

Orthographic influences on agreement: A case for modality-specific form effects on grammatical encoding

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We report two experiments that assessed the role of orthography in constraining subject-verb agreement in written (Experiment 1) and spoken (Experiment 2) French. We contrasted a condition in which the singular and plural forms of the subject head nouns were homophones but *non-homographs* (e.g., *chanson*, song-S, vs. *chansons*, songs-P) with a condition in which the subject head nouns were homophones and *homographs* in their singular and plural forms (e.g., *refus*, refusal-S,P). An effect of the orthographic marking was found in written production but not in oral production. The results, together with our previous findings, suggest modality-specific feedback effects during grammatical encoding: orthographic

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representations influence written production but morpho-phonological representations influence oral production.

Psycholinguistic studies of syntactic production have focused on speech. Whether these processes are the same in writing as in speaking, i.e., whether grammatical encoding is constrained by the same factors in the two modalities, remains an open question. In this paper, we attempt to shed light on this question by studying experimentally how the syntactic operation of subject-verb agreement is realised in writing and speaking.

Two specific questions guide our work. First, do form-level representations influence syntactic operations? Previous work has shown that morpho-phonological factors do influence agreement processes in speech (Franck, Collina, & Vigliocco, 1999; Vigliocco, Anton-Mendez, Franck, & Collina, 1999; Vigliocco, Franck, Anton-Mendez, & Collina, 2002a), but do orthographic factors influence agreement during writing in a similar way? The first experiment addressed this question. Second, if orthographic representations influence written agreement, do these influences extend to the oral modality and play a role in spoken agreement? This is addressed in Experiment 2.

The most influential framework for spoken sentence production was first put forward by Garrett (1982), Dell (1986), and more recently Levelt (1989), Bock (1995) and others. On this approach, speech planning proceeds in three main stages: conceptualisation (the stage in which the to-be-verbalised message is coded in a non-linguistic format), formulation, and articulation. It is commonly assumed that formulation proceeds in two separate, successive stages (Bock & Levelt, 1994; Garrett, 1980). During a first stage, called *grammatical encoding*, semantic and syntactic (e.g., number and gender) properties of words are retrieved, constituting lemma selection. It is only at the subsequent stage of *morpho-phonological encoding* that form properties of words are retrieved (e.g., the final -s of a plural noun in French), constituting lexeme activation. Encoding at this latter stage is called morpho-phonological because it concerns processes that involve phonological (i.e., the final -s on plural nouns) and morphological (the -s reflects a syntactic feature) units.

A fundamental issue concerns the *direction* of information flow between stages (Vigliocco & Hartsuiker, 2002b). In a modular framework (Garrett, 1980; Levelt, Roelofs, & Meyer, 1999), information flows from the top to the bottom in only one direction. As a consequence, a syntactic operation like subject-verb agreement between a source word (i.e., the subject) and a target word (i.e., the verb) is assumed to be guided by the lexico-syntactic features of the subject lemma, but not by its phonological properties at the lexeme level. By contrast, in a non-modular interactive approach (Dell,

1986; Harley, 1993; Vigliocco & Hartsuiker, in press), similar components to the ones identified above are involved in sentence production, but their workings are characterised by a bi-directional flow of information between the higher and lower levels. Features from the source at the lemma and lexeme levels interact such that they both play a role in the syntactic operation of agreement; that is, morpho-phonological influences would be expected on agreement.

In order to investigate morpho-phonological influences on syntax, a series of studies has been conducted in different languages using agreement as a key tool. Unlike early null results in English (Bock & Eberhard, 1993), a number of more recent studies have found that morpho-phonological factors do affect agreement in speech. In a study of pronoun agreement in Dutch, Meyer and Bock (1998) found an effect of morpho-phonological gender marking on the antecedent when the pronoun and the antecedent were part of the same sentence (Meyer & Bock, 1998, Experiment 2). Additional studies (Hartsuiker, Antón-Méndez, & Van Zee, 2001; Hartsuiker, Schriefers, Bock, & Kikstra, 1999) also found effects of morpho-phonological transparency of case and number marking on agreement in spoken Dutch and German.

