

Subject-Verb Agreement in Children and Adults: Serial or Hierarchical Processing?

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Two processes, serial and hierarchical, are generally opposed to account for grammatical encoding in language production. In a developmental perspective, the question addressed here is whether the subject-verb agreement during writing is computed serially, once the words are linearly ordered in the sentence, or hierarchically, as soon as the number features are determined in a hierarchical frame. Adults and children from 3rd to 5th grades were requested to listen to sentences with built-in prepositional phrases or relative clauses and to transcribe them as quickly as possible. A serial hypothesis assumes that subject-verb agreement errors should be equally frequent with both preambles because each has the same length separating the subject head noun and the main verb. Conversely, according to a hierarchical view, errors should be more frequent with a prepositional phrase because the syntactic distance between the subject and the verb is greater than with a relative clause. The results revealed a main effect of the preamble manipulated in 5th graders and adults, but not in 3rd graders. These data were in favor of a hierarchical processing in older writers and a serial one in younger children. However, in 3rd grade, we assumed that the potential serial account was a result of the resource constraint on writing more than of a real serial processing of the agreement.

KEY WORDS: attraction errors; developmental perspective; serial or hierarchical account; subject-verb agreement.

INTRODUCTION

In the tradition of psycholinguistic literature, researchers argue that errors in speaking or in writing are a real window into the architecture of

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the production system. Indeed, the observation of errors reveals which processes are implied during language production and how these processes are in progress (Dell, 1986; Garrett, 1980). This paper investigated subject-verb agreement errors in written French. These errors provide a useful paradigm for understanding how the grammatical encoding is computed. The purpose was to determine if the management of the subject-verb agreement was serial or hierarchical. In this perspective, the agreement errors were induced in simple or complex syntactic structures comprising one or two clauses. The literature already provides a great number of empirical data in favor of a hierarchical view of agreement processing, as opposed to a serial view. However, all the available data were obtained exclusively from adults with paradigms using speaking or comprehension tasks. Here, the question about agreement processing is investigated and addressed in a new way, with a writing task performed by both children and adults.

THEORETICAL PART

In most languages, the rule to make a verb agree with its subject is very simple and can be expressed as: “If the subject of the sentence is singular, then the verb has to be singular; if the subject is plural, the verb has to be plural”. This rule ensures structural relations between lexical units. One problem that a speaker or a writer faces is that the subject and the verb to be formulated may be separated in the sentence by another noun. Both speakers and writers may therefore produce grammatical errors such as “The wall of the houses are white”. In this example, the verb is erroneously made to agree with the noun that immediately precedes the verb—the local noun (houses)—instead of with the head noun, which is the subject of the sentence (wall). Such errors are named proximity concord (Quirk & Greenbaum, 1973) or attraction errors (Zandvoort, 1961).

Serial Hypothesis

The terms “proximity” or “attraction” denote that speakers or writers are not able to maintain in memory the number of the subject noun in order to specify the number of the verb because the subject and the verb are separated by an interfering noun. This refers to what Jespersen (1924) called “the mental energy notion”. Since units in a sentence are contingent to other units and since relations are grammatically marked with inflections, some mental energy is needed to transfer features from source units to target units. During the management of subject-verb agreement, the

number and the person of the source (subject) have to be maintained in working memory and copied to the target (verb). In the case of usual “Subject-Verb-Object” sentences, the number of the subject noun can be maintained without any difficulty until the verb is produced. However, if the source is far from the target, the interfering material, especially if it is another noun, can disrupt memory for the number of the subject head noun and this disruption could increase the probability of agreement errors (see Solomon & Pearlmutter, 2004). The occurrence of errors would thus depend on the length of the interfering material.

The serial view is probably the most natural view of agreement processing. Since the human mind is characterized as having limited storage and processing capacities, the agreement would be more difficult to compute if the subject and the verb were far from each other. In the literature, there is no clear data about a serial processing of agreement. However, some investigations have shown that the availability of cognitive resources plays a significant role in the management of subject-verb agreement (Fayol & Got, 1991). For instance, the impact of working memory overload on the occurrence of agreement errors was investigated in written French (Chanquoy & Negro, 1996; Fayol & Got, 1991; Fayol, *et al.*, 1994; Negro & Chanquoy 2000a). In these works, writers were asked to listen to a sentence (1a) sometimes followed by a series of five monosyllabic words (1b), which represented the secondary task that loaded the working memory:

- (1a) *Les perles de la bague brille* (The pearls of the ring sparkle)⁶
(1b) *pou, roux, doux, sou, cou* (louse, red, soft, cent, neck)

The results showed that errors significantly increased when unrelated words were added to the sentence-recall task. The authors’ interpretation was that the automation of subject-verb agreement resulted in making the verb agree with the immediately preceding noun rather than with the subject noun. When the subject noun and the verb are separated by another noun that mismatches in number with the subject head noun, errors may occur: the writers automatically make the verb agree with the immediately preceding noun instead of with the head subject noun. In order to guarantee a correct agreement, the authors assumed that a checking procedure (or a control process), highly resource-consuming, would need to be activated before graphic transcription (Fayol & Got, 1991; Hupet *et al.*, 1996). Consequently, a secondary task, such as a recall of words, would consume so many cognitive resources that the checking mechanism would fail and agreement errors in the sentence would appear.

⁶ This sentence is literally translated from French.

This explanation of agreement errors does not really provide evidence for a serial processing of agreement, but shows that some “mental energy” is used to make a verb correctly agree with its subject, which supports the serial hypothesis. Related to the models of language production, the serial account supposes that morphemes are added once the words have been ordered in the sentence. The agreement would take place within a syntactic structure, which is considered to be a linear chain of words. This hypothesis refers to a serial organization of language production (Bock & Cutting, 1992; Bock & Miller, 1991). The production of oral or written language is typically divided into three processes during which (1) the ideas are selected from long term memory and organized (conceptual process or planning); (2) the ideas are translated into words (linguistic process or formulation); and (3) the message is orally or graphically produced (execution, see, for writing, Hayes, 1996; Kellogg, 1996). According to the serial hypothesis, the specification of noun and verb number features appears during the linguistic process, once the words have been linearly ordered within the sentences. The verb inflection is determined by copying the features from the source (subject) to the target (verb). In this account, the number of the subject has to be maintained in working memory until the verb occurs. This explains that the number of the subject can be forgotten and erroneous verb inflection can appear as soon as the linear distance between the source and the target increases. The serial hypothesis is the most intuitive and natural prediction that explains grammatical errors in number. This hypothesis addresses the main concern of production models—the role of working memory in complex cognitive tasks such as writing (Kellogg, 1996). The serial hypothesis assumes that the limited capacity of storage or of processing disrupts the management of subject-verb agreement. However, most of the experimental investigations currently argue against this hypothesis and give another explanation for the occurrence of regular agreement errors when the main verb of the sentence is preceded by two nouns mismatching in number.

