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Article abstract

This paper explores the most efficient teaching context to learn words' visual aspects and by second-grade French-speaking children, including those with special needs. Students came from six classrooms and each classroom was randomly assigned to the control group or to one of two experimental interventions (TFS: explicit teaching of semantic and formal properties of words; TF: explicit teaching of formal properties of words). For students without difficulties, the experimental interventions have contributed equally to the learning of the words' visual aspect, whereas no progress was observed for the control group. For students with special needs, only the intervention that combined explicit instruction of semantic and formal properties lead to significant progress. These results suggest that explicit instruction should focus on the semantic and formal properties of words, especially for students with special needs.

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The Effect of Explicit Instruction on the Acquisition of Words' Visual-Orthographic Phenomena By Second-Grade French-Speaking Children

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Introduction

For several decades, many international policy guidelines have emphasized inclusive education, which focuses on the “full and effective participation . . . and achievement of all students” (UNESCO, 2020, p. 13). In such a context, regular classroom teachers must account for diversity in their support for all learners, especially for those with special needs (Larochelle-Audet et al., 2016; Garner, 2009; Lavoie et al., 2013). Given the importance of literacy skills of reading and writing for school, work, and social life (Berman, 2009; Graham & Perin, 2007; OECD, 2016), several authors have recommended teaching literacy subskills to students (Graham, 2020; Graham & Perin, 2007; National Reading Panel, 2000). Thus, learners must acquire specific knowledge that is fundamental for reading and writing, including spelling (Apel et al., 2019; Graham & Santangelo, 2014). Spelling is a complex skill to master for most children, but even more so for children with special needs (Berninger et al., 2008; Daigle et al., 2016; Graham & Santangelo, 2014; Plisson et al., 2013; Ruberto et al., 2016). A variety of variables could explain why children struggle with spelling. Among these, it is important to stress the impact of (a) the orthographic code of the language being learned, (b) the context in which orthographic knowledge is acquired, and (c) the quality of lexical representations stored in memory. The main objective of the study described in this paper was to assess the effectiveness of two intervention approaches for spelling acquisition in French.

French Orthographic Code

Children must develop knowledge about the orthographic code to read and write correctly, that is they must be aware of the general principles underlying the writing system (Apel et al., 2019; Carrillo et al., 2013). Ideally, in alphabetic systems, there would be a one-to-one correspondence between a phoneme (i.e., sound) and a grapheme (i.e., a letter or a sequence of letters that generally corresponds to a sound). However, in French, its 36 phonemes are represented by some 130 graphemes (Catach, 2008). This situation makes the French orthographic code inconsistent. Because of this inconsistency, learning grapheme-phoneme correspondences is challenging for most French-speaking children

(Catach, 2008). That is also true for other inconsistent (or opaque) orthographies such as English and Danish (Seymour et al., 2003); the irregularity of the relations between phonemes and graphemes makes their memorization difficult.

In French, as in other languages like English, graphemes are used to transmit phonological information. This is the case for 83% of graphemes in French (Catach, 2008). This means that when reading a word through grapheme-phoneme correspondences, the reader can activate the pronunciation of the word, allowing access to its meaning if the word is known orally. However, when writing a word, only 50% of phoneme-grapheme correspondences ensure correct spelling (Véronis, 1988). Consequently, to spell correctly, writers must rely on orthographic knowledge other than graphophonological knowledge. Therefore, children must also become familiar with the other properties underpinning the French orthographic code, namely the morphological and the visual-orthographic properties of written words (Catach, 2008; Daigle & Montésinos-Gelet, 2013; Pacton & Deacon, 2008).

One of the main reasons why students struggle to spell words correctly in French is due to the difficulty that they experience in perceiving the words' visual-orthographic phenomena (Daigle et al., 2016; Pacton et al., 2005). Visual-orthographic phenomena in French cannot be processed and acquired through phonology or morphology only (Daigle et al., 2016; Daigle & Montésinos-Gelet, 2013). Indeed, some phenomena necessitate visual-orthographic processing. For example, in French, the graphemes -pp as in *appeler* (to call) and -p as in *apercevoir* (to see) correspond to the same phoneme [p]. In order to spell correctly, the writer needs to take into consideration this specific visual-orthographic phenomena.

Among these visual-orthographic phenomena, two are particularly difficult to master (Daigle et al., 2016). First, there are multigraphemic phonemes that are phonemes that can be written in different ways (e.g., [f] can be written -f, -ff, -ph). Second, silent letters that do not carry meaning also constitute a source of difficulty for most learners (e.g. -e in *pluie* [rain], -s in *toujours* [always]). To respect the orthographic norm, learners need to memorize visual-orthographic characteristics of each word. In French, these characteristics are responsible for about 70% of spelling errors made by students at the end of elementary school (Daigle et al., 2016). This situation is true for most students, whether they have learning difficulties or not (Costerg, 2018; Daigle et al., 2016; Plisson et al., 2013).

To sum up, to correctly spell words in French, children must have recorded in memory all specific sequences of graphemes corresponding to the orthographic norm, many of which are visual-orthographic phenomena (Bosse et al., 2007; Ginestet et al., 2019). For this reason, in French as in some other writing systems, several authors have suggested that children need to become aware of the words' visual-orthographic phenomena that cannot be dealt with only through phonology or morphology to promote the development of quality lexical representations (Chang et al., 2016; Chaves et al., 2010; Ginestet et al., 2019).

Context in which Orthographic Knowledge is Acquired

It is generally agreed that orthographic knowledge (knowledge about the properties of the spelling code and specific word knowledge) develops in different contexts.

First, there is evidence across orthographies of varying transparency that orthographic learning may occur when children are exposed to print, that is, when they

spell or when they read words (in French, see Daigle et al., 2020, Pacton et al., 2005; in English, see Conrad et al., 2019, Cunningham, 2006; in Dutch, see De Jong & Share, 2007; in Hebrew, see Shahar-Yames & Share, 2008; in Spanish, see Suárez-Coalla et al., 2016). Even though there is evidence of orthographic learning after one exposure to a word in different languages (Nation et al., 2007; Share, 2004), learning is enhanced as the number of exposures grows (Bowey & Muller, 2005; Nation et al., 2007).

Second, there is much evidence across orthographies of varying transparency that explicit instruction promotes the development of orthographic knowledge (Graham & Santangelo, 2014; Schlagal, 2007; Simonsen & Gunter, 2001). Studies that have tested the effects of explicit instruction within the context of specific training programs have shown benefits for students in terms of their gains in orthographic knowledge related to the phonological, morphological, and visual aspects of the code (Casalis & Colé, 2009; Daffern, 2017; Daigle et al., 2020; Fayol et al., 2013; Marin & Lavoie, 2017; McLaughlin et al., 2013; Squires & Wolter, 2016). Considering that the study done by Daigle et al. (2020) was, to our knowledge, the only one to address explicit instruction of visual properties of written words in French, other studies are needed.