Data on Romance languages have produced the clearest evidence in support of form influences on agreement in speech. Vigliocco, Butterworth, and Semenza (1995) first reported that Italian speakers produce more subject-verb number agreement errors when the subject is unmarked morpho-phonologically. Similar results were reported in Italian and French for gender agreement between a subject and a predicative adjective (Franck et al., 1999) as well as in Spanish (Vigliocco et al., 1999, 2002a). In Italian and Spanish, most feminine nouns end in *-a*, whereas most masculine nouns end in *-o* (with some exceptions as well as the unmarked ending *-e*). The suffix-gender association is less regular in French, although some endings like *-ation* are more strongly correlated to feminine, others, like *-ment* to masculine, and some, like *-ique*, to both genders. We reported, in the three languages, that speakers produced fewer agreement errors when the head noun's suffix was a good predictor of its gender. Furthermore, we found that French speakers produced fewer agreement errors when the determiner preceding the head noun was marked for gender (as is the case when the article precedes a word starting with a consonant: *le*, the-M vs. *la*, the-F) than when it was unmarked (as is the case when the article *le* or *la* precedes a word starting with a vowel: it is elided, i.e., turned into *l'*, which is used both before feminine and masculine nouns) (Franck et al., 1999). Finally, we found that Spanish speakers made more agreement errors when a feminine subject noun was preceded by the definite determiner *el*, which is the standard masculine determiner (it is required before nouns starting with a vowel), or when the

noun's suffix was a misleading predictor of its gender (Vigliocco et al., 1999, 2002a).

At first glance, these observations appear incompatible with a view of sentence production in which each processing stage is only influenced by the information that immediately precedes it. Rather, morpho-phonological information appears to influence the realisation of a syntactic operation like agreement.¹ This raises the question as to whether similar form constraints apply to written production, i.e., do orthographic properties of the subject influence written agreement?

French is well-suited to investigate orthographic influences on subject-verb number agreement. Only about 30 nouns (less than 1%) are marked for number in spoken French (Dubois, 1965). By contrast, most nouns show an orthographic variation of number, plurality being expressed by adding an -s to the singular form (e.g., *table/tables*, table-S/tables-P), or occasionally an -x (e.g., *neveu/neveux*, nephew-S/nephews-P). An interesting small group of nouns shows no orthographic variation of number in the spoken and written formats. These are nouns whose singular form already ends in -s or -x (e.g., *secours*, rescue/s-S,P or *prix*, price/s-S,P).

Note that the presence of the plural grapheme on the singular form of these nouns is a purely orthographic (formal) marker which does not render them syntactically nor notionally plural. The syntactic number of such nouns is marked on the determiner that precedes them (e.g., *le-S secours* vs. *les-P secours*). These nouns, which have homographic singular and plural forms, contrast with nouns like *ciseaux* (scissors) which are orthographically and syntactically plural, although they are notionally singular (they refer to a single object).

Although the nouns with homographic number forms are quite rare (about 3%, Brulex database; Content, Mousty, & Radeau, 1990), their average frequency is equal or even slightly higher (2350 per 100 million) than the average frequency of regularly marked nouns (1555 per 100 million).

In the first experiment, we compared the occurrence of written verb agreement errors when subjects were orthographically marked for number, i.e., singular and plural forms were homophonic but non-homographic (e.g., *chanson-S/chansons-P*, for song/songs), to when subjects were orthographically unmarked, i.e., singular and plural forms were homophonic and homographic (e.g., *refus-S,P* for refusal). The aim of this experiment was to test the impact of orthographic marking on the written syntactic process of subject-verb agreement. If the agreement procedure

¹ Note that these results may also be reconciled with modular approaches with the introduction of a monitor, an issue we note in the General Discussion.

involved in writing is influenced by form-level information, in a similar way to the morpho-phonological influences reported in spoken production (Franck et al., 1999; Vigliocco et al., 1999, 2002a), writers should commit more agreement errors when head nouns are orthographically unmarked for number.

EXPERIMENT 1: WRITTEN PRODUCTION

Method

Participants. Thirty-two native French students attending the University of Geneva took part in Experiment 1 and received credits for participating.

Materials and design. Sixty-four experimental sentences containing a subject phrase and a verb phrase were constructed. The subject phrase consisted of a head noun (N1) and a so-called “local noun” (N2) (Bock & Miller, 1991) embedded in a prepositional phrase attached to the head. Previous work has shown that the presence of a local noun that mismatches in number or gender with the head noun considerably increases the proportion of agreement errors (Bock & Eberhard, 1993; Bock & Miller, 1991; Hupet, Fayol, & Schelstraete, 1998; Vigliocco & Franck, 1999, 2001). We exploited this phenomenon in order to maximise our observations of agreement errors.

The variables manipulated were: (1) the number of N1 (singular vs. plural), (2) the number of N2 (singular vs. plural), and (3) the orthographic marking of number on N1 (homographs vs. non-homographs). For each item, four different versions were created (SS, SP, PS, PP, with S and P representing the number of N1 and N2). The average frequency of head nouns in the homograph condition was the same as in the non-homograph condition (Brulex database; Content et al., 1990). All local nouns had non-homographic singular and plural forms. Verbs bore no number mark in the oral format and were intransitive. Note that number was always marked phonologically on the determiner that preceded the noun. Examples of sentences are illustrated in Table 1. The materials can be found in the Appendix.

