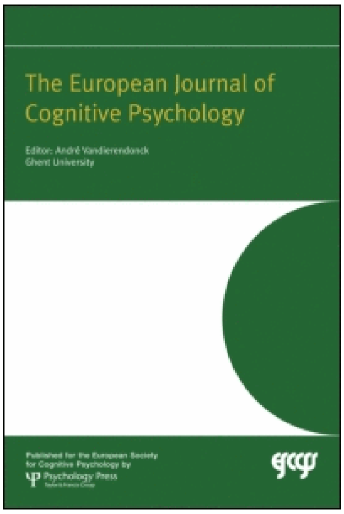

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Assessing the role of orthography in speech perception and production: Evidence from picture-word interference tasks

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Assessing the role of orthography in speech perception and production: Evidence from picture–word interference tasks

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The effects of orthographic and phonological relatedness between distractor word and object name in a picture–word interference task were investigated. In Experiment 1 distractors were presented visually, and consistent with previous findings, priming effects arising from phonological overlap were modulated by the presence or absence of orthographic similarity between distractor and picture name. This pattern is interpreted as providing evidence for cascaded processing in visual word recognition. In Experiment 2 distractors were presented auditorily, and here priming was not affected by orthographic match or mismatch. These findings provide no evidence for orthographic effects in speech perception and production, contrary to a number of previous reports.

Spoken production entails a conversion of meaning into overt speech. The mechanisms by which conceptual knowledge is converted into phonological forms has been a prominent issue in psycholinguistics for a number of years, and detailed computational models of spoken production have been brought forward (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, & Meyer, 1999).

The picture–word interference (PWI) paradigm has, over the last 30 or so years, emerged as one of the preferred research tools for spoken production. In this task, participants are asked to name objects while attempting to ignore so-called distractor words that are either visually superimposed on the object, or spoken. A typical finding is that, if picture and word belong to the same semantic category, responses are substantially slowed relative to a semantically unrelated condition (e.g., Rosinski, Golinkoff, & Kukish, 1975). By contrast, and particularly relevant for the present paper, if the picture

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name and word are form related, response times are faster than in the unrelated case (e.g., Posnansky & Rayner, 1977; Rayner & Posnansky, 1978); we will refer to this facilitation as priming. Similar results are obtained when distractors are presented in the visual or auditory format (e.g., Damian & Martin, 1999; Schriefers, Meyer, & Levelt, 1990). On a very general level, form-related priming effects suggest that the distractor words make contact with the form representations involved in object naming, accelerating responses when distractor and target representations overlap.

Although it is typically (and oftentimes implicitly) assumed that the form influences in the PWI task are purely phonological, it is possible that orthography plays a role as well. Even in languages with irregular spelling-to-sound mappings such as English, spelling and sound are highly confounded. Hence, it is no surprise that virtually all of the several dozen published studies that investigated phonological effects in PWI have used form-related distractors that were phonologically as well as orthographically related to the picture label. However, the two types of similarity can in principle be dissociated, and indeed, a few previous studies have attempted to do so in order to illuminate the mechanisms involved in picture and word processing. This not only promises to yield a more detailed analysis of the mechanisms underlying the PWI task, but potentially also underscores processing principles that apply to spoken production in general.

Lupker (1982) presented visual distractor words that, in his first experiment, were orthographically related but phonologically largely unrelated to the picture label (foot–boot), or unrelated (foot–bar). A priming effect of 56 ms was obtained, which indicates that an orthographical relationship between picture and distractor by itself—and in the absence of much phonological overlap—substantially facilitates picture naming responses. In the second experiment, a condition in which pictures and distractors were phonologically and orthographically related (train–brain) was compared to an unrelated condition (train–noose). Here, a priming effect of 55 ms was obtained. Importantly, a further condition in which picture names and words were phonologically related, but orthographically unrelated (train–cane) yielded a priming effect of 23 ms relative to the unrelated condition, demonstrating a phonological relatedness effect in the absence of orthographic relatedness. These findings suggest that both orthographic and phonological factors combine to yield form-related priming in the PWI task.

