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The development of sentence planning*

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ABSTRACT

This is an exploratory case study of the relation between speech output disturbances (dysfluencies) and the development of language production processes. The data consist of transcribed weekly speech samples of a Dutch boy between 2;4 and 2;11. The period of observation captures the early phase of the transition from 'pre-grammatical' to grammatical language. The frequency of occurrence of dysfluencies (i.e. repetitions, revisions and incomplete phrases) shows a significant increase and a subsequent decline. Whereas in the first half of the observation period the dysfluencies are distributed relatively randomly over sentences, in the second half they tend to concentrate in function words and sentence-initial words. The decline of dysfluency rate is shown to be related to an abundant use of a few 'syntactic frames'. It is argued that these results reflect the emergence of a component in the speech production apparatus which is specifically dedicated to serial-order planning.

INTRODUCTION

'When we turn to studies of development of psychological mechanisms in language production and comprehension there is a relative paucity of information' John Marshall complained in 1979 (Marshall 1979:448) and he is still largely right today, particularly with respect to production. Although most child language research is based on spontaneously produced speech, the predominant approach is competence-oriented. This perspective originated

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in the early days, when language acquisition was considered equivalent with syntax acquisition, and has persevered through shifts of the focus of attention towards semantics (e.g. Schaerlaekens, 1973; Brown, 1973) and, still later, pragmatic and interactive aspects of language (e.g. Bruner, 1975). In each of these areas, researchers have been trying to formulate competence rules that would underly children's behaviour, and have described development in terms of extension, refinement and reorganization of rule systems.

This study takes a different perspective. Instead of 'the body of knowledge' that children acquire in learning to speak, the 'psychological mechanism in language production' is examined. The basic question that is addressed by this research is: does the architecture of the speech production system change during the period in which language is acquired? It will be argued that the answer is affirmative: the transition from 'pre-grammatical' language to morpho-syntactically governed language, which is roughly captured by Brown's (1973) stage II, appears to be associated with an essential modification of the planning mechanism underlying speech production. The context – both methodological and theoretical – for this argument is supplied by some recent studies of language production in mature speakers, which will be briefly discussed below.

Sentence production in adults

According to recent insights, the preparation of spoken utterances involves several levels of processing. In general, three major components are distinguished: (1) the CONCEPTUALIZER, which generates – non-linguistic – messages; (2) the FORMULATOR, i.e. a processing component which moulds the message into linguistic shape; and (3) the ARTICULATOR, which generates and executes articulatory motor programs (Fromkin, 1971; Levelt, 1989).

An important hypothesis, put forth by Fromkin (1971) and elaborated by Garrett (1975, 1980) is that formulating consists of two complementary substages. The primary evidence for this hypothesis comes from systematic distributional differences between two types of speech errors, sound exchanges and word exchanges. Garrett (1975, 1980) observed that most word exchanges involve lexical items from different phrases within the same clause (although some cross clause boundaries) that belong to the same lexical class. Sound exchanges, on the other hand, usually occur within the same phrase, and the words from which the exchanging sounds originate may belong to different lexical classes. Garrett argues that word exchanges originate at a level of processing which selects open class lexical items and maps them onto functional syntactic relations. At this FUNCTIONAL substage of formulating, neither the serial order nor the phonological layout of lexical items has yet been actualized. Sound exchanges, on the other hand, originate at the second, POSITIONAL substage of formulating, which creates ordered and phonologically explicit representations on the basis of developing functional representations and the appropriate word forms (Levelt, 1983). A third class of exchange errors, the so-called STRANDING ERRORS, was observed, in which lexical morphemes incorporated in morphologically complex forms exchange, leaving their associated affixes behind, as it were. The distributional properties of this error type are similar to those of sound exchanges. Consequently, Garrett argues that stranding errors originate during the computation of positional representations, which can be viewed as the 'insertion' of open-class words into 'slots' in a syntactic frame made up of closed class words and syntactically active affixes.

The speech error evidence suggests that the sentence or clause is the primary planning domain. This appears to be confirmed by studies of hesitations in speech. It has been established (cf. Goldman-Eisler 1968) that hesitations, i.e. transitory speech disturbances such as pauses, repeats and false starts are related to the assignment of processing capacity to planning. Boomer (1965) counted all hesitation pauses in samples of spontaneous speech and found that most of them occurred near the beginning of clauses.[1] In a recent extensive study, Holmes (1988) found that not only silent pauses, but also filled pauses and repetitions (of sounds, words and phrases) occurred significantly more often at clause-initial positions than at clause-internal positions. Additionally, she collected evidence which suggests that some 'deep clauses' may be independently planned, depending on their functional relation to a connected surface clause. Constituents (within clauses) may also function as – secondary – planning units. Maclay & Osgood (1959) observed that repetitions typically involved function words (particularly pronouns, determiners, prepositions and conjunctions) which occurred at constituent-initial positions (see also Clark & Clark, 1977). Moreover, corrections of content (open class) words more often involved retracing the antecedent items (mostly function words) than corrections of function words.

It has been suggested that hesitations, such as repetitions and filled pauses specifically reflect difficulties in co-ordinating lexical selection (functional level planning) and the construction of syntactic frames (positional level planning) (Maclay & Osgood, 1959; Butterworth, 1980; Garrett, 1982). Some experimental results appear to sustain this suggestion. Although Garrett's original hypothesis envisioned functional planning and positional planning as strictly hierarchically ordered processing stages, recent studies suggest otherwise. For instance, Dell & Reich (1981) observed a significant degree of phonological similarity between the interacting content words in semantically based substitution errors, which suggests that the selection of

[1] In fact, Boomer defined clauses in phonological terms, but this is of slight importance for the present discussion, since onsets of phonological and syntactic clauses more often than not coincide.

word meaning representations (functional level) is affected by word form characteristics (positional level). This is supported by experimental findings which indicate that when a word form is difficult to access, speakers may opt for a sentence structure that allows this word to be mentioned relatively late (Levelt & Maassen, 1981; Bock, 1987). Thus, decreased accessibility of a word form, which hampers positional level processing, may induce re-allocation of functional syntactic roles at the functional level. Interestingly, Bock (1987) found that in the cases where such problems of co-ordination and subsequent 'corrective planning' could be expected to occur, sentences were more often hesitantly initiated than in cases where sentence formulation was not interfered with.

