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GRAMMATICALITY JUDGMENTS BY APHASICS OF ALPHABETICALLY WRITTEN NUMERAL FORMS

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The syntactical competence of aphasic subjects (Broca's aphasics with or without agrammatism, Wernicke's aphasics, conduction aphasics, and others) was investigated by means of a grammaticality judgment task dealing with the alphabetic numeral coding system for quantities. Contrary to previous reports based on linguistic material, the Wernicke's and conduction aphasics were impaired. Wernicke's aphasics scored high on false recognitions by typically generalizing 1st-order acceptance rules and subrules operating on adjacent numeral lexicon elements categorized into several grammatical classes. Broca's aphasics (and agrammatics also) showed some preserved abilities to handle relatively long-range, 2nd-order dependencies, and their performances were particularly dependent on the precise role (functor, non-functor) of the only grammatical ambiguity of this notational system «cent» (hundred). Thus, these subjects still seemed to have some knowledge of the syntactical structure of alphabetic numeral strings. The results are discussed in reference to the current discussion concerning the level and the generality of the syntactic comprehension disorder manifested by agrammatic patients with linguistic material. The scope of this study is thus not limited to the restricted domain of numerals, for the analyses of the data provide some insight in the processes underlying the syntactical knowledge of aphasics.

Investigations of selectively preserved or impaired abilities of aphasic subjects to handle linguistic tasks offer the opportunity of checking language processing models in normals. This line of research has received considerable attention (Deloche & Andreewsky, 1982; Marin, Saffran & Schwartz, 1976; Patterson, 1981; Saffran, 1982). As an approach to the study of neuropsycholinguistic systems, it has yielded a series of studies devoted to the specific dissociation of various language functions in relation to type of aphasia (see Caramazza & Berndt (1978) for a review).

At the production level, a double dissociation between Broca's and Wernicke's aphasics' skills when operating lexical and syntactical procedures in the sentence anagram task was first demonstrated by Von

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Stockert (1972) and Von Stockert and Bader (1976). Broca's aphasics were able to perform the task only when semantic constraints induced serial ordering, whereas Wernicke's aphasics were found to rely only on syntactical cues. Investigation of comprehension skills of Broca's aphasics (and more particularly of agrammatic patients) seemed to indicate that their difficulties in the receptive modalities closely parallel their deficits on the expressive level (Berndt & Caramazza, 1980; Deloche & Seron, 1981; Parisi & Pizzamiglio, 1970; Schwartz, Saffran & Marin, 1980; Zurif, Caramazza & Myerson, 1972).

A unitary interpretation of the syntactical disabilities of Broca's aphasics was proposed by Zurif and Caramazza (1976) (see also Berndt & Caramazza, 1980), who hypothesized that there is a disruption of that component of the normal language processing system whose specific role is to compute syntactic structures. These conclusions emerged from the results of studies performed with different experimental paradigms. Written sentence-picture matching tasks focusing on subject/object relations indicated by word order (reversible sentences, passives) in declarative, center-embedded, and dative sentences where pragmatic cues given by content words were controlled showed the predominant relevance of lexical semantic strategies in the performances of Broca's aphasics as opposed to the syntactic strategies preferred by Wernicke's aphasics. The comprehension of conduction aphasics was shown to be impaired in the same way as that of Broca's aphasics (Caramazza & Zurif, 1976), whereas according to Hécaen (1972) it should be relatively preserved. Sentence anagram tasks were correctly performed by Wernicke's aphasics (Kinsbourne & Warrington, 1963). Broca's aphasics with agrammatism were impaired (Saffran, Schwartz & Marin, 1980), and a dissociation was found between posterior and anterior lesions (Caramazza, Berndt, Basili & Koller, 1981). Caramazza et al. (1980) reported a case of a conduction aphasic who had no difficulty with this sentence anagram task.

Finally, investigations of the knowledge of syntactical structures was also assessed by means of grammaticality judgments. Such an experimental design avoids both the production stages of anagram solving and the picture decoding involved in sentence-picture matching tasks. Wernicke's aphasics (with jargonaphasia were able to identify dyssyntactic sentences (their own productions were written down by the examiner) (Kinsbourne & Warrington, 1963). Although no difference was observed between anterior and posterior lesions on semantically anomalous sentences, syntactically deviant sentences showed different patterns of

results in the two groups of aphasics (Gardner, Denis & Zurif, 1975). In particular, posterior aphasics were better than anterior patients in using the information conveyed by word order. Based on somewhat different analyses (more phonological than syntactical), Kean's (1977) interpretation of agrammatism also considered that these patients could not construct syntactical representations. Using a stick-copying task, Grossman (1980) generalized the view of Broca's aphasics' impairments in terms of a deficit at the level of a central component handling hierarchical structures, whatever the linguistic or non-linguistic character of the material.

However, some results seem at variance with the claim that Broca's aphasics, or at least those with agrammatism are necessarily unable to derive syntactic structure from sentences. The differential ability of an agrammatic patient to read aloud the French grammatical ambiguity «car» (bus/because) correctly when a noun in a sentence associated to his systematical inability to read it when a conjunction actually demonstrated knowledge of the syntactic structure of the particular sentences (Andreewsky & Seron, 1975). Re-analysing the results of the studies dealing with sentence anagram tasks, Scholes (1982) showed that agrammatic patients did not in fact violate the serial ordering constraints since they produce many more NVN structures than NNV or VNN. Moreover, Linebarger, Schwartz & Saffran (1983) found that their four agrammatic patients were still able to make grammaticality judgments on «sentences» (word strings) like «how many did you see birds» where detecting the non-well formedness implied complex syntactical knowledge. They consequently concluded that the source of the comprehension deficit in agrammatism could not be attributed to an inability to construct syntactic structures. Kolk and Van Grunoven (1984) were led to the same conclusion by observing four agrammatic patients whose mental representation of simple active functor sentences, as assessed by means of the triadic comparison technique (Zurif, Caramazza, Myerson & Galvin, 1974), were perfectly normal.

In summary, first, the syntactic competence of Wernicke's aphasics is generally considered to be preserved, and, when slightly impaired with reference to normals, the disorder is considered to be secondary to some primarily lexical, semantic, or phonological disturbance (Caramazza, Berndt & Basili, 1983); second, there is a dispute concerning the nature of the deficit that underlies the defective comprehension and production of agrammatic Broca's aphasics: are they or are they not able to mentally elaborate syntactic structures?