The importance of orthographic factors in the picture–word interference task was replicated in a study by Underwood and Briggs (1984) that compared adults to children (for the sake of brevity, only the results from the adults will be reported). Participants named pictures on which words were superimposed that were either orthographically related (nose–lose), phonologically related (nose–goes), or unrelated (nose–shut). Crucially, the orthographically related/phonologically unrelated condition yielded a priming effect of 32 ms relative to the unrelated baseline condition, but the phonologically related/orthographically unrelated condition showed only a very weak priming effect (6 ms). Hence, the results confirm Lupker's (1982) observation that orthographic overlap by itself can induce a priming effect, and further downplay the role of phonological factors in creating form-related facilitation in this task.[1]

More recently, Weekes, Davies, and Chen (2002) assessed the orthographic and phonological contributions to PWI in Chinese. The advantage of using Chinese is that it allows these factors to be more cleanly dissociated—phonologically similar words can be written in an unrelated format, and, more important for present purposes, orthographically similar words can be unrelated phonologically. The results suggested that orthography and phonology both contributed to the form facilitation effects, as both types of written distractors facilitated picture naming, and to a similar extent.

These studies highlight a clear role of orthographic relatedness in the PWI paradigm. One plausible interpretation of these results is that the priming reflects the processes of converting the visual distractors to their phonological form and, as such, mainly reflects properties of the reading process (as discussed in more detail in the General Discussion). Another interpretation of these findings, however, hinges on the possibility that spoken perception and production itself may involve the automatic activation of orthographic codes. In psycholinguistic research, the issue of how various subsystems involved in language (i.e., semantic, syntactic, phonological, orthographic) interact in any given language task has been one of the dominating themes. In the case of reading, the interaction between orthography and phonology is relatively well-established (see, for instance, various masked priming studies provide evidence of fast and automatic activation of phonology from print; e.g., Lukatela & Turvey, 1994; Rastle & Brysbaert, 2006), and there is growing evidence that activated phonology feeds back onto orthography prior to written word identification (e.g., Pexman, Lupker, & Reggin, 2002). The reverse case, namely the potential role of phonological–orthographic interactions in speech perception/comprehension is relatively less studied. Nevertheless, over the last 30 or so years, a number of papers provide evidence of orthographic influences on the perception of spoken words (e.g., Chéreau, Gaskell, & Dumay, 2007; Dijkstra, Roelofs, & Fieuws, 1995;

[1] On a related note, Rayner and Posnansky (1978) found that nonword distractors that preserved many visual features of the picture name yielded more priming than nonwords that did not. Priming was shown to be the result of the combination of preserving the first letter, and maintaining the overall shape of the label: "bcnrc" primed naming a horse more than "pynrk" did, and "hgple" primed naming more than "bnrc".

Donnenwerth-Nolan, Tanenhaus, & Seidenberg, 1981; Hallé, Chéreau, & Segui, 2000; Jakimik, Cole, & Rudnicky, 1985; Muneaux & Ziegler, 2004; Racine & Grosjean, 2005; Seidenberg & Tanenhaus, 1979; Taft & Hambly, 1985; Ventura, Morais, Pattamadilok, & Kolinsky, 2004; Ziegler & Ferrand, 1998; Ziegler, Ferrand, & Montant, 2004), suggesting that interactions between these systems are quite general.