In summary, the primary unit in sentence formulation in adult speakers is the (surface) clause. Formulation consists of two substages, functional planning, which is dedicated to lexical selection and the computation of functional syntactic relations, and positional planning, which is dedicated to syntactic frame building and the ordering of phonologically defined lexical items. Speech hesitations reflect the occurrence of sentence planning processes, in particular involving the coordination of the two substages of formulating.

Speech planning in children

Can the production of speech in children be analysed in a manner that is similar to the approaches outlined in the above section? If one inspects the developmental psycholinguistic literature, it may seem as if children neither hesitate nor slip. The latter might be true (cf. Warren 1986), although it could perhaps reflect the difficulty of recognizing incidental speech errors amidst an excess of imperfections that are due to linguistic immaturity. However, children do hesitate, but it appears that the interest in this phenomenon has been largely confined to a research tradition that has not been very well-known to (psycho)linguistics, namely speech pathology. Consequently, the terminology is different; repetitions, false starts, as well as some other disturbances, are usually jointly labelled 'dysfluency'.

The relevant literature in this field indicates that children exhibit considerable variation in the frequency of dysfluency, but that, generally, the amount of dysfluent speech peaks in the preschool years and decreases subsequently (Davis, 1939; Yairi & Clifton, 1972; Bjerkan, 1980; Yairi 1982). The majority of children's dysfluencies are repetitions and revisions (Yairi, 1981; Wexler & Mysak, 1982), which are phenomenologically very similar to those of adults. Moreover, a number of studies show that children's dysfluencies – just like adults' hesitations – tend to occur at syntactically significant positions in utterances, such as clause boundaries and closed class words at the beginning of major constituents (Bloodstein & Gantwerk, 1967;

Helmreich & Bloodstein, 1973; Bernstein, 1981; Bloodstein & Grossman, 1981; Wall, Starkweather & Cairns, 1981). It has been suggested that this distributional pattern reflects the allocation of processing capacity to the planning of stretches of speech that correspond to syntactic units (Bloodstein, 1974; Wall *et al.*, 1981; Nelson 1984).

The basic similarities between hesitation patterns in adults and dysfluency patterns in children seem to suggest that the processing structures underlying speech production are developmentally invariant. There are, however, some reasons to doubt this conclusion. First, most studies of developmental dysfluency represent a large sample approach in which subjects from a wide range of ages are pooled, so that developmental tendencies are likely to be obscured. Secondly, the children in these studies had generally reached the age of four years or older. At this age children have generally reached a level of language competence that is – in the essential aspects of grammar – roughly equivalent to that of adults (Schaerlaekens & Gillis, 1987). Thus, it can be concluded that the development of dysfluency as related to speech production in the earlier phases of language development has not yet been analysed. The widely reported, but hitherto unexplained dysfluency peak occurs during these stages. The present study attempts to relate this phenomenon to the development of the speech planning mechanism, which is hypothesized to be associated with specific developments in linguistic competence.

Between the ages two and four important changes occur in children's language which mark the transition from 'pre-grammatical' or 'telegraphic' speech to 'grammatical' speech. During this stage (roughly stage II in Brown's (1973) scheme), the set of grammatical morphemes is rapidly extended and differentiated as a category from open class vocabulary. Morpho-phonological and morpho-syntactic processes become productive. It appears that these new elements of grammar are those in terms of which positional level planning is distinguished from functional level planning in Garrett's model of sentence formulation. Consequently, it can be conjectured that their emergence in child language is reflective of the development of a positional planning component in the speech production system. This hypothesis will be referred to as the DEVELOPMENT OF THE FORMULATOR HYPOTHESIS. It will be clear that this hypothesis raises two questions. First, in what way can it be tested, or, in other words, what predictions does it make? The second question is, of course: if positional planning is not present as of the first multi-word sentence, what mechanism can be thought to underlie these utterances? The latter question will be addressed later on in this paper, but an answer will inevitably be incomplete and rather speculative.

As regards the first question, a prediction can be made with respect to the distribution of dysfluencies. In the fully developed formulating mechanism, dysfluencies arise as a result of planning activity – particularly the coordination of functional and positional planning – at the boundaries of clauses or sentences and at phrase-initial closed-class words. It can be argued that as long as the formulating mechanism has not reached its eventual two-stage architecture, dysfluencies will not be specifically concentrated in the aforementioned loci. Hence, it can be expected that the 'mature' distribution of dysfluency will gradually emerge over time.

The present study attempts to test this prediction by means of a longitudinal distributional analysis of the developmental dysfluency of a 2-year-old Dutch boy. In addition to this, an attempt will be made to explain the increase and subsequent decline of dysfluency which occurred during the period of observation in terms of the Development of the Formulator hypothesis. A single subject approach, of course, demands reluctance in generalizing the findings. However, in view of the wide inter-individual variability in rate and pattern of both language acquisition and the development of dysfluency (Yairi, 1982), it was considered the most appropriate approach for a detailed explorative study.

This article proceeds as follows. First, some preliminary quantitative results with respect to the development of sentence length and the frequency of dysfluencies will be presented. Then, in order to corroborate the assumption that the kind of grammatical development which is expected during this stage of development takes place in the subject, some data regarding the changing status of closed class words, i.e. prepositions, will be presented. Subsequently, the distribution of repetitions with respect to lexical classes and sentence boundaries are analysed. The next section deals with the question of whether distributional data of another type of dysfluencies, namely self-corrections, corroborate the repetition results. Finally, the developmental course of the frequency of dysfluencies is investigated.

METHOD

Subject

The data set for this study consists of a corpus of utterances transcribed from tape-recordings of one Dutch boy, T, between 2;3·22 and 2;11·22. T had started to use multi-word utterances around 2;2. The mean lengths of utterance in morphemes (Brown, 1973) obtained from the corpus identify T as a stage II child during the period of observation (see Table 1). T's speech and hearing were normal; he was not identified as a stutterer.

Recording and transcription

An approximate total of 25 hours of recordings was collected. The recording sessions were evenly spead over time, so that roughly one hour of tape became available for each week. The recordings were made under various ordinary domestic circumstances. Usually, T was engaged in a conversation with his mother. The recording equipment was of ordinary (non-professional) quality. It was normally put in the direct vicinity of the child, so as to optimally pick up the child's speech.