Hierarchical Hypothesis

The serial hypothesis is an interesting natural explanation, which may be supported by the functioning of working memory during agreement processing. However, this hypothesis does not account for some experimental findings. For example, Bock and Miller (1991) found that the number of errors did not systematically vary with the length of the interfering material. In one of their experiments, speakers were provided with a short (3a) or a long (3b) noun phrase such as:

(3a) The key to the cabinets. . .

(3b) The key to the ornate Victorian cabinets. . .

The participants were asked to exactly repeat each preamble and to complete it in a grammatically-correct sentence. The results showed that writers made as many errors with short as with long phrases. Since there was no effect of the linear distance separating the subject and the verb, the serial hypothesis, which assumes that the subject must be held until the main verb occurs, could not account for these results. The authors thus suggested that the occurrence of agreement errors depends not on the linear distance—which puts burden on working memory—but on the syntactic construction in which the subject and the verb are embedded. This refers to the hierarchical hypothesis, which supposes that the lexical units composing a sentence are processed in clauses before being linearly ordered (Bock & Cutting, 1992; Bock & Miller, 1991; Bock *et al.*, 2001). Errors would be as frequent in (3a) as in (3b), because, in these two noun phrases, the subject and the local nouns belong to the same clause. In this way, the number interference between the head noun and the local noun is as frequent with short as with long preambles.

To support the hierarchical hypothesis, Bock and Cutting (1992) compared the occurrences of agreement errors when the interfering material was either a prepositional phrase (4a) or a relative clause (4b):

- (4a) The editor of the history books...
- (4b) The editor who rejected the books...

As before, the participants' task was to orally recall the preamble and to complete it as quickly as possible in a correct sentence. In this context, speakers produced more agreement errors when the verb was separated from the subject noun by a prepositional phrase than by a relative clause. The authors then formulated a "clause packaging hypothesis", which supposed that the presence of a clause-boundary partially insulated the information of one clause from the information of the other clause. They assumed and demonstrated with their findings that cross-clause errors were less frequent than intra-clause errors. The fact that agreement is clause-bounded easily accounts for fewer errors with a prepositional phrase than with a relative clause. In the first case (4a), there is a possible interference between the number of the subject and the local noun whereas in the second sentence (4b), the clause-boundary serves as a "protection" for the subject noun from a number interference of the local noun.

In this light, the syntactic frame in which the source and the target are embedded is more crucial than the linear distance between them. The syntactic complexity has a larger effect on the agreement processing than does the linear distance (Kaan, 2002). In most models of production, grammatical encoding is assumed to occur at functional and

positional levels (Bock & Levelt, 1994; Garrett, 1980, 1982; Levelt, 1989). The functional level involves, first, assigning grammatical functions (noun, verb, ...) and features to the lexical units (such as number, person, gender, ...). Second, the syntactic relations between the lexical units (subject, object, ...) are specified to create clauses and then the agreement between units is computed (i.e., "number marking": Bock *et al.*, 2001). The lexical units embedded in hierarchical frames bear the same inflectional features (Bock, 1989). At the positional level, the order of the units in the sentence is fixed, the clauses are assembled and specific morphemes are added to the lexical units as a function of the features (gender, number, ...) determined at the functional level. At the positional level, lexical units carrying features as subject and verb have to be arranged so that the units have, for instance, the same features of number (Vigliocco *et al.*, 1996). Agreement errors may occur at the functional level, if a noun mismatching in number with the subject contaminates the subject noun phrase. In this case, the number of the verb differs from the number of the noun phrase. Thus, the noun phrase and the verb phrase have to be reconciled in order to share the same number (i.e., "number morphing": Bock *et al.*, 2001; Bock, Eberhard & Cutting, 2004). The grammatical encoding implies that building hierarchical frames for a sentence is a different process from that of ordering words even if these two processes are highly related (Vigliocco & Nicol, 1998). Assuming that grammatical encoding is divided into two different processing levels accounts for less number interference of when units belong to two different clauses, because the agreement is supposed to be clause-bounded (Bock & Cutting, 1992). In sum, errors tend to occur in simple syntactic structures comprising only one clause and particularly when the nouns preceding the verb mismatch in number. This was attested in a great number of experimental studies realized with expert and/or adult speakers or writers. However, in children, the distribution of errors seems to be different.

Subject-Verb Agreement Errors: Developmental Results

The hypothesis of hierarchical organization and the pattern of subject-verb agreement errors described below have already been supported by evidence in adults. One fundamental finding in written French (for example: Fayol *et al.*, 1994; Hupet *et al.*, 1996) as in spoken English studies (see Vigliocco & Nicol, 1998; Vigliocco *et al.*, 1996) was that adults made more agreement errors when the subject and the local nouns mismatched in number, and particularly when the subject noun was singular and the local noun was plural. In addition, this asymmetry between the noun number marking was also attested in comprehension tasks (Nicol *et al.*,

1997; Pearlmutter, 2000). The researchers accounted for this asymmetry by arguing that singular nouns are unmarked with respect to the number while plural nouns are marked by the addition of a specific inflection (“-s”). As a result, a singular subject, marked by default, would be more vulnerable to contamination by a plural local noun, which is specifically marked with the number (Bock & Eberhard, 1993; Bock, Eberhard & Cutting 2004; Eberhard, 1997; Nicol *et al.*, 1997). Conversely, agreement errors with a plural subject and a singular local noun would be rarer since the subject noun would be explicitly number-marked.