Indeed, a few studies have provided evidence that the orthography of words also affects conceptually driven spoken production. For example, Wheeldon and Monsell (1992) asked participants to produce words in response to definitions in a study phase, and to name pictures in a subsequent test phase. Priming was obtained between homophones that share the same spelling (e.g., generating the spoken word "bat" in response to the definition "Used to hit the ball in cricket" facilitated the later naming of a picture of the animal bat), but not between homophones with different spellings (e.g., generating the word "son" from a definition did not facilitate the naming of picture of a sun). Hence, long-lasting priming for homophones in picture naming depended on the presence or absence of overlap in spelling. Gaskell, Cox, Foley, Grieve, and O'Brien (2003) asked participants to shadow auditorily presented nouns together with the definite article "the", which is typically pronounced as "thee" when occurring before a noun starting with a vowel, and as "thuh" otherwise. They demonstrated that the chosen form depended not only on the pronunciation of the target, but also on its spelling (e.g., "union" was more likely to be preceded by "thee" than "yellow", presumably because the initial letter of only the former corresponds to a vowel). Damian and Bowers (2003) investigated the potential effects of orthography in a task in which participants produced words in response to highly associated prompts. A common finding in this task is that latencies are faster when all responses share the initial phoneme(s), compared to an unrelated condition (e.g., Meyer, 1990). This facilitation effect was replicated when response words shared pronunciation and spelling (kennel, kayak, kidney), but not when the spelling of one item differed (kennel, camel, kidney). However, subsequent studies in Dutch (Roelofs, 2006) and French (Alario, Perre, Castel, & Ziegler, 2007) failed to replicate this effect, pointing towards possible cross-linguistic differences in the nature of orthographic effects in speaking and highlighting the need for further studies in order to clarify the role of orthography in speech production (and perception).

The two studies reported here address this issue using the PWI task. The first experiment aims at replicating the previous results described earlier, which had suggested independent roles of orthographic and phonological overlap in PWI with visual distractors. Assuming we obtain orthographic effects with visual distractors (which we do), it raises the question of whether there are also effects of orthography with *spoken* distractors. If, as a range of studies cited earlier suggest, spoken word perception and production activate orthographic representations, then, orthographic relatedness may modulate priming effects obtained from spoken words as well. On the other hand, if orthographic facilitation with visual distractors is primarily attributable to priming of visually related items during reading, spoken distractors should exhibit priming that is exclusively constrained by phonological, but not by orthographic, factors. This latter result would highlight a limitation on the degree of interactivity between orthography and phonology in speech perception and production, as well as provide insight into the processes involved in reading. Such a finding would also prove useful methodologically: Orthographic effects could be safely ignored in PWI experiments when spoken distractors are employed.

EXPERIMENT 1

As outlined previously, effects of orthography in the PWI task with visual distractors can in principle be investigated in two ways. First, orthographically related, but phonologically unrelated (or less related; see later) targets and distractors (bear–year) can be compared to unrelated pairs (bear–comb). A difference in latencies is then attributed to the orthographic similarity between target and distractor. A problem arising with English stimuli is that the critical pairs typically have residual *phonological* overlap, i.e., "bear" and "year" share the final segment. Phonological overlap of this type may itself cause some priming, and hence orthographic contributions may be overestimated. A different strategy consists of comparing phonologically and orthographically related targets and distractors (train–brain) to pairs that are phonologically related, but orthographically unrelated (train–cane). Again, a difference in latencies would be attributed to the presence or absence of orthographic similarity. In this manipulation, the orthographically unrelated pairs such as train–cane typically have residual *orthographic* overlap, i.e., "train" and "cane" share the letters "a" and "n" (although not in the correct position). Because the latter condition is not entirely unrelated, orthographic contributions are potentially underestimated when these RTs are compared to the experimental condition.

Both problems arise from the fact that despite the irregularity of English grapheme-to-phoneme correspondences, spelling and sound are still highly confounded. In our study, we opted for the more conservative second method, and exclusively investigated priming for distractors that were phonologically similar, and either orthographically similar, or dissimilar, to the picture label. A reduction in priming as a consequence of reduced orthographic similarity can be viewed as evidence supporting the importance of orthographic variables.