Approximately 17 hours of recording were transcribed by two independently working, phonetically trained transcribers. T's speech was transcribed in IPA supplemented with non-standard diacritics indicating dysfluencies and conspicuous aspects of prosody (sentence accents and marked intonation). The adult interlocutor's speech was written down in Dutch orthography. The transcribed tapes cover four periods of three to five weeks, which are evenly spread over the total period of observation (see Table 1).[2]

TABLE 1. *An overview of the corpus*

Period	Week numbers	Total recording time (minutes)	Chronological age	Average MLU	Number of utts.
1	1–4	300	2;3·22/2;4·16	1·98	2050
2	9–12	240	2;5·21/2;7·9	2·6	2261
3	16–20	300	2;8·2/2;9·5	2·64	2675
4	24–26	210	2;10·23/2;11·22	2·73	1711
Totals		1050			8697

The independently produced provisional transcriptions of T's utterances were compared to generate definitive versions. Discrepancies between the transcriptions were resolved by joint listening to the tapes and negotiation. If the transcribers could not reach agreement on either the segmental transcription or the identification of dysfluency, the disputed utterances, or the relevant parts thereof were dismissed from subsequent analysis. The types of dysfluency that were distinguished were: repetition (of sounds, words, or phrases), self-corrections, incomplete sentences, sentence-initial 'warm-ups' and tensed prolongations. Some examples of these types are given in Table 2.

As the notion 'sentence' is central to the hypothesis underlying this research and as formal grammatical definitions of the sentence are not readily applicable to child language, it is necessary to point out how sentence was defined in this study. The primary criterion in deciding whether a string of words would be considered a sentence was 'intonational integrity'. Thus, a discontinuity in the melodic contour of a string of words was considered to

[2] There is one exception. The first two weeks and the second two weeks of the second period are separated by a four weeks' holiday.

TABLE 2. *Examples of speech dysfluencies*

(1) Repetitions:
  (a) sound:
    k... kerstboom (T012- 67)[a]
    ch... christmas tree
  (b) word:
    ik... ik ben ook pap gegeten (T111- 28)
    I... I am also porridge eaten (I also ate porridge)
  (c) phrase:
    heb je... heb je hier hand? (T184- 78)
    have you... have you here hand (do you have a hand here)
(2) Self-corrections:
  doet die sch... doet schoen nou? (T111-303)
  does that sh... does shoe now (what does that shoe do?)
(3) Incomplete sentences:
  eh... dat is... (T111- 89)
  ah... that is...
(4) 'Warm-ups':
  /ndzdz/... door de slang (T041- 34)
  /ndzdz/... through the tube
(5) Tensed prolongations:
  n::iet waar (T185- 8)
  n::ot true

[a] The codes in parentheses represent the corpus identification (T); the sequence number of the week of recording (1–26); the sequence number of the episode within the current week; and, after the dash, the sequence number of the utterance within the episode.

be a sentence boundary, unless an assessment of semantic or pragmatic attributes, based on 'rich interpretation' suggested otherwise. Experimental results (Branigan, 1979) corroborate the validity of this operational criterion. It should be stressed that this criterion was employed throughout the period of observation. Hence, the term 'sentence' as it appears in the ensuing analyses, always refers to operationally similar units. Furthermore, it should be pointed out that decisions regarding the segmentation of sentences, just as those regarding segmental transcription and the identification of dysfluency, were submitted to the criterion of consensus between the two transcribers.

RESULTS

Sentence length

Fig. 1 shows the development of mean sentence length over the total period of observation. The index differs in two aspects from Brown's (1973) MLU. First, it is expressed in number of words, i.e. items that are recognized as such by a competent native speaker. This appears to prevent a number of ad hoc decisions regarding the segmentation of words into morphemes.

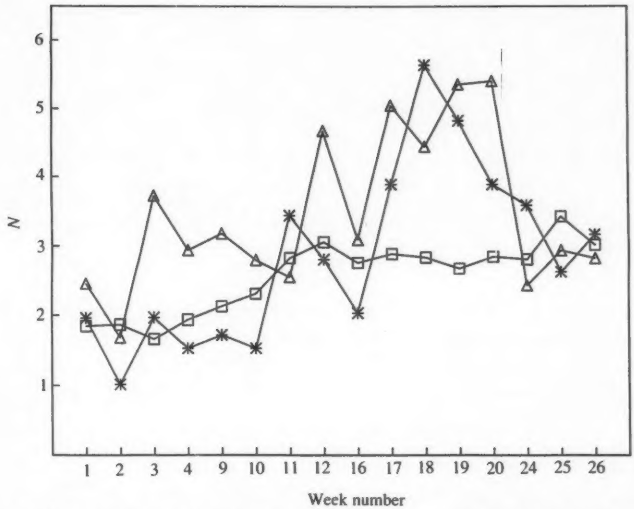

Fig. 1. The mean sentence length (in numbers of words); repetition rate (raw numbers per 100 words) and the total number of interrupted sentences (incomplete sentences and self-corrections) per 100 words, as a function of week of recording. □, sentence length (N words); △, repetitions (N/100 words); * interr. sents. (N/100 words).

Secondly, the statistic is computed on a subset of utterances excluding *yes*'s, *no*'s, vocatives and some standard or memorized expressions (e.g. social routines, counting, nursery rhymes), so that it can be considered a reasonably valid estimation of sentence length tendencies in 'non-formulaic' language. In the first period (week 1 through 4) sentence length is relatively stable around 1·85 words, with the exception of a dip in week 3. Period 2 shows an increase from 2·13 to 3·06. Utterance length in period 3 is again relatively stable, this time between 2·7 and 2·9. In period 4 a slight overall increase was found.

