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Cascaded processing in written naming: Evidence from the picture–picture interference paradigm

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The issue of how information flows within the lexical system in written naming was investigated in five experiments. In Experiment 1, participants named target pictures that were accompanied by context pictures having phonologically and orthographically related or unrelated names (e.g., a picture of a "ball" superimposed on a picture of a "bed"). In Experiment 2, the related condition consisted of target and context pictures that shared the initial letter but not the initial sound. In both experiments, a facilitatory effect of relatedness was observed on the latencies. Experiment 3 tested whether phonology contributes to the facilitation effect found in the written latencies in Experiment 2 by using target and context pictures that shared the initial phoneme but not the initial grapheme. This experiment did not reveal any reliable difference between the related and unrelated conditions. In Experiments 4 and 5, control tasks were used to rule out a perceptual and conceptual account of the orthographic facilitation effect found in Experiment 2. The findings suggest that the recognition of an object leads to the activation of its name, and thus, that the activation within the lexical system in written-naming flows in a cascaded manner.

Keywords: Cascading; Written naming; Picture–picture interference.

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In the present study, we investigate how information flows within the lexical system in written naming. More precisely, we address the issue of how information is passed from the level of orthographic lexemes to the level of individual graphemes (these processing levels are described below). In contrast to speech production research, this issue has not, as yet, given rise to many studies in written naming in adults.

All models of language production distinguish between three major processing levels: conceptualisation, formulation, and execution (e.g., Bock & Levelt, 1994; Caramazza, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, & Meyer, 1999). However, agreement between researchers is limited to this very broad distinction. Indeed, there is little agreement on the precise number of processing levels which are needed to go from a concept to be expressed to its actual execution[1]. Researchers agree that, at the lexical level, in addition to a holistic lexical level (following Goldrick and Rapp, 2007, the neutral term "L-level" is used), a level where individual sounds are represented is needed to account for speech errors such as phoneme exchanges (e.g., "heft lemisphere" for "left hemisphere", Fromkin, 1971) or context-dependent syllabification (e.g., Levelt et al., 1999). Turning to the issue of how information flows within the language production system, there is even less agreement among researchers. For a long time, this issue has fuelled a debate in the field of speech production between proponents of the discrete-serial view (Levelt et al., 1999) and those who support the cascaded (and interactive) views (e.g., Caramazza, 1997; Dell et al., 1997; Humphreys, Riddoch, & Quinlan, 1988). In recent years, however, the bulk of empirical data seem to favour the cascaded view of speech production.

As far as written production is concerned, not enough empirical data have been gathered using real-time experiments in adults. Virtually, all our knowledge comes from the analyses of brain-damaged patients. As a result, models of written-word production have mostly been provided by cognitive neuropsychologists (e.g., Caramazza, 1997; Caramazza & Hillis, 1990; Ellis, 1982, 1984, 1988; Rapp, 2001). The processing levels which have been identified are to some extent similar to those involved in spoken-word production (Bonin & Fayol, 2000; Bonin, Fayol, & Gombert, 1998). As in spoken naming, written naming involves a

[1] There has been some debate as to whether speech production entails the activation of a neutral level, called the lemma, which mediates between concepts and the lexical form of the words (e.g., lexemes), or whether concepts map directly onto lexemes (e.g., Caramazza 1997; Miozzo & Caramazza, 1997; Roelofs, Meyer, & Levelt, 1996). As far as written production is concerned, there has been no such debate but the lemma-lexeme distinction is not critical for the issue we address here.

semantic level and a lexical level which correspond to holistic orthographic representations and sublexical representations. Sublexical orthographic representations corresponding to words include several dimensions: graphosyllables, consonant and vowel status of the graphemes, and identity of the graphemes and geminates (Tainturier & Caramazza, 1996). In handwriting, which is the output mode used in the present experiments, we distinguish between several postorthographic levels: allographic (which specifies case assignment and style), letter shape assignment, graphic motor pattern retrieval, and graphic execution (e.g., Ellis, 1988; Rapp & Caramazza, 1997). In order to clarify the specific predictions examined in the experiments, we have outlined a model of written naming which is based in part on proposals made by Caramazza (1997), Miceli, Benvegnù, Capasso, and Caramazza (1997, 1999), and Bonin, Peereman, and Fayol (2001). The model is depicted in Figure 1.

In the model, a first processing level consists of object identification which results in the activation of structural representations (Humphreys et al., 1988; Humphreys, Lamote, & Lloyd-Jones, 1995). The structural level corresponds to the perceptual descriptions of objects. These representations send activation to the semantic representations. Activation then flows, in parallel, from semantic representations to phonological and orthographic word forms (phonological and orthographic lexemes respectively). Finally, activation propagates from orthographic lexemes to individual graphemes (the grapheme level in Figure 1). Abstract representations corresponding to individual graphemes and their positions are specified at this level. Phonological and orthographic lexemes are not directly connected to each other, but they interact through sublexical connections between phonological and orthographic units (P > O and O > P in Figure 1). Evidence for such links has been provided from analyses of the errors made by brain-damaged patients (e.g., Miceli & Capasso, 1997; Miceli et al., 1997, 1999) and the performance from normals in real-time experiments (Bonin et al., 2001). We will return to this specific issue later when introducing the rationale of Experiment 2. In the model, activation is passed between the different levels in a cascaded manner (e.g., Caramazza, 1997). In contrast to spoken-word production, where evidence for a cascading architecture has accumulated in recent years from experiments involving online techniques, such evidence is clearly lacking in the field of written-word production. Most recent evidence on the cascading issue in speech production has been provided by means of the picture–picture interference paradigm (see below). We used this technique in the current study to provide evidence for a cascaded view of written naming.

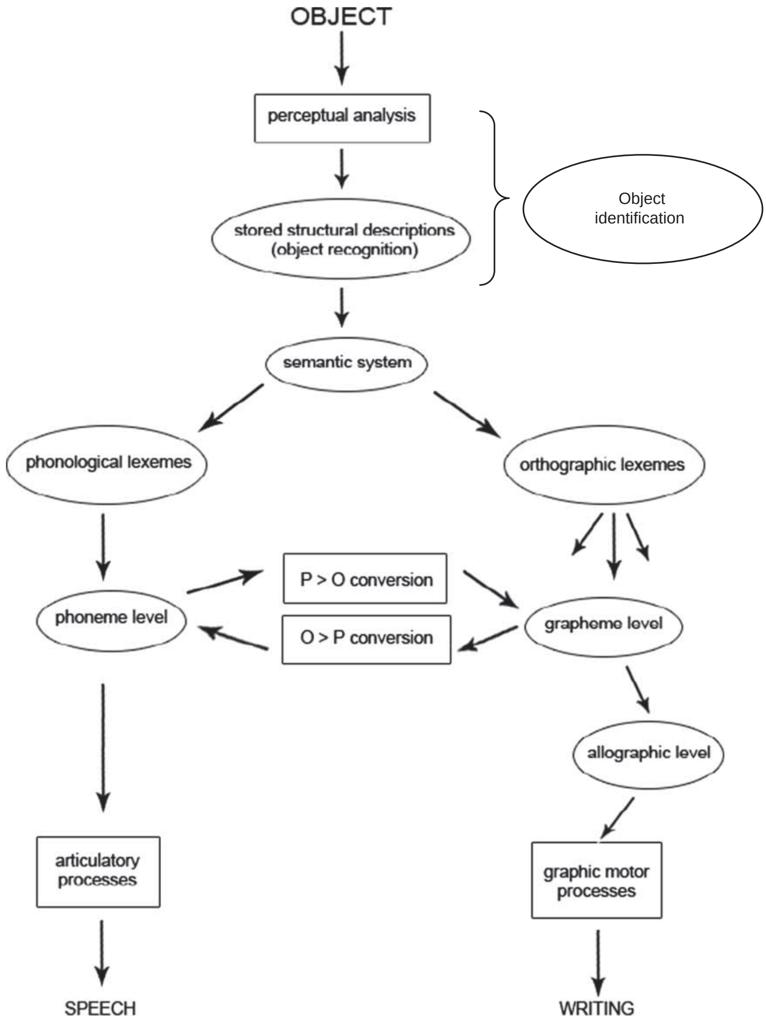

Figure 1. Working model of written naming.