The present investigations does not directly address this question on linguistic material. Different groups of aphasic subjects (Wernicke's, conduction, Broca's aphasics with or without agrammatism, and others) judged the grammaticality of sequences of lexical primitives for numerals like «twenty seven hundred and three». The lexical primitives were the 24 words of the French alphabetic coding system for integer numbers from 0 to 999. This lexicon was thus very limited and very familiar to everyone, and the set of primitives was almost completely distinct from other lexicons. The grammar, which determines whether sequences of numeral lexicon elements are well-formed or not, is simple but not trivial (Deloche & Seron, 1982a; Hurford, 1975; Power & Longuet-Higgins, 1978). It should also be noted that the influence of non-controlled pragmatic factors that, as pointed out by Schwartz et al. (1980), may have biased the results of some studies dealing with syntactic versus semantic dissociations in linguistic skills of aphasic subjects is absent of the domain of quantities. No assumption is made concerning any connection between the syntax of numerical forms and that of language. It is simply presumed that judgments on the well-formedness of strings of alphabetically written numerals imply both *lexical* and *syntactical* processing, in the meaning given to these terms in the formalized descriptions of coding systems in general. Wether the study might contribute to the generality of some double dissociations involving lexical and syntactic disorders whatever the coding system is a matter of discussion and depends on the results.

Material and methods

Experimental procedures

Aphasic subjects were given a list of 135 items written in upper case letters. Each item consisted of two to four lexical primitives of the French numeral lexicon system, for instance «SIX CENT HUIT» and «UN CENT SEPT». The subjects were instructed to indicate the items where the sequence of words was not a well-formed numeral (in the example, the latter item, the former being legal and referring to the number «608»). Only one item was visible at a time. The subjects received no information concerning their performance during testing; when necessary, they were encouraged to continue. The first three items were practice trials. The battery was presented in one session lasting from 10 to 45 minutes, depending on the subjects' paces. The order of the items in the list was random as regards the length dimension

(number of words). Half of the 132 test items were well-formed numerals consisting of twenty-five 2-word, twenty-six 3-word, and fifteen 4-word items; the illegal items consisted of twenty-two 2-word, twenty-nine 3-word, and fifteen 4-word sequences (see Appendix 1).

Subjects

The results reported in this study were obtained from 35 aphasic subjects examined at the «Centre de Rééducation du Langage» (La Salpétrière, Paris) who made at least one error in judging the well-formedness of the 132 test items. Three other patients, all anomic aphasics, were excluded from the analysis since they made no errors. The type of aphasia was assessed according to the standard diagnosis protocol of Ducarne (1976). There were 9 Broca's aphasics without agrammatism, 2 Broca's aphasics with agrammatism, 9 Wernicke's aphasics, 4 conduction aphasics, 3 transcortical sensory aphasics, 3 anomics, and 5 mixed aphasia types. The lesions were vascular in 32 cases, traumatic in 2 cases, and infectious in one. There were 24 men and 11 women. The mean age was 52.3 (range: 18-77). The experiment was conducted at least 6 month after the onset of aphasia.

Results

The subjects' performances (4,620 judgments produced by the 35 aphasic patients for the 132 test items of the battery) will first be analyzed in terms of error percentages (false recognition of illegal numerals and misses of well-formed numerals) as a function of item length; and, for illegal items, of the possibility that a permutation on the elements of the sequence could yield a correct numeral as in «UN CENT SEPT» (incorrect) whereas «SEPT CENT UN» is correct (701). The distributions of the error percentages according to items and subjects will also be analyzed.

The second analysis will consider the subjects' performances with reference to a production model of normal decisions relying on a hierarchicalized set of acceptance/rejection rules operating from left to right on contiguous elements in the item string, these elements (lexical primitives) being categorized into different grammatical classes such as unit names, tens names, and so on. Such an approach does not imply a correspondence between any of these classes («units») and the different parts of speech («verbs»). It simply notes that there exist some syntactical constraints governing the superficial structure of numeral strings and

sentences as well. The rules are of 0, 1st, or 2nd-order, depending on the number of numeral string elements involved: one isolated or two or three adjacent ones. Since the rules are stated in terms of legal/illegal sequences of grammatical classes, they are either general, i.e., the rule stands whatever the particular elements of the class, or they have exceptions, referred to as «subrules». For instance, one 1st-order general rule is Rule 20: «The sequence 'CENT (hundred), tens name' is legal» (see Table 1). Rule 6: «The sequence 'unit name, CENT' is legal» does not apply to the case where «unit name = UN (1)», hence Subrule 7: «The sequence 'UN, CENT' is not legal». As examplified by the pair «Rule 6, Subrule 7», the distinction between what is called the rule and what is the subrule is based exclusively on relative frequency of usage according to the combinational properties of the numeral coding system: Rule 6 applies to eight digit names (from «deux» (2) to «neuf» (9)), whereas Subrule 7 concerns one digit name only. The 2nd-order subrules concern special contextual cases not handled by the lower order rules/subrules. A typical 2nd-order subrule is: «The sequence 'CENT (hundred), unit name, CENT (hundred)' is not legal», as in «CENT TROIS CENT» despite the fact that its two two-element subsequences «CENT TROIS» (103) and «TROIS CENT» (300) are well-formed. The distributions of the cases where each individual rule/subrule is either obeyed or violated will be studied and a computer simulation performed for each of the 35 subjects. This will clarify the particular subject's grammar by adjusting the model to the subject's productions.

The third analysis will investigate the patterns of dissolution of the subjects' performances according to type of aphasia (Broca's aphasia with or without agrammatism, Wernicke's aphasia, and conduction aphasia). Pooling data from different subjects according to the classical semiology of language disorders ensures homogeneous groups with respect to the impairment of common linguistic processing and offers an opportunity to examine the generality of the mechanisms responsible for multiple dissociations between linguistic abilities (syntactic versus semantic) in aphasic syndromes reported by some researchers (Caramazza et al., 1981; Von Stockert, 1972) but, as already mentioned, questioned by others who found, for instance, that agrammatic patients could still make grammaticality judgments and perform sentence anagram tasks on purely syntactical grounds (Linebarger, Schwartz & Saffran, 1981; Scholes, 1982). This approach parallels that of Grossman (1980) in another domain.

Global description of the subjects' performance: Error percentages

The judgments produced by the aphasic subjects were not correct in 1,154 cases out of the 4,620 item instances (error percentage: 25%). False recognition of illegal numerals occurred more frequently than misses of well-formed sequences (error percentage: .32 and .18, respectively). The error frequencies on legal numerals (misses) were .11, .20, and .28 for 2-, 3-, and 4-word sequences, respectively. It is as though the decision-making process considered the adjacent pairs indepently, with a constant rejection score of .11 on each legal pair, the subject's judgment being to reject a sequence as soon as one pair is not considered correct (in that case, the distribution of rejection rates according to item length should be. 11, .21, and .29). However, this interpretation is not supported by the false recognition rates, which were virtually the same for both the 2- and the 3-word items (.35 and .34, respectively).