Quality of Lexical Representations Stored in Memory

The quality of lexical representations that are encoded in memory may also explain difficulties encountered during spelling acquisition. Lexical representations refer to the stored mental representations of known words (Apel et al., 2019; Nation, 2013; Perfetti & Hart, 2001, 2002). Lexical representation is the combination of the knowledge about the semantics (meaning) of a given word and its formal properties, that is, its spoken form and its written form (De Jong & Share, 2007; Nation, 2013; Perfetti, 2007; Perfetti & Hart, 2001, 2002).

By semantics, it is important to distinguish the breadth and depth of the writer's vocabulary. Vocabulary breadth refers to the number of words the student knows the meaning of (McGregor, et al., 2013). However, a writer can know the general meaning of a word without knowing all the subtleties of its meaning. Vocabulary depth is the knowing of various dimensions associated with the meaning of that word (Protopapas et al., 2013). Knowing the meaning of a word refers to concepts and referents that are associated with it (Berthiaume, Anctil, Daigle, 2020). Knowledge of the meaning of a word is based on the student's analysis of the different contexts (sentences, texts) in which a given word may be found. The different contexts in which the student will be able to read and write the word will allow him to acquire referents on how to use the word both orally and in writing and to establish semantic links between different words, either from the same lexical field or to reflect possible collocation links, since the writer will have acquired in-depth knowledge of the real meaning of the word.

By formal properties, it is important to distinguish the spoken form from the written form. The spoken form of a word corresponds not only to its pronunciation, but also to its phonological structure (number of syllables, number of phonemes, etc.). The written form corresponds to the spelling of the word, that is, the graphemes that compose it and the nature of the information that the word transmits (phonological, morphological or visual-orthographic).

Early in their development, children learn to associate spoken forms of words with their meaning. When children are exposed to literacy, they connect these spoken and

semantic representations to written representations (Colenbrander et al., 2019). Therefore, the look, sound, and semantics of words contribute to the quality of lexical representations stored in memory (Ehri, 2014).

According to Perfetti's (2007) lexical quality hypothesis, a word representation is of high quality when all three key elements of word knowledge (i.e., meaning, spoken form, and written form) are retrieved in a coordinated manner. In other words, lexical quality should not only depend on knowledge about the formal properties and the semantics of a given word but also on the connections between them (Nation, 2013; Perfetti, 2007; Perfetti & Hart, 2001, 2002). Variation in the quality of lexical representations leads to variation in reading skills, including comprehension (Perfetti, 2007). Also, results from various studies have supported the lexical quality hypothesis in the context of spelling and spelling acquisition (Conrad, 2008; Conrad et al., 2013; Martin-Chang et al., 2014; Ouellette et al., 2017; Rossi et al., 2018). Thus, high quality representations facilitate word retrieval from memory and ensure higher quality in spelling production (Apel, 2011; Apel et al., 2019).

The quality of word representations depends, at least in part, on formal instruction given in school (Graham & Santangelo, 2014). Vocabulary instruction is often limited to lists of words given by the teacher to be learned at home by children. In this context, there is no teaching of formal or semantic properties (see Daigle & Bastien, 2015; Graham et al., 2008; Mansour, 2012). When formal properties are taught, this teaching is often limited to correspondences between phonemes and graphemes.

Some studies have examined the influence of semantic information on orthographic learning in the context of reading (Álvarez-Cañizo et al., 2018; McKay et al., 2008; Ricketts et al., 2011; van Rijthoven et al., 2018). Results have shown that having prior knowledge about the semantics of words may facilitate orthographic learning and could increase children's reading fluency (i.e., speed or accuracy). However, to our knowledge, very few studies have examined the role of semantic information for orthographic learning in the context of spelling (Ouellette, 2010; Ouellette & Fraser, 2009).

Ouellette and Fraser (2009) conducted a study with 35 Grade 4 English-speaking students. This study consisted of one training session and two posttest sessions, administered respectively 1 and 4 days following the training session. During the training session, participants were exposed to 10 nonwords; five nonwords were accompanied by an oral description and corresponding drawing (semantic condition) and five were not (orthographic-only condition). Orthographic learning was measured by participants' ability to read nonwords in a multiple-choice recognition task and to spell targeted nonwords in a written dictation task. The addition of semantic information improved the posttest performance on the multiple-choice recognition task but not on the spelling dictation task.

Ouellette (2010) conducted a similar study, but with a younger sample of 36 Grade 2 English-speaking children. He incorporated the teaching conditions of Ouellette and Fraser (semantic vs. orthographic only) while also manipulating the type of practice (reading plus spelling vs. reading). This study consisted of one training session and two posttest sessions, administered respectively 1 and 7 days following the training session. During the training session, participants were exposed to 10 nonwords; five nonwords were paired with semantic information and five were not. Half of the participants practiced reading these new items, whereas the other half wrote them. Orthographic learning was measured by an oral dictation of nonwords. Results indicated that the presence of semantic information facilitated orthographic learning and that orthographic learning was better for

reading plus spelling than for reading alone. This result is consistent with theories that suggest spelling practice promotes higher quality representations (Conrad, 2008; Conrad et al., 2019; Ouellette & Sénéchal, 2008; Shahar-Yames & Share, 2008) but is also different from the results obtained in Ouellette and Fraser's (2009) study. The body of work presented so far has indicated that:

- 1) The French orthographic code is complex, especially for the visual properties of words. This difficulty is even more important for younger students and for students with special needs given that they tend to develop less precise lexical representations.
- 2) Both repeated exposition to words through reading and spelling and explicit teaching promote spelling gains. Nevertheless, explicit teaching of words' visual-orthographic phenomena in French seems a more favorable approach than the others.
- 3) Further investigation is necessary to examine the contribution of semantic information in the development of quality lexical representation for spelling in French.

Main Goal and Research Questions

Considering the current stage of knowledge about spelling acquisition in French, the aim of this study was therefore to determine the role of semantic and formal properties of words in developing quality lexical representation among French-speaking children and among those with special needs. Thus, through this study, we tried to answer the following questions: 1) Does the explicit teaching of both semantic and words' visual-orthographic phenomena promote more spelling acquisition than does the explicit teaching of the words' visual-orthographic phenomena alone? 2) If so, is this true also for students with special needs?

The conduct of this study will help to develop knowledge on spelling allowing to specify what works in spelling instruction, particularly in more opaque orthographies like French.

Method

Design

We assessed the effectiveness of two experimental interventions on orthographic knowledge acquisition: one that combined explicit teaching of both semantic and formal properties of words (TSF) and one that focused solely on explicit teaching of formal properties of words (TF). To achieve this purpose, we used a cluster randomized controlled trial design. We randomly assigned classrooms to one of the two intervention groups (TSF or TF) or to the control group (C). We describe the content of each experimental intervention in the *Description of the Experimental Interventions* section. We conducted the study at the beginning of the school year over a 15-week period.