Overall dysfluency

The majority of dysfluencies are repetitions, revisions and incomplete phrases, as is indicated by Table 3. Fig. 1 shows the development of the frequency of these types of dysfluency, expressed as the total number of instances per 100 words. Both the indexes for repetition and for the combined category of revisions and incomplete sentences appear to increase between period 1 and period 3, and decrease from period 3 to period 4. Chi-squared tests confirm that the proportions of occurrences of these two types of

TABLE 3. *The numbers of self-corrections, incomplete sentences, repetitions and other dysfluencies in the four periods of the corpus*

Period	Self-corr.	Incompl. sent.	Repetitions	Other	Total
1	20 (11·3)[a]	28 (15·8)	75 (42·4)	54 (30·5)	177 (100)
2	45 (14·1)	79 (24·7)	137 (42·8)	59 (18·4)	320 (100)
3	62 (13·0)	150 (31·5)	202 (42·4)	62 (13·0)	476 (100)
4	37 (14·0)	75 (28·3)	100 (37·7)	53 (20·9)	265 (100)
Total	164 (13·2)	332 (26·8)	514 (41·5)	228 (18·4)	1238 (100)

[a] Percentages in parentheses.

dysfluency vary significantly across periods (repetitions: $\chi^2 = 21{\cdot}53$, d.f. = 3, $p < 0{\cdot}001$; revisions/incomplete sentences: $\chi^2 = 34{\cdot}34$, d.f. = 3, $p < 0{\cdot}001$). Taken together, these results imply that the amount of dysfluency increases until a peak is reached in period 3, and declines subsequently.

Language change

According to the Development of the Formulator hypothesis, the emergence of positional processing in speech production is associated with particular linguistic developments such as the emergence of closed class vocabulary and the development of morphological processes. In T, quantitative as well as some qualitative observations with respect to the development of function words confirm that the child is in the critical period. The quantitative data concern growth and frequency of use of closed class vocabulary. Words in the corpus were categorized and counted. Nouns, adjectives, and verbs were regarded as content words. Determiners, (non-adjectival) adverbs, pronouns, prepositions and conjunctives were regarded as function words. In Period 1 of the corpus, a total number of 59 different function words (types) was counted. This number increased by 29 (49·2 %) in Period 2 and by another 13 (16·7 %) in Period 3. Figures regarding the use of function words underscore their growing importance. In Period 1, only 27·8 % of all word tokens are function words. This figure almost doubles to 50 % in Period 4.

Some data regarding the use of prepositions by T underscore the changing status of function words during the development stage. In adult language, most prepositions can be considered two-place predicates. The arguments could be tentatively called 'subject' and 'oblique' (cf. Keenan & Comrie, 1977). In a sentence like 'A cat walks on the hot tin roof', 'a cat' is the subject argument of 'on', and 'the hot tin roof' is the oblique argument. All expressions containing prepositions in T's corpus were counted and classified according to the number and types of arguments involved. Thus, four types of expressions resulted: (1) subject argument only (e.g. 'zonnetje op' [sun

TABLE 4. *The numbers of prepositions in either of four contexts of use*

Period	Subject only	Oblique arg. only	Subject and 'er'	Subject and oblique args.	Total
1	29 (36·7)[a]	41 (51·9)	4 (5·1)	5 (6·3)	9 (100)
2	6 (4·1)	84 (57·5)	9 (6·2)	47 (32·2)	146 (100)
3	13 (7·3)	86 (48·0)	8 (4·5)	72 (40·2)	179 (100)
4	1 (0·7)	69 (46·0)	8 (5·3)	72 (48·0)	150 (100)
Total	49 (8·8)	280 (50·5)	29 (5·2)	196 (35·4)	554 (100)

[a] Percentages in parentheses.

on], meaning: there is a sun on something, i.e. T's plate, as suggested by the context); (2) oblique argument only (e.g. 'op het bordje' [on the plate]); (3) subject argument and 'empty' oblique argument, expressed by the indefinite adverb 'er' (e.g. 'pit er uit halen' [take pip out of]); (4) two full arguments (e.g. 'dit is zwarte trein op brug' [this is black train on bridge]).

Table 4 displays the proportions of prepositions in each of the four different contexts throughout the corpus. It appears that in period 1, the majority of all prepositions (88·6 %) are accompanied by just one argument. In 36·7 % of the cases, this is the subject argument. In period 2, the amount of subject-only constructions is dramatically reduced to 4·1 %. At the same time, full-fledged relational use of prepositions emerges, as is indicated by the increase of two-argument constructions from 6·3 % in period 1 to 32·2 % in period 2, and a subsequent growth to 48·0 % in period 4. These results seem to imply that at the outset of the observation period prepositions function as (unspecific) modifiers (cf. McNeill, 1966) and subsequently change into relational words. Similar patterns of development have been observed before (Tomasello, 1987).

It is of some importance to note that the relation that is denoted by a preposition is grammatically encoded by the order of the arguments. Thus, acquiring the relational character of prepositions, as it is observed in T, seems to pose the necessity of learning to plan the order of sentence elements. That this may cause initial trouble is illustrated by some incidental and, therefore, striking reversals which were noted by T's mother in her diary:

(1) lepel mette appesap (intended: 'appelsap met lepel' [apple juice with spoon])
(2) bed inne pop (intended: 'pop inne bed' [doll in bed])
(3) boot zit in pappa beer (intended: pappa beer zit in boot [daddy bear sits in boat])

Repetitions and lexical classes

The distribution of dysfluencies in mature speakers is known to be affected by the open class-closed class distinction. Consequently, it can be predicted that if this distinction is acquired during the period of observation, the distribution of dysfluency will change concurrently. To test this prediction, the numbers of function words and content words affected by word- and sound repetitions in each of the four periods were counted. Table 5 indicates

TABLE 5. *The numbers of content words and function words affected by word and sound repetitions and in a fluent random sample*

	Repetitions		
Period	Content words	Function words	Total
1	47 (69.1)[a]	21 (30.9)	68 (100)
2	65 (52.0)	60 (48.0)	125 (100)
3	53 (30.9)	118 (69.1)	171 (100)
4	39 (42.9)	52 (57.1)	91 (100)
Total	204 (44.8)	251 (55.2)	455 (100)
	Fluent random sample		
Period	Content words	Function words	Total
1	185 (63.6)	106 (36.4)	291 (100)
2	254 (53.0)	225 (47.0)	479 (100)
3	348 (54.8)	287 (45.2)	635 (100)
4	247 (49.9)	248 (50.1)	495 (100)
Total	1034 (54.4)	866 (45.6)	1900 (100)

[a] Percentages in parentheses.

that the proportion of function words in the set of words affected by repetitions appears to increase gradually from period 1 to 3. This change is reflected by a significant chi-square ($\chi^2 = 32.19$; d.f. = 3; $p < 0.001$). In order to establish whether the proportions of content and function words involved in repetitions differed from those in fluent speech, a random sample of fluently pronounced words was drawn from the corpus. The numbers of content and function words in the fluent random sample are indicated in Table 5. The figures in this table suggest that the proportions of content words and function words in the repetition and fluent samples do not differ much in periods 1 and 2. In periods 3 and 4, however, the proportion of function words seems to be larger in the repetition sample than in the fluent sample. Thus, it seems that, in concordance with the above prediction, repetitions are approximately randomly distributed with respect to word class in the first two periods, whereas, in periods 3 and 4, they concentrate in function words.