In spite of these tendencies, the rare cross-sectional studies on subject-verb agreement errors have suggested that beginner writers manage the agreement encoding in a different way (Fayol *et al.*, 1999; Fayol *et al.*, 1993; Negro & Chanquoy, 2000b). The experimental data led researchers to distinguish four successive levels. During the 1st grade, agreement errors mainly result from the non-mastery of rules. Children make agreement errors which only correspond to an ignorance of the appropriate grammatical rules. From the 2nd grade, the grammatical rules are mastered, but they are not automatically applied in spontaneous productions: the knowledge is still declarative before being procedural (Anderson, 1983; Anderson & Fincham, 1994). In other words, beginner writers are not able to write a production and correctly make the verbs agree with their subjects because the computation of the agreement is too resource-consuming (Fayol *et al.*, 1999). They make the verb agree in the singular form by default because they write as they hear, and they rarely add specific verb inflections. The agreements are thus correct when the subject is singular and erroneous when it is plural. From the 3rd grade, the grammatical rule responsible for subject-verb agreement is correctly applied in simple sentences. However, when the subject noun phrase comprises two nouns, subject-verb agreement errors occur as soon as the subject and/or local noun is plural. Finally, from the 5th or 6th grade, children are able to make a verb agree with its subject in Subject-Verb-Object frames, but make errors when the noun phrase comprises an interfering plural local noun mismatching in number with the singular subject. Thus, children’s performances in these grades are close to adults’ ones. These observations suggest that the 5th/6th grade constitutes a transition period for the implementation of grammatical processing.

Since the patterns of results from younger writers differ from those of 5th graders or adults, we may assume that the specific errors made from 2nd to 5th grade express a difference in the management of subject-verb agreement. In other words, as agreement errors in expert writers or speakers are interpreted according to a hierarchical account, novices’ errors are probably due to a different computation of the agreement. Whilst their writing

processes are still unautomated, children have to adopt different strategies. For example, Bereiter and Scardamalia (1987) suggested that beginner writers use a "knowledge telling strategy", which implies a translation of ideas into words while they are retrieved. According to this view, young writers or speakers are not able to create hierarchical arrangements, that is to elaborate superordinate or co-ordinate links that relate the items with each other (Bock, 1987). Likewise, we may assume that the production of language in children follows a serial more than a hierarchical organization. Each idea is translated into words, which are put one after the other in order to produce a sentence. In this view, the number of the source unit would have to be held in working memory until the target unit occurs in the sentence. This would explain why the subject-verb agreement is particularly highly resource-consuming in younger writers (Fayol *et al.*, 1999).

To test the relevance of the change from a serial processing of grammatical encoding in beginner writers to a hierarchical one from 5th graders to adults, we investigated the frequency of agreement errors in writing, within sentences in which the interfering material was either a prepositional phrase or a relative clause (as in Bock & Cutting, 1992). This experiment, comparing performance in relative vs. prepositional sentences, was first carried out in speaking with Anglo-Saxon adults. We replicated this study while adapting it to test the written performance of French-speaking participants, such that they were required to recall and write down orally presented sentences. Even with a French writing paradigm, it will be possible to compare our results with findings from spoken English for two reasons. First, according to models of language production, there is no reason to suppose deep differences between processes underlying speech or writing. The same processing levels are assumed in both media (see for example the similarities between the models from Levelt, 1989 for oral and Kellogg, 1996 for writing). Second, the main findings on subject-verb agreement errors obtained in oral English were replicated in written French. In both paradigms, adults make more agreement errors when the two nouns of a complex noun phrase mismatch in number, and particularly when the subject is singular and the local noun is plural (see Vigiocco & Nicol, 1998 regarding oral language and Fayol *et al.*, 1994 regarding written language).

HYPOTHESES

The following two hypotheses were tested.

- (1) The processing of the agreement is supposed to be different as a function of the participants' expertise, since the pattern of errors change from one grade level to another (see *supra*). In younger writers, lexical units are assumed to be serially processed. Agreement

errors should be as frequent with a complex noun phrase as with a relative clause since the linear distance separating the subject and the verb is the same. Conversely, adults, as well as 5th grade writers whose performance is close to that of experts (Fayol *et al.*, 1999), should make more agreement errors with a complex noun phrase than with a relative clause. Indeed, the hierarchical account predicts that the number information would interfere in the noun phrase whereas the number of the subject and the verb would be “protected” when the intervening material is embedded in another clause such as a relative clause: the information of one clause should not interfere with the information of another clause (Bock & Cutting, 1992).

- (2) An interaction between the number of the nouns and the level of writing expertise was expected. As demonstrated in previous experiments, 3rd graders should be inclined to make agreement errors as soon as the subject noun phrase comprises a plural noun (Fayol *et al.*, 1999; Negro & Chanquoy, 2000b). In the 5th grade, agreement errors with a plural subject should decrease (i.e., plural-plural and plural-singular condition), while those with a singular subject and a plural local noun (i.e., SP) should increase. Finally, adults should make more agreement errors when the subject and the local nouns mismatch in number, particularly when the subject is singular and the local noun is plural (SP condition; see Bock & Eberhard, 1993; Eberhard, 1997). This pattern of errors should occur especially with prepositional phrases if the hierarchical hypothesis is attested.

METHOD

Participants

Twenty nine 3rd graders (mean age: 8.7, ranging from 8.3 to 9.1), twenty six 5th graders (mean age: 10.8 y.o., ranging from 10.3 to 11.2) from a primary school in Martinique and 23 university students from the University of Antilles-Guyane (mean age: 27.5, ranging from 21.2 to 42.8) volunteered to take part in this experiment. All were native French speakers.

Material

Thirty two experimental and 16 filler sentences were built (see Appendix A). In experimental sentences, the subject noun and the verb were separated either by a prepositional phrase or a relative clause as follows:

- Prepositional phrase: “Noun 1 + Prepositional phrase (of + Adjective + Noun 2) + Verb.”
Example: “*Le gamin des jeunes voisins parle*” (The kid of the young neighbors speaks).⁷
- Relative clause: “Noun 1 + Relative Clause (who + Verb + Noun 2) + main Verb.”
Example: “*Le singe qui imite les oursons grimpe*” (The monkey who imitates the bears climbs).

The prepositional phrase was as long as the relative clause (about 7–9 syllables) in order to control the linear distance separating the subject and the main verb of the sentence. Noun 1 was always the subject of the verb and Noun 2 (the local noun) was consistently the complement of Noun 1. The noun phrase was constructed in such a way that both nouns bore plausible relations to the verb. To determine the plausibility of nouns with verbs, 10 participants, different from those of the experiment, were asked to evaluate the plausibility of 40 triplets (for example: *singe—ourson—grimper* (monkey—bear—to climb)) on a three-point scale (from 0: both nouns are non-plausible to 3: both nouns are plausible). The sentences were elaborated with triplets for which the mean score was at least 2.5.