In Week 1, we administered four control measures to verify if groups were similar on baseline characteristics. We compared the participants' performances on four tasks (plausibility judgment, visual-orthographic judgment, word dictation, and word reading) that measured skills known to have an influence on spelling acquisition in French (see Appendix A for details). In Week 2, we conducted the pretest (T1). From Weeks 3 to 9, participants from the two intervention groups (TSF and TF) received an intervention of 13 sessions of 50 minutes each. We administrated the immediate posttest (T2) in Week 10 and the delayed posttest (T3) in Week 15.

In other words, participants in the C group did the pretest (Week 1) and posttests (Week 10 and Week 15) but received no specific experimental intervention. They continued with the normal Grade 2 program.

Sampling Procedure

We performed a statistical power analysis in G*Power 3.1 (Faul et al., 2007) to determine the size of a sample required to be sufficient for a repeated measures ANOVA with three groups. To detect a large effect size ($f = .40$) according to Cohen's criteria (1988) using an alpha of .05 and a power of .95, we aimed minimally to have 120 participants. Given that a minimum of 40 participants per group was needed and that Grade 2 classrooms in Quebec contain an average of 25 students, we needed two classrooms per group, or six classrooms in total.

Prior to the beginning of the study, an ethics certificate had been granted by the Research Ethics Committee of the University of Montreal. The study had also been approved by the parents' committee of each school, and all the children received parental approval before the beginning of the study.

Participants

A total of 131 French-speaking children (mean age: 7.5 years) from the greater Montreal area (Quebec, Canada) participated in this study. Each participant had to be in a Grade 2 regular classroom of a francophone school and had to have no known cognitive disabilities. Participants came from three different public schools that were in similar middle socioeconomic background.

The sample included 24 participants with special needs. To avoid any conceptual confusion about participants' status, we decided to use the term *students with special needs* (SWSN) as defined by the Government of Quebec (MELS, 2007). It refers to students who have handicaps, social maladjustment, learning disabilities or learning difficulties. By law, all students with special needs require an Individualized Education Plan (Government of Quebec, 2011, Education Act, s. 96.14). This plan is a legal document that contains adapted interventions to optimally support students' progress in developing the competencies and knowledge required for success in school. Also, teachers confirms that SWSN had spelling difficulties prior the beginning of the study.

Because whole classrooms were randomly assigned to an intervention or control group, all participants were included in the sample for the analyses, regardless of individual differences among the participants. Table 1 presents the distribution of participants per group according to individual characteristics.

Table 1
Distribution of participants per group according to individual characteristics

Group	n	Age			Gender		French language status		SWSN	
		M	SD	Mdn	Girls	Boys	FL1	Other	Yes	No
TSF	43	7.47	.31	7.46	19	24	40	3	8	35
TF	44	7.52	.39	7.42	21	23	42	2	8	36
C	44	7.51	.27	7.50	22	22	42	2	8	36

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only; C = Control; SWSN = Students with special needs.

Material

Participants were taught 24 words. The 24-word list used in this study is found in Appendix B. The selection of words was based on two criteria. First, because we considered spelling acquisition to be distinct from vocabulary acquisition, we chose words that the participants did not know in writing but knew orally. If the participants had already known the spelling of words before they had been trained, it would have been very difficult to assess their progress in spelling following the intervention. Second, the words also had to contain at least one visual-orthographic phenomena targeted by this study, namely a silent letter that does not carry meaning (i.e., *-e* or *-s*) or a multigraphemic phoneme (i.e., [ã] or [l]).

We created a bank of 72-words that met both criteria. To do this, we consulted the spelling lists published by the Government of Quebec (MEES, 2019) for students in Grades 4, 5, and 6. To ensure that these words were known orally and not in writing, they were all presented to 42 Grade 2 students who did not participate in the study. For each word, the students saw four pictures. The experimenter pronounced the item a first time and the students had to circle the corresponding picture. The experimenter uttered the word a second time so that the students could write it down. Of the 72 items presented to the students, we selected 24. For an item to be selected, it had to be known by at least 75% of students orally and up to 25% of students in writing.

Outcomes and Outcome Measure

The first outcome was the effect of the experimental intervention on participants' spelling acquisition. The second outcome was the effect of the experimental intervention on participants' spelling acquisition based on their status, that is, whether or not their status was SWSN.

We measured these outcomes by comparing participants' mean performance in each group before and after the intervention by using three gap dictations created for this study. The first dictation was carried out before the intervention (T1) and the other two one week and six weeks after the intervention (T2, T3), respectively.

Even if the text in each gap dictation was different, the task was always the same. The gap dictations included the same 24 words taught during the intervention but presented in a different order. Also, the length of each gap dictation was around 400 words. The

measures were administered in class and lasted 30 minutes. The participants' scores (in %) obtained at each test were based on the number of correctly spelled words out of 24.

Description of the Experimental Interventions

We created two different sets of experimental teaching interventions that were each used in one of the two experimental groups to be compared, that is in the TSF or in the TF group. As mentioned in the *Design* section participants in the C group did the pretest and posttests but received no specific experimental intervention. They continued with the normal Grade 2 program.

The intervention lasted six weeks during which 13 lessons of 50 minutes were delivered to the TSF and TF groups. Also, because we recruited intact classes and the project was aimed at all students, we did not want the results to be attributable to a possible teacher effect. To control this effect, the first author (who has had 10 years of teaching experience) performed the experimental interventions in each TSF and TF group classroom. Also, by having the same person to care of the intervention, we wanted to minimize variations in how the intervention was delivered between classrooms (duration, activities).

To teach spelling in context, we created sequences of activities where the same backstory was used for the two conditions to ensure that participants' interest in the reading texts or activities did not vary from one condition to another. The project was called the Adventures of Balou. The children were invited to learn the spelling of words through Balou's stories and the activities that he proposed to them. In total, four stories of similar length (220-230 words) were presented to the participants. Each story included six new words that the participants were required to learn to spell. We ensured that the frequency and length of the words in each story were similar. The same six words were taught in the classrooms assigned to the TSF and the TF groups, but the stories differed in the two experimental conditions (see Appendix C):

- In the TSF group, because the semantic properties were taught, the words were inserted into a story inspired by a common theme. For example, in the story where Balou visits the fire station, the words taught were *policier* (police officer), *angoisse* (anxiety), *sirène* (siren), *ruelle* (alley), *incendie* (fire) and *secours* (aid). It is important to emphasize that the oral form of all the words was known by at least 75% of the students (see section dedicated to the presentation of the material). However, to develop a high-quality representation of the word, it is important that the writer develops a fine knowledge of the meaning of each word. To do this, the words were not only defined, but semantic links were also created between them.
- In the TF group, the same words were inserted into a story that had no connection to the previously defined theme. For example, the same words (i.e., *policier*, *angoisse*, *sirène*, *ruelle*, *incendie*, *secours*) were inserted into a story describing a day when Balou spent time in the forest with a friend.