The error frequency for the individual items varied from .03 (three legal numerals each missed only once by the 35 subjects) to .83 (29 false recognitions of the item «QUARANTE UN», the legal one being «QUARANTE ET UN» (41)). The mean number of errors per item was 8.7. As previously indicated, false recognition occurred more often than misses. This global result was not induced by one or another particular item score since, when the items were arranged according to error scores, the proportion of illegal and well-formed numerals in the two halves of the scale clearly indicated a general shift of illegal numerals towards high error scores: 44 out of the 62 items having more than 8 errors were not well-formed numerals, whereas 41 out of the 58 items having less than 8 errors were correct numerals. There were 15 illegal numerals that could be transformed into correct numerals by some permutation of their elements like «QUARANTE TROIS CENT» → «TROIS CENT QUARANTE» (340) or → «CENT QUARANTE TROIS» (143). This factor seemed to affect the subjects' performance since 12 such items (mean length: 2.7) were among the 33 illegal items having the highest error rates, whereas only 3 (same mean length value) belonged to the 33 illegal items with the lowest error scores.

The number of errors per subject varied from 5 to 70 (mean: 33; median: 42) with 10 subjects being responsible for half the error total. The frequency of false recognition varied among the subjects from .03 to .74, and the misses varied from .00 to .51. The judgments of some of the subjects seemed to be distributed at random, for instance, Subject Ba (false recognitions: .52; misses: .47). However, this interpretation based on global statistical distributions, is ruled out because computer simula-

tion of a proper modification of the normal grammar leads to an approximation of the subject's productions with rather good fits (see below). False recognitions were more frequent than misses in 27 patients; the reverse occurred in 7 cases; and no difference appeared in one subject. There were some subjects whose errors were highly biased toward false recognition like Subject Fr (false recognitions: .56; misses: .03), or to misses like Subject Ve (false recognitions: .11; misses: .30). The performance of these subjects will be analyzed in detail below.

Analysis with reference to a normal production model

The 24 lexical primitives of the French alphabetic coding system for integer numbers from 0 to 999 may be grammatically categorized as follows: units names (from «UN» (1) to «NEUF» (9)), tens names (from «DIX» (10) to «SOIXANTE» (60)), «particulars» names (the 2-digit numbers from «ONZE» (11) to «SEIZE» (16)), and the three elements «ZERO» (0), «CENT» (hundred), and «ET» (and). The neuropsycholinguistic relevance of such categorization has been discussed in detail elsewhere (Deloche & Seron, 1982a, b; Seron & Deloche, 1983). Briefly, the notion of psycholinguistic procedures operating on stack-like structures was substantiated by analyses of aphasic patients' performances (correct responses; types and systematicity of erroneous productions) in transcoding integer quantities from alphabetic script to Arabic digits and the reverse. Stacks are simply one-dimensional arrays in which the elements are indexed by their position. The data demonstrated the differential role of the two independent types of information characterizing lexical primitives (the stacks to which they belong and their positions within stacks) when aphasic subjects processed numeral lexicon elements. Identification errors that confused the stack information were rare (6%) and occurred twice as much among the Broca's aphasics as among the Wernicke's (Deloche & Seron, 1982b). Errors dealing with the position information accounted for only 3% of the total errors among the Wernicke's aphasics, and none of this kind were found among the Broca's. It thus seemed legitimate to design a model of the decision-making process at work in the present grammaticality judgment task that assumes the correct categorization of units, tens, and particulars names into the corresponding U-, T-, and P-stacks and that assumes too that some lexicon elements could be correctly positioned with reference to one value (combining the tens name «DIX» (10) with a unit name is correct only for «SEPT» (7), «HUIT» (8), and «NEUF»

(9): «DIX-HUIT» (18) is well-formed whereas «DIX-TROIS» is illegal, hence the necessity of comparing units names to 7; see Subrule 13). Finally, some lexical primitives have special roles and must consequently be recognized as such: two unit names, «UN» (1) (Subrules 7, 12) and «QUATRE» (4) (in composed tens; Subrules 5, 23, 24); three tens names, «DIX» (10), «VINGT» (20), and «SOIXANTE» (60) (Subrule 13 and in composed tens, Subrules 5, 15, 17, 23, 24); «CENT» (hundred), «ZERO» (0) and «ET» (and). As shown in Table 1, a set of acceptance/rejection rules/subrules operating from left to right on the numeral element string is thus able to determine their legality/illegality.

Most of the rules are of the 1st order, thus concerning two adjacent lexical primitives. As previously indicated, some apply without exception, like Rule 3: «The sequence 'Unit Particular' is incorrect and cannot be found in legal numerals»; or Rule 20: «'CENT' (hundred) may be followed by any tens name». Other rules have exceptions, like Rule 16: «Two tens names cannot be adjacent», except for «SOIXANTE DIX» (70) (Subrule 17). Thus, as given in Table 1, the decision on a «TT» pair requires one to address the exception subrule indexed by the main rule. When the rules and their possible subrules are of the 1st order, then the verification process may continue shifting one numeral element to the right until the table shows an illegal pair or the end of the numeral string is reached. But some pairs point to the 2nd-order subrules, like the 1st-order main Rule 19: «'CENT' (hundred) may be followed by any unit name», on the condition that «the unit should not be followed by another 'CENT'», as expressed by the 2nd-order Subrule 27. The 2nd-order subrules tend, of course, to handle contextual situations that could not be solved by operating consecutively two 1st-order main rules: the TUC string «TRENTE CINQ CENT» is not legal (and is detected as such by Subrule 26) whereas both «TU» (main Rule 11) and «UC» (main Rule 6) are well-formed pairs. The rules and subrules governing the use of the arithmetical operator «ET» (and) may be stated as follows: «ET» must be preceded by a tens name and followed either by «UN» (1) (except if the tens name is «DIX» or is «VINGT» when the latter is preceded by «QUATRE»); or by the particular «ONZE» (11) if the tens name is «SOIXANTE». Such complicated rules were not included in Table 1 since our material contained only three items relevant to the usage of «ET»: two illegal numeral forms, «QUARANTE UN» («ET» missing) and «CINQUANTE ET TROIS» («ET» in excess), and one correct numeral «CINQUANTE ET UN» (51). Thus rule 12 is only an approximation of the normal production system that is appropriate to the items in the present battery.