Noun 1 and Noun 2 matched (Singular–Singular (SS), Plural–Plural (PP)) or mismatched in number (Singular–Plural (SP), Plural–Singular (PS)). All the verbs were conjugated with the present tense and chosen in such a way that the third singular (e.g., *il chante* (he sings)) and the third plural persons (e.g., *ils chantent* (they sing)) did not differ phonologically.

The filler sentences were designed to provide writers with sentences comprising different syntactic frames in order to avoid the detection of regularity of the experimental sentences. These fillers were in either singular or plural form:

- Singular: *Le pianiste étonne les spectateurs* (The pianist amazes the audience)
- Plural: *Dans la mer, les plongeurs découvrent des poissons* (In the sea, the divers discover some fishes).

Each participant had a booklet in which to transcribe the orally presented sentences. The pages of the booklet were numbered (from 1 to 48).

⁷ The sentences are literally translated from French even if they are not necessarily correct in English language.

Procedure

Before the beginning of the experiment, the experimental and filler sentences as well as three training sentences were recorded by the same female voice. The participants of each grade level were divided into small groups in order to randomize the order in which the sentences were presented. The experimenter played a single sentence and paused the audiotape at the end. This cued the participants to transcribe the sentence on one page of the booklet as quickly as possible. Then, the writers were required to turn the page immediately after the transcription. Neither revision nor corrections were allowed. In order to account for the great number of sentences to be transcribed, a two-session experiment was organized for 3rd and 5th graders. The recall task was supposed to simulate the conditions of spontaneous production during which writers store words in a phonological buffer and transcribe them one by one.

Orthographic Knowledge

The experimental session was followed by an orthographic task designed to evaluate whether the writers knew or were ignorant of the subject-verb agreement rule. For this test, all the experimental sentences were written on one sheet of paper with the verb to be completed (i.e., "*Le bébé des jeunes voisins parl...*"). The participants were requested to correctly make the verb agree for each sentence. The writers from each grade who failed this task were discarded from the data analyses.

Scoring and Data Analyses

The responses of each participant in each experimental condition were assigned to one of the following categories: (1) correct responses, which were scored when the words of the sentence were completely recalled with a correctly inflected verb form; (2) agreement errors, in which the recall met the criteria above but the verb did not agree with the subject; (3) number transcription errors, in which the number of the subject or the local noun was modified; (4) other transcription errors, in which the writer failed to correctly transcribe a part of the sentence.

The analyses of variance were only carried out with the mean proportion of agreement errors. The proportion referred to the number of errors divided by the number of acceptable sentences. An acceptable sentence was defined as one in which all the units were correctly recalled and with correct morphological marks on the nouns. Non-acceptable sentences corresponded to sentences with recall and/or number transcription

(categories (3) and (4) above). The computation of error proportions takes into account the number of transcription errors since making two agreement errors among four sentences recalled is different from making two errors among two sentences completely recalled.

A 3 (participants' grade level : 3rd, 5th and university students) \times 2 (type of the interfering material : prepositional phrase or relative clause) \times 2 (match or mismatch condition) \times 2 (number of the local noun : singular or plural) analysis of variance was carried out with repeated measures on the last three factors. Then, an analysis for each participant's grade level was computed with a 2 (type of the interfering material) \times 2 (conditions) \times 2 (number of the local noun) factors, with repeated measures. Both ANOVAs were carried out with participants (*F1*) and with sentences (*F2*) as random factors.

RESULTS

The application of the scoring criteria and the participants' results for the orthographic test led to the elimination of some participants in each grade level. The results of 20 writers in each level were thus analyzed below. The scoring criteria yielded 1519 correct responses (394 in 3rd grade, 539 in 5th grade and 586 in adults), 365 agreement errors (284 in 3rd grade, 85 in 5th grade and 46 in adults), 20 errors in recalling the number marking of nouns (9 in 3rd grade, 6 in 5th grade and 5 in adults), and 17 errors in recalling words (6 in 3rd grade, 7 in 5th grade and 4 in adults) among the 1920 sentences collected (see Table I).

Table I. Proportions of Agreement Errors, Global Number of Erroneous Agreement (between brackets) and Standard Deviations (in italics) according to the Experimental Conditions

	Prepositional Phrase				Relative Clause			
	SS	PP	PS	SP	SS	PP	PS	SP
3rd Grade	0 (0)	0.52 (41)	0.70 (54)	0.28 (21)	0 (0)	0.70 (55)	0.65 (52)	0.14 (11)
	<i>0</i>	<i>0.33</i>	<i>0.35</i>	<i>0.21</i>	<i>0</i>	<i>0.31</i>	<i>0.3</i>	<i>0.22</i>
5th Grade	0 (0)	0.13 (10)	0.19 (15)	0.37 (29)	0 (0)	0.17 (12)	0.19 (14)	0.06 (5)
	<i>0</i>	<i>0.16</i>	<i>0.21</i>	<i>0.22</i>	<i>0</i>	<i>0.25</i>	<i>0.21</i>	<i>0.14</i>
Adults	0 (0)	0 (0)	0.1 (8)	0.32 (24)	0 (0)	0 (0)	0.08 (6)	0.1 (8)
	<i>0</i>	<i>0</i>	<i>0.15</i>	<i>0.3</i>	<i>0</i>	<i>0</i>	<i>0.18</i>	<i>0.19</i>

General Analysis

As shown in Table I, the proportion of agreement errors varied with the participants' level, the number of the nouns and the type of the interfering material. Furthermore, the last two factors seemed to interact with participants' level. These descriptive results were attested by the analyses of variance.

There was a significant effect of the participants' level ($F(2, 57) = 71.85$, $p < 0.001$; $F(2, 48) = 89.59$, $p < 0.001$). The proportion of agreement errors was significantly higher in 3rd graders than in 5th graders (respectively, 0.37 vs. 0.14; $F(1, 57) = 79.27$, $p < 0.001$; $MSe = 0.06$; $F(2, 24) = 77.58$, $p < 0.001$; $MSe = 0.01$) and in 5th graders than in adults (0.07; $F(1, 57) = 6.24$, $p < 0.05$; $MSe = 0.06$; $F(2, 24) = 15.84$, $p < 0.001$, $MSe = 0.01$). The effect of the interfering material was also significant with the participants as a random factor ($F(1, 57) = 8.63$, $p < 0.005$; $F(2, 24) = 1.36$, $p = 0.26$): the writers made more errors with a prepositional phrase (0.22) than a relative clause (0.17). Agreement errors were more frequent in the mismatch (0.27) than in the match conditions (0.13; $F(1, 57) = 74.52$, $p < 0.001$; $F(2, 24) = 13.60$, $p < 0.005$). Finally, agreement errors increased with a plural local noun (0.23) compared to a singular one (0.16; $F(1, 57) = 22.79$, $p < 0.001$; $F(2, 24) = 3.72$, $p = 0.06$).

