ELSEVIER

Acta Psychologica 99 (1998) 311–328

acta psychologica

Masked form priming in writing words from pictures: Evidence for direct retrieval of orthographic codes

Patrick Bonin [a,*], Michel Fayol [a], Ronald Peereman [b]

[a] *LAPSCO/C.N.R.S., Universitê Blaise-Pascal, 34 Avenue Carnot, F-63037 Clermont-Ferrand, France*

[b] *L.E.A.D./C.N.R.S., Universitê de Bourgogne, F-21000 Dijon, France*

Received 9 December 1996; received in revised form 3 June 1998; accepted 8 June 1998

Abstract

Three experiments used the masked priming paradigm to investigate the role of orthographic and phonological information in written picture naming. In all the experiments, participants had to write the names of pictures as quickly as possible under three different priming conditions. Nonword primes could be: (1) phonologically and orthographically related to the picture name; (2) orthographically related as in (1) but phonologically related to a lesser degree than in (1); (3) orthographically and phonologically unrelated except for the first consonant (or consonant cluster). Orthographic priming effects were observed with a prime exposure duration of 34 ms (Experiments 1 and 2) and of 51 ms (Experiment 3). In none of the experiments, did homophony between primes and picture names yield an additional advantage. Taken together, these findings support the view of the direct retrieval of orthographic information through lexical access in written picture naming, and thus argue against the traditional view that the retrieval of orthographic codes is obligatorily mediated by phonology. © 1998 Elsevier Science B.V. All rights reserved.

PsycINFO classification: 2300; 2340

Keywords: Written picture naming; Masked priming; Orthography; Phonology

* Correponding author. Tel.: 33 04 73 40 61 07; fax: 33 04 73 40 64 82; e-mail: patrick.bonin@lapsco.univ-bpclermont.fr

0001-6918/98/$19.00
PII: S 0 0 0 1 - 6 9 1 8 (9 8) 0 0 0 1 7 - 1

1. Introduction

While substantial research has been devoted to lexical access in spoken picture naming, few studies have addressed the corresponding problem in written picture naming. It is fair to say that the study of speech production is more advanced than the study of written production. This "dearth of experimental research" for low level processing components in writing can be explained by the fact that current studies have focused on higher processing levels, such as planning (Hayes and Flower, 1980), or revising (Flower et al., 1986), and that the investigation of writing had to cope with serious methodological problems (see Fayol, 1997, for a review).

In the present study, we investigated lexical access in written picture naming. We assumed that current views of speech production provide a general theoretical framework from which hypotheses specific to writing can be derived. It is generally held that speech production (e.g., naming a word from a picture) involves several processes (see Bock and Levelt, 1994, for a review). After selection of the concept, activation spreads to semantic features and to the appropriate lemma nodes (Levelt et al., 1991a; Schriefers et al., 1990). In turn, the lemma node activates its corresponding phonological representation (i.e., a lexeme). The final step consists of the computation of, or access to, the articulatory gestures (Levelt, 1989; Levelt and Wheeldon, 1994). Although some controversies exist about the relative time course of the processing levels (e.g., Dell and O' Seaghdha, 1991; Humphreys et al., 1988; Levelt et al., 1991b), this modeling of speech production is supported by various findings, including the analyses of speech errors in normal subjects and brain-damaged patients (Dell and Reich, 1981; Fay and Cutler, 1977; Fromkin, 1971; Garrett, 1975, 1980, 1982; Henaff-Gonon et al., 1989; Kay and Ellis, 1987), the tip-of-the-tongue phenomena (Brown and McNeill, 1966; Jones and Langford, 1987), as well as by several experimental studies involving normal subjects (Levelt et al., 1991a; Schriefers et al., 1990).

It is generally assumed that writing and speech production systems share the conceptual-semantic level (Bonin et al., in press; Caramazza and Hillis, 1990; Hillis and Caramazza, 1991, 1995; Rapp and Caramazza, 1994). Written production would subsequently involve a graphemic level (Ellis, 1982; Margolin, 1984) specifying the syllable structure and the identity of individual graphemes (Caramazza and Miceli, 1990). Henceforth, this processing level will be referred to as the *orthographic lexeme level*. Letters would then be specified in terms of spatial description at the *allographic level* (Ellis, 1982; Weekes, 1994), and the graphic motor patterns would be retrieved at the *graphic level* (Van Galen, 1980). Such distinctions between the processing levels are supported by analyses of errors in normal and brain-damaged patients (Baxter and Warrington, 1986; Ellis, 1979; Goodman and Caramazza, 1986; Miceli et al., 1985; for a review, Bonin, 1997).

A current debate concerning the involvement of lexical access in writing is related to the role played by phonological information. Traditionally, it is assumed that written language skills rely on spoken language knowledge and processes (Geschwind, 1969; Luria, 1970). Hence, access to orthography would be dependent on the prior retrieval of the lexical phonological representation of the word. This hypothesis is referred to as the *obligatory phonological mediation hypothesis* (Rapp and Caramazza, 1994, 1997; Rapp et al., 1997). This phonological mediation hypothesis mirrors the fact that spoken language precedes, ontogenetically and phylogenetically, written language (Scinto, 1986). In addition, this hypothesis is seen as consistent with the observations of phonologically based errors in written productions such as homophone substitutions (e.g., the word "there" written "their"; the word "often" written "oven"; Aitchison and Todd, 1982) and with our introspective experiences of inner speech that accompanies writing (Hotopf, 1980).

In contrast, according to the *orthographic autonomy hypothesis* (Rapp and Caramazza, 1994, 1997; Rapp et al., 1997), orthographic and phonological representations can be addressed independently in language production. Hence, contrary to the obligatory phonological mediation hypothesis, retrieval of the orthographic codes does not require access to phonology.