Tab. 1 — Acceptance and rejection rules/subrules for numeral strings[a]

rules	*accept*			*reject*		*subrule*[b]	*examples* I = incorrect C = correct
0-order							
1				ZERO (O)			CENT ZERO TROIS (I)
1st-order							
2				U[c]	U		QUATRE DEUX (I)
3				U	P		HUIT TREIZE (I)
4				U	T	5	TROIS VINGT (I)
5	U = QUATRE	T = VINGT				(23) (24)	QUATRE VINGT (C)
6	U	C				7	TROIS CENT (C)
7				U = UN	C		UN CENT (I)
8				P	U		SEIZE DEUX (I)
9				P	T		DOUZE SOIXANTE (I)
10				P	P		QUINZE DOUZE (I)
11	T	U				12 13 (25) (26)	TRENTE CINQ (C)
12				T	U = UN		QUARANTE UN (I)
13				T = DIX	U < 7		DIX TROIS (I)
14				T	P	15	DIX QUINZE (I)
15	T = SOIXANTE	P					SOIXANTE DOUZE (C)
16				T	T	17	SOIXANTE TRENTE (I)
17	T = SOIXANTE	T = DIX					SOIXANTE DIX (C)
18				T	C		TRENTE CENT (I)
19	C	U				(27)	CENT TROIS (C)
20	C	T					CENT QUARANTE (C)
21	C	P					CENT SEIZE (C)
22				C	C		CENT CENT (I)
2nd-order							
23	U = QUATRE	T = VINGT	P				QUATRE VINGT ONZE (C)
24	U = QUATRE	T = VINGT	T = DIX				QUATRE VINGT DIX (C)
25				T U	T		CINQUANTE QUATRE VINGT (I)
26				T U	C		TRENTE HUIT CENT (I)
27				C U	C		CENT CINQ CENT (I)

Some systematic deviations from correct responses can be predicted on the basis of the decision-making model. First, rules and subrules can be ignored or inverted; second, when there is a main rule like Rule 6: «UC» is correct, with an exception subrule (7: «U = UN C» is not legal), the main rule could be overgeneralized (main rule applied, subrule ignored: every «UC» sequence is considered well-formed); third, the main rule and the exception subrule could be reversed («UN CENT» indicated as correct whereas any «UC» pair with U ≠ UN must be rejected): fourth, the exception subrule could be generalized to become the rule (any «UC» pair rejected). Before discussing such systematic deviations from normal processing, we will consider the way each individual rule and subrule was observed or not.

The preservation rates shown in Table 2 were computed as follows. Let a rejection rule or subrule be, for instance, Subrule 7. The subrule was examplified in 3 items of the battery: «UN CENT», «UN CENT SEPT», and «UN CENT DOUZE». Seventeen out of the 35 patients correctly indicated the first item as being illegal. The two other items being three words long, the decision process may involve not only Subrule 7 but also the 1st-order Rule 19 for «CU» in the substring «CENT SEPT» and Rule 21 for «CP» in «CENT DOUZE». Since the two were acceptance rules, rejection of these two latter items could result from errors on the acceptance rules (19 and 21) as well as from correct use of Subrule 7. Consequently, we cannot conclude the preservation or violation of Subrule 7 in these two items from rejections. On the contrary, acceptances that occurred 10 times on each of the two items necessarily implied the violation of Subrule 7. The preservation rate was thus computed in reference to 55 instances (35 + 10 + 10) and was (17 + 0 + 0)/55 = .30. While such scoring is quite conservative, it does ensure the correctness of the inferences.

The results indicate very high and homogeneous preservation rates for the acceptance rules and subrules, from .99 to .90 in the case of 1st-order rules and subrules and a little lower for the two 2nd-order subrules: .85 and .79. The distribution was essentially non-homogeneous in the case of rejection rules, some being preserved (Rules 22, 10, 9, and 8 were obeyed in more than 75% of the cases), while others were reserved: Rule 4 was violated in the proportion of 3 times out of 4. In some cases,

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[a] For Walloon see appendix 2.

[b] Consult the indicated subrule number for exceptions to the rule stated on this line of the Table. Subrule numbers indicated between parentheses refer to higher order subrules.

[c] U, P, T for Units, Particulars and Tens names, respectively; C for «Cent» (hundred).

Tab. 2 — Preservations rates of 1st- and 2nd-order rules/subrules

rule type	rule number[a]	number of items in the battery	number of instances[b]	rule obeyed (%)[c]
rule without exceptions				
accept	20	31	743	.99
	21	8	168	.90
reject	22	1	35	.82
	10	1	35	.80
	9	2	70	.78
	8	1	35	.77
	3	2	45	.64
	18	1	35	.60
	2	5	114	.35
main rule, with exceptions				
accept	6	30	808	.97
	11	32	867	.97
	19	23	451	.96
reject	16	6	168	.52
	14	5	128	.51
	4	10	179	.25
subrule, 1st order				
accept	17	6	151	.98
	5	7	183	.97
	15	5	144	.95
reject	13	2	50	.44
	7	3	55	.30
subrule, 2nd order				
accept	24	1	35	.85
	23	3	92	.79
reject	27	8	161	.72
	25	4	140	.62
	26	10	192	.45

[a] As defined in Table 1.
[b] Population: 35 subjects.
[c] Percentages in reference to total indicated in the preceding column.

like Subrule 5 and Rule 6, the scores were random. Thus, these results indicate that the general tendency already found toward more false recognitions than misses was not an undifferentiated effect among the set of acceptance/rejection rules/subrules but was due to the violation of some specific kinds of rules and subrules. As shown in Table 2, rejection rules (except Rule 2) were better preserved when they had no exception subrules than when they had an acceptance subrule. The 0-order Rule 1 examplified on 5 different items was obeyed only 25 times out of 59 cases (frequency: .42). Finally, the three items dealing with «ET» (and) were generally considered as legal numerals, as decision correct for «CINQUANTE ET UN» (51) (frequency: .80), thus indicating an overgeneralization both of the use of this arithmetical operator (.60 false recognitions of «CINQUANTE ET TROIS») and of Rule 11 relative to Subrule 12 (.80 false recognitions of «QUARANTE UN»). Altogether, the results support the hypothesis of patterns of dissolution affecting specifically some components of the normal decision-making process. Consequently, it should be the case that some degenerated models might fit the subjects' responses. Before investigating this issue by trying to approximate each patient's judgments by computer simulation of modified grammars we shall consider the general tendencies governing the relations between the main rules and their subrules.