Twenty filler sentences containing verbs that were phonologically marked for number and that introduced some new syntactic structures (relative clauses, double prepositional phrases) as well as animate head nouns were included in the materials. Four 84-item lists were created with the 64 experimental and 20 filler sentences arranged randomly.

Procedure. Participants were tested in groups of between 10 and 15. They were required to transcribe sentences presented orally into a

TABLE 1
Different versions of two items in Experiment 1

	<i>Non-homographs</i>	<i>Homographs</i>
SS	Le carrelage du corridor brille The-S pavement-S of the-S corridor-S shines	Le croquis du bâtiment traîne The-S sketch-Ø of the-S building-S lies around
SP	Le carrelage des corridors brille The-S pavement-S of the-P corridors-P	Le croquis des bâtiments traîne The-S sketch-Ø of the-P buildings-P
PS	Les carrelages du corridor brillent The-P pavements-P of the-S corridor-S	Les croquis du bâtiments traînent The-P sketches-Ø of the-S building-S
PP	Les carrelages des corridors brillent The-P pavements-P of the-P corridors-P	Les croquis des bâtiments traînent The-P sketches-Ø of the-P buildings-P

Note: S corresponds to singular and P to plural. The first letter refers to the head noun whereas the second letter refers to the local noun. The plural on the verb (-nt) is not audible.

notepad. They were asked to write as fast as possible and were not allowed to correct any errors. After the 10 first sentences, they turned the page of the notepad and took a 5-minute break before transcribing the next 10 sentences, and so on until the 84 sentences were copied. Breaks were introduced every 10 sentences in order to allow participants to relax their hand. A testing session lasted about one hour.

Scoring. The scoring categories were: (1) *Correct responses* in which participants correctly wrote all parts of the sentence they heard. (2) *Number agreement errors* in which participants correctly wrote the sentential subject but wrote a verb form that failed to agree in number with the subject head noun.² (3) *Orthographic errors* in which participants failed to correctly write the subject head noun. The great majority of these orthographic errors consisted in omitting the final “s” on singular nouns with homographic singular and plural orthography (e.g., *le croqui* was written instead of *le croquis*). (4) *Miscellaneous errors* in which participants miswrote any other part of the sentence (e.g., missing NP, change of NP or verb, no response at all).

Data analysis. Statistical tests were carried out using the frequency of agreement, orthographic, and miscellaneous errors as dependent measures. Balanced ANOVAs were run both with participants (F_1) and items (F_2) as random factors, with the number of N1 and N2 as within-participant and within-item factors, and the orthography of N1 as a within-participant but between-item factor.

² Note that no agreement errors were produced between the determiners and the nouns.

Results

We obtained 97 (4.7%) subject-verb agreement errors, 65 (3.2%) orthographic errors and 38 (1.9%) miscellaneous errors. The distribution of errors is illustrated in Table 2.

Number agreement errors. Agreement errors were more common for homograph head nouns (59) than for non-homograph heads (38) [$F_1(1, 31) = 8.86, p < .001; F_2(1, 62) = 4.87, p < .05$]. Singular head nouns yielded more errors than plural head nouns [$F_1(1, 31) = 19.31, p < .001; F_2(1, 62) = 30.56, p < .001$] whereas plural local nouns yielded more errors than singular local nouns [$F_1(1, 31) = 8.74, p < .005; F_2(1, 62) = 13.83, p < .001$]. We found a significant interaction between the number of the head and the number of the local noun [$F_1(1, 31) = 56.43, p < .001; F_2(1, 62) = 25.55, p < .001$].

Orthographic errors. Most of these errors occurred in the homograph condition [$F_1(1, 31) = 39.86, p < .001; F_2(1, 62) = 24.58, p < .001$], mostly on the singular head nouns of this condition as shown by the interaction between homography and the head noun’s number [$F_1(1, 31) = 24.84, p < .001; F_2(1, 62) = 15.32, p < .001$]. They consisted in omitting the final “s”.

Miscellaneous errors. There were no significant effects ($F_s < 2$).