EVIDENCE FOR CASCADING IN PICTURE NAMING WITH THE PICTURE–PICTURE INTERFERENCE PARADIGM

In the picture–picture interference paradigm, participants have to name a target picture while ignoring a superimposed context picture. The relationship between the target and the context pictures is manipulated. Morsella and Miozzo (2002) found that oral naming latencies in English were facilitated when the context pictures were phonologically related to the target pictures. More precisely, Morsella and Miozzo used line drawings of simple objects which were printed in two different colours (green and red). The two pictures were superimposed (e.g., the context picture "bell" surperimposed on the picture "bed") and participants had to name one of the two pictures (called the target picture), which was always the green one, while ignoring the red one. The context and target picture names were either phonologically related or unrelated. A reliable 22-ms phonological facilitation effect was found. Since this effect was found to be not significant in Italian participants (for whom the phonological relation does not apply), an interpretation in terms of perceptual or conceptual differences was ruled out. The finding was therefore interpreted as indicating that the phonology of the context picture is automatically activated, even though it has to be ignored. According to Morsella and Miozzo (2002), this finding challenges serial-discrete models and provides evidence for cascaded models. In effect, serial-discrete models assume that phonological activation is restricted to a selected lexical unit (a selected lemma according to Levelt et al., 1999), whereas cascaded models propose that multiple lexical candidates may become phonologically activated (Caramazza, 1997; Humphreys et al., 1988).

The findings obtained by Morsella and Miozzo (2002) have been replicated in Spanish (Navarrete & Costa, 2005) and in English (Meyer & Damian, 2007) but not in German (Jescheniak, Oppermann, Hantsch, Wagner, Mädebach, & Schriefers, 2009). Moreover, the phonological facilitation effect has been observed in a colour-naming task (Kuipers & La Heij, 2009; Navarrete & Costa, 2005) in which participants had to name the colour of a line drawing or a superimposed patch while ignoring the meaning of the object (e.g., the colour "blue" for the object "bed").

Most of the evidence relating to the flow of information in written naming comes from analyses of the errors made by brain-damaged patients. The existence of certain semantic substitution errors (e.g., "train" for a picture of a car) in picture-naming tasks suggests that not only is the target concept phonologically encoded but also the names of its semantic neighbours (e.g., Miceli, 2001; Rapp, Benzing, & Caramazza, 1997). However, for errors of selection to be taken as evidence that multiple lexical candidates are phonologically activated by target concept, it has to be established that the locus of the damage is not at the semantic level. Patients having a damage at the semantic level produce semantic substitution errors in all lexical tasks, whereas patients who have a damage within the lexical system, but not at the semantic level, produce semantic substitution errors in writing or in speaking but not in word comprehension (see Miceli, 2001, for a review). As far as speech errors are concerned, Levelt et al. (1999) have argued that they constitute derailments of the normal speech production system and do not tell us very much about normal functioning. Given this view, speech error data should be taken with great care.

The present study

For a long time, theories of written-word production were silent regarding the temporal dynamics of the activation of orthographic and phonological codes (e.g., Ellis, 1988). The situation was prevailing in part because the investigation of written naming with the use of on-line paradigms was very rare. Actually, there is still little chronometric data in the field of written-word production. Bonin and Fayol (2000) argued that cascading occurs in written naming on the basis of findings obtained with the picture–word interference paradigm. They found that distractor words which were semantically related to picture targets slowed down written naming, whereas phonologically and orthographically related distractors facilitated it, a result which is consistent with other findings reported in the speech production literature (e.g., Meyer & Schriefers, 1991; Schriefers, Meyer, & Levelt, 1990; Starreveld, 2000). More importantly, they also found that the semantic interference effect was reliably reduced when the distractors were also phonologically and orthographically related as compared to the unrelated distractors. According to the serial-discrete view, the semantic interference effect takes place at the level of lemmas whereas the facilitation effect acts at the level of phonological lexemes (Schriefers et al., 1990). Thus, the semantic interference effect should not be reliably modulated by a phonological relationship. The interaction between the factors of semantic and phonological relatedness found in both written and spoken naming (Bonin & Fayol, 2000; Damian & Martin, 1999; Starreveld & La Heij, 1995) has been taken to be at variance with the discrete-serial view, and instead, to favour a cascaded view of word production. However, this finding has given rise to a technical and complex debate (Roelofs, Meyer & Levelt 1996; Starreveld & La Heij, 1996).

In our view, what is needed is converging evidence for a cascading view of written naming obtained from real-time experiments involving healthy adults. This was precisely the goal of the experiments reported below. But why should we specifically address the cascading issue in written naming? After all, it could be argued that there are no principle reasons for which written production should be different from speech production concerning the temporal dynamics. Thus, the findings obtained in spoken-word production research should simply be translated to written-word production. Although this would not be a scientific attitude, such a claim has not as yet received strong empirical support, and thus, is essentially based on intuitive arguments. Also, writing is slower than speaking (Zesiger, Orliaget, Boë, & Mounoud, 1994) and whereas speakers have to strive for fluency, it may not be important to the same extent during writing. As a result, it is not obvious that information flows in cascade in writing, as has been found in speaking. Indeed, it seems plausible to hypothesise that writing permits serial-discrete processing.

Our assumption is that it is necessary to gather empirical data if we wish to propose views on the temporal dynamics of lexical access in written-word production. Given the strong theoretical implications that the findings obtained with the picture–picture interference have had in the field of spoken-word naming, it is a logical step to determine whether such effects can be observed in written naming. More importantly, at a theoretical level, we wanted in addition to determine whether cascading in written naming occurs between the orthographic lexemes and the individual grapheme levels or is mediated by phonological representations (Experiments 2 and 3). In effect, it has often been claimed that writing is entirely dependent on spoken language representations and processes (Aitchison & Todd, 1982; Geschwind, 1969; Hotopf, 1980; Luria, 1970). Hence, access to orthography would be dependent on the prior retrieval of the lexical phonological representation of the word. However, as we shall explain later, this traditional view has been seriously called into question (Rapp et al., 1997). Experiments 4 and 5 were control experiments designed to test whether the orthographic facilitation effect in written latencies is attributable to perceptual and conceptual factors.

EXPERIMENT 1

In Experiment 1, participants were presented with pictures of superimposed line drawings of objects, one in red (context) and one in green (target). They had to write down the name of the target picture while ignoring the context one. Our prediction was that written latencies should be shorter when the names of the target and context pictures were phonologically *and* orthographically related than when they were unrelated. Meyer and Damian (2007) obtained a context facilitation effect in a picture-naming task in British English when the context pictures were part of the response set, whereas Morsella and Miozzo (2002) obtained the effect when the context pictures were not present in the response set, that is to say they did not appear as targets in other trials. In Experiment 1, as in Morsella and Miozzo (2002), the context pictures were not overtly named and thus were not also used as target responses.

Method

Participants

Thirty-three undergraduate psychology students from Blaise Pascal University took part in the experiment in exchange for course credits. All were native speakers of French and reported having normal or corrected-to-normal vision.

Stimuli

Sixty-six pictures were selected from the Cycowicz, Friedman, Rothstein, and Snodgrass (1997) and Snodgrass and Vanderwart (1980) databases: 22 target pictures, 22 context pictures that served to create both the related and unrelated conditions and the 22 unrelated filler pictures. The superimposed picture stimuli were created with Photoshop CS2 software and fitted into squares of approximately 10 cm. The target pictures (line drawings of simple objects) were coloured green and the context pictures were coloured red. Each picture had a name agreement higher than 80%. The list of superimposed pictures is presented in the Appendix.

Each target picture appeared four times each: once without any distractor (i.e., the target picture was presented alone), once with a related distractor (e.g., "BOUGIE-banc" meaning CANDLE-bench; "PILE-pipe" meaning BATTERY-pipe), and twice with unrelated distractors. In the orthographically/phonologically related condition, the picture names of the target and distractor (context) shared at least the first phoneme and grapheme. We refer to these related composites as the related condition and the target picture is presented in capital letters. To create the unrelated control condition, the same target and context pictures were recombined (e.g., "BOUGIE-pipe" or "PILE-banc"). To reduce the number of related trials, 22 new context pictures were randomly paired with the targets. When designing the unrelated conditions, we were careful to avoid producing any pairs of semantically related pictures.

Apparatus

The presentation of the stimuli was controlled by a Macintosh (iMac) computer running the Psyscope v.1.2.5 software (Cohen, MacWhinney, Flatt, & Provost, 1993). A graphic tablet (Wacom Intuos 2) and a contact pen (UP-401) were used to record the written latencies.

Procedure

Participants were tested individually and comfortably seated in a quiet room. The experimental phase was preceded by a familiarisation and a training phase. During the familiarisation phase, the whole set of 66 individual pictures (i.e., the 22 target pictures, the 22 context pictures that served to create both the related and unrelated conditions and the 22 unrelated filler pictures) corresponding to black-and-white line drawings was presented twice in a random order on the computer screen. During the first presentation, the participants had to pay attention to the name of each picture which was printed below it. During the second presentation, the pictures were shown alone and the participants had to write down their names. A training phase was then administrated in which participants were instructed to write down the name of the target (green) pictures while ignoring the distractor (red) pictures. None of the superimposed pictures used during this phase were reused in the experiment proper. Overall, the experimental phase contained 88 trials (22 related pictures, 22 unrelated control pictures, 22 unrelated filler pictures, and 22 target pictures alone). There were four blocks of 22 trials with the same approximate number of "alone", "related", and "unrelated" trials. In each block, a given target picture appeared only once and four times across blocks. The presentation of the blocks was counter-balanced across participants. Within each block, the items were randomly presented.