Given a 1st-order main rule and its 1st-order exception subrule, we tried to assess the preservation/impairment of this hierarchical structure by analyzing the concomitant performances with both elements of the pair. The four possibilities are indicated in Table 3: (i) main rule and exception subrule both preserved; (ii) main rule overgeneralized and applied without exception (subrule ignored); (iii) exception subrule overgeneralized to become the rule applied in all cases (main rule ignored); (iv) main rule and exception subrule reversed thus yielding misses of correct numeral sequences together with false recognition of illegal sequences. The same conservative procedure already described to compute preservation/violation rates of isolated rules/subrules was used to establish the distribution of the subjects' productions according to the four possible cases. The items examplifying the main rule and its exception subrule were scored first for each individual subject. The scores were then summed up for the 35 subjets. Finally, the results were expressed as frequency values in each of the four cases (the correct decisions and the three kinds of modification of the rule/subrule structure).

Tab. 3 — Concomitant preservations, reversions, and overgeneralizations of 1st-order main rules and their exception subrules

main rule[a]	exception[a] subrule	both preserved	main rule over-generalized	exception subrule over-generalized	main and exception reversed
6 A[b]	7 R[b]	.32	.65	.01	.02
4 R	5 A	.23	.00	.75	.02
14 R	15 A	.53	.02	.43	.02
16 R	17 A	.51	.01	.48	.00

[a] Rule numbers defined in Table 1.
[b] A:Acceptance; R: Rejection rules/subrules.

For the four pairs of 1st-order main rule with one 1st-order exception subrule, the results given in Table 3 indicate that the vast majority of errors corresponds to an overgeneralization of acceptance over rejection (Rule 6 over Subrule 7, and Subrules 5, 17, 15 over Rules 4, 16, 14). Although the scoring procedure may have biased the results in this direction since items of more than two lexical primitives were considered only when accepted, thus emphasizing acceptance over rejection, the effect is very clear, accounting for 90% to 98% of the errors.

The set of acceptance/rejection rules of Table 1 was then organized into an algorithm for computer simulation of the decision process. The productions of each individual subject were compared to those of the program that is to say to normal judgments. A percentage index was computed to assess the goodness-of-fit between the two. This index is simply the number of instances where the subject's responses and the program's judgments (accept or reject the numeral element string) were the same divided by the total number of items in the battery (132 judgments). The goodness-of-fit index varied for the 35 subjects from .47 to .96 with the mean at .75. By modifying the rules and subrules of the normal grammar so as to best approximate each particular subject's responses, the values of the goodness-of-fit indexes of subjects and their new grammars rose to .68 and .97 with .84 as the mean. The number of rules/subrules to be changed varied from 1 to 15 per subject, with the mean at 6.5. Since most of the rules/subrules were of the 1st-order and since most of the lexical primitive sequences of the test battery had more than two elements, the grammaticality judgments often implied two different rules/subrules, and thus any change in a given rule/subrule may have an effect on the judgment of the sequences, depending on the state

of the other rules/subrules involved in the same items. Such an approach to the analysis of each subject's decision-making process supplements the preceding conservative method used to assess preservation or impairment of each of the rules/subrules and of their hierarchical structures. As already indicated, the first method of analysis concerned only those subjects' judgments where information on the state of the rules/subrules could be inferred without any ambiguity. The new approach, however, covers all the subjects' judgments, but the inferences might be biased by the distribution of co-occurrences of rules/subrules in the items of the test battery.

The grammars of some of the subjects will be discussed in detail below in reference to the nature of the linguistic disorders displayed by these aphasic patients. Irrespective of the differences in the analytical methods, the results of the computer simulations paralleled and expanded those of Tables 2 and 3. First-order rules without exceptions (and particularly acceptance rules) were better preserved than those with exceptions. In the set of 1st-order rules without exceptions, the violations ranged from one case (out of the 35 subjects) for the acceptance Rule 20 to 14 cases for the rejection Rule 18. Conversely, violations of main rules with exception subrules ranged from 13 cases (Main Rule 14) to 15 cases (Main Rules 6 and 16). As regards the modifications of the structure of 1st-order main rules and their 1st-order exception subrules, 9 subjects overgeneralized the acceptance Main Rule 6 (Subrule 7 ignored); 3 subjects did the reverse (Main Rule 6 ignored and Subrule 7 overgeneralized); and 3 subjects inverted the hierarchical structure (the acceptance Main Rule 6 changed into rejection whereas the rejection Subrule 7 was changed into acceptance). The rejection Main Rules 4, 14, and 16 were overgeneralized only once each, while their corresponding acceptance Subrules 5, 15, and 17 were overgeneralized in the remaining errors (14, 12 and 14 instances, respectively). These results thus demonstrate the general tendency to generalize acceptance over rejection in the rule/subrule structure, even when acceptance is less frequent than rejection in the normal system, i.e., even in the cases where the main rule is of the rejection type. The 0-order Rule 1 was reversed by 7 subjects who did not consider the occurrence of «ZERO» (0) as a sufficient condition to detect illegal numerals. The rejection Subrule 13 was ignored by 13 subjects, who generalized the acceptance Main Rule 11 and thus had false recognitions of strings of two lexical primitives like «DIX TROIS» instead of the corresponding one-word string (the particular «TREIZE» (13) in this case). The rules governing the usage of the arithmetical

operator «ET» (and) were preserved in 11 subjects' grammars; in 18 cases «ET» was accepted whatever the unit name that followed; the reverse occurred 5 times («ET» rejected in all unit name contexts) and, finally, the main and exception rules were inverted once («ET UN» rejected, «ET TROIS» accepted). The three 2nd-order rejection subrules (25, 26, 27) were ignored in 8, 5, and 3 grammars, respectively, the corresponding pairs of 1st-order acceptance rules being obeyed.