The obligatory phonological mediation hypothesis is faced with various problems such as the production of the correct orthographic form of homophones (i.e., *seen* vs. *scene*, Largy et al., 1996), silent graphemes (i.e., *h* in the French word *harpe*), and double letters (i.e., *pp* in the French word *nappe*). Moreover, neuropsychological reports indicate that written performance can be relatively spared when compared to spoken production (Assal et al., 1981; Hier and Mohr, 1977; Lhermitte and Derouesnê, 1974; Patterson and Marcel, 1977; Rapp and Caramazza, 1994). For example, Lhermitte and Derouesnê (1974) described a patient who was 74% correct in written production but only 8% correct in spoken production. Such cases are problematic for the phonological mediation hypothesis because it is difficult to argue that spoken neologistic responses form the basis for the retrieval of correct written responses. Moreover, some of the individuals producing neologisms have little or no trouble in reading aloud (Miceli and Caramazza, 1993), therefore ruling out the hypothesis that neologisms arise at an output stage. Additional difficulties for the obligatory phonological mediation hypothesis come from neuropsychological observations that some patients produced semantic errors in reading and spoken picture naming but not in writing (Caramazza and Hillis, 1990). These observations are compatible with the view that semantic errors in spoken production lie at the level of phonological encoding, and that orthographic lexemes can be accessed without phonological mediation. Indeed, in the phonological mediation hypothesis, semantic errors should also have been observed for written production.

Although the orthographic autonomy hypothesis seems suitable to account for neuropsychological data, we are not aware of clear confirmative evidence from normal subjects. In the present study we examined whether, in normal subjects, phonology is *obligatorily* accessed when writing picture names. The masked form priming paradigm allows us to evaluate, directly, the orthographic autonomy hypothesis while, at the same time, avoiding the use of predictive strategies. In this technique, initially developed to investigate visual word recognition (Evett and Humphreys, 1981; Forster and Davis, 1984), the prime visibility is reduced by using short prime duration and forward and backward masking. In such priming conditions, the prime is generally not available for conscious report, and it is therefore unlikely that the participants use the primes strategically to predict the targets (e.g., to expect the presentation of a picture depicting a "rose" upon the presentation of the nonword prime "roze"). This paradigm was recently used by Ferrand et al. (1994) to study spoken picture naming and word naming.

In Ferrand et al.'s study (Ferrand et al., 1994), three different nonword primes were used. In a first condition (*pseudohomophone prime condition*), the primes were homophonic with the picture names, and shared most of their letters with the picture names. In a second condition (*orthographic prime condition*), primes were also orthographically related to the picture names, but were not homophonic although phonologically similar with the picture names. Finally, in a third – control (*control prime condition*) – the orthographic and phonological overlap between primes and picture names was restricted to the first consonant or consonant cluster. The results showed that spoken picture naming was facilitated by pseudohomophone primes when compared to orthographic primes and to controls. The latter two conditions gave rise to similar performances. Thus, spoken picture naming was facilitated by the preactivation of phonological representations, but not by the preactivation of orthographic information. As the priming effect for spoken picture naming was similar in size when the prime was either the picture label or when it was a pseudohomophone, Ferrand et al. (1994) concluded that the pseudohomophone priming effect resulted from the preactivation in memory of the phonological representation corresponding to the picture name.

The aim of the present study is to investigate the role of phonological and orthographic codes in written picture naming through the use of the three priming conditions employed by Ferrand et al. (1994) in spoken picture naming. Hence, pictures were primed by pseudohomophones and orthographically related nonwords (referred to as "pseudohomophone primes"), orthographically related nonwords but less phonologically related nonwords (referred to as "orthographic primes"), or nonwords that were orthographically and phonologically related to the target picture names only on the first consonant or consonant cluster (referred to as "control primes").

Fig. 1 presents a general working model of lexical access in written picture naming that clarifies the predictions examined in the experiments. According to this model, the presentation of the picture causes activation of structural representations in memory (Humphreys et al., 1995). Then, activation flows from structural representations to semantic representations. According to the hypothesis of the direct retrieval of orthographic information, activation would spread directly from semantic features to orthographic codes, and subsequently to the corresponding allographic codes. The optional phonological route to orthography is represented in Fig. 1 by the arrow between phonological and orthographic codes (via lexical or sublexical links).

Supposing that orthographic codes are activated through phonology, written picture naming should be facilitated when the nonword primes are homophonic with

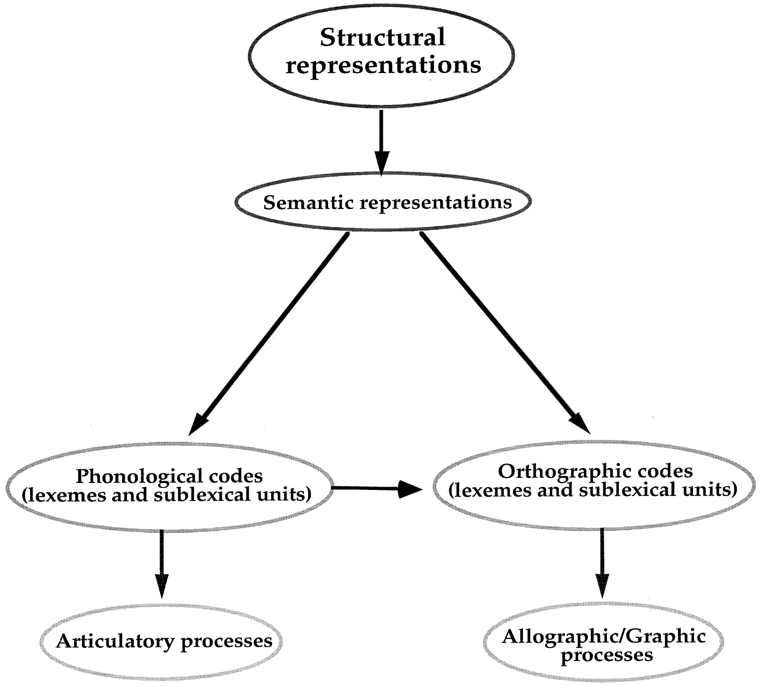

Fig. 1. Working model of lexical access in written picture naming.

the picture label. Indeed, because the pseudohomophone primes have a larger phonological overlap with the picture names than the orthographic primes, they should facilitate more the retrieval of the phonological codes, and the subsequent access to the associated orthographic specifications. On the contrary, if, as depicted in Fig. 1, orthographic codes can be accessed directly from the picture concept, then priming with orthographic primes should be as efficient as priming with pseudohomophone primes, as these two primes are equally similar, orthographically, to the picture names. A preliminary experiment showed that a prime duration of 17 ms (one refresh cycle) was too short to generate reliable priming effects. Therefore, a prime duration of 34 ms (two refresh cycles) was used in Experiment 1. To permit direct comparisons with the data described by Ferrand et al. (1994) in spoken picture naming, all nonword primes and picture labels were identical to those used by Ferrand et al. (1994).