There were several significant interactions. As most of them involved the participants' level, ANOVAs with repeated measures were carried out for each grade level.

3rd graders

There was no significant effect of the type of the interfering material: prepositional phrases (0.37) led to as many errors as relative clauses (0.37; $F(1, 19) < 1$; $F(2, 24) < 1$). 3rd graders made more errors in the mismatch (0.44) than in the match conditions (0.30; $F(1, 19) = 19.04$, $p < 0.001$; $F(2, 24) = 6.10$, $p < 0.05$). The proportion of errors was higher with a plural (0.41) than a singular local noun (0.34; $F(1, 19) = 9.26$, $p < 0.01$; $F(2, 24) = 1.40$, $p = 0.25$).

The conditions significantly interacted with the number of the local noun ($F(1, 19) = 49.84$, $p < 0.001$; $F(2, 24) = 91.15$, $p < 0.001$; see Fig. 1).

Figure 1 showed that the number of agreement errors significantly increased as soon as a noun was plural in the noun phrase (PP = 0.61; PS = 0.68; SP = 0.21) compared to the SS condition (0; $F(1, 19) = 194.79$, $p < 0.001$; $MSe = 0.04$; $F(2, 24) = 58.09$, $p < 0.001$, $MSe = 0.03$). Furthermore, 3rd graders made significantly more errors when the subject

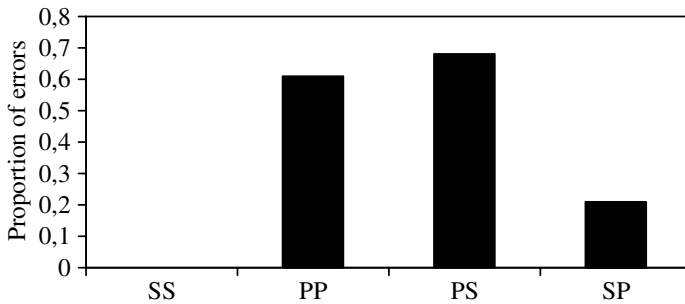


Fig. 1. Interaction between the conditions and the number of the local noun in 3rd grade.

noun was plural (PP and PS) than when the subject noun was singular in the SP condition ($F1(1, 19) = 22.07, p < 0.001, MSe = 0.22$; $F2(1, 24) = 39.73, p < 0.001, MSe = 0.03$) and more errors in the PS than in the SP condition ($F1(1, 19) = 26.21, p < 0.001, MSe = 0.17$; $F2(1, 24) = 34.96, p < 0.001, MSe = 0.03$).

These two factors (condition and number of the local noun) interacted with the nature of the interfering material ($F1(1, 19) = 4.73, p < 0.05$; $F2(1, 24) = 1.37, p = 0.25$; see Fig. 2).

The distribution of errors differed between prepositional phrases and relative clauses as a function of the number of the nouns preceding the verb. In the SP condition, agreement errors were significantly more frequent with a prepositional phrase (0.28) than with a relative clause but only with participants as a random factor (0.14 ; $F1(1, 19) = 7.85, p < 0.01$; $MSe = 0.03$; $F2(1, 24) = 1.33, p = 0.26$; $MSe = 0.03$). Conversely, the difference between the interfering material was not significant in the SS, PP and the PS conditions.

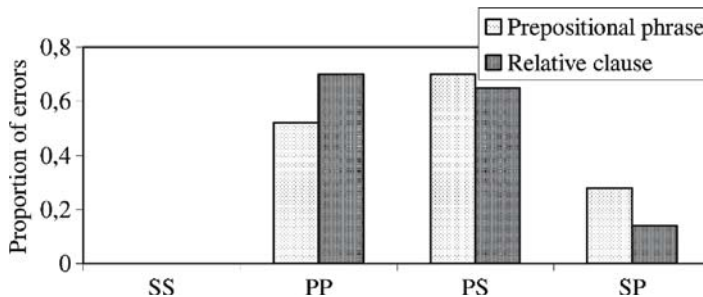


Fig. 2. Interaction between the nouns number and the interfering material in 3rd grade.

5th Graders

The proportion of agreement errors was higher with a prepositional phrase (0.17) than with a relative clause with participants as a random factor (0.11; $F1(1, 19) = 6.85$, $p < 0.05$; $F2(1, 24) = 2.12$, $p = 0.16$). 5th graders made more errors in the mismatch (0.20) than in the match conditions (0.08; $F1(1, 19) = 19.79$, $p < 0.001$; $F2(1, 24) = 6.91$, $p < 0.05$). Errors were more frequent with a plural local noun (0.18) than with a singular one (0.10; $F1(1, 19) = 9.81$, $p < 0.01$; $F2(1, 24) = 3.33$, $p < 0.09$).

There was a significant interaction between the type of material, the match/mismatch condition and the number of the local noun, with participants as a random factor ($F1(1, 19) = 19.61$, $p < 0.001$; $F2(1, 24) = 3.17$, $p = 0.08$; see Fig. 3).

No agreement error was observed in the SS condition regardless of the nature of the intervening material. There was a significant difference between prepositional phrases (0.37) and relative clauses (0.06) in the SP condition ($F1(1, 19) = 40.65$, $p < 0.001$; $MSe = 0.02$; $F2(1, 24) = 10.48$, $p < 0.05$; $MSe = 0.02$) whereas the difference was not significant in the PP (0.13 and 0.17) and the PS conditions (0.19 and 0.20). Moreover, 5th Graders made more errors with a prepositional phrase in the SP condition than in the PP and the PS conditions ($F1(1, 19) = 9.27$, $p < 0.05$; $MSe = 0.06$; $F2(1, 24) = 7.24$, $p < 0.06$; $MSe = 0.02$) whereas this comparison was not significant with a relative clause ($F1(1, 19) = 5.32$, NS; $MSe = 0.04$; $F2(1, 24) = 1.52$, NS; $MSe = 0.02$).