Each trial began with a fixation point (+) displayed in the middle of the screen for 700 ms. The stimulus was then displayed in the middle of the screen and remained there until the participant's response or a 3,000-ms delay had elapsed. The participants were instructed to write down the name of the green picture as quickly (and as accurately) as possible on a graphic tablet while ignoring the context (red) picture. Written latencies were measured to the nearest millisecond from the onset of the visual display to the initialising of the first handwriting movement corresponding to the first letter name. The next trial was presented after an intertrial interval of 3,000 ms.

Results

Despite their high name agreement scores (i.e., more than 80%), the pictures "ballon" (meaning ball) and "tirelire" (meaning piggy bank) were named "balle" (meaning balloon) and "cochon" (meaning pig), respectively, in more than half of the trials. Thus, the latencies corresponding to these pictures were discarded from further analyses.

In Experiment 1, as well as in the following experiments, observations were discarded from the latency analyses whenever any of the following conditions applied: (a) a spelling error was produced; (b) a technical error occurred; (c) the participant did not remember the picture name or used a name other than the expected one; and (d) the written latency was longer than 2,000 ms or shorter than 300 ms. This resulted in the exclusion of 2.3% of the data.

Analyses were performed on written latencies and on errors with the Type of Distractor (no-distractor, related distractor, unrelated–recombined distractor) entered as the main factor. ANOVAs were conducted separately with participants and items as random factors (F_1: by participants; F_2: by items).

TABLE 1
Mean latencies, their standard deviations, and error rates obtained in Experiment 1 as a function of the Type of Distractor (no-distractor, related, unrelated)

	Latency		
Type of Distractor	*Mean*	SD	*Error rate (%)*
No-distractor	944	177	1.67
Related	1,026	144	2.42
Unrelated	1,042	154	2.88
Relatedness effect	−16		

Mean latencies, together with the associated standard deviations and error rates, are presented in Table 1.

The analyses of the error rates revealed no reliable effects of the Type of Distractor, $F_1(2, 64) = 1.61$; $F_2(2, 38) = 2.16$, $p < .10$. The main effect of the Type of Distractor was significant on latencies, $F_1(2, 64) = 55.35$, $MSE = 1{,}643$, $p < .001$; $F_2(2, 38) = 55.82$, $MSE = 1{,}074$, $p < .001$. As can be seen from Table 1, written latencies were the shortest in the no-distractor condition compared to the other distractor conditions. Importantly, related target pictures were named faster than unrelated pictures, $t_1(32) = 2.52$; $p < .02$; $t_2(19) = 1.74$, $p = .099$.

We examined whether the latency differences between the distractor conditions changed over the repetition of the material across blocks. A by-participant analysis[2] with Block included as a factor revealed a main effect of Block, with latencies decreasing over blocks (1,079, 1,011, 1,008, and 959 ms), $F_1(3, 96) = 28.98$, $MSE = 8{,}263$, $p < .001$, and of the Type of Distractor, $F_1(2, 64) = 93.14$, $MSE = 5{,}009$, $p < .001$, and no interaction between the two factors, $F_1 < 1$, was found.

Discussion of Experiment 1

The results showed that a relationship between the target and context picture names has a reliable influence on written-naming latencies. Thus, this result extends to the written modality the phonological facilitation effect found in the spoken modality (Meyer & Damian, 2007; Morsella & Miozzo, 2002; Navarrete & Costa, 2005). As far as written naming is concerned, it suggests that the orthographical lexemes of both the target and context pictures activate their individual graphemes. According to this hypothesis, the target name is produced faster because, in the related context condition, some graphemes are shared unlike in the unrelated condition where no graphemes

[2] Since there were only about one third of the items in each condition which were tested in each block, a by-item analysis was not feasible.

are shared. Since in the related context condition, the target and context picture labels shared not only the initial grapheme but also the initial phoneme, the locus of the context facilitation effect remains to be determined. It is not possible to conclude that the facilitation effect is due to the cascading of orthographic lexeme information to individual graphemes. An alternative scenario, which involves the mediation of phonological information in written naming, remains a possibility. This was tested in Experiment 2.

EXPERIMENT 2

According to the obligatory phonological mediation hypothesis, access to orthography in written-word production is dependent on the prior retrieval of the corresponding phonological representations (Geschwind, 1969; Luria, 1970). This traditional position is consistent with the observations of phonologically based spelling errors (Aitchison & Todd, 1982) such as homophone substitutions (e.g., "there" for "their"), or phonologically plausible pseudoword production (e.g., "dirth" for "dearth"), and with the introspective experiences of the inner speech that accompanies writing (Hotopf, 1980). However, the obligatory phonological mediation hypothesis has been called into question by analyses of errors in brain-damaged patients. First of all, written performance in naming can be relatively spared when compared to spoken performance even though the difficulties in the latter skill cannot be ascribed to the articulatory processes (e.g., Rapp et al., 1997; Shelton & Weinrich, 1997). Secondly, some patients exhibit inconsistent lexical responses in written and spoken productions in response to the same target (e.g., a correct written response and a spoken semantic error, or the reverse; or, two distinct semantic errors, for example, the spoken response "fork" and the written response "spoon" to the target picture "plate", Miceli & Capasso, 1997; Miceli et al., 1997, 1999). According to the obligatory phonological mediation hypothesis, different semantic responses for the same target in spoken (vs. written) picture naming are not expected because phonology underlies both forms of language production. To account for the neuropsychological data, the orthographic autonomy hypothesis (Miceli et al., 1997; Rapp et al., 1997) assumes that the retrieval of orthographic codes does not obligatorily require the prior access to phonology. This is because activation from semantic representations propagates directly and in parallel to the orthographic and phonological word forms and then to individual graphemes (see Figure 1). Nevertheless, phonology plays a constraining role in accessing orthographic representations by means of a sublexical conversion procedure as the pathological data strongly suggest (see Miceli et al., 1997, 1999). Moreover, in healthy adults, Bonin et al. (2001)

have provided evidence in written-picture-naming experiments which accords with the hypothesis that phonology constrains written production in picture naming, at a sublexical level, through a phoneme–grapheme conversion procedure.

Given the above theoretical background, it is possible to hypothesise that the facilitation effect found in Experiment 1 occurs because of a phonological influence in written production. In this scenario, cascading activation takes place at the level of phonological lexemes and individual phonemes. Activated phonemes are then converted into graphemes by means of the conversion procedure. In the related context condition, the shared graphemes of the target and context pictures receive more activation than in the unrelated conditions because of the involvement of the sublexical phoneme–grapheme procedure. Thus, the facilitation effect observed in Experiment 1 can, in principle, be accounted for without assuming the cascading of information from the orthographic lexeme level to the level of individual graphemes.

In order to test this hypothesis, we used pairs of pictures whose names were orthographically related but phonologically unrelated. More precisely, the target and context pictures shared the initial grapheme but not the initial phoneme. In this way, it was possible to distinguish between the contributions of phonology and orthography in the facilitation effect found in Experiment 1.

Method

Participants

Twenty-seven undergraduate psychology students taken from the same pool as in Experiment 1 were involved and were given course credits. None of them had taken part in Experiment 1.

Stimuli

The drawings taken from the same databases as in Experiment 1 were used. The target pictures were coloured green and the context pictures were coloured red. Target and distractor (context) pictures were then paired in line with the (orthographically) related and unrelated experimental conditions. In the related condition, the target and the context picture names shared the initial grapheme but not the initial phoneme. For example, the French words "cigar" (cigar) and "camion" (truck) share the same initial grapheme "c", but they have different initial phonemes, /s/ and /k/, respectively. Since the relationships between graphemes and phonemes in French are quasi-systematic, there are only a few words which share the same first grapheme but have a different initial phoneme. We were therefore able to select only 17 pairs of superimposed pictures in the orthographically related condition. Thirty-four superimposed pictures were used to create the unrelated conditions. As in Experiment 1, the unrelated condition was created by recombining the target and context pictures from the related condition. Also, to reduce the number of related trials, we included as fillers 17 new distractor pictures that were matched to the 17 target pictures. The list of items is provided in the Appendix.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1. There were 68 trials in the experimental phase (17 in the orthographically related condition, 34 in the two unrelated conditions, and 17 in the no-distractor condition). Four blocks of 17 trials were created. As in Experiment 1, we were careful to avoid producing pairs of pictures that were semantically related. A no-distractor condition was again included, in which each target picture was presented alone.