2. Experiment 1

In Experiment 1, target pictures were primed for 34 ms with the three different types of nonwords previously described.

2.1. Method

Participants: Twenty-seven undergraduates at Bourgogne University participated in the experiment. They were given course credits for their participation. The participants were native speakers of French and all had normal or corrected-to-normal vision.

Stimuli: Thirty black-on-white drawings of objects served as picture targets. The picture labels were identical to those used by Ferrand et al. (1994). The drawings were taken from Snodgrass and Vanderwart's corpus (Snodgrass and Vanderwart, 1980), except for seven pictures that were scanned from children's books. Thus, except for these seven pictures, all the pictures were identical to those used by Ferrand et al. (1994) as these authors also selected their pictures from Snodgrass and Vanderwart's corpus (Snodgrass and Vanderwart, 1980). The written form associated with the pictures had an average frequency of 234 occurrences per million (according to Imbs, 1971). For each picture, three types of nonword prime were used: (1) pseudohomophone primes (e.g., the picture of a tooth – corresponding to the French word DENT – was preceded by the pseudohomophone DANT); (2) orthographic primes (e.g., DUNT) and (3) control primes (e.g., DISE). All primes shared the first phoneme and the first letter with the targets. The magnitudes of the phonological overlap and of the orthographic overlap between the targets and the primes were estimated by computing the percentages of phonemes and letters shared, in the same position, between targets and primes. The phonological overlap between primes and targets was 100% for the pseudohomophone primes, 60% for the orthographic primes and 31% for the controls. The orthographic overlap was 76% for the pseudohomophones primes, 76% for the orthographic primes and 27% for the controls. As already stated, the primes were identical to those used by Ferrand et al. (1994).

Apparatus: The experiment was performed using PsyScope, version 1.0.1. (Cohen et al., 1993) and run on a Macintosh LC III. A graphic tablet and a contact pen (SP-210) were used to record written latencies.

Procedure: The participants were tested individually. Before starting the experiment, they were given a booklet showing the target pictures together with their appropriate labels. They were required to study the correct labels and to use them in the experiment. For each target, the three priming conditions were counterbalanced across three groups of participants. The procedure allowed no participant to see any single prime or picture more than once. However, each participant was exposed to all experimental conditions. The participants sat in front of the computer screen at a viewing distance of approximately 60 cm. A trial had the following structure. A forward pattern mask (:: : : : :) was presented in the center of the screen for 500 ms. This mask was immediately followed by a prime that remained visible for 34 ms [1]

[1] In all the experiments, we were careful that the durations of the primes were set, depending on the experiment, to have either two constant refresh rates or three constant refresh rates, across the items. PsyScope has a built-in control which allowed us to ensure that primes were presented at 34 ms (two refresh rates) or at 51 ms (three refresh rates).

and was followed by a backward pattern mask (∷ ⁝ ⁝ ⁝ ⁝) presented for 17 ms. The pattern mask [2] consisted of dots presented in Chicago 14. The picture was presented centered on the screen immediately after the backward pattern mask offset. The picture remained on the screen until the participant initiated the response. The intertrial interval was set to 5 s. The primes were presented in uppercase letters. The participants were required to concentrate on the center of the screen and to write the name of the picture as quickly as possible. They were not informed of the presence of the primes. The experimenter sat near the participant to record the responses. Written latencies were timed as follows. The participants sat with the stylus hovering above the tablet so that latencies corresponded to the time elapsing between the picture onset and the contact of the pen with the graphic tablet. The stimulus presentation was pseudorandomized. The experiment began with six practice trials.

2.2. Results

Trials on which participants did not remember the picture label, or used an incorrect picture label were left out of the analyses, as were trials in which a technical problem occurred. As a result, 3.6% of the data was excluded. Responses corresponding to misspellings, to the use of a different picture label, or corresponding to responses longer than two standard deviations above the item and participant's means were considered as errors. Mean written latencies, standard deviations, and error rates for Experiment 1 are presented in Table 1.

Analyses were performed on written latencies and on errors with Priming condition (pseudohomophone primes; orthographic primes; control primes) entered as the main factor. Following Clark (1973), ANOVAs were conducted separately with participants and items as random factors (F1: by-participants; F2: by-items).

The effect of Priming condition was significant on both participants and items, $F_1(2,52) = 10.56$, $p < 0.0001$, $MSE = 3778.98$; $F_2(2,58) = 4.11$, $p < 0.02$, $MSE = 9374.17$. Planned comparisons revealed that responses were faster with the orthographic primes than with the control primes, $F_1(1,26) = 16.49$, $p < 0.0004$, $MSE = 3196.30$; $F_2(1,29) = 5.41$, $p < 0.027$, $MSE = 9902.35$. Also, the pseudohomophone primes yielded faster responses than the control primes, $F_1(1,26) = 11.77$, $p < 0.002$, $MSE = 5628.49$; $F_2(1,29) = 5.11$, $p < 0.03$, $MSE = 12099.47$. There was no significant difference between the pseudohomophone prime condition and the orthographic prime condition, both F_1 and $F_2 < 1$. The ANOVAs performed on the error data revealed a nonsignificant effect of Priming condition, both F_1 and $F_2 < 1$.