In order to statistically substantiate this conclusion, Table 5 was submitted to loglinear analysis, which is aimed at finding a linear model which captures the most parsimonious combination of factors (in this case: period, sample [repetitions vs. fluent] and word class) and interactions of factors that optimally predicts the observed data. It was established, however, by means of likelihood ratio tests that none of the parameters in the full loglinear model could be set to zero. This means that only the so-called 'saturated' model, with non-zero parameters at all levels (main effects, second order interactions, third order interactions) gives a sufficient fit to the data, which is uninformative. It is still possible, however, to test which parameters are mainly responsible for this 'non-zero' test result. In view of the above prediction we are particularly interested in whether the increase in the proportion of function words as a function of time (period) is different for the two samples (repetitions vs. fluent speech). Specifically, it was tested whether the ratios of the proportions of function words were identical in the two samples for each pair of successive periods. Since there are four periods, three hypotheses were tested. Estimates of the relevant parameters were obtained by maximum likelihood estimation. Pearson χ^2 statistics were calculated for each of the three hypotheses (for details, see Haberman 1974). For the first hypothesis, contrasting period 1 with period 2, the Pearson χ^2 statistic had a value of 0·7021 ($p = 0{\cdot}402$). For the second hypothesis, contrasting period 2 and period 3, Pearson $\chi^2 = 12{\cdot}25$ ($p = 0{\cdot}0005$), and for the third hypothesis, contrasting periods 3 and 4, Pearson $\chi^2 = 5{\cdot}55$ ($p = 0{\cdot}018$).

These results confirm the impression given by the figures in Table V. A clear significant 'shift' in the distribution of repetitions occurs between periods 2 and 3, resulting in a disproportionate number of function words involved in repetitions, as compared to fluent speech. The significant test result on the third hypothesis confirms the impression that the difference between fluent and non-fluent samples diminishes in period 4.

An alternative explanation for this repetition 'shift' could be stated in terms of vocabulary growth. When many new words are acquired, many new articulatory patterns have to be exercised, which could lead to a considerable number of pronunciation breakdowns. Indeed, as was indicated in the previous section, the number of function words (types) increased during the time of observation. However, explanations of dysfluency rate in terms of vocabulary increase have to be rejected, since they make the wrong prediction with respect to the content words. During the same time in which the number of function words grew, the number of content words grew as well, and much faster at that. For example, a total of 180 nouns was counted in period 1, which almost doubled during period 2 ($N = 352$). Another 127 (36·1%) were added in period 3. In spite of this explosive growth in vocabulary size, the amount of repetitions in content words seemed to reduce rather than grow.

Sentence boundaries

The Development of the Formulator hypothesis predicts that in the course of development dysfluencies should shift toward sentence boundaries. In order to test this prediction, the distribution of repetitions over sentence positions was examined. Table 6 shows the numbers of repetitions at sentence-initial positions in each of the four periods. These values were tested against the average estimated chance that a repetition would occur in a sentence-initial word, given a random distribution of repetitions over all words in the sentence. The estimated chance values are: 0·38 for Period 1; 0·28 for Period 2; 0·29 for Period 3 and 0·25 for Period 4. Binomial test results were non-significant for period (1 ($z = 1·139$; $p > 0·10$) and period 2 ($z = 0·600$; $p > 0·20$), but significant for periods 3 ($z = 6·158$, $p < 0·0001$, one-tailed) and 4 ($z = 2·782$, $p < 0·005$, one-tailed). Thus, in the first two periods, the distribution of repetitions over sentence positions does not differ from chance expectations, whereas in periods 3 and 4, repetitions occur more often on sentence-initial words than is predicted by chance estimates. In other words, in the course of time repetitions appear to 'shift' towards sentence boundaries.

TABLE 6. *The distribution of words affected by repetitions over sentence-initial and non-initial positions*

Period	Sentence-initial position	Non-sentence-init. position	Total
1	20 (47·6)[a]	22 (52·4)	42 (100)
2	30 (31·3)	66 (68·8)	96 (100)
3	70 (53·4)	61 (46·6)	131 (100)
4	29 (39·7)	44 (60·3)	73 (100)
Total	149 (43·6)	193 (56·4)	342 (100)

[a] Percentages in parentheses.

The validity of this 'repetition shift' as an argument in favour of the Development of the Formulator hypothesis rests on the assumption that repetitions in the present subject are reflective of planning activity. It has been found that the amount of speech planning is positively correlated to the size of the planning domain (cf. Butterworth, 1980; Elbers, 1983). Consequently, it can be predicted that if dysfluency reflects planning activity, long sentences should yield higher proportions of dysfluency than short sentences, particularly at syntactic boundaries, where the bulk of planning is assumed to take place.

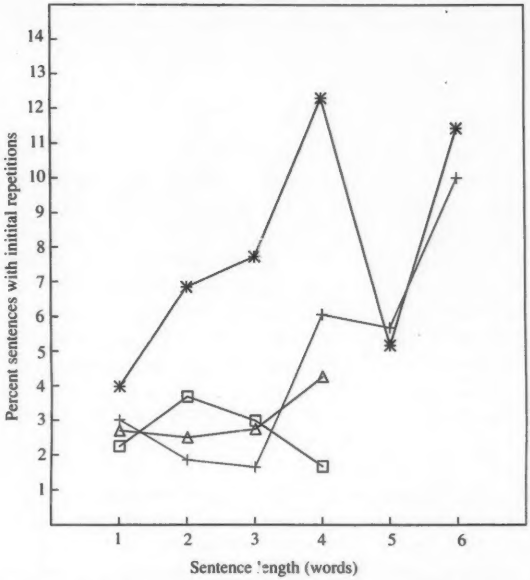

Fig. 2. The percentage of sentences incorporating sentence-initial repetitions as a function of sentence length (in words) for each of the four periods. □, Period 1; △, Period 2; *, Period 3; +, Period 4.