Discussion

The main result of this experiment is that French writers made more subject-verb agreement errors when the head was orthographically unmarked for number. These results parallel past reports of morpho-phonological influences on subject-verb agreement in the spoken modality:

TABLE 2
Distribution of errors in Experiment 1 (written production)

	<i>Agreement errors</i>		<i>Orthographic errors</i>		<i>Miscellaneous errors</i>	
	<i>Non-homographs</i>	<i>Homographs</i>	<i>Non-homographs</i>	<i>Homographs</i>	<i>Non-homographs</i>	<i>Homographs</i>
SS	3 (0.15)	6 (0.29)	0	25 (1.22)	3 (0.15)	5 (0.24)
SP	25 (1.22)	30 (1.46)	3 (0.15)	27 (1.32)	6 (0.29)	3 (0.15)
PS	6 (0.29)	14 (0.68)	1 (0.05)	5 (0.24)	6 (0.29)	5 (0.24)
PP	4 (0.20)	9 (0.44)	0	4 (0.20)	2 (0.10)	8 (0.39)
Total	38 (1.86)	59 (2.87)	4 (0.20)	61 (2.98)	17 (0.83)	21 (1.02)

Note: Percentages are in parenthesis.

speakers make use of morpho-phonological information to mark syntactic relationships, whereas writers make use of orthographic information.

Second, our results replicate the traditional “mismatch effect”: participants made more errors when the number of the head noun was different from the number of the local noun (SP and PS conditions) than when these two numbers were the same (SS and PP conditions). Furthermore, errors were more common in the presence of a singular head followed by a plural local noun (SP) than when a plural head was followed by a singular local noun (PS), a pattern that has often been reported (Bock & Eberhard, 1993; Bock & Miller, 1991; Fayol, Largy, & Lemaire, 1994; Hupet et al., 1998; Vigliocco et al., 1995). The common explanation for this finding is that the singular verb form is the processor’s default value, which is normally blocked by a plural head but which can also be blocked occasionally by the presence of a plural local noun (Bock & Eberhard, 1993).

Interestingly, writers had difficulties with the orthography of nouns in the homograph condition whose singular form ends with a typical plural ending like -s or -x (3.2% errors). Most of these errors consisted in omitting the final -s or -x on the singular head nouns. It might be argued that this spelling difficulty contributed to the agreement errors, in which case the orthographic effect we report on agreement would not reflect any mechanism related to agreement per se. However, such an interpretation does not fit with the data for two reasons. First, only one agreement error was produced in combination with an orthographic error. In other words, the difficulty of retrieving the correct orthography of the head noun does not predict the occurrence of agreement errors. Second, the independence of agreement and orthographic errors is demonstrated by the absence of a significant correlation between the two across subjects ($r = -.209$, $p > .10$).

EXPERIMENT 2: SPOKEN PRODUCTION

Although the influence of orthographic representation of syntactic processing in speech has not received any attention to date, experimental research has investigated the relationship between orthographic and phonological codes in various single word processing tasks, which may be of interest here. Growing evidence has emerged in favour of interactive processing between orthographic and phonological systems, even under conditions in which there is no functional requirement to consider both orthographic and phonological knowledge. For example, in the case of spoken word processing, Seidenberg and Tannenhaus (1979) found that yes/no rhyme decisions to spoken words were more difficult when their orthographic bodies (the written representation of the rhyme) were

dissimilar (rye/lie) compared with when they were the same (e.g., tie/lie). Another example comes from Ziegler and Ferrand (1998) who found that words with phonological rimes that could be spelled in multiple ways (e.g., /- ip/ → “-eep” or “-eep” produced longer auditory lexical decision latencies and more errors than did words with rhymes that could be spelled only one way (e.g., /uk/ → “-uck”), again suggesting that orthography affects the perception of spoken words. But perhaps most strikingly, illiterate speakers have difficulty performing various metaphonological tasks despite normal comprehension and production in the verbal domain, again suggesting an important contribution of orthographic processes on tasks that would normally be considered phonological. The reverse pattern of phonology affecting single word orthographic processing (and orthographic structure) has also been demonstrated in numerous situations (Bowers & Michita, 1998; Pexman, Lupker, & Jared, 2001; Treiman, Mullennix, Bijeljacabic, & Richmondwely, 1995).

Taken together, these findings support the conclusion that orthographic and phonological representations are often co-activated in the lexicon, with behavioural consequences. Given that the agreement process is influenced by formal properties of the words (i.e., orthographic properties in writing, as shown in Experiment 1, and morpho-phonological properties in speaking, as shown by Franck et al., 1999), and given that the phonological and orthographic codes activate each other, one may expect to find that orthographic information has an impact on spoken agreement as well. In other words, the question now is: do feedback influences found within a modality of production (Experiment 1 for writing and Franck et al., 1999, for speaking) occur across modalities? Experiment 2 tests the influence of orthography on the realisation of agreement in spoken speech.

Method

Participants. Forty-eight native French speakers attending the University of Geneva who had not taken part in Experiment 1 participated in Experiment 2. They received credits.

Materials. Materials consisted of the experimental and filler sentential subjects used in Experiment 1 (i.e., the items of Experiment 1 without the verbs). Materials were arranged in the same presentation order as in Experiment 1.