The models of the decision-making process evidenced by computer simulation merit comment particulary in the case of the three subjects Ba, Ve, and Fr, who were mentioned in Section I above. Ba seemed to perform the task at random whereas Fr's judgments were nearly perfect on well-formed numerals but erroneous on illegal strings half on the time; conversely, Ve had more misses than false recognitions. The goodness-of-fit index of subject Ba was .51 in function of normal judgments. Changing into acceptance the 0-order rejections Rule 1, the 1st-order rejection rules/subrules (except Subrule 7 and Rules 18 and 22), and the 2nd-order rejection Subrule 25, and changing into rejection the acceptance Main Rule 6, yielded a goodness-of-fit index of .89. Anticipating the issues concerning the possible relation between some of the formal characteristics of the modifications of the grammars of the subjects as they emerged from our particular task and some dimensions of their linguistic disorders to be discussed in Section III below, we note here that Subject Ba was one of the agrammatic patients involved in our previous studies (Deloche & Seron, 1982b; Seron & Deloche, 1983). Ba's performances on both transcoding tasks were highly sensitive to the syntactical role of «CENT» (hundred). When it was a multiplicand, «CENT» was often omitted, as in «1,602» (MILLE SIX CENT DEUX) → «MILLE SIX DEUX» or «320» (TROIS CENT VINGT) → «TROIS VINGT», whereas no such omission occurred on items like «127» (CENT VINGT-SEPT) or «130» (CENT TRENTE), where «CENT» plays only a lexical role. The same dissociation was observed in the reverse transcoding task: whereas «CENT» was correctly transcribed by digit «1» when lexical as in «*CENT* VINGT» (*1*20), errors apeared when it was a multiplicand, as in «TROIS *CENT* VINGT» (320) → «3*1*20». Such differential abilities in the processing of «CENT» according to its lexical (preserved)/syntactical (impaired) role in the structure of the numeral element string seem to parallel the findings of Andreeswsky & Seron (1975) who reported on the selective skills of an agrammatic patient in reading aloud sentences with the ambiguous homograph «car» (bus/because) depending on its grammatical class

(noun (preserved)/conjunction (impaired). Considered in this theoretical framework, the grammaticality judgments of Ba are consistent with the previous interpretations of his performances in transcoding tasks and of an agrammatic subject's behavior in reading aloud since the occurrence of «CENT» (hundred) in numeral lexicon element strings was considered grammatical when it was the first element of the string (i.e., in lexical/additive role) but non-grammatical in any other position (i.e., in functor/multiplicand role). Calling «CENT» a «functor» in some cases in the same way that prepositions, conjunctions, and other part-of-speech classes are «functions words», is thus substantiated from a neuropsycholinguistic point of view by these findings. Another justification comes from the formal analysis of the linguistic structure of numerals (Power & Longuet-Higgins, 1978).

Patient Ve (a Broca's aphasic) had a goodness-of-fit index of .80. Modifying the set of acceptance/rejection rules in the following way yielded a model fitting her decisions with an index of .92. The arithmetical operator «ET» (and) when present in a numeral element string determined its categorization as an illegal numeral; acceptance Rules/Subrules 5, 15, 17, 23 and 24 were reversed, thus becoming rules of the rejection type. Since these five rules/subrules are precisely those that deal with the complex structures of composed tens names, this result parallels the findings of Grossman & Haberman (1982) which indicate that Broca's aphasics experienced special difficulties with grammaticality judgments in sentences when the sentential frame was complex as in passives (contrary to the six first tens names «DIX» (10),..., «SOIXANTE» (60), the three others are composed of two or three lexical primitives: 70 is «SOIXANTE-DIX» by 70 = 60 (SOIXANTE) + 10 (DIX); 80 is «QUATRE-VINGTS» by 80 = 4 (QUATRE) × 20 (VINGT); and 90 is «QUATRE-VINGT-DIX» by 90 = (4 × 20) + 10).

Patient Fr (a Wernicke's aphasic) scored high on false recognitions (.56) and had nearly no misses of well-formed numerals (.03). The best approximation (index value: .88) was found with a grammar where each acceptance rule/subrule was generalized, the corresponding rejection subrule/rule being ignored. Such behavior might tentatively be considered as parallel to the ability of Wernicke's aphasics to arrange words into syntactically well-formed but semantically incorrect sentences (Von Stockert & Bader, 1976) or to the neurolinguistic analysis of dyssyntaxia in Wernicke's aphasics who substitute for the target word an item of the same grammatical class and can thus preserve general 1st-order syntactical constraints concerning the serial ordering of grammatical classes

themselves but violate local lexical restrictions (Lecours & Rouillon, 1976).

Analysis of subjects' performances according to type of aphasia

Four groups of subjects will be considered: the Wernicke's aphasics (9), the conduction aphasics (4), Broca's aphasics without agrammatism (9), and the 2 subjects with agrammatism.

The Mann and Whitney Test for small samples failed to show any difference between the Broca's and the Wernicke's aphasics in the distribution of error percentages when judging the well-formedness of numeral element strings. The mean error frequencies were .23 (range .04-.05) and .29 (range .06-.53), respectively. The error scores varied from .09 to .25 for the conduction aphasics (mean: .13), and were .43 and .24 for the two agrammatic patients. The tendency to produce more false recognitions than misses was found in each group: the 2 agrammatics, 8 out of the 9 Broca's, 7 out of the 9 Wernicke's, and 3 out of the 4 conduction aphasics.

The relevance of a spatial factor of difficulty supposedly affecting predominantly Wernicke's aphasics with reference to Broca's aphasics (Dahmen et al., 1982) was assessed by comparing false recognition rates to the six items composed of two lexical primitives, such as «TRENTE CENT», a permutation of the elements of which is a well-formed numeral («CENT TRENTE» (130) is correct), to the scores on those 14 items where no permutation can lead to a well-formed numeral (neither «SEPT DEUX» nor «DEUX SEPT» is correct). The false recognition frequencies were .50, .41, .52, and .21 on the former and .54, .35, .38, and .27 on the latter for the agrammatics, the Broca's, the Wernicke's, and the conduction aphasics, respectively. The effect, if any, reached the .05 significance level in none of these four groups. In both item conditions, the performances of the Wernicke's aphasics differed significantly neither from those of the Broca's nor from those of the agrammatics.

In each group of subjects, the analysis of preservation rates of 1st-order rules with/without exceptions and of 1st/2nd-order subrules according to their type (acceptance/rejection) was conducted in the same conservative manner as for Table 2 above. The preservation rates were better for acceptance than for rejection in each group and under all rule/subrule conditions. The scores for acceptance rules/subrules were quite homogeneous across groups and rule/subrule types with the exception of

2nd-order subrules, which were violated significantly more frequently than any other kind of acceptance rule/subrule both by the Wernicke's and the Broca's aphasics. The scores for the rejection rules without exceptions were significantly better in the group of the conduction aphasics (.82) than in the three other groups (.48, .56, and .57 for the agrammatics, the Broca's and the Wernicke's, respectively). These three groups were significantly better in obeying 2nd-order rejection subrules than main rejection rules with exceptions. The only statistically significant difference between the Wernicke's and the Broca's aphasics was found on 2nd-order rejection subrules (preservation rates: .47 and .61, respectively; $\chi^2 = 5.18$, d.f. $= 1$; $p < .05$). The score of the agrammatics was .66, but, possibly due to the small size of the sample, the difference with the Wernicke's aphasics was not significant. Since preservation scores of 1st-order rules (acceptance and/or rejection) did not differ for these three groups, the latter result might imply that the ability of the Broca's aphasics, and, perhaps, of the agrammatics, in handling relatively long (2nd-order) range dependencies were better preserved than those of the Wernicke's aphasics. The lack of a difference between the two types of aphasics on 2nd-order acceptance subrules could be attributed to a ceiling effect (preservation rates: .82 for the Broca's and .79 for the Wernicke's aphasics).