We made an attempt to match distractor stimuli on a variety of psycholinguistic variables across the conditions. Furthermore, previous studies (i.e., Lupker, 1982; Underwood & Briggs, 1984) presented pictures and distractors with a simultaneous onset. Given that priming effects have been observed across a range of intervals between picture and distractor onsets (stimulus–onset asynchronies, or SOAs; e.g., Damian & Martin, 1999; Starreveld, 2000), we included a range of SOAs in order to increase the power of our experiment: An effect of orthography emerging at any of the tested SOAs would provide relevant evidence.

Method

Participants. Twenty-eight undergraduate students at the University of Bristol took part in exchange for course credit. All were native speakers and had normal or corrected-to-normal vision.

Materials. Eighteen line drawings of common objects served as the targets. All had monosyllabic names, with a Kucera-Francis frequency of 52, and an average frequency of 22 per million in the CELEX database of spoken English (Baayen, Piepenbrock, & Gulikers, 1995). For these picture labels, phonologically and orthographically related (PO) distractor words were chosen that rhymed and shared the spelling of the body of the word (e.g., "train"–"brain"). Phonologically related, but orthographically dissimilar (P) distractors were chosen that rhymed but differed in the spelling of the body portion ("train"–"cane"). Care was taken to avoid semantic or associative relationships between pictures and distractor words. Homophones were also avoided. All distractors were monosyllabic. Distractors in each condition were recombined with pictures to form two corresponding unrelated (U) conditions, in which there was no phonological, orthographic, or semantic relationship.

The lexical properties of distractor words are shown in Table 1. Items were statistically matched across the two conditions on word length in letters and phonemes, Kucera-Francis frequency, Celex written and spoken frequency (all Fs < 1), and consistency of orthography-to-phonology mapping, i.e., the number of words with the same spelling body, and their summed frequency (Ziegler et al., 1997). Additionally, we estimated the degree of orthographic and phonological overlap between distractor words and corresponding picture names with a similarity measure ranging from 0 to 1, computed as the average of (a) the fraction of shared letters/phonemes between distractor and picture label in and out of position, and (b) the fraction of shared letters/phonemes that occurred in the same position within each word (this index, also used in Damian & Martin, 1999, was adapted from Lesch & Pollatsek, 1993). The values shown in Table 1 indicate

TABLE 1
Mean lexical properties of distractor stimuli used in Experiments 1 and 2 (frequencies indicate occurrence per million)

	Phonologically and orthographically related	*Phonologically related*
Word length—letters	4.4	4.4
Word length—phonemes	3.3	3.3
Kucera-Francis frequency	52	47
Celex—written frequency	84	54
Celex—spoken frequency	29	40
Spelling–phonology consistency[a]	600 (9.9)	603 (10.0)
Overlap with target—phonemes[b]	0.45 (0.02)	0.45 (0.02)
Overlap with target—letters[b]	0.50 (0.06)	0.30 (0.07)
Duration (in ms; Experiment 2)	626	631

[a]*Source*: Ziegler, Stone, and Jacobs (1997). Summed Kucera-Francis frequency, and number of words (in parentheses), with same spelling body. [b]Numbers in parentheses indicate overlap in the corresponding unrelated condition.

that words in the PO and the P conditions are matched in their phonological similarity to the picture name ($F < 1$). Numbers in parentheses indicate overlap between corresponding unrelated picture–distractor combinations, which is essentially zero. By the same token, the P distractors should ideally be as orthographically dissimilar to the picture names as the U distractors. But because orthography and phonology are confounded in English, this is very difficult to accomplish. Although the P distractors are significantly less orthographically similar to the picture label than the PO distractors ($p = .002$), they are nevertheless more orthographically similar than the unrelated condition ($p < .001$). This confound, of course, works *against* our objective of demonstrating effects of orthography in this task. A full list of the stimuli is provided in the Appendix.