Procedure. Participants were tested individually. Items were presented auditorily via headphones. Participants were instructed to listen to the sentence beginnings, and then repeat and complete them in order to create a full sentence. They were asked to speak as quickly as possible and to use

the verb “to be” (*être*) in order to have verbs marked for number. This procedure is the same as in previous studies on agreement in spoken production.

Scoring. Scoring was the same as in Experiment 1 except in three respects. (1) There was no category for orthographic errors. (2) Given their high proportion, we created a category for *Repetition errors* which were scored when participants changed the number of N1 or the number of N2 (i.e., producing a singular rather than a plural noun or conversely). (3) As a result, agreement errors occurring in combination with repetition errors were scored separately.

Design and data analyses. These were the same as in Experiment 1.

Results

We obtained 74 (2.41%) number agreement errors, 95 (3.09%) repetition errors and 106 (3.45%) miscellaneous errors. We also obtained 11 (0.35%) agreement errors in combination with repetition errors, but these errors were discarded from the statistical analysis given their low proportion. The distribution of errors is shown in Table 3.

Number agreement errors. More errors were produced with plural than with singular head nouns ($F_1(1, 47) = 7.91, p < .01$; $F_2(1, 62) = 5.56, p < .05$) and with plural local nouns $F_1(1, 47) = 31.64, p < .001$; $F_2(1, 62) = 22.24, p < .001$). Crucially, no difference was found between the homographic (39) and non-homographic (35) conditions ($F_s < 1$).

Repetition errors. Significantly more errors were found with plural heads $F_1(1, 47) = 20.35, p < .001$; $F_2(1, 62) = 11.99, p < .001$) and with

TABLE 3
Distribution of errors in Experiment 2 (spoken production)

	<i>Agreement errors</i>		<i>Repetition errors</i>		<i>Miscellaneous errors</i>	
	<i>Non-homographs</i>	<i>Homographs</i>	<i>Non-homographs</i>	<i>Homographs</i>	<i>Non-homographs</i>	<i>Homographs</i>
SS	1 (.03)	2 (.07)	9 (.29)	5 (.16)	11 (.36)	21 (.68)
SP	11 (.36)	12 (.39)	9 (.29)	13 (.42)	14 (.46)	16 (.52)
PS	3 (.10)	9 (.29)	10 (.33)	11 (.36)	10 (.33)	12 (.39)
PP	20 (.65)	16 (.52)	25 (.81)	33 (1.07)	11 (.36)	11 (.36)
Total	35 (1.14)	39 (1.27)	53 (1.73)	62 (2.02)	46 (1.50)	60 (1.95)

Note: Percentages are in parenthesis.

plural local nouns ($F_1(1, 47) = 22.28, p < .001$; $F_2(1, 62) = 13.13, p < .001$). The interaction between the number of the head and the number of the local noun was also significant ($F_1(1, 47) = 9.25, p < .005$; $F_2(1, 62) = 5.45, p < .05$).

Miscellaneous errors. None of the variables did have a significant effect on miscellaneous errors ($F_s < 2$).

Discussion

The main result of this second experiment is that orthographic number marking did not affect agreement in spoken French. This observation suggests that when computing the syntactic operation of subject-verb agreement, speakers are not influenced by the written representation of the head noun. This contrasts with the significant effect of orthography found in Experiment 1 when participants were producing written agreement. Accordingly, orthographic influences on agreement appear to be modality-specific.

Two other results merit brief mention. First, speakers produced fewer errors overall (2.4%) than writers (4.7%). We would suggest that this is due to the fact that whereas number was phonologically marked on verbs in the spoken task (participants used the verb *être*, to be, i.e., *est*-S and *sont*-P), number was phonologically unmarked on the verbs used in the written task. Consistent with this interpretation, Largy and Fayol (2001) found that writers commit more agreement errors when writing regular verbs, i.e., verbs that bear no phonological number distinctions, than when writing irregular verbs which are phonologically marked for number. Importantly, however, the null effect of number marking on spoken agreement cannot be attributed to the low error rates given that we nevertheless collected many (74) agreement errors (compared with 97 in Experiment 1).

Second, the pattern of agreement reported for plural head nouns differed from the usual finding in that a considerable number of these were made with plural head nouns, and in particular in the condition where both the head and the local nouns were plural. Repetition errors were also more common with plural heads, i.e., participants tended to erroneously turn plural nouns into singular nouns. These two findings suggest that the items in the plural condition might have some particularities in common that renders them difficult to process. However, the two error types did not occur on the same items, as indicated by the absence of a significant correlation between agreement and repetition errors across items ($r = .204, p > .10$). Also, in the written experiment, agreement errors were more frequent with singular head nouns, which further suggests that the

high error rate with plural heads in the spoken experiment is not specifically related to some properties of the items.