In the TSF and the TF groups, words were taught through specific steps allowing students to become sensitive to the formal properties of words, especially to the presence of multigraphemic phonemes and of silent letters that do not carry meaning. The TSF group had two extra steps to teach the semantic knowledge associated to the target words (see Appendix D).

Data Analysis

We formulated two research hypotheses, each related to the outcomes described earlier. To verify our two research hypotheses, we conducted group comparisons through a series of statistical analyses.

First, we hypothesized that the intervention in the TSF group would promote more spelling acquisition than would the intervention in the TF group. To compare groups on the primary outcome, we performed a two-way mixed ANOVA with the group (TSF, TF, C) as a between-subjects variable and time of testing (T1, T2, T3) as a within-subjects variable.

Second, we hypothesized that the intervention in the TSF group would promote more spelling acquisition than would the intervention in the TF group, not only for typical participants but also for those whose status was SWSN. To compare groups on the secondary outcome, we performed a three-way mixed ANOVA with group (TSF, TF, C) and students' status (SWSN or not) as between-subjects variables and time of testing (T1, T2, T3) as a within-subjects variable.

We decided to reject the null hypothesis if the observed p value of a test was smaller than 5% ($p < .05$). Also, we interpreted effect sizes according to Cohen's (1988) criteria for η^2_p : .01 for a small effect size; .06 for a medium effect size; and .14 for a large effect size.

When we observed a significant effect in either of the ANOVAs, we conducted post hoc analyses (multiple Bonferroni comparisons) to determine which teaching conditions promoted the greatest gains in learning.

Results

Baseline Data

As we stated earlier, we randomly assigned intact classrooms (all students from each classroom) to the intervention or the control groups, regardless of the individual differences among participants (see Table 1). To assess baseline equivalence regarding individual characteristics, we performed a series of statistical analysis. We ran a one-way ANOVA for group (TSF, TF, C) to verify if the mean age of participants was similar from one group to another. We ran chi-square tests to determine whether there was a statistically significant difference between groups for gender (boys vs. girls) and student status (typical vs. SWSN status). The results showed no significant differences between groups for age, $F(2, 128) = 0.231, p = .794, \eta^2 = .004$; gender, $\chi^2(2) = .299, p = .883, V = .048$; French language status, $\chi^2 = 2.556, df = 4, p = .708, V = .099$; or for student status, $\chi^2(2) = .003, p = 1.000, V = .005$.

We also assessed baseline equivalence by comparing the participants' performances on the four tasks described in detail in Appendix A (plausibility judgment, visual-orthographic judgment, word dictation, and word reading). These four tasks have been used, because they assess skills underlying the development of spelling knowledge in French. Also, these tasks had been used in similar studies that have focused on teaching and spelling acquisition in French (Daigle, 2003; Daigle et al., 2016; Plisson, 2017; Costerg, 2018).

For each task, we performed a one-way ANOVA to compare participants' performance between groups (TSF, TF, C): Plausibility Judgment Task, $F(2,128) = 0.381,$

$p = .684$, $\eta^2_p = .006$; Visual-orthographic Judgment Task, $F(2,128) = 0.001$, $p = .999$, $\eta^2_p = .000$; Word Dictation Task: $F(2,128) = 0.189$, $p = .828$, $\eta^2_p = .003$; and Word Reading Tasks: Regular Words, $F(2,128) = 0.674$, $p = .512$, $\eta^2_p = .010$; and Irregular Words, $F(1,128) = 0.688$, $p = .505$, $\eta^2_p = .011$. We observed no statistical differences between groups for any of the tasks. Thus, we confirmed that the groups were equivalent before the start of the intervention.

Statistics and Data Analysis

First outcome: overall results. We hypothesized that the intervention in the TSF group would promote more spelling acquisition than would the intervention in the TF group for all the participants. Table 2 shows the participants' mean scores according to the group to which they had been assigned and to the time of testing. The participants' performance, expressed as a percentage, is the mean number of words correctly spelled (24 words in total).

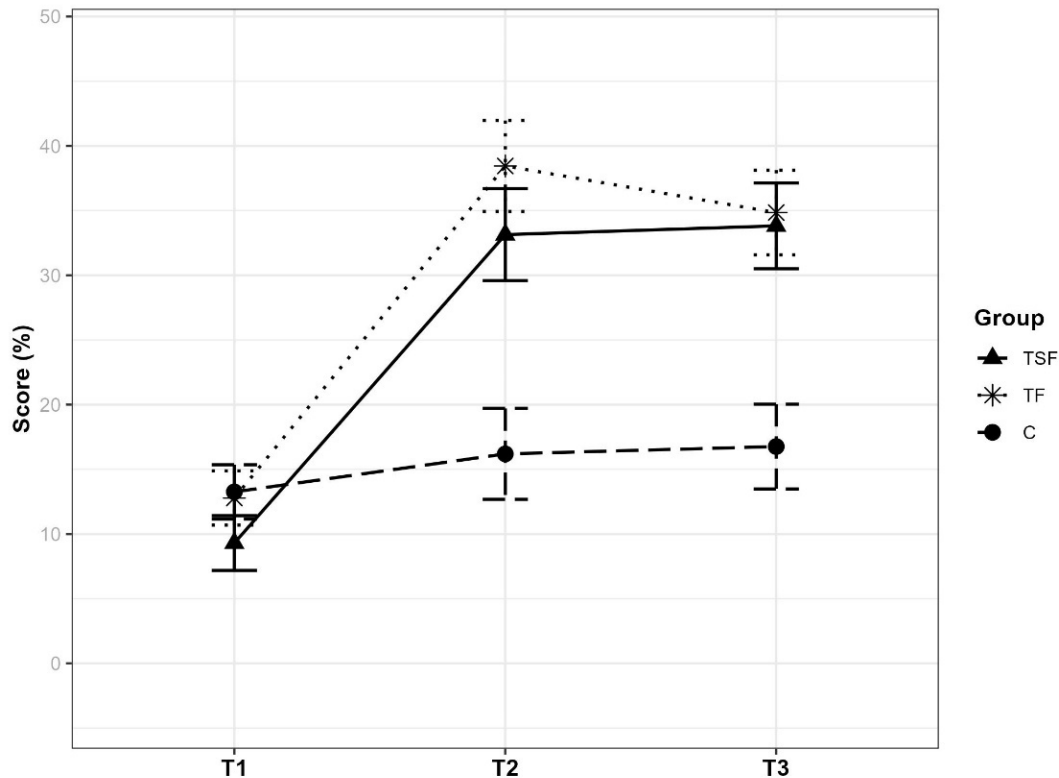
Table 2

Overall results for the gap dictation test (24 items; Scores in %)

Group	N	T1		T2		T3	
		M	SD	M	SD	M	SD
TSF	43	9.30	11.50	33.14	20.99	33.82	18.95
TF	44	12.78	14.28	38.45	28.92	34.85	27.58
C	44	13.26	15.60	16.19	18.79	16.76	17.11

Note. TSF = Teaching semantic and formal properties; TF= Teaching formal properties only; C = Control; T1 = pretest; T2 = immediate posttest; T3 = delayed posttest.