Results

The data corresponding to two pictures ("ail" meaning garlic, "agenda" meaning diary, and "oignon" meaning onion) were excluded from the analyses because of a high error rate, that is, more than 25%. As a result, the analyses were performed on the remaining 14 items. We then applied the same exclusion criteria to the written latencies as those used in Experiment 1. This led us to discard 4.1% of the data. The analyses were run on the mean latencies and the error rates with participants and items as random factors and with the Type of Distractor (no-distractor, related distractor, unrelated distractor) as an experimental factor.

There were no reliable effects of the Type of Distractor on error rates, $F_1(2, 52) = 1.81$; $F_2(2, 26) = 1.00$, but a reliable one on latencies, $F_1(2, 52) = 24.02$, $MSE = 1{,}097$, $p < .001$; $F_2(2, 26) = 10.62$, $MSE = 1{,}264$, $p < .001$. Target pictures were named faster in the no-distractor condition than in distractor conditions. As shown in Table 2, target pictures were named faster in the related condition than in the unrelated condition, $t_1(26) = 4.55$; $p < .001$; $t_2(13) = 2.25$, $p < .05$.

As in Experiment 1, we examined whether the latency differences between the experimental conditions changed across blocks. The analysis with Block included as a factor indicated that there was a main effect of Block, with latencies decreasing over blocks (903, 777, 751, and 747 ms),

TABLE 2
Mean latencies, their standard deviations, and error rates obtained in Experiment 2 as a function of the Type of Distractor (no-distractor, related, unrelated)

	Latency		
Type of Distractor	*Mean*	SD	*Error rate (%)*
No-distractor	743	144	2.65
Related	771	142	4.50
Unrelated	805	150	3.44
Relatedness effect	−34		

$F_1(3,\ 78) = 37.09$, $MSE = 11{,}791$, $p < .001$, and of the Type of Distractor, $F_1(2,\ 52) = 21.57$, $MSE = 5{,}195$, $p < .001$, and no interaction between the two factors, $F_1(6,\ 156) = 1.39$.

Discussion of Experiment 2

A context facilitation effect was also observed in Experiment 2. Importantly, the context effect was due to the orthographic relationship since the target and distractor (context) picture names shared initial graphemes and not initial phonemes. Before we discuss the implications of the data, we need to comment on the overall latencies. The written latencies were 200–300 ms shorter overall in Experiment 2 than in Experiment 1. The explanation that most readily comes to mind to account for the difference in latencies is a difference in the objective frequencies of the target object names (and/or the distractor object names) used in the two experiments. An examination of a number of different frequency measures for the target (and distractor) names taken from the Lexique database (New, Pallier, Ferrand, & Matos, 2001; New, Pallier, Brysbaert, & Ferrand, 2004) revealed that neither the frequency values calculated for web-based material, nor those calculated for text corpora could account for the overall difference in latency because none of the differences was reliable. We then examined several other potential variables which could account for the difference in latency across the two experiments. More precisely, we considered the visual complexity of the pictures, as well as image agreement and name agreement for both the target and the distractor, respectively. The results of these analyses were negative: none of the variables could be identified as a potential explanation for the difference. At present, we are unable to think of any other possible variable that might account for the fact that the general mean latency was longer in Experiment 1 than in Experiment 2. We therefore suggest that the use of different participants in the two experiments is responsible for the difference. Importantly, although the overall written latency in Experiment 2 was short, this finding is not exceptional since a number of previous written picture naming studies have found an overall mean written latency close to the value which we observed (in Bonin & Fayol's, 2000, Experiment 3, the overall mean written latency was 840 ms, while the corresponding values were 678 and 735 ms in Zhang and Damian's, 2010, Experiments 1 and 2, respectively).

If we now look at the difference in the size of the relatedness effects between Experiments 1 and 2, we find that the effect was twice as large in the second than in the first experiment (34 ms vs. 16 ms, respectively). Could this difference be because the orthographic relationship was smaller in Experiment 1 than in Experiment 2? The percentage orthographic overlaps between the distractor and the target (i.e., when the same letter occurred at the same position in both the distractor and the target) were 30% and 35%, respectively, and the difference was found to be nonsignificant, $t(37) = 1.05$, $p > .05$. If we now consider the size of the effects using the η^2, the values were .165 in Experiment 1 and .443 in Experiment 2. In line with Cohen (1988), both effects are qualified as "large". One remaining way to account for the numerical (related-unrelated) difference between Experiments 1 and 2 would be to suggest that, because the latencies were longer in the former than in the latter experiment, a part of the form facilitation effect had dissipated by the time the participants started writing.

The form facilitation effect found in Experiment 2 has a strong theoretical implication because it suggests that the orthographic representations of both the target and context pictures simultaneously activate their graphemes, as proposed by a cascaded view of written naming. However, before accepting this explanation, we have to examine two alternative hypotheses. First of all, even though we selected pairs of items that were orthographically, but not phonologically, related, it could still be argued that the facilitation effect is due to phonological code activation. In effect, in the sublexical version of the obligatory phonological mediation hypothesis (Luria, 1970), the orthographic facilitation effect in Experiment 2 would be because the phonological lexemes activate their individual phonemes which are subsequently converted into individual graphemes. However, the assumption that the orthographic facilitation effect results from the conversion procedure does not resolve the question of how this procedure leads to the correct production of the target grapheme in cases where the correspondence between phonology and orthography is not the one that occurs most frequently. This problem arises from the fact that it has often been assumed that the conversion process uses frequency criteria when applying phoneme–grapheme correspondences, that is, by selecting the most frequent ones (Tainturier & Rapp, 2001). A close examination of the stimuli used in Experiment 2 revealed that 8 of the 14 context stimuli had names whose initial phoneme was associated with the most frequent grapheme and corresponded to that of the target name. Even though the evidence that has so far been collected strongly supports the orthographic autonomy view (Rapp et al., 1997; Miceli, 2001), according to which the activation of phonological codes is not a prerequisite for orthographic encoding, this hypothesis does not preclude the possibility that phonological codes may play a role in orthographic encoding. As a result, we cannot exclude the possibility that, at least in some trials, phonology contributed to the orthographic facilitation effect found in Experiment 2. We therefore designed a third experiment to test the hypothesis of a phonological contribution in the facilitation effect found in Experiment 2 more directly. As reported below, Experiment 3 complemented Experiment 2 by presenting pairs of pictures whose name–initial segments were phonologically, but not orthographically, related, for example, "singe" (monkey) – "ceinture" (belt).

Second, it could be argued that the target pictures in Experiment 2 were more difficult to distinguish from the context pictures in the unrelated than in the related condition, thus inadvertently creating what we have interpreted as a form relatedness effect. In other words, the clear advantage of the related over the unrelated condition could be because more time is needed to extract the visual information of the green target from the red lines of the context drawing in the unrelated condition than in the related condition. Thus, the difference in written latencies between these two conditions could be explained by differences arising at the level of perceptual and conceptual identification processes instead of being considered to reflect the activation of orthographic representations. To test this hypothesis, we used an object identification task in Experiment 4.

EXPERIMENT 3

A crucial tenet of the orthographic autonomy view (Miceli, 2001; Rapp et al., 1997) is that the activation of phonological codes is not a prerequisite for orthographic encoding. However, the orthographic autonomy view does not exclude the possibility that phonological codes are a source of input to the output orthographic lexicon (see Figure 1). In particular, there is evidence that sublexical phonology contributes to orthographic encoding by means of a phoneme-to-grapheme conversion procedure (Alario, Schiller, Domoto-Reilly, & Caramazza, 2003; Miceli et al., 1999). If sublexical phonology contributes in the orthographic facilitation effect found in Experiment 2, a form facilitation effect should be observed in written-naming performance when the superimposed pictures have names which are phonologically, but not orthographically, related. The purpose of Experiment 3 was, thus, to identify the locus of the (orthographic) form facilitation effect found in Experiment 2, by selecting picture pairs which shared the initial phoneme, but not the initial grapheme, for example, "cup" and "kick".

Method

Participants

Thirty undergraduate psychology students from the University of Bourgogne (Dijon) took part and were given course credits. None of them had been involved in any of the previous experiments.

Stimuli

In this experiment, the drawings were again taken from the same databases as in Experiments 1 and 2. The target pictures were coloured green and the context pictures were coloured red. In the related condition, the target and the context picture names shared the same initial phoneme but not the same initial grapheme, as for example in the pairs "singe" and "ceinture" where the sound /s/ is shared but the graphemes are different ("s" and "c", respectively). Twenty pairs of superimposed pictures were selected in the phonological-related condition. Twenty superimposed pictures were used for the unrelated conditions which were, as the previous experiments, created by recombining the target and context pictures from the related condition. We also included 20 new distractor pictures to reduce the number of related trials. The list of items is provided in the Appendix.

