phenomenon resembling within-word synonymic intrusions in rapidly executed patterns of finger movement. The task was to tap synchronously with the fingers of both hands. That is, if the fingers of each hand, palm down, are labeled 1 to 4 from left to right, the subject's task was to simultaneously tap fingers 1 to 4 with both hands. Out of 50 subjects, not one was able to repeat this simple task 20 times at maximal rate without making an error. A frequent type of error took this form: the right (dominant) hand produced the correct pattern, 1234, but the left hand produced the error 1224. Note that the erroneous finger (2) of the left hand tapped in synchrony with the anatomically homologous finger (3) of the right hand — the defining characteristic of homologous intrusions.

Like synonymic intrusions, homologous intrusions reflect the incursion of one motor program on another, simultaneously activated motor program. And in some sense, homologous intrusions represent the optimal case for a cross-talk model of motor intrusions: the interacting programs for the right and left hand are simultaneously activated at a peripheral level and provide observable rather than inferential evidence for a cross-talk interpretation.

Motor intrusions in other species

Phenomena that are based largely on learning in higher animals often depend largely on genetic or innate components in lower animals. Motor intrusions are a case in point. Consider the findings of Dilger (1962), who crossbred Fisher lovebirds, which carry nesting materials in their bill (a species-specific behavior), with peach-faced lovebirds, which carry nesting material in their rump feathers. The hybrid offspring from these matings showed a conflict between the two inherited behavior tendencies — between the Fisher carrying pattern and the peach-faced carrying pattern. The hybrids would attempt one pattern or the other but at first were incapable of completing either pattern without intrusions of elements from the other. However, the simpler (Fisher) program eventually became dominant: after three years the hybrids usually succeeded if they began to carry the nesting material in their bill, but not if they began to tuck the materials in their rump feathers, a finding which is readily explained in a cross-talk model. Complexity seems to play a role in motor intrusions even when the determining tendency calling up the two conflicting action patterns is relatively permanent and genetically based. Perhaps, as Freud (1901) suggested, the principles underlying synonymic intrusions and other 'more important' behavioral and cognitive errors are the same. It seems likely that these principles and the methods for determining them will be quite different from those that Freud suggested. But only further research can tell.

Notes

The author gratefully acknowledges the support of UCLA Grant 2426, National Institute of Mental Health Grant 1-R01-MH-19964-01 and United States Public Health Service Grant 16668-01. The study was carried out in part in the Department of Experimental Psychology, University of Sussex. Received for publication August 17, 1972; revision, October 13, 1972.

1. Ambiguity and synonymy constitute analogous problems in a more general sense, synonymy on the output side and ambiguity on the input side. Both problems are ubiquitous: just as no two words or phrases are completely synonymous (Lyons, 1969), no word or phrase is completely unambiguous. And both problems present a similar challenge for psychology. For ambiguity, the question

is why formally ambiguous sentences are usually psychologically unambiguous — or equivalently, why formally ambiguous sentences are usually perceived in only one way. The analogous question for synonymy is why formally nonsynonymous sentences are often psychologically synonymous. For example, although 'solely' and 'totally' are not formally synonymous in all contexts, they are psychologically synonymous in the context 'He was solely (totally) responsible for that.'

2. We have used English examples wherever possible, although our data are in German. Note that the exact location of the break is sometimes ambiguous. Consider the synonymic intrusion 'sotally,' a combination of 'solely' and 'totally' in the context 'He was *sotally* responsible for that.' The break either precedes or follows the 'o' in 'sotally.' In the data to be presented, we always placed the break at the last point at which the initial word could be considered to stop. However, our basic results were unaffected when these ambiguous cases were eliminated or when we defined the break as the *first* possible point at which the initial word could be considered to stop.

3. Statistical tests were always carried out on the raw data. Percentages are given in the text and tables to facilitate exposition.

4. Meier's frequency count was based on Kaeding (1897), who examined a corpus of about 11 million German words. Nevertheless, only about 75% of the initial and sequel words in Meringer's intrusions were included in Meier's frequency count, partly because many were in Austrian dialect.

5. Note that postbreak consonants in the initial and sequel words cannot be identical by definition: a break is defined by the point where a different phoneme from the sequel word intrudes.

6. We might note in passing that Wundt's switching hypothesis also fails as a general theory of perceptual attention. Using a dichotic listening task, we find, not switching, but parallel processing for at least certain aspects of unattended inputs — aspects such as intensity and wavelength (Broadbent, 1958, and others), and meaning as well (Lewis, 1970, and others). Note also that phoneme fusions, besides contradicting the switching hypothesis, also suggest that phonemes are not the lowest level unit in speech production: the phoneme, like the atom, must be divisible. But there is still some doubt in psycholinguistics whether the phoneme, unlike the atom, is a unit at all. Whereas physicists have demonstrated that the mass of an atomic nucleus exceeds the summed mass of its component particles, psycholinguists have no analogous demonstration that phonemes represent anything more than a set of independent distinctive features.

7. This word-length effect contradicts Wells's (1951) hypothesis that the words combined in a synonymic intrusion tend to be equally long. Wells based his 'equal length' hypothesis on a very small sample of English intrusions ($N = 11$) — a sample that may be unrepresentative of most English intrusions, although we were unable to prove this statistically by examining the small number of English within-word intrusions reported in Fromkin (1971) and elsewhere.

8. It might also be noted that analogous phenomena occur in perception as well. For example, perceptual fusions reflect a process of input concatenation that sometimes occurs in dichotic listening tasks. For example, when 'poduct' and 'roduct' are presented simultaneously to the two ears, subjects sometimes hear 'product,' a perceptual fusion of the two inputs (Day, 1967). Perceptual fusions don't always result in words. By dichotically presenting 'shmekt' and

'merkt,' we found that English-speaking subjects often heard 'shmerkt,' a nonword bearing more than a passing resemblance to a synonymic intrusion. Indeed, 'shmerkt' actually *was* such an intrusion, produced some 80 years ago in German, a motor concatenation of 'shmekt' and 'merkt.' Moreover, our preliminary experiments suggest that variables such as syllabic stress play a similar role in synonymic intrusions and in perceptual fusions. For example, when we dichotically presented the nonsense syllables '*stro*blick' and 'spla*blim*' (stressed syllables italicized), the subjects usually heard 'stroblim.' And when we paired 'stro*blick*' and '*spla*blim,' they usually heard 'splablick.' As in the case of synonymic intrusions, stressed syllables seem to intrude in perceptual fusions. It would seem that further exploration of the similarities and differences between these intrusions and perceptual fusions may further our understanding of both.

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