University Students

There was a main effect of the interfering material ($F1(1, 19) = 6.81$, $p < 0.05$; $F2(1, 24) = 4.69$, $p < 0.05$). Adults made more errors with a prepositional phrase (0.11) than with a relative clause (0.04). There were only agreement errors in the mismatch condition (0.15 vs. match condition = 0;

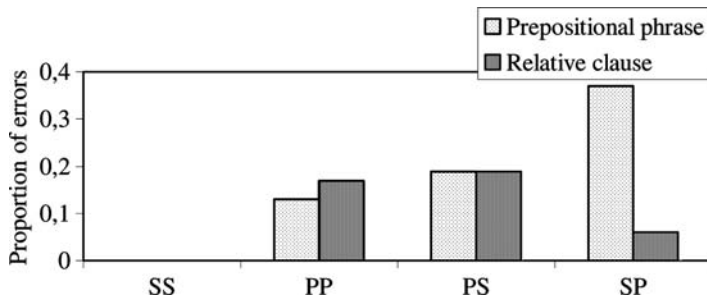


Fig. 3. Interaction between the nouns number and the interfering material in 5th graders.

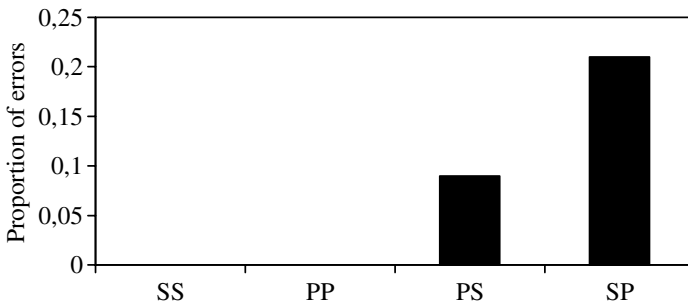


Fig. 4. Interaction between the conditions and the number of the local noun in university students.

$F1(1, 19) = 45.81, p < 0.001; F2(1, 24) = 28.70, p < 0.001$). The frequency of errors increased when the local noun was plural (0.11) compared to singular (0.04; $F1(1, 19) = 4.80, p < 0.05; F2(1, 24) = 4.78, p < 0.05$).

The match/mismatch condition interacted with the number of the local noun ($F1(1, 19) = 4.80, p < 0.05; F2(1, 24) = 4.78, p < 0.05$; see Fig. 4).

Figure 4 revealed that University students (1) made errors only in the mismatch conditions and (2) made significantly more agreement errors in the SP than in the PS condition ($F1(1, 19) = 4.80, p < 0.05; MSe = 0.06; F2(1, 24) = 9.56, p < 0.01; MSe = 0.006$).

The type of the interfering material significantly interacted with the condition and the number of the local noun, with participants as a random factor ($F1(1, 19) = 5.18, p < 0.05; F2(1, 24) = 3.07, p = 0.09$; see Fig. 5).

The comparison between the prepositional phrase (0.32) and the relative clause (0.10) was only significant in the SP condition ($F1(1, 19) = 8.45,$

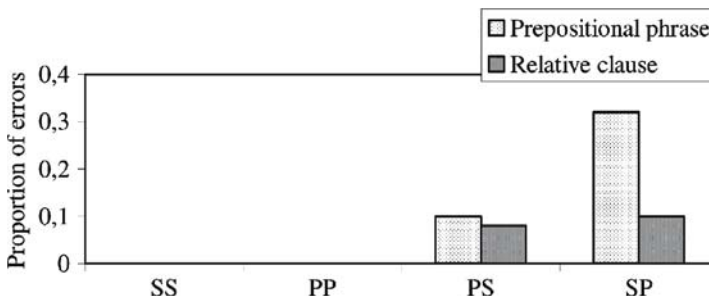


Fig. 5. Interaction between the nouns number and the interfering material in university students.

$p < 0.05$; $MSe = 0.06$; $F2(1, 24) = 15.35$, $p < 0.01$; $MSe = 0.006$). In the PS condition, there was no significant difference between the prepositional phrase (0.10) and the relative clause (0.08; $F_s < 1$). Furthermore, the opposition between the SP and the PS conditions was significant with a prepositional phrase ($F1(1, 19) = 8.12$, $p < 0.05$; $MSe = 0.06$; $F2(1, 24) = 15.52$, $p < 0.01$; $MSe = 0.006$) while no such difference in error frequencies appeared with a relative clause ($F_s < 1$).

DISCUSSION

This experiment was designed to assess the management of grammatical encoding in a developmental perspective. Two parallel hypotheses are assumed in the literature. The serial hypothesis supposes that the main problem that speakers and writers face is the linear distance separating the subject and the verb because the number of the source (subject) would need to be maintained in working memory until the target (verb) occurs. The agreement accuracy depends on the length of the interfering material: the frequency of errors increases when the subject is far from the verb. Conversely, according to the hierarchical hypothesis, the agreement depends on the nature of syntactic frames in which the subject and the verb are embedded. The agreement between units would be made within the same clause. Likewise, there would be no possible feature interference between units belonging to different clauses: clause boundaries would insulate the information of one clause from that of another. This hierarchical view supposes that writers make more errors when a sentence is built with prepositional phrases, in which the lexical units belong to the same clause, than when the sentence contains a main clause and a relative clause.

These hypotheses were tested by analyzing the mean proportion of agreement errors in 3rd and 5th graders as well as in university students.

We first hypothesized that young writers would manage the agreement serially whereas 5th graders and adults would be able to hierarchically organize and syntactically process words within clauses before ordering them. The results are very clear and are consistent with this hypothesis. In the 3rd grade, there was no effect of the interfering materials, whereas 5th graders and adults made more errors with a prepositional phrase than with a relative clause.

These findings seem to provide evidence for a serial management of agreement by younger writers. According to the serial hypothesis, the agreement is computed once the words are linearly ordered in the sentence. The 3rd graders were not able to super-ordinate the lexical units

within a hierarchical structure (see Bereiter & Scardamalia, 1987). This view accounts for the lack of impact of the syntactic structure on the frequency of errors in our experiment, since the prepositional phrase and the relative clause had the same length. However, the serial processing in beginner writers could be a result of their management of the writing task. Indeed, the writing task is particularly resource-consuming, due to the cognitive cost of low-level processes (such as translating ideas into words, spelling, graphic transcription), which are not yet automated at this level. Bereiter and Scardamalia (1987) suggested that young and/or beginner writers use a knowledge-telling strategy, which implies a direct translation of retrieved ideas into words. This strategy may allow beginner writers to carry out a production task despite the limited capacity of storage and processing and the cognitive cost of low-level processes (see Alamargot & Chanquoy, 2001; Bourdin & Fayol, 2000, 2002). In this view, the costly management of different writing processes accounts for the fact that the frequency of errors was equivalent with both prepositional phrases and relative clauses. Consequently, the observed data may not reveal a linguistic account of processing the subject-verb agreement (i.e., a serial account) but rather a means to adapt limited resources to cognitive constraints of writing.