[2] As Ferrand et al. (1994) did not provide the detailed characteristics of their masking pattern, the pattern mask we used was different.

Table 1
Mean latencies (RT, in ms) with standard deviations (SD) and error rates (E, in percentages) per experimental condition from Experiment 1

Exposure duration	Pseudohomophone primes			Orthographic primes			Control primes		
	RT	SD	E	RT	SD	E	RT	SD	E
34 ms	926	166	3.7	934	183	2.6	996	186	4.4

2.3. Estimated visibility of the primes

A post hoc measure of prime visibility was performed with the stimuli of Experiment 1 and using an exposure duration of 34 ms. To assess the amount of information available to awareness, nine well-trained participants, all members of the laboratory at Bourgogne University, were told to write down every letter they saw (or thought they saw) from the prime. On average, 21% of the primes were correctly reported. The percentage of prime identifications did not differ significantly across the priming conditions, $F_1(2,16) = 1.17$; $F_2 < 1$, (24%, 21% and 17%, for the orthographic primes, pseudohomophone primes and control primes, respectively). This percentage, although higher than the 10% reported by Ferrand et al. (1995), nevertheless indicates that little information was extracted from the prime stimuli. Post hoc analyses were conducted on item latencies from Experiment 1 to investigate whether the small differences in prime visibility across priming conditions were associated with differences in the size of the priming effects. A first analysis examined the correlation between the size of the RT advantage caused by the orthographic primes relative to the control primes, and the differences in visibility between the orthographic and control primes. A similar analysis was carried out between the size of the RT advantage caused by the pseudohomophone primes relative to the control primes, and the differences in visibility between the pseudohomophone and control primes. Both analyses yielded nonsignificant correlations ($r = 0.073$, $p = 0.71$; $r = -0.037$, $p = 0.85$; respectively). Second, analyses of covariance were conducted to ensure that, when compared to the control condition, the orthographic prime advantage and the pseudohomophone prime advantage still occurred when the differences in prime visibility were introduced as covariates. The RT difference between the orthographic and the control prime conditions was still significant when the difference in prime visibility between these two types of primes was used as covariate, $F(1,28) = 4.80$, $p < 0.05$, $MSE = 9871.09$. Similarly, a significant advantage of the pseudohomophone prime condition when compared to the control prime condition was still observed when the difference in prime visibility was introduced as covariate in the analysis, $F(1,28) = 4.78$, $p < 0.05$, $MSE = 12514.16$. Thus, it seems unlikely that the differences across priming conditions observed in Experiment 1 were due to differences in prime visibility.

2.4. Discussion

Using an exposure duration of 34 ms, Experiment 1 shows that pseudohomophone primes did not facilitate written picture naming over and above orthographic primes. As the phonological overlap with the target was 100% in the pseudohomophone condition, and 60% on average in the orthographic condition, the data suggest that the facilitatory effect observed in written picture naming is attributable to the orthographic similarity between the primes and the picture names. Finally, analyses performed on errors did not reveal a significant effect associated with priming conditions.

The finding of Experiment 1 that orthographic but not phonological priming occurs with a 34 ms prime duration fits well with the hypothesis of a direct, non-phonologically mediated, access to the orthographic codes. Such an observation contrasts with the phonological priming effect described by Ferrand et al. (1994) in spoken picture naming. However, before further considering the differences across output modalities, one possible limitation of the present finding needs to be addressed. Indeed, as revealed by the control of prime visibility, the percentage of prime identifications was higher than that reported by Ferrand et al. (1995). Although prime duration in Ferrand et al. (1994) was slightly shorter (29 ms), it is unlikely that the 5 ms difference with the prime duration used in Experiment 1 was responsible for the difference in prime visibility. Therefore, the aim of Experiment 2 was to ensure that the orthographic priming effect captured with a 34 ms exposure duration would be replicated using another pattern mask that more strongly reduced the visibility of the prime stimuli.

3. Experiment 2 – Priming with nonwords using a different pattern mask (34 ms)

The purpose of Experiment 2 was to replicate Experiment 1 using a pattern mask that maximally prevents prime identification.

3.1. Method

Participants: Twenty-seven undergraduates were taken from the same pool as in the previous experiment. All the participants were native speakers of French and had normal or corrected-to-normal vision. None of them had participated in the previous experiment.

Material, apparatus, and procedure: They were identical to Experiment 1, except that a new pattern mask was used and that the primes and the pictures were presented in white on a black background.

In a preliminary study, prime identification with a 34 ms exposure duration was investigated using various pattern masks, including the string of hash marks (#) used in most priming studies. Our criteria for selecting another pattern mask was to get a percentage of correct identifications as close as possible to the percentage reported by Ferrand et al. (1995). The stimuli were as previously described. Among the various masks used, the lower percentage of correct identifications of the prime was obtained with a pattern mask consisting of a row of seven Japanese characters in the font Hiragana Brush-24 (日日日日日日日) when primes, masks, and pictures were presented in white on a black background.

The mean percentage of correct identifications as collected from a sample of 18 well trained students was 11%. The percentages of correct reports did not significantly differ across conditions, $F(2,34) = 1.38$ (11%, 13% and 8% for the orthographic primes, pseudohomophone primes and control primes, respectively). The Hiragana pattern mask was used in Experiment 2.

3.2. Results and discussion

Adopting the same criteria as used in Experiment 1 led to the rejection of 2% of the trials. Responses corresponding to misspellings, or to the use of a different picture label as well as responses longer than two standard deviations above the item and participant's means were considered as errors. Mean written latencies, standard deviations, and error rates are shown in Table 2.