The analysis of concomitant preservations/violations of the 4 pairs of 1st-order main rules and their exceptions (Table 3) showed a tendency to generalize acceptance (rule or subrule) over the three other possibilities. Cumulating Rule 6 and Subrules 5, 15, and 17 led to score generalization of acceptance in the four groups at .48, .59, .72, and .73 for the conduction, the Broca's, the Wernicke's, and the agrammatic aphasics, respectively. In addition to the relatively low error rate of the conduction aphasics, the highly significant difference between the Broca's and the Wernicke's aphasics' performances should be noted. Considering that the acceptance Rule (6) and the Subrules (5, 15, 17) concerned «CENT» (hundred) in the multiplicand position and composed tens names, the difference thus confirms the difficulties experienced by Broca's aphasic in handling complex syntactical structures (Grossman and Haberman, 1982).

Discussion

Given the classic reports (except Grossman & Haberman, 1982) on the preservation of syntactic knowledge in Wernicke's aphasia, the first

point to be noted here is the strikingly high error scores of these subjects when judging the grammaticality of numeral lexicon element strings. The differential analysis of the performance of the four groups of subjects together with results of the single cases reported in detail above indicate that Wernicke's aphasics typically overgeneralized 1st-order acceptance rules and subrules. Such behavior closely parallels the dys-syntaxia in Wernicke's aphasia described by Lecours and Rouillon (1976): the subjects produce sequences of words that are not well-formed sentences but, when individual words are replaced by grammatical labels indicating their part-of-speech classes, the serial ordering of labels do not violate the syntactical constraints considered at a higher formal level. The syntactical competence of Wernicke's aphasics could thus tentatively be conceptualized as some knowledge of contiguous dependencies operating on an abstract level (grammatical categories) but with impaired knowledge of particular lexical constraints. This appears clearly to be the case in our task in which most of the subrules imply for correct processing not only identification of the grammatical class of the element but also identification of the element within its class («QUATRE» for units; «VINGT» for tens, etc.). This interpretation would apply to language as well as to the special domain of the alphabetical coding system for quantities. It is consistent with the report of Grossman and Haberman (1982) that Wernicke's aphasics experienced greater difficulties than Broca's in detecting anomalies between pronouns and verbs when violations concerned number of person (intra class substitutions) and thus preserved the part-of-speech dimension, while no difference was found between the two groups of aphasics in detecting case violations, i.e., anomalies that modified the grammatical class. Confusions between two elements of the same class (first vs third person or singular vs plural) are equivalent, on an abstract level, to confusions in the position of a lexical primitive in its stack, while case violations (subject vs object for pronouns) parallel inter-stack confusions. Since identification errors bearing on the precise position within the stack but preserving the stack information were made predominantly by the Wernicke's aphasics as we observed in a previous study (Deloche & Seron, 1982b), the unitary interpretation of their so-called preserved syntactical competence seems to be supported, but on condition that exception subrules of the acceptance type should be generalized (without the latter condition, no confusion within the tens names class can account for the well-formed numeral «SOIXANTE-DIX» (70)). For the most part, the errors of the Wernicke's aphasics appear of a «semantic»

nature, in that they reflect difficulty in obeying rules or subrules that depend on precise lexical constraints existing within a particular grammatical class.

The Broca's aphasics performed relatively well in this grammaticality judgment task. Moreover, they did better than the Wernicke's aphasics in handling long-range (2nd-order) dependencies (one Broca's aphasic did better in detecting syntactical anomalies of the 2nd-order than those of the 1st-order). The performance of the two agrammatic aphasics also showed the preservation of some syntactical knowledge. The abilities of such patients to apply 2nd-order rejection subrules and their specific inabilities to accept composed tens thus suggests some recognition of the syntactical structures, as did the findings of Andreewsky and Seron (1975) with linguistic material. Although our subjects were far from performing as well as those agrammatic aphasics reported by Linebarger et al. (1983) and not as poor as the two Broca's aphasics reported by Caramazza et al. (1981), our results seem to support the interpretation of the former. Some aspects at least of syntactical structure, not restricted to simple 1st-order acceptance/rejection rules operating on contiguous elements, are preserved by the Broca's aphasics and also by the agrammatics.

Finally, the conduction aphasics showed some impairment, unlike the patient reported by Caramazza et al. (1981). It might be that our task is more sensitive to syntactical difficulties than the sentence anagram task because of the chance of pragmatic cues. An interpretation of the disorder in terms of a short-tem memory deficit is difficult to accomodate with sequences of 2 to 4 written elements.

Conclusion

In conclusion, our results have to be considered in the framework of two main interrelated areas of research in neuropsychology; first, the neurolinguistic analyses of language breakdown in aphasic condition and, second the characterization of the language component of the acalculia's syndromes.

At a neurolinguistic point of view, the difficulties experienced by Wernicke's aphasics seem to result from semantic identification impairments, whereas the categorization process of lexical primitives into their part-of-speech dimension seems to be preserved. Such an interpretation is in accordance with the report of Grossman and Haberman (1982), which indicates in Wernicke's patients similar confusions on another

linguistic material (personal pronouns). In the same direction results obtained by Broca's and agrammatic aphasics indicate the preservation of some syntactic knowledge by these patients and thus support some recent reinterpretation of that aphasic syndrome (Andreewsky & Seron, 1976; Branchereau & Nespoulous, 1986; Linebarger et al., 1983).

As acalculia syndromes are concerned, the present investigation is relevant to the studies aiming at clarifying and fractionating the classically labelled «verbal component of acalculia». Altogether, these studies point to the existence of different language-related processes involved in the acquisition, elaboration and selective disruptions of the various notational systems representing quantities as shown in a variety of tasks: number transcoding (Deloche & Seron, 1982a, b; Seron & Deloche, 1983); counting (Seron & Deloche, in press) and retrieval of arithmetical facts (Kahn, 1986; Warrington, 1982). However, the influence of specific troubles remains to be analyzed more pricisely for what concerns various verbal component processes on the patients' performances in other and less elementary mathematical tasks such as magnitude comparison (see Deloche & Seron, in preparation), calculation and problem solving.