A series of observations reported in the literature indicates that French speakers have more trouble with plurals than speakers of other languages like English, Italian, or Spanish (for a discussion see Franck, Vigliocco & Nicol, 2002). The fact that number marking is rarely realised phonologically in French (less than 1% of the nouns present a number variant in the oral format) may partially account for the high number of repetition as well as agreement errors that French speakers tend to produce in the spoken format, in contrast to their low occurrence in writing.

GENERAL DISCUSSION

In two experiments we assessed the impact of orthographic representations on subject-verb agreement for number. Experiment 1 assessed writing performance and showed fewer agreement errors for subjects whose singular and plural forms were marked orthographically compared with cases in which number was orthographically unmarked. By contrast, orthographic marking was irrelevant to agreement marking in speaking as shown in Experiment 2. Form-level influences on agreement appear to play a role only within the modality of production: orthographic properties influence written production (Experiment 1) and morpho-phonological properties influence spoken production (Franck et al., 1999; Hartsuiker et al., 1999, 2001; Meyer & Bock, 1998; Vigliocco et al., 1995, 2002a). These observations are compatible with a view of a single grammatical encoder that interfaces with phonological and orthographic information in similar ways. However, whereas the general mechanism of syntactic agreement appears to be the same in written and oral production, form influences depend on whether we speak or write: lemmas trigger the activation of phonological word forms during speaking, whereas they trigger the activation of orthographic word forms during writing.

One possible account for the contrasting results in the two experiments is that we employed different tasks: sentence dictation in the written experiment, and sentence completion in the spoken experiment. The failure to observe form influences in the latter experiment may reflect a task rather than a modality constraint. However, we believe that such concerns are unfounded. Previous studies on written agreement have used the transcription technique (Fayol et al., 1994; Hupet et al., 1998), and similar results have been obtained in spoken tasks, and indeed, both techniques have been argued to tap into the process of agreement production (Bock & Miller, 1991; Fayol et al., 1994). But most importantly, significant morpho-phonological influences on spoken agreement were

previously reported using the same sentence completion task employed in Experiment 2 (Franck et al., 1999; Vigliocco et al., 1995, 1999, 2002a). Accordingly, the null effects of orthographic marking on spoken agreement cannot be due to the insensitivity of the technique.

What are the potential mechanisms of orthographic influence on written agreement?

A first interpretation, which we prefer, lies in an interactive perspective of sentence production (Dell, 1986). Orthographic (or morpho-phonological) properties are assumed to affect directly the construction of agreement via bi-directional connections between formal and lexico-syntactic properties of number in the lexicon. In most cases in French, the orthography of the singular noun differs from the orthography of the plural noun (non-homography). The orthographic representation therefore provides the speaker with unambiguous information concerning number that can help compute correct agreement. By contrast, nouns with homographic singular and plural forms have a single, opaque orthographic representation which provides an ambiguous signal to the syntactic processor in charge of ensuring verb agreement.

In the present study, we can assume that the final -s is an index of plurality, since it is the regular way of marking plurality in French. On one version of the feedback hypothesis, the orthographic information that feeds back to the agreement process is a *rule* linking graphemes and syntactic number (i.e., any final grapheme other than -s feeds back to singular nodes, whereas final -s feeds back to plural nodes). In this case, erroneous plural agreement should occur more often with singular nouns with homographic number marking (since these end in -s) than with singular nouns with heterographic marking (since these do not end with an -s). This is what we observed. However, this hypothesis does not account for the higher agreement error rate with plural head nouns in the homographic condition (23) as compared with plural heads in the non-homographic condition (10) since nouns in these two conditions are similarly marked for plural by the final -s.

An alternative hypothesis is that orthographic influences on agreement operate on the *statistics* of the association between the orthography of the complete noun (i.e., lexical-orthography) and its syntactic number: whereas this association is predictive for nouns with different singular and plural orthographies (one-to-one mapping between orthography and syntax), it is unhelpful for nouns with a single orthographic representation (one-to-many mapping between orthography and syntax). For example, in the case of *table* v. *tables*, the orthographic form [*table*] is consistently associated with the singular

feature and [tables] with the plural feature, and as a consequence, feedback from the word form can help support the selection of the appropriate number feature. However, in the case of a word with ambiguous orthographic number marking, feedback is unhelpful. For example, the orthographic representation of the word [secours] (meaning rescue) is associated with both singular and plural syntactic markers, and as a consequence, any feedback from [secours] is unhelpful. In this way, the higher error rates for plural head nouns in the homographic compared with non-homographic condition can be explained, contrary to the rule-based account described above.