Analyses were similar to those conducted on the data from Experiment 1. Analyses of written latencies showed a significant main effect of Priming condition, $F_1(2,52) = 10.98$, $p < 0.0001$, $MSE = 7776.72$; $F_2(2,58) = 6.226$, $p < 0.003$, $MSE =$ 20270.02. Planned comparisons revealed that the orthographic primes yielded faster latencies than the control primes, $F_1(1,26) = 10.39$, $p < 0.003$, $MSE = 11050$; $F_2(1,29) = 5.58$, $p < 0.025$, $MSE = 29416$. Also, the pseudohomophone primes resulted in faster latencies than the control condition, $F_1(1,26) = 14.03$, $p < 0.0009$, $MSE = 9978.4$; $F_2(1,29) = 8.34$, $p < 0.007$, $MSE = 25346.7$. There was no significant difference between the pseudohomophone prime condition and the orthographic prime condition, F_1 and $F_2 < 1$. The ANOVAs performed on the error data revealed that the main effect of Priming condition was not significant, all Fs < 1.

To summarize, Experiment 2 replicates the orthographic priming effect observed in Experiment 1 using a pattern mask that allowed less numerous prime identifications. It is worth noting that the latencies were longer in Experiment 2 (1211 ms) than in Experiment 1 (952 ms) and that the percentage of errors was higher in Experiment 2 (6%) than in Experiment 1 (3.5%). Although these differences might be attributable to the use of different participants, it is also possible that the use of a white on black background introduced additional difficulties in picture identification

Table 2
Mean latencies (RT, in ms) with standard deviations (SD) and error rates (E, in percentages) per experimental condition from Experiment 2

Exposure duration	Pseudohomophone primes			Orthographic primes			Control primes		
	RT	SD	E	RT	SD	E	RT	SD	E
34 ms	1174	187	6.3	1184	184	7	1276	264	5.3

given that participants were trained with black on white background pictures at the onset of the experimental session.

4. Experiment 3 – Priming with nonwords (51 ms)

Experiments 1 and 2 suggest that orthographic information in written picture naming can be accessed without phonological mediation. Whereas pseudohomophone primes improved spoken picture naming when presented for 29 ms in Ferrand et al.'s (1994) study, Experiments 1 and 2 showed that homophony between primes and picture names did not lead to an additional advantage in written picture naming. However, although the data reported by Ferrand et al. (1994) suggest that a 34 ms prime duration is sufficient to cause phonological activation, it remains possible that there was not enough time for phonological activation to spread to orthographic codes. Therefore, increasing the exposure duration of the prime might produce an additional advantage for the pseudohomophone primes compared to the orthographic primes. Experiment 3 was designed to examine this prediction using a 51 ms prime duration.

4.1. Method

Participants, material, and procedure: The participants consisted of 27 undergraduates taken from the same pool as for the preceding experiments. None of them had participated in the previous experiments. The material and procedure were identical to Experiment 2 except that the prime duration was increased to 51 ms.

4.2. Results and discussion

Applying the same deadline criteria as used in Experiments 1 and 2 led to the removal of 3.4% of the data from the analyses. Mean written latencies, standard deviations, and error rates are shown in Table 3. Analyses were similar to those conducted on the data from Experiments 1 and 2.

Table 3
Mean latencies (RT, in ms) with standard deviations (SD) and error rates (E, in percentages) per experimental condition from Experiment 3

Exposure duration	Pseudohomophone primes			Orthographic primes			Control primes		
	RT	SD	E	RT	SD	E	RT	SD	E
51 ms	1219	209	4.4	1196	217	4	1300	212	4.1

Analyses on written latencies revealed a significant effect of the priming condition, $F_1(2,52) = 13.05$, $p < 0.0002$, $MSE = 6149.51$; $F_2(2,58) = 7.37$, $p < 0.001$, $MSE = 9420.467$. Planned comparisons indicated that RTs in the orthographic priming condition were significantly shorter than in the control priming condition, $F_1(1,26) = 39.98$, $p < 0.0001$, $MSE = 3652$; $F_2(1,29) = 14.025$, $p < 0.0008$, $MSE = 9289.3$. There was also a reliable latency advantage for the pseudohomophone primes when compared to the control primes, $F_1(1,26) = 11.41$, $p < 0.002$, $MSE = 7639.94$; $F_2(1,29) = 6.51$, $p < 0.01$, $MSE = 10473.2$. Finally, the difference between the pseudohomophone prime condition and the orthographic prime condition was not significant, $F_1(1,26) = 1.05$ and $F_2(1,29) = 1.17$. When errors are considered, the effect of Priming condition turned out to be not significant, both $F\text{s} < 1$. Hence, as for Experiments 1 and 2, an orthographic priming effect was observed. Using a longer prime duration did not give rise to the emergence of an additional benefit for pseudohomophone primes.

5. General discussion

The present study was undertaken to investigate the role of orthographic and phonological information in written picture naming. As we were primarily interested in fast and obligatory processes involved in written picture naming, the masked form priming paradigm was thought to be appropriate as the brief prime exposure durations generally prevent conscious identification.

Three experiments were designed to determine the nature of the information involved in writing words from pictures. Two contrasting views of lexical access were considered. In line with the obligatory phonological mediation hypothesis of lexical access in written picture naming, accessing orthographic information would require the prior retrieval of phonological information (Geschwind, 1969; Luria, 1970). In contrast, according to the orthographic autonomy hypothesis, orthographic information could be retrieved directly (Rapp and Caramazza, 1994, 1997; Rapp et al., 1997). The latter view was favored as it provides a better understanding of neuropsychological observations (Assal et al., 1981; Hier and Mohr, 1977; Lhermitte and Derouesnê, 1974; Patterson and Marcel, 1977; Rapp and Caramazza, 1994).

The findings of Experiments 1, 2 and 3 are clear-cut. At 34 ms (Experiments 1 and 2) and 51 ms (Experiment 3) both pseudohomophone primes and orthographic primes facilitated written picture naming when compared to control primes. In addition, while Ferrand et al.'s (1994) findings showed that pseudohomophone primes, but not orthographic primes, speeded up spoken picture naming, our present findings revealed priming effects of similar size for both orthographic and phonological primes. Because the same nonword primes were used both in Ferrand et al.'s (1994) study and in the present experiments, the lack of phonological effect in written picture naming cannot result from an unsatisfactory manipulation of phonological similarity between the primes and the picture names. It is fair to conclude that the present results support the autonomous view of lexical access in written picture naming illustrated in Fig. 1, according to which orthographic codes can be retrieved directly without prior access to phonological codes.