Apparatus

The apparatus was the same as in the previous experiments.

Procedure

We used the same procedure as in Experiments 1 and 2. There were 80 trials divided into four blocks of 20 trials each: 20 in the phonologically related condition, 20 in each of the two unrelated conditions, and 20 in a no-context condition in which each target picture was presented without any distractors. None of the pairs of pictures was semantically related.

Results

The same exclusion criteria that had been used in Experiments 1 and 2 were again applied to the written latencies. This led us to discard 3.6% of the data. The analyses were run on the mean latencies and the error rates with participants and items as random factors and with the Type of Distractor (no-distractor, related distractor, unrelated distractor) as an experimental factor.

As shown in Table 3, there were fewer errors in the no-distractor condition than in the distractor conditions. The main effect of the Type of Distractor

TABLE 3
Mean latencies, their standard deviations, and error rates obtained in Experiment 3 as a function of the Type of Distractor (no-distractor, related, unrelated)

	Latency		
Type of Distractor	*Mean*	SD	*Error rate (%)*
No-distractor	684	117	2.33
Related	767	129	5.00
Unrelated	771	134	3.17
Relatedness effect	−4		

on the error rates was significant, $F_1(2, 58) = 3.17$, $MSE = 0.705$, $p < .05$; $F_2(2, 38) = 3.41$, $MSE = 0.982$, $p < .05$. The difference in the error rates between the related and the unrelated conditions was reliable in the by-participants analysis only, $t_1(29) = 1.73$, $p < .05$; $t_2(19) = 1.59$, *ns*. In the case of latencies, the main effect of the Type of Distractor was reliable, $F_1(2, 58) = 110.15$, $MSE = 655.92$, $p < .001$; $F_2(2, 38) = 27.49$, $MSE = 1{,}878.16$, $p < .001$. Target pictures were named faster in the no-distractor than in the distractor conditions. As shown in Table 3, the relatedness effect was small (–4 ms) and not significant, t_1 and $t_2 < 1$.

Discussion of Experiment 3

The aim of Experiment 3 was to assess whether there was a (sublexical) phonological contribution to the form facilitation effect found in Experiment 2. In effect, even though analyses of the naming performances of brain-damaged patients strongly favour the orthographic autonomy view of written-word production, according to which phonological code activation is not obligatory for orthographic code retrieval (Miceli & Capasso, 1997; Miceli et al. 1997, 1999; Rapp et al., 1997), some of the data obtained from both unimpaired and impaired adults suggest that phonological codes may, under some circumstances, play a role in orthographic encoding (Zhang & Damian, 2010). More precisely, there is evidence that a phoneme-to-grapheme conversion procedure is involved in orthographic encoding (Bonin et al., 2001; Folk & Jones, 2004; Miceli et al., 1997, 1999). Consequently, if, as explained above, the orthographic facilitation effect in Experiment 2 were due to the conversion of activated phonemes into graphemes, then this would imply that cascading takes place at the level of phonological lexemes and individual phonemes, and not at the level of orthographic lexemes and individual graphemes. In Experiment 3, we selected picture pairs whose name–initial word segments were phonologically related, but orthographically unrelated. When selecting the context pictures, we made sure that the initial phonemes of the associated picture names corresponded to the most frequent grapheme of the target names (e.g., for the pair “singe” (distractor) “ceinture” (target), the most frequent rendering for the phoneme /s/ is “c”). We adopted this approach because it has often been suggested that the conversion procedure converts sublexical phonological units to orthographic units on the basis of the frequency of the phoneme–grapheme correspondences (Tainturier & Rapp, 2001). The findings of Experiment 3 were clear-cut: There was no reliable difference in the naming latencies between the related and unrelated distractor conditions. Experiment 3 strongly suggests that the form facilitation effect found in Experiment 2 was not driven by the activation of (sublexical) phonological codes. Finally, it is noteworthy that even though our results make clear that *sublexical phonology* does not underlie the orthographic facilitation effect found in Experiment 2, it could be argued that they do not rule out a *lexical* phonological contribution in orthographic encoding. Indeed, there are at least two ways to implement the influence of form-specific information on lexical selection. The first postulates direct connections between lexical representations in the phonological and orthographic lexicon, while the second postulates sublexical connections via sublexical conversion procedures. Nevertheless, the available evidence clearly favours the sublexical over the lexical version of the orthographic autonomy view since, when the sublexical conversion processes are severely damaged, lexically inconsistent responses are observed in multiple picture-naming tasks (Alario et al., 2003), whereas when these processes are spared there are no such inconsistent lexical responses. Moreover, when only one of the sublexical conversion procedures is damaged (e.g., phoneme–grapheme conversion), inconsistent lexical responses are produced in only one direction (e.g., say then write) in the double-naming task (Miceli et al., 1999). This set of observations provides clear support for the hypothesis that modality-specific lexical representations interact through sublexical conversion processes (Miceli et al., 1999). However, it should be recalled that the main purpose of our study was not to disentangle the two versions of the orthographic autonomy view, and it is clear that this issue will require further investigation.

The form effect found in Experiment 2 is most readily accounted for by assuming that information is cascaded from orthographic lexemes to individual graphemes (Figure 1). How these findings relate to earlier observations of a phonological influence in orthographic encoding will be addressed in the “General Discussion” section.

EXPERIMENT 4

In Experiment 4, we used an object identification task in which participants are presented first with a written name and then with a picture, and have to decide whether or not they both refer to the same object. This task has previously been used in several studies to control for perceptual and conceptual factors involved in picture naming (e.g., Bonin, Chalard, Méot, & Barry, 2006; Jescheniak & Levelt, 1994). In an in-depth examination of this task, Stadthagen-Gonzalez, Damian, Pérez, Bowers, and Marin (2009) provided evidence that it is a valid control task since it appears to be insensitive to lexical influences. If the facilitation effects observed in written picture naming in our experiments occur at the object recognition level, the target pictures ought to be identified more rapidly in the related than in the unrelated control conditions.

Method

Participants

Thirty undergraduate students were again taken from the same pool as in the previous experiments and rewarded with course credits for their participation. None of them had participated in any of the previous experiments.

Stimuli

The superimposed pictures that were presented in Experiment 2 were used in Experiment 3 for the "positive" (match) trials. To allow a direct comparison with the results from Experiment 2, we used only those pictures that were included in the analyses (i.e., the pictures of "ail", "agneau", and "oignon" were not included). Thus, there were 14 superimposed pictures in the related condition, 14 superimposed pictures in the unrelated condition, plus the set of 14 unrelated pictures that served as fillers in Experiment 2. As in Experiments 1 and 2, a no-context condition was used in which the 14 target pictures were displayed alone. In 56 positive trials, the target picture (in green) and the word referred to the same concept (e.g., the printed word "cigare" was followed by the superimposed pictures "CIGARE-camion"). In the 56 negative trials, the green picture and the printed word referred to two different concepts. The words used in the negative trials were the picture names of the target pictures of the positive trials. For the pictures of the negative trials, we took a new set of 56 pictures from the same databases. As for the positive trials, the negative trials consisted of 42 unrelated superimposed pictures and 14 isolated pictures. Overall, there were 112 randomly presented trials.

Apparatus

The presentation of the stimuli and the recording of the latencies were controlled by PsyScope 1.2.5 running on a Macintosh computer.

Procedure

Participants were tested individually in a quiet room. The experimental phase was preceded by a familiarisation task, which was the same as in Experiments 1–3. Importantly, the pictures used for the positive were presented together with those used for the negative trials. The experimental phase contained 112 trials. As in Stadthagen-Gonzalez's et al. (2009) study, each trial began with a printed word displayed in black in the middle of a white screen for 1,000 ms, immediately followed by a fixation point ("+") displayed for 750 ms. A randomly selected pair of superimposed green/red pictures was then displayed. The participants had to ignore the red picture, and decide, as fast and as accurately as possible, if the printed word and the green (target) picture referred to the same concept or not. They had to give their answer using two push buttons on the keyboard. They were instructed to use their dominant hand to press the "match" button. The superimposed pictures remained in view until the participant's response. If no answer was provided after a 1,500-ms delay, the next trial was initiated. Two consecutive trials were separated by a 900-ms delay.