We compared group mean performance using a two-way mixed ANOVA with group (TSF, TF, C) as a between-subjects variable and time of testing (T1, T2, T3) as a within-subjects variable. We found a significant Group \times Time interaction, $F(4, 256) = 23.567$, $p < .001$, $\eta^2_p = .269$, indicating that the effect of group for mean performance differed according to the time of testing. We ran post hoc analyses using multiple Bonferroni comparisons to see where these differences were located. Figure 1 illustrates this interaction.



Error bars: Standard error at +/- 1

Figure 1. Interaction of time of testing with group. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only; C = Control; T1 = pretest; T2 = immediate posttest; T3 = delayed posttest.

Prior to the intervention (T1), the results showed no differences between groups. The performance of the TSF group was similar to that of the TF group ($p = .736$) and to that of the C group ($p = .562$). Also, the performance in the TF group did not differ from that of the C group ($p = 1.000$). After the intervention (T2 and T3), pairwise comparisons indicated that the mean scores for the TSF and the TF groups were not significantly different ($p = .872$), but the scores obtained in both groups were significantly higher than the scores in the C group ($p = .003$ and $p < .001$, respectively).

The mean scores for the TSF and the TF groups were significantly higher for T2 and T3 than for T1 ($p < .001$ in all four cases). However, the mean score for the TSF group did not significantly differ between T2 and T3 ($p = 1.000$), whereas a significant decrease was observed for the TF group between T2 and T3 ($p = .045$). As for the C group, the mean score did not differ between T1 and T2 ($p = .639$), between T1 and T3 ($p = .352$), nor between T2 and T3 ($p = 1.000$). No progress was therefore observed for the C group participants over time.

Second outcome: effects of the intervention for students with special needs. We hypothesized that the intervention in the TSF group would promote more spelling acquisition than the intervention in the TF group for participants with SWSN status. Table 3 shows participants' mean scores according to the group to which they had been assigned, their status (SWSN or

not) and time of testing. The participants' performance, expressed as a percentage, is the mean number of words correctly spelled (24 words in total).

Table 3
Effect of participants' status on spelling acquisition (24 items; Scores in %)

Group	n	T1		T2		T3	
		M	SD	M	SD	M	SD
TSF							
SWSN	8	2.60	3.82	17.71	13.13	21.35	11.01
Without difficulties	35	10.83	12.14	36.67	20.98	36.67	19.33
TF							
SWSN	8	1.04	1.93	11.98	13.63	8.33	11.99
Without difficulties	36	15.39	14.53	44.33	28.19	40.74	26.64
C							
SWSN	8	3.65	3.48	7.81	9.30	10.42	12.40
Without difficulties	36	15.39	16.45	18.06	19.92	18.17	17.82

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only; C = Control; SWSN = Students with special needs; T1 = pretest; T2 = immediate posttest; T3 = delayed posttest.

We compared the groups' mean performance using a three-way mixed ANOVA. Group (TSF, TF, C) and status (SWSN or not) were between-subjects variables. Time of testing (T1, T2, T3) was a within-subjects variable. We found a significant Group × Time × Status interaction, $F(4, 250) = 2.789, p = .027, \eta^2_p = .043$, which meant that the intervention did not have the same effect for SWSN and for participants without difficulties according to the group and the time of testing. Because the intervention did not have the same effect for SWSN and for participants without difficulties, we conducted two post hoc analyses using multiple Bonferroni comparisons. The interaction of time of testing with group is illustrated in Figure 2 for participants without difficulties and in Figure 3 for those with SWSN status.

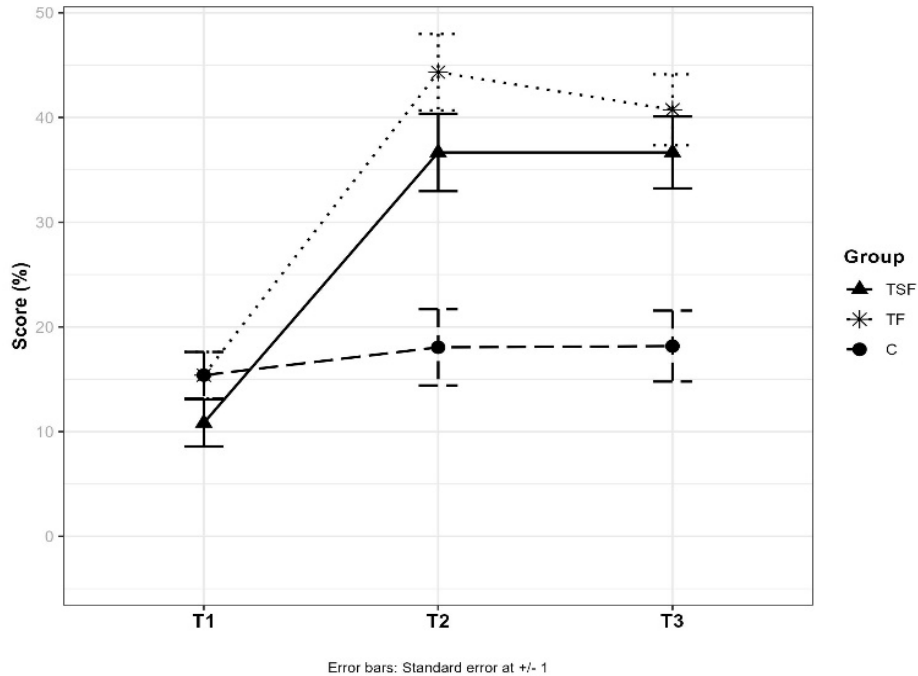


Figure 2. Interaction of time of testing with group for participants without difficulties
 TSF = Teaching semantic and formal properties; TF = Teaching formal properties only;
 C = Control; T1 = pretest; T2 = immediate posttest; T3 = delayed posttest.