It might be argued that the present findings are also compatible with a phonological mediation account if the facilitatory effects observed with pseudohomophones and matched orthographic control primes are assumed to have different origins. Because pseudohomophone primes match phonological representations in the phonological lexicon, any advantage relative to control primes might be attributed to the phonological priming of the picture label. For orthographic primes, the facilitation effect relative to control primes would be orthographic. Hence, accordingly, the facilitation produced by pseudohomophone primes would have a lexical, phonological, locus, whereas the facilitation produced by orthographic primes would have a sublexical, orthographic, locus. [3] One potential problem with such hypothesis relates to the underlying assumption that the lexical activation of phonological codes is restricted to pseudohomophone primes. Numerous results suggest that nonhomophonic pseudowords cause partial activation of orthographic and phonological codes within the lexicon (e.g., Glushko, 1979). Moreover, phonological activation from printed letter strings seems to occur very early even with nonhomophonic pseudowords (Berent and Perfetti, 1995). It is therefore hard to see why the larger phonological overlap between pseudohomophone primes and target labels would not be associated with a larger benefit in performance. An additional difficulty is that it would be necessary to explain why the sublexical orthographic level – at which the orthographic priming effect is assumed to originate – does not also increase facilitation for pseudohomophone primes over and above the facilitation already produced at the phonological level.

Additional data compatible with the autonomous assumption have been recently observed using a different methodology (Bonin and Fayol, 1996; Bonin et al., 1997). In a series of experiments reported by Bonin et al. (1997), the role of phonological and orthographic information in written picture naming was assessed using the picture–word interference paradigm. It was found that written picture naming was facilitated when the initial silent letter of the picture label was superimposed on the picture, when compared with an unrelated letter. In contrast, the auditory presentation of the first sound of the picture label did not improve written picture naming, whereas spoken picture naming was facilitated. In conformity with the orthographic autonomy hypothesis, these results suggested that orthographic information, but not phonological information, was involved in written picture naming. These findings suffered, however, from two major limitations. First, the facilitation effect caused by the superimposed silent letter did not generalize across items. Second, because the superimposed letter remained visible until the participant's response, it could not be excluded that the participants were using this information strategically.

[3] We are grateful to Brenda Rapp for pointing out this possibility.

Although our findings suggest direct access to orthographic codes from semantics (as depicted by the link between semantic representations and orthographic codes in Fig. 1), they do not indicate that phonological information never contributes to the written production of words. As mentioned in the introduction, it might be argued that phonological mediation is optional in accessing orthographic representations. In Fig. 1, this possible route to orthography is represented by an arrow connecting phonological and orthographic codes. According to Rapp et al. (1997), two main observations support the hypothesis of an optional phonological pathway in written production. First, introspectively, most individuals report that inner speech accompanies writing. Second, some written errors produced by normal individuals seem to have a phonological basis.

However, as already pointed out by Rapp et al. (1997), to maintain the phonological mediation hypothesis it is necessary to specify the conditions which favor or impede the use of the phonological pathway. For example, it might be the case that orthographic activation through phonology is generally too slow to affect performance. Therefore, longer prime durations than those we used might eventually yield an advantage for pseudohomophone primes. An additional question would be to determine whether the phonological contribution in the building-up of the orthographic code follows from lexical connections between phonological and orthographic lexemes, or from sublexical connections between analytical knowledge.

In conclusion, whereas the present study suggests that orthographic codes can be accessed directly in written picture naming, the data do not preclude phonological contributions under different conditions. Nevertheless, the convergence between the present findings and other observations gathered in the picture–word interference paradigm (Bonin et al., 1997) increases our confidence that phonological codes are not a prerequisite for access to orthographic codes. Finally, from a methodological point of view, the masked form priming paradigm, which had been widely used in identification tasks, lexical decision, and spoken picture naming, also appears to be a useful tool for investigating the processes and the representations underlying lexical access in written picture naming.

Acknowledgements

The authors wish to thank Brenda Rapp, Gezinus Wolters, and three anonymous reviewers for helpful comments on previous versions of the manuscript, Magali Nieddu for running Experiment 1, Annie Zielinski for running Experiment 2, Sandrine Brunie for running Experiment 3 and Fabienne Baudot for drawing the model depicted in Fig. 1.

Appendix A

Materials from Experiments 1, 2 and 3 (approximate English translation of the picture names are given in parentheses; phonetic transcription of the stimuli is given into //).