Fig. 2 depicts the relation between sentence length and the probability of sentence-initial dysfluency for each of the four periods in the corpus. It appears that in periods 1 and 2, the proportions of sentences with a repetition in the first word does not systematically vary across samples of sentences with different lengths (Period 1: $\chi^2 = 1{\cdot}93$, d.f. = 3; Period 2: $\chi^2 = 8{\cdot}04$, d.f. = 4). In periods 3 and 4, however, the proportion of sentences with initial repetitions increases as a function of sentence length (Period 3: $\chi^2 = 14{\cdot}07$, d.f. = 5, $p < 0{\cdot}02$; Period 4: $\chi^2 = 17{\cdot}73$, d.f. = 5, $p < 0{\cdot}01$). Thus, there seems to be no evidence for a relation between sentence length and initial repetition in the first half of the corpus, whereas in the second half the probability of sentence-initial repetition is positively correlated with sentence length. This finding confirms that planning of speech in sentence-sized units does not emerge until period 3.

In summary, the repetition data seems to reflect the genesis of a speech planning mechanism that possesses some of the essential characteristics of the mature system. In the following sections two questions will be addressed:

First, do other dysfluencies corroborate the developmental pattern as suggested by the repetitions? Second, can the Development of the Formulator hypothesis account for the development of dysfluency rate?

Interrupted sentences and self-corrections

Sentences are usually interrupted because the speaker has detected some infelicity or error. The occasion for an interruption, and, more importantly in view of the present analysis, its locus in the sentence, can, however, only be assessed if the speaker provides a clue, in the form of an overt repair. Thus, the considerable amount of incomplete sentences – i.e. sentences that are interrupted, but not repaired – in T's corpus is not very helpful in the exploration of production processes. We are left with the suggestion that the increase of incomplete sentences from period 1 to period 3 may reflect the increasing processing difficulty associated with the hypothesized reorganization of the speech planning mechanism.

The number of self-corrections, i.e. interruptions and subsequent repairs, in T's corpus was 164, of which 152 occurred in fully interpretable multiword sentences. In the following paragraphs, two aspects of spontaneous self-corrections will be discussed which seem to be relevant for the Development of the Formulator hypothesis. First, we will have a look at the distribution of errors over sentence positions, and secondly, we will analyse the pattern of restarting after interruption and repair.

The corrected errors were divided into three categories: phonological, lexical and syntactic. Phonological errors involved substitutions of speech sounds, such as

treetje ['trecə]...treintje ['trɛincə] op (T022-71)
(*train on*)
is ə bebisj ['bebɪɕ]...babietje ['bebicə] in ə bed he? (T101-90)
(*is little baby in bed eh?*)

Lexical errors involved word substitutions:

hier rood...paars (T121-216)
(*here red...purple*)
in...op de huis (T182-88)
(in...on the house)

Syntactic errors involved apparent deletions or misorderings:

moet ə...ik moet ə poepje doen (T123-135)
(*have to...I have to make poopoo*)
zit...de Kermit kikker zit (T185-70)
(*sit...the Kermit frog sit*)

TABLE 7. *The distribution of phonological errors and words over sentence positions*

	Errors		
Period	Sent.-Init.	Other	Total
1+2	7 (31·8)[a]	15 (68·2)	22 (100)
3+4	14 (50)	14 (50)	28 (100)
Total	21 (42)	29 (58)	50 (100)
	Words		
Period	Sent.-Init.	Other	Total
1+2	22 (28·2)	56 (71·8)	78 (100)
3+4	28 (25·9)	80 (74·1)	108 (100)
Total	50 (26·9)	136 (73·1)	186 (100)

[a] Percentages in parentheses.

On the basis of the repetition data it was argued that the hypothesized reorganization of the speech production mechanism, i.e. the emergence of positional planning, gets under way approximately between period 2 and 3 in the corpus. Thus, as of period 3, a significant amount of planning activity can be assumed to take place at sentence beginnings. If it is assumed that processing capacity is limited, it can be predicted that when much of this capacity is assigned to planning, this may intefere with the execution of subsequent steps in speech production, for instance the preparation of phonetic programs and articulation. Consequently, an increase of speech-sound related errors at sentence-initial positions can be expected to occur as of period 3.

Table 7 contains the numbers of sentence-initial and non-sentence-initial phonological (self-corrected) errors, as well as the numbers of words in sentence-initial and other positions in the affected sentence, which can be interpreted as chance estimates of the distribution of errors. Due to the sparseness of the observations, the first two periods and the last two periods have been collapsed. It can be read from Table 7 that the percentage of phonological errors at sentence-initial positions increases from 31·8 % to 50 %. The percentage of sentence-initial words, on the other hand decreases from 28·2 % in the first two periods to 25·9 % in the last two periods. Thus, in periods 3 and 4 there are almost twice as much phonological errors in sentence-initial positions than is predicted by chance estimates.

Table 7 was submitted to loglinear analysis, in order to assess the interactions between the factors Sample (errors vs. words), Period and Sentence Position. The most restricted model that yielded a sufficient fit to the data included parameters for each of the main effects, as well as for the interaction of sample and sentence position. The interpretation of this model is that sentence position interacts with sample, independently of period (Fienberg 1981). Thus, unfortunately, the impression that the difference between observed distribution of errors and estimated distribution (words) is affected by period cannot be statistically substantiated.

TABLE 8. *The numbers of instant repairs and retraced restarts in self-corrections of errors involving words in second or subsequent positions*

Period	Instant repair	Retracing to sentence bound.	Other retraced restarts	Total
1	6 (75)[a]	1 (12·5)	1 (12·5)	8 (100)
2	19 (86·4)	2 (9·1)	1 (4·5)	22 (100)
3	14 (53·8)	10 (38·5)	2 (7·7)	26 (100)
4	15 (62·5)	9 (37·5)	0 (0)	24 (100)
Total	54 (67·5)	22 (27·5)	4 (5·0)	80 (100)

[a] Percentages in parentheses.