Results

Latencies corresponding to incorrect responses amounted to 1.2% of the data and were removed from the analyses. Like Stadthagen-Gonzalez et al. (2009), we considered latencies corresponding to correct "match" responses. According to these authors, the "match" responses are a better index of the object recognition stage than the "no-match" responses since the latter are thought to be underpinned by more complex processes than "match" responses[3]. The analyses were run on mean latencies and on the error rates, with participants and items as random factors and with the Type of Distractor as an experimental factor.

There were no reliable effects on the error rates, both Fs < 1. The effect of the Type of Distractor was significant on decision times, $F_1(2, 58) = 4.52$, $MSE = 895$, $p < .05$; $F_2(2, 26) = 4.21$, $MSE = 610$, $p < .05$. Decision times were shorter when target pictures were presented alone (see Table 4) than when they were presented with a superimposed context picture. However, unlike in the previous experiments, mean decision latencies in the orthographically related condition did not differ reliably from those in the unrelated condition, $t_1(29) = 1.13$, *ns*; $t_2(13) < 1$. In the analysis with Block as a factor, the main effect of Block was reliable, $F_1(3, 87) = 6.99$, $MSE = 5{,}768$, $p < .01$, as well as that of the Type of Distractor, F_1(2,

[3] Stadthagen-Gonzalez et al. (2009) argued that no-match latencies might also reflects the use of a deadline response criterion for negative responses.

TABLE 4
Mean RTs, their standard deviations, and error rates obtained in Experiment 4 as a function of the Type of Distractor (no-distractor, related, unrelated)

	RTs		
Type of Distractor	*Mean*	SD	*Error rate (%)*
No-distractor	508	74	1.12
Related	520	70	1.34
Unrelated	524	69	1.12
Relatedness effect	−4		

58) = 7.47, $MSE = 5{,}835$, $p < .01$. However, the Block × Type of Distractor interaction effect was not significant, $F_1(6, 174) = 1.603$, $MSE = 4{,}781$.

Discussion of Experiment 4

Since the decision times in the object recognition task did not differ reliably in the related and unrelated conditions, it is not possible to account for the difference in naming times between the two conditions in terms of difficulties arising at the object recognition stage. However, although the difference between the related and unrelated conditions was not reliable, the trend was in the predicted direction. It could be argued that the object decision task we used was not sensitive enough to detect differences arising at the recognition stage involved in picture naming. We therefore used another control task, namely a natural-artifact categorisation task, in Experiment 5.

EXPERIMENT 5

The goal of Experiment 5 was to use a semantic categorisation task to test in more detail whether the facilitation effect found in the naming experiment was attributable to difference arising at the perceptual/conceptual level.

Method

Participants

Thirty-two psychology students from the same pool as the previous experiments were involved. They had normal or corrected-to-normal vision. They were given course credits for their participation.

Stimuli

These were the superimposed green/red pictures used in Experiment 4.

Procedure

The participants were tested individually in a quiet room. They were presented with the same familiarisation phase involving the black-and-white drawings used in Experiment 3. The experimental phase contained 56 trials. In 42 trials, the target pictures in green were superimposed over a context picture in red. In the remaining 14 trials, target pictures were presented alone. Each trial started with a fixation point (" + ") displayed for 1,000 ms. A randomly selected composite picture (or a single target picture) was then displayed. Participants were instructed to ignore the red context picture and to indicate, using two keys on the keyboard, as quickly (and accurately) as possible, whether the green target green picture depicted a natural or a man-made object. In the pool of 14 target pictures, 8 pictures corresponded to a natural item, and 6 corresponded to an artifact. The item remained on the screen until the participant made a response or was removed after 2,000 ms.

Results and Discussion

Latencies corresponding to errors amounted to 1.17% of the data and were removed from the Reaction Times (RTs) analyses. The analyses were run on categorisation latencies and on the error rates, with the Type of Distractor (no-distractor, related, unrelated) as an experimental factor and with participants and items as the random factors.

There were no reliable effects on the error rates, $F_1(2, 62) = 1.19$; $F_2(2,26) = 1.20$, but a reliable one on categorisation times, $F_1(2, 62) = 11.45$, $MSE = 2{,}300$, $p < .001$; $F_2(2, 26) = 18.33$, $MSE = 493$, $p < .001$.

As can be seen from Table 5, target pictures were categorised faster when they were presented alone than when they were accompanied by a superimposed picture. Target pictures were not categorised significantly faster when the context picture names were orthographically related than when they were unrelated, $t_1(31) < 1$; $t_2(13) = 1.03$, *ns*. With Block introduced as factor, the main effect of Block was reliable, $F_1(3, 93) = 12.03$, $MSE = 11{,}353$, $p < .001$, as well as that of the Type of Distractor, $F_1(2,$

TABLE 5
Mean RTs, their standard deviations, and error rates obtained in Experiment 5 as a function of the Type of Distractor (no-distractor, related, unrelated)

	RTs		
Type of Distractor	*Mean*	SD	*Error rate (%)*
No-distractor	614	131	1.79
Related	662	148	1.12
Unrelated	665	133	0.67
Relatedness effect	−3		

62) = 9.77, $MSE = 10{,}695$, $p < .001$. As in the previous control experiment, the Block × Type of Distractor interaction effect was not significant, $F_1(6, 186) = 1.55$, *ns*.

Overall, neither the decision times in the object recognition task in Experiment 4, nor the categorisation times in Experiment 5, differed significantly between the related and the unrelated conditions. Thus, it seems difficult to argue that the difference in the naming latencies between the two context conditions can be explained in terms of difficulties arising at the perceptual or the conceptual stage involved in picture naming.

GENERAL DISCUSSION

In five experiments we addressed the issue of how information cascades through the written production system. As explained in the "Introduction", this question is a subject of debate in the literature on spoken-word production. However, to our knowledge, this theoretical issue has not given rise to much empirical work in the field of written-word production. Much of the evidence on this issue has been provided by cognitive neuropsychologists. Cascaded models of word production hold that word planning consist of processing steps which are temporally ordered but which may overlap in time (Caramazza, 1997; Dell et al., 1997; Humphreys et al., 1988). A more specific question has been whether every concept that is activated in a speaker's mind leads to the automatic activation of the corresponding name (Morsella & Miozzo, 2002) or whether the activation of the name information is restricted in some way (Kuipers & La Heij, 2009).

In a series of five experiments conducted in French, we have obtained evidence for a cascading view of written-word production. In Experiment 1, participants named superimposed pictures of line drawings (a target picture in green and a context picture in red) whose names were phonologically and orthographically related or unrelated. In Experiment 2, the related condition consisted of target and context pictures that shared the same initial letter but not the initial sound. In both experiments, the written latencies were shorter with a distractor picture that was phonologically and/or orthographically related to the target than in the unrelated control conditions. Experiment 3 was the mirror image of Experiment 2 in that the form-related condition consisted of target and context pictures that shared the same initial sound but not the initial grapheme. In this experiment, the difference between the related and the unrelated conditions was not significant. In Experiment 4, an object identification task and in Experiment 5, a semantic categorisation task were used to test a perceptual/conceptual account of the orthographic facilitation effect found in Experiment 2. In both Experiments 4 and 5, the difference between the related and unrelated distractor conditions was not reliable. Experiment 1 thus extends to the written modality the main findings obtained by Morsella and Miozzo (2002) in the field of spoken naming. More importantly, the findings from Experiments 2 and 3 have an important theoretical implication because they strongly suggest that the locus of the context facilitation effect is at the level of orthographic representations and is not mediated by phonological information in accordance with the orthographic autonomy hypothesis (Rapp et al., 1997) and in contrast to the traditional obligatory mediation view (Aitchison & Todd, 1982; Geschwind, 1969; Hotopf, 1980; Luria, 1970). To our knowledge, our study is the first to report findings from the picture–picture interference paradigm which support the model of written-word production outlined in the "Introduction" in which information flows in a cascading manner from the level of the orthographic lexemes to the level of the individual graphemes. Given that writing is less common, less practiced than speaking and generally slower than speaking, and also because speakers but not writers, have to strive for fluency, it was not obvious that information flows in cascade in the writing system.