Picture name	Pseudohomo. prime	Ortho. Prime	Control prime
bras (arm) /bra/	brat /bra/	brai /bre/	borl /bɔrl/
cerf (stag) /sɛr/	cers /sɛr/	cerl /sɛrl/	caun /kon/
chat (cat) /ʃa/	chax /ʃa/	chap /ʃap/	chul /ʃyl/
clef (key) /kle/	clee /kle/	cleu /klø/	clon /klɔ̃/
croix (cross) /krwa/	croie /krwa/	croin /krwɛ̃/	cleun /kløn/
dent (tooth) /dɑ̃/	dant /dɑ̃/	dunt /dœ̃/	dise /diz/
gant (glove) /gɑ̃/	gans /gɑ̃/	gane /gan/	geuf /gøf/
grue (crane) /gry/	grus /gry/	gral /gral/	gleu /glø/
lampe (lamp) /lɑ̃p/	lanpe /lɑ̃p/	larpe /larpə/	lourm /lurm/
livre (book) /livrə/	lyvre /livrə/	lovre /lovrə/	lorme /lɔrmə/
loup (wolf) /lu/	lous /lu/	loun /lun/	lide /lid/
luge (sledge) /lyʒ/	luje /lyʒ/	lube /lyb/	lain /lɛ̃/
main (hand) /mɛ̃/	maim /mɛ̃/	mail /mɛl/	mour /mur/
noeud (knot) /nø/	noeux /nø/	noeur /nœr/	nise /niz/
noix (nut) /nwa/	nois /nwa/	noil /nwal/	neul /nøl/
pain (bread) /pɛ̃/	paim /pɛ̃/	pail /pɛl/	plor /plɔr/
peigne (comb) /pɛɲ/	peygne /pɛɲ/	pelgne /pɛlɲə/	pramer /prame/
pied (foot) /pje/	piez /pje/	pien /pjɛ̃/	peul /pøl/
pince (pinch) /pɛ̃s/	pimce /pɛ̃s/	pirce /pirs/	plour /plur/
pipe (pipe) /pip/	pype /pip/	pope /pɔp/	plir /plir/
poids (weight) /pwa/	poidt /pwa/	poide /pwad/	plur /plyr/
poire (pear) /pwar/	poirt /pwar/	poiri /pwari/	panir /panir/
porc (pig) /pɔr/	pore /pɔr/	porl /pɔrl/	pame /pam/
prise (plug) /priz/	prize /priz/	prine /prin/	puir /pwir/
roue (wheel) /ru/	rous /ru/	roun /run/	reil /rɛl/
scie (saw) /si/	scis /si/	scic /sik/	seun /søn/
singe (monkey) /sɛ̃ʒ/	sinje /sɛ̃ʒ/	sinle /sɛ̃l/	sorlt /sɔrlt/
tigre (tiger) /tigrə/	tygre /tigrə/	togre /tɔgrə/	touls /tuls/
toit (roof) /twa/	tois /twa/	toin /twɛ̃/	tabe /tab/
verre (glass) /vɛr/	veire /vɛr/	venre /vɑ̃r/	viler /vile/

References

Aitchison, J., Todd, P., 1982. Slips of the mind and slips of the pen. In: Chir, B.N., von Raffler-Engel, W. (Eds.), Language and Cognitive Styles: Patterns of Neurolinguistic and Psycholinguistic Development. Swets and Zeitlinger B.V.-Lise.

Assal, G., Buttet, J., Jolivet, R., 1981. Dissociations in aphasia: A case report. Brain and Language 13, 223–240.

Baxter, D.M., Warrington, E.K., 1986. Ideational agraphia a single case study. Journal of Neurology, Neurosurgery and Psychology 49, 369–374.

Berent, I., Perfetti, C.A., 1995. A rose is a REEZ: The two-cycles model of phonology assembly in reading English. Psychological Review 102, 146–184.

Bock, J.K., Levelt, W.J.M., 1994. Language production: Grammatical encoding. In: Gernsbacher, M.A. (Ed.), Handbook of Psycholinguistics. Academic Press, New York.

Bonin, P., 1997. Produire des mots isolês oralement et par êcrit. Revue de Neuropsychologie 7, 29–70.

Bonin, P., Fayol, M., 1996. Producing isolated words from pictures, from orally and visually presented words: An on-line study of naming and writing. In: Rijlaarsdam, G., van den Bergh, H., Couzijn, M. (Eds.), Theories, Models and Methodology in Writing Research. Amsterdam University Press, Amsterdam.

Bonin, P., Fayol, M., Gombert, J.E., 1997. Role of phonological and orthographic codes in picture naming and writing: An interference paradigm study. Current Psychology of Cognition 16, 299–320.

Bonin, P., Fayol, M., Gombert, J.E., in press. An experimental study of lexical access in the writing and naming of isolated words. International Journal of Psychology.

Brown, R., McNeill, D., 1966. The "tip of the tongue" phenomenon. Journal of Verbal Learning and Verbal Behavior 5, 325–337.

Caramazza, A., Hillis, A., 1990. Where do semantic errors come from?. Cortex 26, 95–122.

Caramazza, A., Miceli, G., 1990. The structure of graphemic representations. Cognition 37, 243–297.

Clark, H.H., 1973. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior 12, 335–359.

Cohen, J., McWhinney, B., Flatt, M., Provost, J., 1993. PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. Behavior Research Methods, Instruments, and Computers 25, 257–271.

Dell, G.S., O' Seaghdha, P.G., 1991. Mediated and convergent lexical priming in language production: A comment on Levelt et al. Psychological Review 4, 604–614.

Dell, G.S., Reich, P.A., 1981. Stages in sentences production: An analysis of speech error data. Journal of Verbal Learning and Verbal Behavior 20, 611–629.

Ellis, A.W., 1979. Slips of the pen. Visible Language 13, 265–282.

Ellis, A.W., 1982. Spelling and writing (and reading and speaking). In: Ellis, A.W. (Ed.), Normality and Pathology in Cognitive Functions. Academic Press, London.

Evett, L.J., Humphreys, G.W., 1981. The use of abstract graphemic information in lexical access. Quarterly Journal of Experimental Psychology 33A, 283–321.

Fay, D., Cutler, A., 1977. Malaproprisms and the structure of the mental lexicon. Linguistic Inquiry 8, 505–520.

Fayol, M., 1997. Des idêes au texte. Psychologie cognitive de la production verbale, orale et êcrite. Presses Universitaires de France, Paris.

Ferrand, L., Grainger, J., Segui, J., 1994. A study of masked form priming in picture and word naming. Memory and Cognition 22, 431–441.

Ferrand, L., Segui, J., Grainger, J., 1995. Amorèage phonologique masquê et dênomination. L'Annêe Psychologique 95, 645–659.

Flower, L., Hayes, J.R., Carey, L., Schriver, K., Stratman, J., 1986. Detection, diagnosis, and the strategies of revision. College Composition and Communication 37, 16–55.

Forster, K.I., Davis, C., 1984. Repetition priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition 10, 680–698.

Fromkin, V.A., 1971. The non-anomalous nature of anomalous utterances. Language 47, 27–52.

Garrett, M.F., 1975. The analysis of sentence production. In: Bower, G. (Ed.), Psychology of learning and motivation, vol. 9. Academic Press, New York.