A final observation regarding the self-corrections regards the pattern of restarting as a function of age. When speakers repair a part of an utterance, they may resume speaking at the error location, immediately substituting a new element for the erroneous one, or they may repeat some elements which directly preceded the error. The latter case is called a 'retraced restart', the former an 'instant repair'. Levelt (1983) found that adult speakers of Dutch virtually always restart at a syntactic boundary, but at the same time he established that this is virtually inevitable in a right-branching language. The present analysis will be confined to sentence boundaries. Table 8 summarizes the numbers of immediate and retraced restarts upon errors in non-sentence-initial words. (None of the sentence-initial errors were followed by a retraced restart.) The figures show an increase of retraced restarts such that the ratio of retraced restart to instant repairs in periods 1 and 2 differs significantly from the ratio in periods 3 and 4 ($\chi^2 = 4{\cdot}39$, d.f. $= 1$, $p < 0{\cdot}05$). Moreover, the restarts increasingly occur at sentence boundaries. These results support the conjecture that the developmental changes between periods 1 and 2 on the one hand, and periods 3 and 4 on the other, involve the emergence of sentences as units in speech planning.

The rise and fall of dysfluency

Up till now the analyses were focused on the distribution of dysfluency. The distributional changes of dysfluencies were argued to reflect the emergence of positional planning. Now, the discussion will return to the frequency of occurrence of dysfluencies. The question that needs to be addressed is whether the growth and subsequent decline of the dysfluency rate can be explained within the framework of the Development of the Formulator hypothesis.

Let us first, however, consider an alternative proposition. There is a significant correlation between mean sentence length (in words) and mean total number of repetitions and revisions over time ($r = 0.53$, $t = 2.34$, d.f. $= 14$, $p < 0.05$, two-tailed). It could be argued that the developmental increase of dysfluency rate is due to the increase of sentence length, given the assumption that longer sentences demand more planning, and hence yield more dysfluencies. It should be recalled, however, that the growth of dysfluency is observed in spite of the fact that dysfluency rate is expressed in a measure that is independent of sentence length (i.e. number of occurrences per 100 words, see Fig. 1). Consequently, it can be concluded that the growth of dysfluency is DISPROPORTIONAL to the increase of utterance length.

This conclusion is unequivocally supported by an analysis of dysfluency rate in which sentence length is controlled. For the subsets of 2-word utterances within the four periods of T's corpus, the mean dysfluency rate (total repetitions and self-corrections per 100 words) was computed. These values, as well as the associated standard deviations, are summarized in Table 9. A one-way ANOVA indicates that the dysfluency rate varies significantly over periods ($F(3, 1312) = 4.182$, $p < 0.01$). Thus, sentences that are equivalent from a statistical point of view yield different degrees of production difficulty in different periods. In sum, it can be concluded that although increasing sentence length may contribute to the developmental increase of dysfluency, it appears subsidiary to some other factor.

TABLE 9. *Dysfluency rate (mean total repetitions and revisions per 100 words) in two-word sentences in each of the four periods*

Period	Number of observations	Mean dysfluency	Standard deviation
1	407	3.194	15.365
2	319	4.232	19.570
3	321	6.854	22.003
4	269	2.045	11.650

The factor suggested by the Development of the Formulator hypothesis is the development of new computational routines, which are dedicated to serial order planning. It can be imagined that the 'implementation' of these routines demands a considerable portion of processing capacity, which interferes with speech delivery and thus causes the remarkable increase of dysfluency. The subsequent decline of dysfluency can be explained as well within this framework. It can be thought to reflect an increase of automaticity in sentence formulation, which is associated with a reduction in the processing capacity allocated to planning.

The development of automaticity may be helped by practising, i.e. repeatedly performing the same, or similar actions (cf. Bock, 1982). There is a phenomenon in the present corpus that is suggestive of practising. In the second half of the corpus, particularly in period 4, T's speech became increasingly stereotypical. An analysis of sentence schemes revealed an increasing number of sentences that were started by a pronoun and a verb (or auxiliary) – in either order (Pro-V-X). This construction has been reported to occur frequently in Dutch child language (cf. Verhulst-Schlichting, 1985). Table 10 indicates the proportions of sentences with a Pro-V-X frame in each period. It is remarkable that in period 4, when dysfluency is declining as compared to the previous period, OVER A QUARTER of all sentences fit the frame. This is suggestive of a relation between sentence frame variability and dysfluency rate.

TABLE 10. *The numbers of uninterrupted, non-formulaic, fully interpretable sentences; the subset of sentences with more than two words; the subset of sentences fitting the Pro-V-X frame*

Period	Total *N* of sentences	*N* of sents. > 2 words	Pro-V-X frames
1	1201	261 (21·7)[a]	72 (6)
2	1339	650 (48·5)	183 (13·7)
3	1381	733 (53·1)	248 (18)
4	1067	632 (59·2)	288 (27)
Total	4988	2276 (45·6)	791 (15·9)

[a] Percentages in parentheses.

A comparison of dysfluency rates (i.e. mean numbers of revisions and repetitions per 100 words) between sentences involving the Pro-V-X frame and other sentences is summarized in Table 11. It appears that in Periods 3 and 4 non-frame sentences are significantly more dysfluent than frame sentences, notwithstanding the fact that all frame sentences – by definition – incorporate at least three words (namely pro + V + minimally one other word) and therefore are on average longer than non-frame sentences.

It does not seem to matter whether or not T consciously (or intentionally) employs the sentence frame Pro-V-X. Whatever the case, the frequency of its use appears to be a significant factor in reducing dysfluency. Moreover, it may explain the decline of the distributional effects from Period 3 to Period 4 that was repeatedly observed. A final, important observation is that the

TABLE 11. *Dysfluency rates (mean total repetitions and revisions per 100 words) in sentences corresponding to the Pro-V-X frame and in other (non-frame) sentences*

Period	Frame	Non-frame	t statistic	d.f.	one-tailed p
1	5·39	4·00	0·77	87	0·222
2	6·09	6·72	−0·49	337	0·313
3	6·08	10·91	−4·14	797	0·001
4	4·44	7·56	−3·07	1030	0·001

dysfluency reducing effect of the use of sentence-frames is only significantly present from Period 3 onwards. This finding suggests that as of Period 3, sentence frames and 'lexical content' have become separate entities in the preparation of speech, which support the claims made by the Development of the Formulator hypothesis.