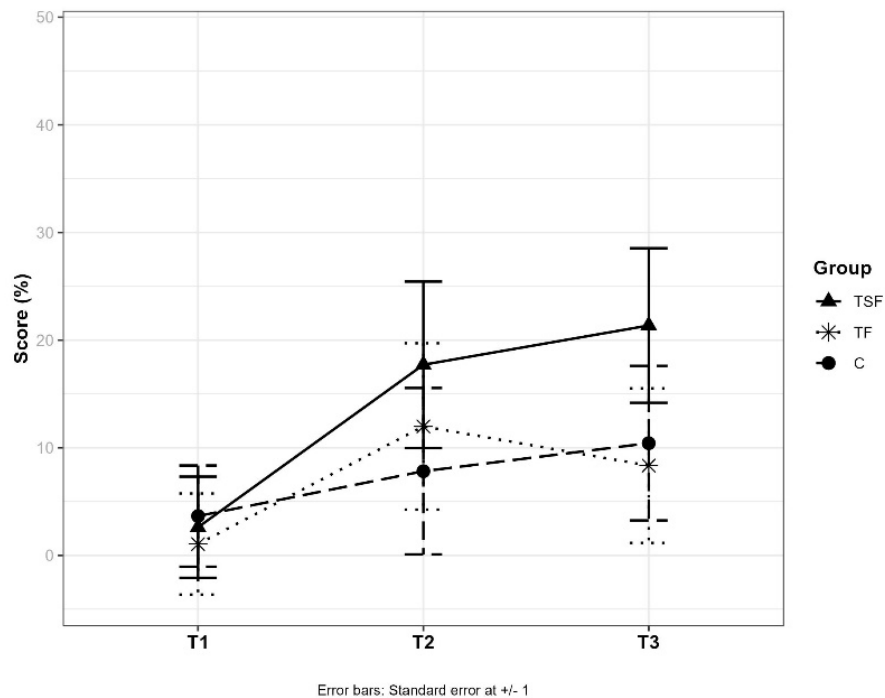


Figure 3. Interaction of time of testing with group for participants with student with special needs. TSF = Teaching semantic and formal properties; TF = Teaching formal

properties only; C = Control; T1 = pretest; T2 = immediate posttest; T3 = delayed posttest.

The performance of the participants without difficulties in the TSF and the TF groups after the intervention (T2 and T3) was significantly higher than it was before the intervention (T1: $p < .001$ in all four cases). Also, there were no significant differences in the performance of the participants without difficulties in the TSF and the TF groups between T2 and T3 ($p = 1.000$ and $p = .087$, respectively). The performance of participants without difficulties in C did not differ between T1 and T2 ($p = .867$), between T1 and T3 ($p = .729$), nor between T2 and T3 ($p = 1.000$).

The results observed for the participants with SWSN status were different from the results for those without difficulties. Thus, the performance of the participants with SWSN status in the TSF group after the intervention (T2 and T3) was significantly higher than before the intervention (T1; $p = .015$ and $p < .001$, respectively). Also, there were no significant differences between T2 and T3 ($p = .875$). The performance of the participants with SWSN status in the TF group did not differ between T1 and T2 ($p = .124$), between T1 and T3 ($p = .447$), nor between T2 and T3 ($p = .875$). The situation was the same for those with SWSN status in the C group. Their performance did not differ between T1 and T2 ($p = 1.00$), between T1 and T3 ($p = .541$), nor between T2 and T3 ($p = 1.00$).

Discussion

The main objective of this study was to assess the effectiveness of two intervention approaches on spelling acquisition in French for students with and without special needs. We wanted to assess whether explicit instruction about the semantic properties of words could contribute to spelling acquisition beyond what can be achieved by teaching only the formal properties of words. Our results are interesting because they provide insights into the practices on which teachers should focus to promote spelling acquisition and, more specifically, the learning of words' visual-orthographic phenomena. Even though this study was about the development of French's orthographic representations, results could be relevant for other inconsistent orthographies such as English. These results will be discussed according to our two research questions. Also, we will present the limitations of the study.

Does the explicit teaching of both semantic and words' visual-orthographic phenomena promote more spelling acquisition than does the explicit teaching of words' visual-orthographic phenomena alone?

When we look at the overall results presented in Section 3.3.1, the intervention implemented for the participants in the TSF and TF groups seemed to have contributed equally to the development of orthographic knowledge in the context of word production, and this learning seemed to have lasted for six weeks after the end of the intervention. In other words, whether the teaching focused solely on the words' visual-orthographic phenomena and semantic properties of words, the spelling gains were similar. These results are encouraging because they are consistent with studies that have tested the effects of explicit instruction within the context of specific training programs that have shown benefits for students in terms of gains in orthographic knowledge in French, as it is the case

with other inconsistent orthographies (Casalis & Colé, 2009; Daffern, 2017; Daigle et al., 2020; Fayol et al., 2013; Marin & Lavoie, 2017; McLaughlin et al., 2013; Squires & Wolter, 2016).

By developing the different experimental teaching conditions, we wanted to evaluate whether teaching semantic properties could contribute to learning to spell beyond what teaching the formal properties of words alone can provide. Indeed, as we saw in Section 1.3, lexical representations are made up of a body of knowledge that contributes to the quality of these representations (Apel, 2011; Perfetti & Hart, 2001, 2002). More specifically, students have phonological and semantic knowledge associated with these words to which can be added knowledge of a spelling nature. However, we did not see any differences between the overall performances of participants in the TSF and TF groups regardless of the time of testing. We think that the most obvious explanation for this is related to our choice of words. As we described in Section 2.4, we decided to select words that were known orally and not known in writing because we did not want to use a vocabulary teaching approach. If words were known orally, it indicated that the participants were familiar with their meaning. This may explain why teaching semantic properties may not have added value in terms of orthographic knowledge acquisition for the participants without difficulties in a context of word production. However, we felt that teaching the semantic properties of words would consolidate the knowledge that the participants already had and thereby contribute to spelling acquisition.

Teaching semantic properties probably consolidates the quality of lexical representations in memory (i.e., vocabulary learning), but the influence on the development of the formal properties of written words may be more negligible when we try to explain the performance of the participants without difficulties. On a more positive note, the teaching of semantic properties seemed to be particularly relevant for the participants with SWSN status in our study.

Does the explicit teaching of both semantic and words' visual-orthographic phenomena promote more spelling acquisition than does the explicit teaching of words' visual-orthographic phenomena alone based on students' status (without difficulties, SWSN)?

We observed that the participants without difficulties always performed better than those with SWSN status regardless of the group and time of testing. This finding is unsurprising and reflects the results of numerous studies that have shown that SWSN are weaker in spelling than students without difficulties in French and for other inconsistent orthographies (Berninger et al., 2008; Daigle et al., 2016; Maughan et al., 2009).

Also, we observed that the intervention did not have the same effect for the participants without difficulties and for those with SWSN status. The results for participants without difficulties were similar to the overall results presented in Section 3.3.1. The intervention implemented was as beneficial for students of the TSF group as it was for the TF group. This result is not surprising considering that more than 80% of the participants in our sample (see Section 2.3) were students without difficulties.