We should acknowledge, however, that form-level effects on agreement may also be accounted for within a strictly feed-forward, modular view of sentence production. In Levelt's (1989) model, production errors are monitored via the comprehension system using two routes: one route consisting of monitoring the actual production after its occurrence (external loop); the second route consisting of monitoring speech before its actual articulation (internal loop). Although Levelt's theory does not consider writing, one could assume a similar role for a monitor during written sentence production. The presence of orthographic number information might increase the probability of error detection through an internal loop. In this framework, form-level influences on agreement do not arise during sentence production but as a failure to detect agreement errors (for a discussion of this view, see Vigliocco and Hartsuiker, 2002b). In any case, the finding of an orthographic effect provides evidence that number selection for the verb does not proceed in complete isolation but rather takes into account lexeme properties of the subject noun, either through feedback connections within the production system or through the intervention of a monitor system.

Are form-level influences on agreement modality-specific?

In the introduction to Experiment 2, we mentioned different studies suggesting that orthographic and phonological knowledge are strongly interconnected (Seidenberg & Tannenhaus, 1979; Ziegler & Ferrand, 1998). Why did we then fail to observe any orthographic effect in the spoken modality? We suggest two explanations.

A first possibility is that lemma selection only activates the relevant form systems: orthographic in the case of writing, phonological in the case of speaking. In such a situation, the only way that orthographic codes can become activated during speech production is via phonology—and indeed, this should be expected given the evidence that orthographic and phonological codes are strongly interconnected. But if orthography is only

activated via phonology, then the key orthographic information that was found to constrain agreement in writing in Experiment 1 (namely, the presence/absence of an -s) cannot be selected since all singular and plural nouns are homophones, i.e., they are phonologically undifferentiated. For example, if the lemma for TABLE selectively activates the unmarked phonological word /table/, then this code cannot in turn activate the appropriately marked orthographic forms [table] or [tables], since /table/ is connected to both forms. Accordingly, the relevant feature [s/~s] cannot feedback on the syntactic processor to constrain agreement. In order for orthographic forms to constrain agreement, orthographic forms need to be activated directly by lemmas (which are syntactically specified for number), allowing the proper orthographic form to become active, which in turn can feedback to the lemma level. On this view, the results of our two experiments suggest that noun's orthography is activated by lemmas only in writing.

A second, and closely related, possibility is that the degree to which a lemma activates its corresponding orthographic or phonological word forms (and thus the degree of feedback) is a function of the output modality. During speaking, lemmas may only weakly activate the relevant orthographic word forms, rendering any feedback ineffective. Indeed, the relatively strong feedback from the unmarked phonological forms onto orthography during speech might further block the selection of the relevant orthographic marker [s/~s], as again, the unmarked phonological codes would non-selectively activate the singular and plural orthographic forms.

Whatever the proper explanation is, the present findings clearly indicate that feedback from form systems plays an important role in agreement within but not between modalities.

CONCLUSION

The present study has shown that the orthographic marking of number on a subject influences subject-verb agreement in writing, similar to past work in which the phonological form of the subject influences agreement in the spoken domain. In addition, our results suggest that form-level influences are restricted to the modality of production, since orthographic properties influenced syntactic processes in written production, but not in spoken production. Although the present data provide evidence in favour of the hypothesis that orthographic processes feed back onto syntactic processes, the nature of the orthographic information that feeds back is still an open question. On the basis of our results, we advanced the hypothesis that feedback effects reflect the influence on agreement processes of the association between a particular noun's orthography and its syntactic

number, rather than the influence of general orthographic rules of the language (like -s being the regular plural marker in French).

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APPENDIX

Materials used in Experiment 1 (preambles without the brackets) and in Experiment 2 (full sentences including the brackets) presented in the Singular, Singular (SS) condition only. Frequencies of the head nouns in Brulex are in parentheses.