It should be remembered that the issue of cascading in word production has been a matter of intense debate in the speech production literature. A number of findings which have been reported as favouring a cascading view have been criticised by the proponents of the serial-discrete view (Levelt et al., 1999). A review of the different criticisms which have been raised against these studies is beyond the scope of the present paper. We simply wish to illustrate the types of criticism which have been put forward using the example of the Humphreys et al. (1988) study. Humphreys et al. (1988) showed, in picture naming, that word frequency had a greater impact in the case of pictures of objects belonging to structurally dissimilar categories (e.g., tools) than with pictures belonging to structural similar categories (e.g., fruits). This finding is consistent with a cascading view of spoken naming in which the information flow cascades from the structural level to the phonological level. As acknowledged by Levelt et al. (1999), the serial-discrete stage model of word production does not predict that structural similarity and name frequency will interact since the two factors affect different processing stages (the conceptual and the phonological lexeme levels respectively) which are serially connected. However, Levelt et al. (1999) have argued that word frequency might have been confounded with conceptual familiarity in the Humphreys et al. (1988) study. If this were the case, the interaction found by Humphreys et al. (1988) in picture naming latencies would not be at variance with a serial-discrete model. In effect, since conceptual familiarity and structural similarity act at the conceptual level, the discrete-serial view predicts an interaction between the two factors. Findings which pose difficulties for the discrete-serial view have often been criticised on such a priori methodological grounds. Furthermore, the proponents of the serial-discrete view have often argued against the cascaded view of word production on the basis of the absence of reliable effects in a variety of tasks. For instance, using a dual-task paradigm (i.e., picture naming and auditory lexical decision), Levelt et al. (1991) did not find evidence that the semantic neighbours of a target (e.g., "*goat*" for target "*sheep*") are phonologically encoded (see also Jescheniak, Hahne, & Schriefers, 2003) and consequently argued in favour of a discrete transmission of information. However, using the picture-word interference paradigm with multiple distractors (and not only one for any given trial as is generally the case), Abdel Rahman and Melinger (2008) found reliable inhibitory effects in picture naming latencies in Dutch when using multiple distractors which were phonologically related to the semantic neighbours of the target (e.g., "Haai" meaning shark was presented with the distractors "Dokter" and "Mandarijn" which are phonologically related to the semantic neighbour "Dolfijn" meaning dolphin). Thus, arguing against cascading in spoken naming on the basis of the absence of reliable effects, such as phonological relatedness effects of semantic distractors in picture naming latencies, holds only until the subtle differences in question have not been observed.

It could be argued that the evidence for cascading in written naming is less obvious than might appear at first glance. First of all, one may ask whether the learning of the pictures is responsible for the facilitation effects observed in the written-naming experiments. In effect, it could be that the learning phase had the outcome of preactivating lexical representations of the distractor pictures. However, Meyer and Damian (2007) have demonstrated in spoken naming using the same paradigm that the phonological relatedness effect was obtained in the presence, as well as in the absence, of a phase during which participants have to learn the names of the pictures. Second, in the control experiments (Experiments 3 and 4) that we conducted to rule out a perceptual or conceptual source of the facilitation effects found in written naming, although the difference between the related and unrelated conditions was not significant, it pointed in the same direction as the reliable effect obtained in Experiment 2. The same kinds of results were observed by Morsella and Miozzo (2002). It should be recalled that some researchers have criticised the phonological relatedness effect in the picture-picture paradigm since the presentation of superimposed picture complicates the visual identification processes. As stressed by Jescheniak et al. (2009), the critical interaction between the language (naming in Italian and in English) and distractor relatedness was not reported in the Morsella and Miozzo (2002) study. The authors considered that it is essential to observe a significant interaction between relatedness and the language of production before it is possible to definitely reject the perceptual stage as a potential locus for the phonological facilitation effect found in English. The same comment also applies to our data. Thus far, we have shown that the difference between the related and unrelated context condition was not reliable in the control tasks but we have not examined the interactions between the task (naming vs. control tasks) and the distraction conditions. Following the comment made by Jescheniak et al. (2009), we analysed the interaction between the Type of Distractor and the Type of Task used in Experiments 2 and 3 (written naming vs. conceptual verification task, respectively). The interaction was significant in the by-participant analysis, $F_1(2, 110) = 5.97$, $MSE = 990$, $p < .01$, and in the by-items analysis, $F_2(2, 26) = 3.92$, $MSE = 676$, $p < .05$. Overall, we feel confident that the reliable distractor effect found in Experiment 2 cannot be due to the perceptual characteristics of the stimuli. Finally, in the same vein, it could be argued that the lack of any reliable phonological facilitation effect in Experiment 3 was due to the fact that it was more difficult to recognise the target pictures in the related than in the unrelated phonological condition. In other words, the form facilitation effect would be cancelled out by the opposite inhibitory effect of the visual processing of the superimposed pictures in the related compared to the unrelated condition. To ensure that this type of visual confound was not responsible for the lack of a reliable phonological facilitation effect in Experiment 3: (1) we performed additional by-items analyses on the perceptual characteristics of the stimuli and (2) we ran an additional control experiment (the same control task as used in Experiment 4) to rule out a perceptual confound in the lack of any form facilitation effect. Following Székely and Bates (2000), we considered the objective visual complexity of the stimuli, namely the file size (in bytes) of the pictures. An ANOVA run on the visual complexity scores of the stimuli revealed a main effect of the Type of Distractor, $F(2, 38) = 24.76$, $MSE = 49{,}653$, $p < .001$. As expected, the objective visual complexity was less in the alone (175.4 bytes) than in both the related (262) and unrelated conditions (261), $t(19) = 7.99$, $p < .001$. Importantly, the visual complexity scores of pictures corresponding to the (form) related condition did not differ reliably from those in the unrelated condition, $t < 1$. Moreover, the correlation performed on the items between the size of the phonological effect and the size of the visual complexity scores was not reliable, $r(19) = .402$, *ns.* In the control name–object verification experiment performed with the stimuli from Experiment 3, the main effect of the Type of Distractor was significant, $F_1(2, 58) = 42.1$, $MSE = 24{,}509$, $p < .001$; $F_2(2, 38) = 26$, $MSE = 16{,}775$, $p < .001$. Decision times were shorter when target pictures were presented alone (448 ms) than when they were presented with a superimposed context picture (500 and 495 ms for the related and unrelated condition respectively), $t_1(29) = 11.1$, $p < .001$; $t_2(19) = 7.66$, $p < .001$, a finding which reflects a greater visual processing cost in the latter two conditions than in the former condition. However, the difference of 5 ms between the related and unrelated condition was not significant, all *t*s < 1. Overall, we are confident that the lack of a reliable phonological facilitation in Experiment 3 is not due to differences arising in the processing of perceptual characteristics of the set of stimuli used.

It now seems accepted that there is a cascading of information between the levels of the lexical and individual segments in the spoken language production system. The issue is now to identify the degree of cascading through the speech production system (Kuipers & La Heij, 2009; Oppermann, Jescheniak, Schriefers, & Görges, 2010; Rapp & Goldrick, 2000). According to the full-cascading position (e.g., Caramazza, 1997), any active concept automatically sends activation to its lexical and phonological representation. A second position, referred to as the limited-cascading view, exists in two versions (Kuipers & La Heij, 2009). The dominant version is that cascading ends at the lexical level and that only the lexical representation that is selected for production (the lemma) sends activation to its phonological representations (Levelt et al., 1999). A second version of the limited-cascading view (Bloem & La Heij, 2003) holds that a single concept which has been selected activates a number of semantically-related lexical items, which then send activation to their phonological representations. According to this version of the limited-cascading view, cascading starts at the lexical level. Thus, according to these two latter versions information does not automatically flow through the speech production system. In two experiments, Kuipers and La Heij (2009) found evidence for the limited-cascaded view. Using coloured pictures, they found that when the picture name was phonologically related to the name of the corresponding colour, the colour-naming task was facilitated more than when it was not. They also found that the effect was stronger when the participants had previously practiced picture naming. In contrast, the colour name had no effect on object naming whether or not colour naming had been practiced. Kuipers and La Heij (2009) therefore concluded that the findings could be reconciled with the full-cascading view of speech production if it is assumed that the activation of an object's identity leads to the automatic activation of its name whereas the activation of an object's attributes, such as its colour, does not necessarily activate their phonology. Although our study provides evidence for a cascaded model of written naming, it is unable to distinguish between the full-cascading and the two versions of the limited-cascading views. However, the future studies will need to examine the boundaries of cascading activation in written naming.