We observed a different pattern of results for the participants with SWSN status. The results show that the SWSN of the TSF group made significant progress over time, but no statistically significant progress was observed for the SWSN of the TF and the C groups. This result is of particular interest because it shows that teaching semantic properties seems relevant, but this is especially the case for SWSN who are often considered to have less

precise lexical representations (Coleman et al., 2008; Daigle et al., 2016; Plisson et al., 2013). Thus, those with SWSN status probably need additional support when learning to spell. This support, which we operationalized as teaching the formal and semantic properties of words, showed that this interaction of knowledge of different natures probably contributes best to the quality of the lexical representation developed by students and thus on their spelling ability (Apel et al., 2019; Nation, 2013; Perfetti & Hart, 2001, 2002). The teaching of formal and semantic properties of words may also be beneficial for students who enter school with a more limited vocabulary because they have, for example, a developmental language disorder, or because they have grown up in a less stimulating environment (McGregor et al., 2013; Motsch & Marks, 2015). This additional support also seems relevant when the diversity in today's classrooms with students from different linguistic backgrounds is considered (Bauer et al., 2019; Larochelle-Audet et al., 2016; Nation, 2013).

It is also possible that the differences between SWSN and participants without difficulties that we observed may be the consequence of the small number of SWSN in our sample and the type of analyses that we conducted. Thus, considering that there were only eight SWSN in each group and that each response was scored as correct or incorrect (1 or 0), we found more variability in the pattern of results for the SWSN than for the participants without difficulties.

Limitations and Implications for Further Research

The first limitation relates to the assessment of the semantic properties associated with the words. Unfortunately, it is impossible to know whether the participants had made progress in the detailed knowledge of the meaning of words because these data were not tested. Although this research focused on the effects of intervention on learning the formal properties of words, it would have been interesting to see whether the intervention also promoted learning the semantic properties of words. To do this, a measure to assess meaning (such as an association test between words and definitions) could be developed and tested in future studies to verify students' learning associated with different types of knowledge related to words.

The second limitation of this study relates to the small number of SWSN in each group ($n = 8$) and the lack of precision in identifying the origin and nature of these students' specific difficulties. Because we intended to conduct a study that was as ecological as possible, we selected intact classes. Given that the education system tends to be more and more inclusive, the classrooms included a variety of students among which there were SWSN. However, these students, although relatively numerous, were not the majority in these regular classes. Comparing their performance with those of students without difficulty was an interesting way to understand the effects of the intervention on the development of the spelling skills of primary school students. This allowed us to establish performance profiles as well as interventions appropriate for these profiles. If the number of SWSN had been greater, statistical analyses would have been more powerful.

Although the limitations of the study, the results obtained during this study have implications for further research. First, it would be interesting to conduct a similar study comparing two groups of the same size (with approximately the same number of students) but each group with a different status (without difficulty, SWSN).

Second, it would be interesting that in a future research, teachers implement in their classroom the experimental intervention protocol we developed for this study. By conducting action research, we could describe the appropriateness of these practices for teachers and promote their integration into different school environments. A larger number of studies, including training studies, would allow a definite advance both theoretically and practically.

The implementation of this study was strongly tied to our desire to contribute to the improvement of spelling teaching practices among French-speaking students in primary schools with and without special needs. The results of this study exceed French-speaking students; they can also be considered for the teaching of other inconsistent orthographies. The implications for further research proposed earlier imply that teachers have previously been made aware of the different properties that characterize the French spelling code (and more specifically the words' visual-orthographic phenomena) and the teaching principles underlying their acquisition.

It is on this premise that the recommendations for the initial and continuing training of teachers are based. Indeed, the results of this research can be useful to decision makers (to update the educational curriculum, for example), to teacher trainers (pedagogical advisors, lecturers), to current teachers, and to future teachers. Also, the data obtained provide information on aspects of spelling that are more complex for students to internalize. Finally, the results can contribute to updating teacher training (initial and continuous) to promote the use of teaching practices that support the development of spelling proficiency and, thereby, literacy skills.

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Declaration of interest

The authors report there are no competing interests to declare.

Ethical adherence statement.

The authors declare that this study was performed in accordance with the research ethical guidelines and was approved by the research ethics board of the Université of Montreal.

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Appendix A

Description of baseline measures.

Plausibility Judgment Task (Daigle, 2003)

Daigle, D. (2003). *Étude des traitements phonémique, syllabique, morphologique et visuo-orthographique en lecture chez des élèves sourds du primaire et du secondaire* [Unpublished doctoral thesis]. Université de Montréal.

30 minutes, with the whole classroom

To assess the quality of the phonological representations of the participants, we administered a plausibility judgment task from Daigle (2003). During the test, three pseudowords were presented to the student. Participants were asked to read each pseudoword silently and circle which of the two bottom items (*manilpo* or *maniplo*) most closely resembled the top item (*manipro*). In this case, *maniplo* was more like *manipro*, because the two items have the same syllabic structure. One point was awarded for each correct answer (total out of 40). No points were awarded for errors. The score of each participant corresponded to the percentage of success in this test.

Visual-Orthographic Judgment Task (Plisson, 2017)

Plisson, A. (2017). *L'appropriation des connaissances visuo-orthographiques par des élèves de la première à la quatrième année du primaire* [Doctoral thesis, Université de Montréal]. Papyrus. <http://hdl.handle.net/1866/20055>

45 minutes, with the whole classroom

To assess the quality of the orthographic representations of the participants, we administered a visual-orthographic judgment task from Plisson (2017). During the test, three homophone spellings of the same words were presented to the students (e.g., *lappin** [bunni*], *lapain** [buny*], *lapin* [bunny]). Participants were asked to read each pseudoword silently and circle the correct spelling among the three homophones presented (e.g., *lapin* [bunny]). No words were inflected, either in the plural or in the feminine. One point was awarded for each correct answer (total out of 88). No points were awarded for errors. The score of each participant corresponded to the percentage of success in this test.

Word Dictation Task (Ruberto et al., 2016)

Ruberto, N., Daigle, D., & Ammar, A. (2016). The spelling strategies of francophone dyslexic students. *Reading and Writing*, 29(4), 659-681.
<https://doi.org/https://doi.org/10.1007/s11145-019-09965-4>

30 minutes, with the whole classroom

To assess the participants' ability to produce words, we administered a gap-dictation test of 24 words varying in complexity and in complexity. This test was developed by

Ruberto et al. (2016) and was used in other studies such as Costerg (2018), Plisson (2017) and Daigle et al. (2020). One point was awarded for each word that was read correctly and no points were awarded for errors. One point was awarded for each correct answer (total out of 24). No points were awarded for errors. The score of each participant corresponded to the percentage of success in this test.