In contrast to the youngest writers, 5th graders and adults seem to process lexical units hierarchically since they made more errors with prepositional phrases than with relative clauses. This suggests that intra-clause errors are more common than cross-clause ones. Bock and Miller's (1991) and Bock and Cutting's (1992) findings in spoken English with adults are replicated here in written French. The agreement is clause-bounded: the information of the relative clause does not interfere with the information of the main clause. As a result, these data suggest that agreement is computed at the functional level in which units are built in clauses prior to the positional level in which words are linearly ordered (Bock, *et al.*, 2001; Vigliocco & Nicol, 1998).

The second hypothesis relative to the effect of the nouns' number was also confirmed. In the 3rd grade, the interaction between the match/mismatch condition and the number of the local noun revealed that agreement errors increased as soon as the interfering material comprised a plural noun regardless of its syntactic function (subject or local noun). As previously demonstrated, younger writers make frequent agreement errors in the PP and the PS conditions, and they do not use the verb plural marking, probably because the verb number has no conceptual sense for them (Fayol *et al.*, 1999; Fayol, *et al.*, 1993; Negro & Chanquoy, 2000b). Furthermore, in this grade, proximity errors in the SP condition begin to appear but always less frequently than in the PS condition. In 5th graders

and adults, the interaction between the condition and the number of the local noun revealed that agreement errors significantly increased when the nouns mismatched in number, and particularly with a singular subject noun and a plural local noun (i.e., in the SP condition).

However, a more interesting result was that which concerned the interaction between the type of the interfering material, the match/mismatch conditions and the number of the local noun. Errors in the SP condition were notably more frequent when the interfering material was a prepositional phrase than when it was a relative clause, regardless of age group. Moreover, in 5th graders and adults, attraction errors with a prepositional phrase were more frequent in the SP condition than in the PS conditions whereas this opposition was not significant with a relative clause. In other words, the number feature of the local noun interfered with the number feature of the subject noun particularly in a prepositional phrase, when the subject and the local noun were grammatically specified within the same clause. In this case, the number of the local noun contaminated the number of the noun phrase and this false number was erroneously transmitted to the verb (Vigliocco & Nicol, 1998). Furthermore, the interference was most common when the local noun was plural due to the asymmetry of the number marking (Bock & Eberhard, 1993; Eberhard, 1997). Conversely, when the modifier was a relative clause, there were as many errors in the match as in the mismatch condition and in the SP as in the PS condition because the “clausal packaging partially insulated the information in one clause from the information in another” (Bock & Cutting, 1992, p. 104).

As underlined by Bock and Cutting, the clause structure serves as a protection for the subject noun from the interference of the local noun, but only partially so. They reported that expert writers made a substantial number of errors with relative clauses. Likewise, without challenging the clausal organization of language production, a more general hypothesis was recently proposed to account for subject-verb agreement (Franck *et al.*, 2002; Hartsuiker *et al.*, 2001). These authors assumed that rather than by a “clausal packaging”, agreement errors are determined by the syntactic distance between the local noun and the subject noun in a syntactic tree (such as shown by examples in Fig. 6a, b). The number of phrase nodes between the subject noun and the local noun seems to be particularly relevant to account for subject-verb agreement errors. In theories of language production, the grammatical encoding is successively functionally and positionally processed (Bock & Levelt, 1994; Garrett, 1980, 1982; Levelt, 1989). At the functional level, units are syntactically organized and their features are specified. Then, the positional process consists of ordering the units in a sentence and reconciling the features of the subject and

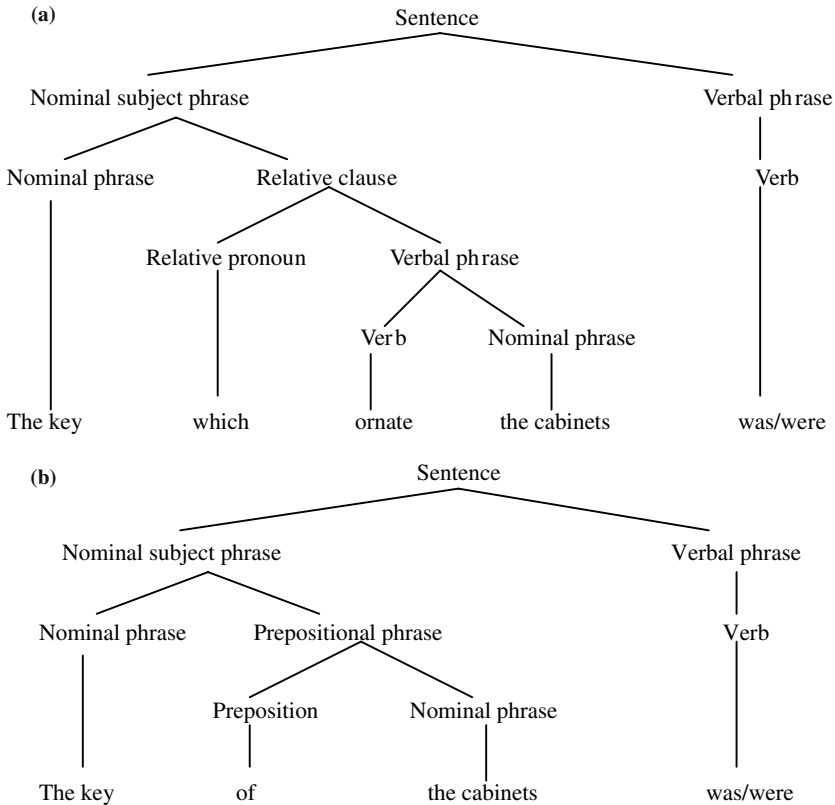


Fig. 6. (a) Syntactic tree for intervening material such as a relative clause: the syntactic path from the local noun to the nominal subject phrase is long (from Hartsuiker *et al.*, 2001). (b) Syntactic tree for intervening material such as a prepositional phrase: the syntactic path from the local noun to the nominal subject phrase is short (from Hartsuiker *et al.*, 2001).

the verb. The positional level is conceived as a syntactic tree in which the smaller units are the phrases. In this architecture, the syntactic path from the local noun to the highest node of the subject noun phrase is longer in a relative clause (6a) than in a prepositional phrase (6b).