Garrett, M.F., 1980. Levels of processing in sentence production. In: Butterworth, B. (Ed.), Language production, vol. 1. Academic Press, New York.

Garrett, M.F., 1982. Production of speech: Observations from normal and pathological use. In: Ellis, A. (Ed.), Normality and Pathology in cognitive functions. Academic Press, London.

Geschwind, N., 1969. Problems in the anatomical understanding of the aphasias. In: Benton, A.L. (Ed.), Contributions to clinical neuropsychology. Aldine, Chicago, IL.

Glushko, R.J., 1979. The organization and activation of orthographic knowledge in reading aloud. Journal of Experimental Psychology: Human Perception and Performance 5, 674–691.

Goodman, R.A., Caramazza, A., 1986. Dissociation of spelling errors in written and oral spelling: The role of allographic conversion in writing. Cognitive Neuropsychology 3, 179–206.

Hayes, J.R., Flower, L., 1980. Identifying the organisation of the writing processes. In: Gregg, L.W., Steinberg, E.R. (Eds.), Cognitive Processes in Writing. Lawrence Erlbaum, Hillsdale, NJ.

Henaff-Gonon, M.A., Bruckert, R., Michel, F., 1989. Lexicalization in an anomic patient. Neuropsychologia 27, 391–407.

Hier, D.B., Mohr, J.P., 1977. Incongruous oral and written naming. Brain and Language 4, 115–126.

Hillis, A.E., Caramazza, A., 1991. Mecanisms for accessing lexical representations for output: Evidence from a category-specific semantic deficit. Brain and Language 40, 106–144.

Hillis, A.E., Caramazza, A., 1995. Converging evidence for the interaction of semantic and sublexical phonological information in accessing lexical representations for spoken output. Cognitive Neuropsychology 12, 187–227.

Hotopf, W.H.N., 1980. Slips of the pen. In: Frith, U. (Ed.), Cognitive Processes in Spelling. Academic Press, New York.

Humphreys, G.W., Lamote, C., Llyod-Jones, T.J., 1995. An interactive activation approach to object processing: Effects of structural similarity, name frequency, and task in normality and pathology. Memory 3, 535–586.

Humphreys, G.W., Riddoch, M.J., Quinlan, P.T., 1988. Cascade processes in picture identification. Cognitive Neuropsychology 5, 67–103.

Imbs, P., 1971. Etudes statistiques sur le vocabulaire franèais. Dictionnaire des frêquences. Vocabulaire littêraire des XIXe et XXe siécles. Centre de Recherche pour un trêsor de la langue franèaise (CNRS). Nancy.

Jones, H.G.V., Langford, S., 1987. Phonological blocking in the tip of the tongue state. Cognition 26, 115–122.

Kay, J., Ellis, A.W., 1987. A cognitive neuropsychological case study of anomia: Implications for psychological models of word retrieval. Brain 110, 613–629.

Largy, P., Fayol, M., Lemaire, P., 1996. The homophone effect in written French: The case of noun-verb inflection errors. Language and Cognitive Processes 11, 217–255.

Levelt, W.J.M., 1989. Speaking: From intention to articulation. MIT Press, Cambridge, MA.

Levelt, W.J.M., Schriefers, H., Vorberg, D., Meyer, A.S., Pechmann, T., Havinga, J., 1991a. The time course of lexical access in speech production: A study of picture naming. Psychological Review 98, 122–142.

Levelt, W.J.M., Schriefers, H., Vorberg, D., Meyer, A.S., Pechmann, T., Havinga, J., 1991b. Normal and deviant lexical processing: Reply to Dell and O' Seaghdha (1991). Psychological Review 98, 615–618.

Levelt, W.J.M., Wheeldon, L., 1994. Do speakers have access to a mental syllabary?. Cognition 50, 239–269.

Lhermitte, F., Derouesnê, J., 1974. Paraphasies et jargon-aphasie dans le langage oral avec conservation du langage êcrit. Revue Neurologique 130, 21–38.

Luria, A.R., 1970. Traumatic aphasia. Mouton, The Hague.

Margolin, D.I., 1984. The neuropsychology of writing and spelling: Semantic, phonological, motor, and perceptual processes. The Quarterly Journal of Experimental Psychology 36A, 459–489.

Miceli, G., Caramazza, A., 1993. The assignement of word stress.Evidence from a case of acquired dyslexia. Cognitive Neuropsychology 10, 273–295.

Miceli, G., Silveri, C., Caramazza, A., 1985. Cognitive analysis of a case of pure dysgraphia. Brain and Language 25, 187–212.

Patterson, U.E., Marcel, A.J., 1977. Aphasia, dyslexia and the phonological coding of written words. Quarterly Journal of Experimental Psychology 29, 307–318.

Rapp, B., Benzing, L., Caramazza, A., 1997. The autonomy of lexical orthography. Cognitive Neuropsychology 14, 71–104.

Rapp, B., Caramazza, A., 1994. The dissociation of grammatical categories in the spoken vs. written production of a single patient. Report 94-4, Hopkins University.

Rapp, B., Caramazza, A., 1997. The modality-specific organization of grammatical categories: Evidence from impaired spoken and written sentence production. Brain and Language 56, 248–286.

Schriefers, H., Meyer, A.S., Levelt, W.J.M., 1990. Exploring the time course of lexical access in langage production: Picture-word interference studies. Journal of Memory and Language 29, 86–102.

Scinto, L.F., 1986. Written language and psychological development. Academic Press, New York.

Snodgrass, J.C., Vanderwart, M., 1980. A standardized set of 260 pictures: Norms for names agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning and Memory 6, 174–215.

Van Galen, G.P., 1980. Handwriting and drawing: A two-stage model of complex motor behavior. In: Stelmach, G., Requin, J. (Eds.), Tutorials in motor behavior. North-Holland, Amsterdam.

Weekes, B.S., 1994. A cognitive-neuropsychological analysis of allograph errors from a patient with acquired dysgraphia. Aphasiology 8, 409–425.