Word Reading Task (Jacquier-Roux et al., 2010)

Jacquier-Roux, M., Lequette, C., Pouget, G., Valdois, S. et Zorman, M. (2010). *BALE : batterie analytique du langage écrit*. Laboratoire Cogni-Sciences.

5 minutes, individually in a quiet room of the school

To assess the participants' ability to recognize words, we used the word reading test in the *Batterie Analytique du Langage Écrit* (Jacquier-Roux et al., 2010). Individually, each participant should read aloud 40 words (20 regular words and 20 irregular words) as quickly and as correctly as possible. One point was awarded for each word that was read correctly and no points were awarded for errors. Two scores were calculated for each participant in this test: one from the number of regular words read correctly (total out of 20) and one from the number of irregular words read correctly (total out of 20).

Appendix B

List of 24 words selected for the intervention.

Word frequency is calculated according to the *Manulex* database (Lété et al., 2004).

Lété, B., Sprenger-Charolles, L. & Colé, P. (2004). MANULEX: A grade-level lexical database from French elementary school readers. *Behavior Research Methods, Instruments & Computers*, 36(1), 156-166. <https://doi.org/10.3758/bf03195560>

MANULEX is a Web-accessible database that provides grade-level word frequency lists of nonlemmatized and lemmatized words (48,886 and 23,812 entries, respectively) computed from the 1.9 million words taken from 54 French elementary school readers. For this study, we considered the U statistic, that is the estimated frequency per million words.

Words 1-6: Balou on vacation (TSF) / Balou at Halloween (TF)

Word	Written known	Orally known	Oral syllables	Frequency
<i>vallée</i> [valley]	7 %	98 %	2.00	45.13
<i>hôtel</i> [hotel]	7 %	98 %	2.00	49.20
<i>prudence</i> [prudence]	10 %	100 %	2.00	17.76
<i>ocean</i> [ocean]	17 %	98 %	3.00	70.33
<i>parcours</i> [journey]	0 %	83 %	2.00	24.90
<i>frontière</i> [border]	17 %	86 %	2.00	12.65
Mean	10 %	94 %	2.17	36.66

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only.

Words 7-12: Balou at the hospital (TSF) / Balou at the zoo (TF)

Word	Written known	Orally known	Oral syllables	Frequency
<i>professionnelle</i> [professional]	2 %	100 %	4.00	1.25
<i>épaule</i> [shoulder]	10 %	98 %	2.00	132.59
<i>menton</i> [chin]	10 %	98 %	2.00	22.86
<i>vivant</i> [living]	10 %	95 %	2.00	54.62
<i>héros</i> [hero]	7 %	98 %	2.00	16.49
<i>blesure</i> [injury]	5 %	100 %	2.00	18.88
Mean	7 %	98 %	2.33	41.11

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only.

Words 13-18: Balou visits the fire station (TSF) / Balou in the forest (TF)

Word	Written known	Orally known	Oral syllables	Frequency
<i>ruelle</i> [alley]	19 %	93 %	2.00	8.17
<i>policier</i> [police officer]	21 %	100 %	3.00	26.04
<i>incendie</i> [fire]	7 %	100 %	3.00	45.51
<i>angoisse</i> [anxiety]	2 %	76 %	2.00	20.52
<i>secours</i> [aid]	0 %	98 %	2.00	81.73
<i>sirène</i> [siren]	7 %	100 %	2.00	30.66
Mean	10 %	94 %	2.33	35.44

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only.

Words 19-24: Balou at the end of the school year (TSF) / Balou and gift wrapping (TF)

Word	Written known	Orally known	Oral syllables	Frequency
<i>nouvelle</i> [news]	21 %	81 %	2.00	49.05
<i>scolaire</i> [related to school]	12 %	98 %	2.00	31.15
<i>enveloppe</i> [envelope]	2 %	98 %	2.00	33.39
<i>reconnaissance</i> [recognition]	0 %	75 %	4.00	9.61
<i>succès</i> [success]	0 %	88 %	2.00	35.85
<i>apprentissage</i> [learning]	8%	96%	2.00	3.69
Mean	7 %	89 %	2.33	27.12

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only.

Appendix C

Titles of the stories read and the words taught according to group assignment.

Story	Group		Session	Details of the session
	TSF	TF		
# 1: Words 1-6	Balou on vacation	Balou at Halloween	1	Teaching of words 1-3
			2	Teaching of words 4-6
			3	Revision of words 1-6
# 2: Words 7-12	Balou at the hospital	Balou at the zoo	4	Teaching of words 7-9
			5	Teaching of words 10-12
			6	Revision of words 7-12
# 3: Words 13-18	Balou visits the fire station	Balou in the forest	7	Teaching of words 13-15
			8	Teaching of words 16-18
			9	Revision of words 13-18
# 4: Words 19-24	Balou at the end of the school year	Balou and gift wrapping	10	Teaching of words 19-21
			11	Teaching of words 22-24
			12	Revision of words 19-24
All	Balou's bingo!	Balou's bingo!	13	Revision of words 1-24

Note. TSF = Teaching semantic and formal properties; TF = Teaching formal properties only.

Appendix D

Step-by-step teaching protocol of words according to the TVS and TV groups

Step	Description	TSF	TF
1	Identify the picture corresponding to the spoken word. After reading the story, three images were presented to the students. They were then asked to vote for the image corresponding to the target word. (e.g.: Which of these three images corresponds to the word <i>vallée</i> ?)	✓	
2	Define each word with the students and situate them in the context of the story (meaningful context). Students were then asked to define the target word based on the context of the story read to them. After that, the definition appeared under the image of the target word. Links with other words of the same lexical field were also made.	✓	
3	Divide each word into syllables. To guide the participants in their reflection, empty boxes corresponding to the number of oral syllables in the word appeared on the screen. (e.g., What syllables do you hear in the word <i>vallée</i> ? [va] [le])	✓	✓
4	Divide each syllable into phonemes. (e.g., What is the first sound you hear in the syllable [va]?)	✓	✓
5	Transcribe each phoneme by a grapheme. The written form of the word was shown to the participants to help them make connections between the oral and written forms. (e.g., What letter or group of letters allows you to write the sound [v]?)	✓	✓
6	Look at the presence of silent letter(s). If there was a silent letter in the word, it was highlighted in another color. Thus, the participants could realize that certain letters sometimes convey only information of a visual nature. (e.g., Is there a silent letter in <i>vallée</i> ? If so, which letter is it?)	✓	✓
7	Pay attention to potential spelling errors called “traps.” The participants were asked to think about the same visual-orthographic phenomena during the study (multigraphemic phonemes and silent letters). The word <i>vallée</i> had two traps: -ll and the silent -e.	✓	✓