<i>Non-homographs</i>	<i>Homographs</i>
La série (5007) de l'acteur (rapporte)	Le secours (5007) du pompier (arrive)
The series of the actor (brings up)	The assistance of the fireman (arrives)
Le mélange (3403) de l'épiciier (embaume)	Le remords (3343) de l'agresseur (augmente)
The mix of the grocer (smells good)	The remorse of the aggressor (increases)
Le puzzle (106) de l'enfant (délassé)	Le thermos (106) de l'artiste (coule)
The jigsaw of the child (relaxes)	The flask of the artist (drips)
Le lingot du (123) voleur (dépasse)	Le châssis (127) du copain (craque)
The gold bar of the thief (tops)	The window frame of the friend (breaks)
Le cassoulet (63) du cuisinier (mijote)	Le tournevis (63) du garagiste (traîne)
The casserole of the cook (simmers)	The screwdriver of the mechanic (lies around)
La citerne (251) du voisin (perce)	Le tracas (272) de l'étudiant (continue)
The tank of the neighbour (is piercing)	The worry of the student (continues)
Le cachot (502) du prisonnier (pue)	Le parcours (493) du maquisard (serpente)
The cell of the prisoner (stinks)	The route of the resistance fighter (turns)
Le tableau (8538) du portraitiste (fascine)	Le discours (8602) du commissaire (fatigue)
The painting of the portrait painter (fascinates)	The discourse of the superintendent (is tiring)
Le collage (106) de l'écolier (gondole)	Le devis (106) de l'architecte (enfle)
The pasting of the schoolboy (curls)	The estimate of the architect (swells)
Le massage (114) de la kiné (relaxe)	Le canevas (114) de la brodeuse (décore)
The passage of the kinesiologist (relaxes)	The map of the sewer (decorates)
La chanson (4033) du rockeur (résonne)	Le refus (4016) du gréviste (persiste)
The song of the rocker (echoes)	The refusal of the striker (continues)
Le rideau (5862) de la concierge (bouge)	Le permis (5922) de la touriste (expire)
The curtain of the doorkeeper (moves)	The permit of the tourist (expires)
La revue (5739) du correspondant (dégénère)	Le palais (5785) du gouvernement (ouvre)
The review of the correspondent (deteriorates)	The palace of the government (opens)
Le remède (2795) du médecin (soigne)	Le procès (2769) du criminel (s'éternise)
The remedy of the doctor (cures)	The trial of the criminal (drags out)
La facture (319) du chauffagiste (baisse)	Le relais (314) du camionneur (lasse)
The bill of the heating engineer (lowers down)	The service station of the truck driver (is boring)
La devise (982) de la mafia (dérange)	Le matelas (969) de la banquette (glisse)
The motto of the mafia (disturbs)	The mattress of the bench (slips)
La vitrine (1157) du magasin (choque)	Le remous (1165) de la cascade (bouillonne)
The window of the shop (shocks)	The whirlpool of the waterfall (bubbles)

La cagnotte (21) du lotto (explose)	La mi-temps (21) du tournoi (dure)
The money of the lottery (explodes)	The half-time of the tournament (lasts)
Le jeton (191) du vestiaire (roule)	Le treillis (191) de la prairie (balance)
The token of the cloakroom (rolls)	The fence of the field (moves)
La soutane (957) du curé (sèche)	La brebis (944) du berger (court)
The dress of the priest (dries)	The ship of the shepherd (runs)
Le rôle (12085) de l'assemblée (change)	Le prix (13396) de la marchandise (dégringole)
The role of the assembly (changes)	The price of the merchandise (falls down)
Le reportage (310) sur la famine (scandalise)	Le prospectus (306) su la pilule (informe)
The report on hunger (scandalises)	The pamphlet about the pill (informs)
La fumée (5743) de la cheminée (empeste)	Le repas (5671) de la cantine (rassasie)
The smoke of the chimney (smells)	The meal of the cafeteria (feeds in)
La copie (1408) de l'article (circule)	L'autobus (1391) de l'école (démarre)
The copy of the paper (circulates)	The bus of the school (starts)
La guérilla (68) dans la ville (progresses)	Le tumulus (68) dans le pré (intrigue)
The guerilla in the town (progresses)	The small hill in the meadow (is intriguing)
Le muguet (136) sur la platebande (pousse)	Le cadenas (140) sur la valise (coince)
The lily on the flower bed (grows)	The padlock on the suitcase (sticks)
Le carrelage (327) du corridor (brille)	Le croquis (327) du bâtiment (brûle)
The tiling of the corridor (shines)	The sketch of the building (burns)
Le volet (2437) de la fenêtre (grince)	Le surplus (2399) du marché (diminue)
The shutter of the window (creaks)	The surplus of the market (diminished)
La dépêche (1216) de l'agence (tombe)	Le congrès (1220) du parti (début)
The report of the agency (arrives)	The conference of the party (starts)
Le transport (3114) vers la campagne (commence)	L'accès (3067) vers la galerie (ferme)
The transport to the campaign (starts)	The access to the gallery (closes)
L'influence (7785) de la publicité (s'amplifie)	Le progrès (7827) de la technologie (évolue)
The influence of advertising (increases)	The progress of the technology (evolves)
La machine (7377) de l'entrepôt (siffle)	Le succès (7474) de l'entreprise (épat)
The machine of the warehouse (whistles)	The success of the enterprise (amazes)

Note: Some of these translations are awkward in English but they sound natural in French.