An important theoretical point addressed by our study is the locus of the context facilitation effect in written naming. As far as written naming is concerned, a central theoretical issue in this field concerns the role of phonological codes in this process, namely whether orthographic representations are independently accessed from semantic representations (Rapp et al., 1997) or whether access to orthography is mediated by phonological information (Geschwind, 1969; Luria, 1970). The analyses of performances of brain damaged patients in spoken and written picture naming have provided evidence that orthographic representations can be accessed independently of phonological representations (Miceli & Capasso, 1997; Miceli et al. 1997, 1999; Rapp et al., 1997). However, phonological codes do play a role in the access to orthographic codes by means of the phoneme-to-grapheme (and grapheme-to-phoneme) conversion procedures (Bonin et al., 2001; Miceli et al., 1997, 1999). In Experiments 2 and 3, we examined whether the facilitation effect found in written-naming latencies was due to orthographic information cascading to individual orthographic lexemes or whether cascading was mediated by the phoneme-to-grapheme conversion procedure. In effect, in accordance with the model outlined in the introduction, the results of Experiment 1 could have been due to the occurrence of cascading activation at the level of phonological lexemes and individual phonemes. In Experiment 2, the targets shared the same initial grapheme but not the same initial phoneme, whereas in Experiment 3, the reverse manipulation was applied, that is, the targets shared the same initial phoneme but not the same initial grapheme. Taken together, the findings of our study strongly suggest that the locus of the facilitation effect found in written-naming latencies is due to cascading between the orthographic lexeme and individual grapheme levels. However, given that data both from patients with acquired dysgraphia (e.g., Folk, Rapp, & Goldrick, 2002; Folk & Jones, 2004) and from unimpaired adults (Bonin et al., 2001; Zhang & Damian, 2010) have provided evidence of the involvement of the sublexical system in word spelling, it is still necessary to explain how these previous findings fit in with those reported here. It should be remembered that the influence of phonological codes in writing remains controversial (Zhang & Damian, 2010). In their masked priming picture naming experiments, Bonin et al. (1998) found that, compared to unrelated nonword primes, nonword primes that were phonologically and orthographically related to target names provided no priming advantage in terms of latencies compared to nonwords which had an equivalent orthographic relation but were less closely related than the former primes at the phonological level (at prime exposure durations of both 34 ms and 51 ms). This pattern of results suggests that the role of phonology in writing is relatively limited. However, Bonin et al. (2001) found a consistency effect in written latencies when they used picture names which were inconsistent in their initial and middle/final segments, but not when they were inconsistent in the middle and end only. More recently, Zhang and Damian (2010) used the picture-word interference paradigm to investigate the degree to which phonological codes support the written production of words from pictures. Distractor words which were both orthographically and phonologically related ("*hand–sand*") to target picture names facilitated responses at an early SOA of 0 ms, whereas those that were only orthographically related ("*hand–wand*") did not. An orthographic facilitation effect was found with a later SOA of +100 ms. In a second experiment, they used an articulatory suppression manipulation, that is, the participants had to count aloud while writing down the picture names. This time, the significant effect of phonology found in their first experiment was no longer reliable. According to Zhang and Damian (2010), articulatory suppression might have saturated the phonological pathway or, alternatively, slowed down processing in such a way that its influence on orthographic retrieval was no longer detectable. In line with Zhang and Damian's (2010) account, it is possible that the picture-picture interference paradigm imposes a load on the conceptual selection process (Roelofs, 2008), which has the effect of saturating the phonological pathway. Indeed, the evidence that is currently available suggests that phonological codes are less strongly involved in orthographic encoding during handwriting in healthy adults than one might infer from Bonin's et al. (2001) findings. We therefore suggest that the direct pathway from semantics to orthography is the most important one in the generation of handwritten responses in healthy adults. However, it is already clear that the issue of the dynamics of phonological code activation in spelling requires further in-depth study.

To conclude, our study makes a valuable contribution because it is the first to provide chronometric evidence, based on the picture–picture interference paradigm, in support of the hypothesis that information flows in a cascaded manner within the lexical system in written naming.

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APPENDIX

TABLE A1
List of target pictures and distractor picture names from Experiment 1

Targets (English name)	*Related*	*Distractors (English name)*	
		Unrelated Recombined	*Unrelated New*
Bague (ring)	Balai (broom)	Tasse	Violon (violin)
Ballon (ball)	Balcon (balcony)	Cheval	Montagne (mountain)
Biberon (baby's bottle)	Baignoire (bathtub)	Peigne	Asperge (asparagus)
Bougie (candle)	Banc (bench)	Carnet	Ceinture (belt)
Briquet (lighter)	Brouette (wheelbarrow)	Chenille	Aigle (eagle)
Camion (truck)	Carnet (book)	Lampe	Echelle (ladder)
Chaussette (socks)	Chenille (caterpillar)	Tracteur	Quille (skittle)
Citron (lemon)	Ciseau (chisel)	Baignoire	Pelle (shovel)
Crabe (crab)	Crayon (pencil)	Loupe	Roue (wheel)
Lion (lion)	Lampe (lamp)	Rose	Bouteille (bottle)
Louche (ladle)	Loupe (magnifier)	Trombone	Bouton (button)
Noeud (knot)	Nez (nose)	Crayon	Colonne (column)
Palmier (palm)	Panier (basket)	Balcon	Tétine (nipple)
Pile (battery)	Pipe (pipe)	Nez	Chaise (chair)
Plante (plant)	Plume (feather)	Banc	Croix (crucifix)
Poire (pear)	Peigne (comb)	Tambour	Cloche (bell)
Robot (robot)	Rose (rose)	Balai	Tampon (stamp)
Serpent (snake)	Sifflet (whistle)	Brouette	Fleur (flower)
Talon (heel)	Tasse (cup)	Sifflet	Noix (walnut)
Tirelire (piggy bank)	Trombone (paper clip)	Pipe	Fourche (fork)
Toupie (spinning top)	Tambour (drum)	Ciseau	Crevette (shrimp)
Trompette (trumpet)	Tracteur (tractor)	Panier	Bobine (spool)

TABLE A2
List of target pictures and distractor picture names from Experiments 2, 4, and 5

	Distractors (English name)		
Targets (English name)	*Related*	*Unrelated Recombined*	*Unrelated New*
Ail* (garlic)	Aigle (eagle)	Camion	Scorpion (scorpion)
Aile (wing)	Aiguille (needle)	Casque	Pelle (shovel)
Ananas (pineapple)	Ange (angel)	Coffre	Banc (bench)
Cerf (hart)	Clef (key)	Ange	Vase (vase)
Cerise (cherry)	Crayon (pencil)	Hélice	Bougie (candle)
Cigare (cigar)	Camion (truck)	Orange	Bateau (boat)
Cintre (coat hanger)	Coffre (safe)	Agneau	Balcon (balcony)
Ciseau (scissors)	Casque (helmet)	Aigle	Peigne (comb)
Cloche (bell)	Cercle (circle)	Garçon	Bouton (button)
Crabe (crab)	Citron (lemon)	Hache	Tasse (cup)
Giraffe (giraffe)	Garçon (boy)	Clef	Maison (house)
Guitare (guitar)	Gilet (waistcoat)	Oiseau	Lampe (lamp)
Hamac (hammock)	Hélice (propeller)	Cercle	Domino (domino)
Hibou (owl)	Hache (axe)	Aiguille	Fusil (rifle)
Oie (goose)	Orange (orange)	Gilet	Tomate (tomato)
Oignon* (onion)	Oiseau (bird	Crayon	Fourmi (ant)
Agenda* (agenda)	Agneau (lamb)	Citron	Gateau (cake)

Note: The items marked with an (*) were not used in Experiments 4 and 5.

TABLE A3
List of target pictures and distractor picture names from Experiment 3

		Distractors (English name)	
Targets (English name)	*Related*	*Unrelated Recombined*	*Unrelated New*
Antenne (antenna)	Empreinte (fingerprint)	Citron	Roue (wheel)
Camion (truck)	Koala (koala)	Girafe	Lapin (rabbit)
Carotte (carrot)	Klaxon (klaxon)	Aiguille	Moto (motorcycle)
Enclume (anvil)	Ampoule (bulb)	Citrouille	Lampe (lamp)
Enveloppe (envelope)	Ambulance (ambulance)	Canapé	Voiture (car)
Fusée (space rocket)	Phoque (seal)	Cerise	Tortue (tortoise)
Hélice (helix)	Aimant (magnet)	Koala	Domino (domino)
Hérisson (hedgehog)	Aiguille (needle)	Cigarette	Lance (lance)
Jambon (ham)	Gilet (waistcoat)	Cintre	Cube (cube)
Jumelles (binoculars)	Girafe (giraffe)	Ciseaux	Mouton (sheep)
Kangourou (kangaroo)	Canapé (sofa)	Aimant	Montre (watch)
Orange (orange)	Autruche (ostrich)	Ceinture	Poisson (fish)
Quille (skittle)	Képi (cap)	Gilet	Papillon (butterfly)
Sapin (fir tree)	Ciseau (scissors)	Klaxon	Lunettes (glasses)
Serpent (snake)	Citrouille (pumpkin)	Ambulance	Porte (door)
Sifflet (whistle)	Cigarette (cigarette)	Autruche	Louche (ladle)
Singe (monkey)	Ceinture (belt)	Képi	Peigne (comb)
Sirène (mermaid)	Cerise (cherry)	Ampoule	Loupe (magnifying glass)
Soleil (sun)	Cintre (round arch)	Phoque	Tampon (plug)
Souris (mouse)	Citron (lemon)	Empreinte	Nuage (cloud)