This theoretical framework accounts for the increase in agreement errors in a clause structure such as one in which the subject noun is syntactically closer to the mismatching noun. Franck *et al.*, (2002) found that in a completion task of a preamble of three nouns (“The computer with the program of the experiment. . .”) the interference between the number of the subject noun and the number of the mismatching noun was higher when the two nouns mismatch-

ing in number were syntactically close (“The computer with the programs of the experiment. . .”) rather than distant (“The computer with the program of the experiments. . .”). Therefore, the clause boundaries are not sufficient to account for agreement errors, and the crucial factor seems to be the syntactic distance between the two nouns (Bock, Eberhard & Cutting, 2004). However, researchers recently suggested that agreement was not only a syntactic process depending on a hierarchical computation but the system of production may use all the available information for the agreement process (e.g. semantic information: Haskell & McDonald, 2003; Thornton & McDonald, 2003). In this way, Solomon and Pearlmutter (2004) showed that occurrence of agreement errors varied among different prepositional phrases depending on the semantic integration of the nouns.

In sum, the units are number-specified at the functional level and perhaps earlier during the message (Vigliocco & Franck, 2001). Then, the number of the source and the target are arranged in a hierarchical structure in order to share the same features. Finally, units are ordered and morphologically marked. It is during the hierarchical frame that the highest local noun in the syntactic tree may interfere with the correct number of the subject noun phrase. There is a feature migration which implies a number unification with the verb number. Since the verb has been already specified in number, a migration of the local noun number to the noun phrase node in the tree requires a revision of the number of the verb and a unification of the noun phrase number with the verb phrase number. The sentence produced respects the syntactic rules of language production since the noun phrase has the same number as the verb phrase even when this number could be incorrect because of feature migration.

The originality of this paper lay in its capacity to provide a developmental view of the subject-verb agreement processing in writing, whereas previous data in the literature could only be generalized to adults and speaking production. Our data suggest that the management of grammatical encoding differs between younger and older writers. Third graders made as many agreement errors with a prepositional phrase as with a relative clause, when the two modifiers had the same length. Conversely, 5th graders and adults made more errors with a prepositional phrase than with a relative clause because of the difference of the syntactic distance. The data are in favor of a serial construction of sentences in younger writers and a hierarchical computation from the 5th grade. In this context, the 4th grade may appear to be a transitional step between the use of serial and hierarchical processing. Nevertheless, it was assumed that the younger writers’ results would not reveal a mechanism of computation different from those used by experts, but that they would be a consequence of the management of resource-consuming processes involved in writing. In other words, younger writers may

build hierarchical frames which are disrupted by the cognitive cost of the writing management. This hypothesis is reinforced by the fact that younger writers made more attraction errors in the SP condition with a prepositional phrase than with a relative clause. This result leads us to hypothesise that experts and beginner writers use the same type of processing—a hierarchical one—to manage the subject-verb agreement. Even though several researchers demonstrated that patterns of subject-verb agreement errors differed according to the writer's expertise, the models of oral (Bock, 1987, 1989; Garrett, 1980; Levelt, 1989) and written production (Hayes & Flower, 1980; Kellogg, 1996) do not suggest that children process sentences differently from experts. In this context, a new investigation consisting of a production task that limits the consummation of cognitive resources—such that the process of graphic transcription is not implied—should reveal a hierarchical processing of the subject-verb agreement even in the 3rd grade. Finally, we underlined, as previous authors have assumed, that attraction errors do not depend on clause insulation, but rather on the syntactic distance of a noun mismatching in number with the subject.

APPENDIX A

Experimental Sentences

*Prepositional Phrases*⁸

- SS: - *Le moteur du gros camion brûle*
(The engine of the big truck burns)
- *Le genou du fameux chasseur tremble*
(The knee of the famous hunter trembles)
- *La poupée de la petite fille marche*
(The doll of the young girl walks)
- *La plume de la douce colombe vole*
(The feather of the smooth dove flies)
- PP: - *Les crayons des petits garçons tombent*
(The pens of the young boys fall)
- *Les tiroirs des vieux bureaux craquent*
(The drawers of the old desks creak)
- *Les mamans des bons élèves chantent*
(The mothers of the good students sing)
- *Les chansons des grands-parents bercent*
(The songs of the grandparents rock)

⁸ The sentences are literally translated from French.

- SP: - *Le bébé des jeunes voisins parle*
(The baby of the young neighbors talks)
- *Le visage des fiers gamins change*
(The face of the proud kids changes)
- *La porte des modestes cabanes grince*
(The door of the modest huts creaks)
- *La famille des fidèles copines campe*
(The family of the faithful friends camps)
- PS: - *Les cochons du célèbre fermier mangent*
(The pigs of the famous farmer eat)
- *Les neveux du nouveau gardien fument*
(The nephews of the new guard smoke)
- *Les feuilles de la fragile plante bougent*
(The leaves of the delicate plant move)
- *Les blessures de la brave sportive saignent*
(The wounds of the brave sportswoman bleed)

Relative Phrases

- SS: - *Le tonnerre qui inquiète le chien gronde*
(The thunder which worries the dog rumbles)
- *Le chanteur qui porte l'enfant rentre*
(The singer who carries the child comes back in)
- *La gamine qui mange la crêpe saute*
(The kid who eats the pancake jumps)
- *La médaille qui orne la couronne brille*
(The medal which trims with the circlet sparkles)
- PP: - *Les arbitres qui guident les joueurs soufflent*
(The referees who guide the players blow)
- *Les enfants qui aident les danseurs louchent*
(The children who help the dancers squint)
- *Les ficelles qui nouent les branches cassent*
(The strings which tie the branches break)
- *Les minutes qui forment les journées passent*
(The minutes which form the days pass)
- SP: - *Le singe qui imite les oursons grimpe*
(The monkey who imitates the bears cub climbs)
- *La fermière qui soigne les enfants pleure*
(The farmer's wife who looks after the children cries)
- *Le client qui compte les passants flâne*
(The customer who counts the passersby strolls)
- *La barque qui pousse les bouées flotte*
(The small boat which pushes the buoys floats)

- PS: - *Les pêcheurs qui tirent le poisson nagent*
(The fishermen who pull the fish swim)
- *Les gardiens qui logent le soldat ronflent*
(The guards who billet the soldier snore)
- *Les artistes qui saluent la foule dansent*
(The artists who greet the crowd dance)
- *Les rubans qui décorent la voiture bougent*
(The ribbons which decorate the car move)

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