Appendix 1

The 66 well-formed numerals and the 66 illegal numerals of the test battery are given here, classified according to number of words (2, 3 and 4), with indication of their formal lexical structure according to the categorization into units (U), particulars (P), tens (T), «cent» (C, hundred) and zero (Z).

25 well-formed two-words numerals:
T U: DIX SEPT; DIX HUIT; VINGT TROIS; VINGT QUATRE; VINGT SEPT; TRENTE CINQ; QUARANTE NEUF; SOIXANTE NEUF
T P: SOIXANTE DOUZE; SOIXANTE QUATORZE
T T: SOIXANTE DIX
C U: CENT DEUX; CENT TROIS; CENT SIX; CENT HUIT
C P: CENT ONZE; CENT SEIZE
C T: CENT TRENTE; CENT QUARANTE
U C: DEUX CENT; TROIS CENT; CINQ CENT; SIX CENT; NEUF CENT
U T: QUATRE VINGT

22 illegal two-words numerals:
T U: DIX TROIS; QUARANTE UN
T P: DIX QUINZE; QUARANTE SEIZE; VINGT ONZE
T T: SOIXANTE TRENTE; DIX SOIXANTE; VINGT DIX; QUARANTE DIX
T C: TRENTE CENT
C C: CENT CENT
U C: UN CENT
U T: QUARANTE SOIXANTE; TROIS VINGT

U P: HUIT TREIZE
U U: QUATRE DEUX; SEPT DEUX
U Z: CINQ ZERO
P U: SEIZE DEUX
P P: QUINZE DOUZE
P T: TREIZE CINQUANTE; DOUZE SOIXANTE

26 well-formed three-words numerals:
T and U: CINQUANTE ET UN
U C T: DEUX CENT TRENTE; TROIS CENT QUARANTE; SIX CENT CINQUANTE; SEPT CENT CINQUANTE
U C U: DEUX CENT SEPT; SIX CENT DEUX; SIX CENT HUIT; NEUF CENT CINQ
U C P: SIX CENT QUATORZE; HUIT CENT QUINZE; NEUF CENT SEIZE
U T U: QUATRE VINGT DEUX; QUATRE VINGT CINQ
U T T: QUATRE VINGT DIX
U T P: QUATRE VINGT ONZE; QUATRE VINGT SEIZE
C T U: CENT VINGT SIX; CENT TRENTE DEUX; CENT QUARANTE CINQ; CENT QUARANTE NEUF; CENT CINQUANTE TROIS; CENT CINQUANTE SIX
C U T: CENT QUATRE VINGT
C T T: CENT SOIXANTE DIX
T T U: SOIXANTE DIX HUIT

29 illegal three-words numerals:
T and U: CINQUANTE ET TROIS
U C U: UN CENT SEPT
U C P: UN CENT DOUZE
U T U: QUATRE DIX NEUF; SIX CINQUANTE TROIS
U T T: QUATRE VINGT CINQUANTE; QUATRE SOIXANTE DIX
U T P: SIX QUARANTE TREIZE; HUIT VINGT QUINZE
U U U: NEUF DEUX SEPT
C U C: CENT TROIS CENT; CENT CINQ CENT; CENT SEPT CENT; CENT HUIT CENT
C U P: CENT CINQ ONZE
C U U: CENT NEUF TROIS
C Z U: CENT ZERO DEUX
C T Z: CENT TRENTE ZERO
C U Z: CENT SEPT ZERO
T T U: CINQUANTE QUARANTE CINQ; SOIXANTE DIX DEUX
T U C: TRENTE CINQ CENT; TRENTE HUIT CENT; QUARANTE TROIS CENT; SOIXANTE SEPT CENT
T U T: TRENTE QUATRE VINGT; QUARANTE QUATRE VINGT; CINQUANTE QUATRE VINGT; SOIXANTE QUATRE VINGT

15 well-formed four words numerals:
C U T P: CENT QUATRE VINGT QUINZE
C U T U: CENT QUATRE VINGT CINQ
U C T U: DEUX CENT TRENTE SEPT; DEUX CENT CINQUANTE NEUF; TROIS CENT CINQUANTE HUIT; CINQ CENT TRENTE SIX; SIX

CENT CINQUANTE NEUF; SEPT CENT QUARANTE HUIT; HUIT CENT QUARANTE TROIS; NEUF CENT TRENTE CINQ
U C T P: DEUX CENT SOIXANTE TREIZE; TROIS CENT SOIXANTE QUATORZE; SEPT CENT SOIXANTE QUINZE
U C T T: DEUX CENT SOIXANTE DIX
U C U T: SIX CENT QUATRE VINGT

15 illegal four-words numerals:
C U T U: CENT TROIS SOIXANTE CINQ; CENT SIX CINQUANTE TROIS; CENT SEPT QUARANTE HUIT
C U Z U: CENT NEUF ZERO CINQ
C U U U: CENT UN NEUF QUATRE
C T U C: CENT TRENTE NEUF CENT; CENT QUARANTE SEPT CENT; CENT CINQUANTE HUIT CENT
C U C U: CENT SIX CENT DEUX
C U C T: CENT HUIT CENT TRENTE
C U C P: CENT NEUF CENT DOUZE
U C U C: HUIT CENT TROIS CENT
T U C U: TRENTE CINQ CENT NEUF
T U C T: QUARANTE SIX CENT TRENTE
T U C P: CINQUANTE SEPT CENT TREIZE

APPENDIX 2:
ACCEPTANCE AND REJECTION RULES/SUBRULES FOR THE WALLOON NUMERAL

The French and Walloon numeral systems present some interesting structural differences: in Walloon the alphabetic forms of the numbers in the 70s and 90s obey the regular one-word decade («SEPTANTE» and «NONANTE», respectively) unit name pattern, whereas in France, multiple word decade names («SOIXANTE DIX» and «QUATRE VINGT DIX», respectively) are used and can be composed with particulars. As a consequence, acceptance and rejection rules and subrules for numeral strings were much more simpler in Walloon than in French. Walloon acceptance/rejection rules/subrules are thus the subset of Table 1 obtained by deleting 1st order subrules 15 and 17, and 2nd order subrules 23 and 24.

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