DISCUSSION

Perhaps the most important outcome of this study is that it demonstrates that 'performance oriented' studies of child language, analogous to those in adults, are feasible and may provide some fresh insights into developmental processes that may supplement the results of competence studies. The findings can be summarized as follows. A significant increase in dysfluency rate is observed between age 2;4 and 2;9, followed by a decline. The bulk of dysfluency is formed by repetitions, revisions and incomplete phrases. Concurrently with the increase of the frequency of occurrence of dysfluencies, their distributional patterns change. Repetitions concentrate in function words. Repetitions and, possibly, speech errors 'shift' toward sentence-initial positions, and the length of utterances comes to affect the proportion of sentence-initial dysfluency. Moreover, the number of self-corrections involving retraced restarts shows an increase. In short, the pattern of dysfluency that emerges in the second half of the observation period is remarkably similar to the hesitation patterns in adults.

These results are in agreement with the Development of the Formulator hypothesis. According to this hypothesis, the type of planning that is observed developing in T is POSITIONAL level planning, which is specifically dedicated to computing serially ordered representations in accordance with the demands of developing morpho-syntax. Supportive evidence for the development of positional planning is provided by the results regarding sentence frames. The notion 'sentence frame' has figured before in several accounts of language learning. It has been argued, for instance, that sentence frames are (partly) unanalysed strings of WORDS which children employ, by means of variation and extension, to construct linguistic knowledge (cf. Peters, 1983). Thus, these frames are seen as a 'point of departure' for the developmental process. The frames that are observed in the present data, however, consist of syntactic CATEGORIES, and can be viewed as a 'result' of development. They may be thought to reflect the emergence of syntactic frames as autonomous computational structures in the preparation of speech, which is the hallmark of positional level planning. Finally, not only the changes in distribution of dysfluencies, but also the development of dysfluency rate can be accounted for by the Development of the Formulator hypothesis. Dysfluencies in mature speakers were argued to specifically reflect the coordination of functional level planning and positional level planning. It can be argued that the increase of dysfluency in T reflects the vast problems of coordinating different levels of processing in the developing two-stage sentence planning mechanism.

Of course, these interpretations raise the question as to the nature of the speech production mechanism BEFORE the two-stage formulating module is in place. Is there planning in 'telegraphic speech'? Not more than a rather vague and speculative answer can be given at this moment. It has been argued that children who have started to use multi-word utterances try to express various semantic relations (cf. Brown, 1973; Schaerlaekens, 1973; Golinkoff, 1981), and one should expect this to require some sort of prior decision making, at least with respect to the selection of words and their assignment to the intended semantic roles. Furthermore, durational and intonational data obtained by Branigan (1979) seem to imply that early multi-word utterances are integrated within a single prosodic format. Therefore, some kind of planning must be assumed to occur with the advent of multi-word sentences. In speculative terms, I would propose to call this 'integrated planning'. This term is intended to indicate that the functions which are separated in Garrett's model, namely on the one hand selection of lexical items and mapping these onto functional relations (which, at this stage of development could be entirely defined in terms of semantic roles) and, on the other hand, serial ordering and morpho-phonological planning, are not yet differentiated. This rather speculative idea illuminates the affinity of the Development of the Formulator hypothesis to theories of language development that stress the discontinuity between early, semantically based, and subsequent, syntactically based grammars (cf. Gleitman, 1981; Gleitman & Wanner, 1982). It should also be clear that the proposed developments in the language production apparatus are not indifferent to the development of linguistic knowledge. Rather, the Development of the Formulator hypothesis assumes a close connection between alterations in the child's knowledge of language (for instance, regarding the assignment of words to syntactic categories) and the development of performance.

Can it be assumed that the developmental process that is suggested on the basis of T's dysfluency data occurs in all children? It has been observed that nearly all children show dysfluency peaks between roughly 2 and 3 years of age (Yairi, 1982). Since the developmental process as depicted by the Development of the Formulator hypothesis was argued to be responsible for increases of dysfluency, the generality of fluency deterioration between ages 2 and 3 could imply the generality of the developmental process as sketched by the Development of the Formulator hypothesis. However, there are massive inter-individual differences in the degree of fluency deterioration and rate of recovery. It is clear that for the Development of the Formulator hypothesis to be truly valid, it should be able to accommodate this variation. Thus further research along the lines set out in this study is warranted.

A particularly interesting and clinically relevant problem to which the Development of the Formulator hypothesis might be applied concerns the ontogenesis of stuttering. Some speech pathologists think that stuttering sprouts from 'normal' developmental dysfluency, while others argue that there are significant qualitative differences between 'pathological' and 'normal' dysfluency patterns from the onset onward (cf. Yairi & Lewis, 1984). The results of the present study show some interesting correspondences to those obtained from children that were identified as stutterers (Bloodstein & Gantwerk, 1967; Wall *et al.*, 1981; Elbers, 1983). The distributional pattern of dysfluency that was found in stuttering children is similar to the pattern of dysfluency in the second half of the present corpus. This is suggestive of a continuity between 'normal' dysfluency and stuttering, not only in terms of overt behaviour, but also in terms of underlying process. It is tempting to speculate that 'pathological' dysfluency may be the symptom of a developmental problem in language production.

It has been suggested that a reduction in the variability of language output, i.e. stereotyped behaviour, may be helpful in the development of automaticity of language production (Bock, 1982). The present study indicates that a decline in dysfluency, which followed the spectacular increase associated with the emergence of positional planning, is – at least partially – linked to an increase in the use of fixed sentence frames, which agrees with Bock's proposal. Increased dysfluency is the result of imperfect functioning of a newly acquired system; practising, i.e. repeatedly using a restricted set of output formats, helps in making the system run smoothly. Perhaps children whose speech is persistently dysfluent fail to invent appropriate practising strategies. It might be worthwhile to investigate whether childhood stuttering is reduced by interventions that aim at (temporarily) restricting output variability.

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