Design. The experimental design included relatedness (related vs. unrelated), type of relatedness (phonologically and orthographically related vs. phonologically related), and SOA (–100 ms, 0 ms, + 100 ms, and + 200 ms) as within-participants and within-items variables. For each participant, each picture was displayed under every relatedness and SOA condition, resulting in 288 combinations. Trials were blocked by SOA. The order in which participants received the SOA blocks was varied according to a Latin square design. Items were presented in a pseudorandom fashion such that any particular picture was never repeated on consecutive trials. A new random sequence was generated for each participant and each block.

Apparatus. Stimuli were presented from an IBM-compatible computer on a 17-inch monitor using DMDX 3.0 (Forster & Forster, 2003). The objects were digitised as line drawings to a size of approximately 8×8 cm, and were presented as black line drawings on light grey background. Distractor words were presented in black 18 point Arial bold font in the centre of the screen. A headset (Sennheiser mb40) with attached microphone was connected to the computer. DMDX determined the onset of the vocal responses to the nearest millisecond.

Procedure. Participants were tested individually. At the beginning of the experiment, they were instructed that their task would be to name objects as fast and as accurately as possible. They were familiarised with the set of experimental pictures by viewing all objects on the screen in a miniaturised display, with the corresponding name printed below each image. In a first practice block, each object was then presented and named once in random order; responses other than the ones expected were corrected. In a second practice block, the pictures were accompanied by unrelated distractor words; again, unexpected responses were corrected. Subsequently, four experimental blocks of 72 trials each were carried out. Breaks were provided between the blocks. Each testing session consisted of 288 experimental trials, and took approximately 30 min to complete.

Each individual trial was structured as follows: A fixation cross was presented for 500 ms. After a blank period of 500 ms, the target picture was shown for 2000 ms. Distractor words were presented at the appropriate interval relative to object onset. Latencies were measured from the onset of the target to the response. Following each trial, the experimenter judged the response to be either correct or incorrect; incorrect responses consisted of responses other than the expected ones, repairs, stuttering, or mouth clicks. An intertrial interval of 1500 ms concluded each trial.

Results

Responses judged to be incorrect by the experimenter for the reasons described previously were excluded from the response latency analysis (1.4%). Latencies faster than 250 ms or slower than 1500 ms were considered outliers and eliminated (2.0%). Table 2 presents the mean latencies and error percentages, varied by relatedness, type of relatedness, and stimulus–onset asynchrony (SOA). As can be seen, the PO condition shows substantial priming relative to the unrelated baseline across all SOAs. By contrast, the P condition shows numerically much smaller priming effects, with a large effect only emerging at SOA = + 100 ms.

TABLE 2
Experiment 1: Visual distractors: Mean response latencies (in ms) and mean error proportions (in parentheses), varied by picture–word stimulus–onset asynchrony and relatedness

Condition	SOA (ms) –100	0	+100	+200	Overall
PO	692 (2.2)	693 (1.4)	706 (1.6)	663 (2.4)	688 (1.9)
U	714 (4.0)	718 (2.4)	742 (2.8)	683 (2.8)	714 (2.9)
Effect	+22 (+1.8)	+25 (+1.0)	+36 (+1.2)	+20 (+0.4)	+26 (+1.0)
P	694 (1.8)	717 (2.6)	718 (2.4)	675 (1.0)	702 (1.9)
U	698 (2.4)	728 (2.8)	749 (3.4)	682 (3.0)	714 (2.0)
Effect	−4 (+0.6)	+11 (+0.2)	+31 (+1.0)	+7 (+2.0)	+12 (+1.0)

SOA = stimulus–onset asynchrony; PO = phonologically and orthographically related; P = phonologically related; U = unrelated.

Analyses of variance (ANOVAs) were conducted on the response latency means computed by participants and by items, with relatedness, type of relatedness, and SOA as within-participants and within-items variables. We found a main effect of relatedness, $F1(1, 27) = 28.96$, $MSE = 39{,}168$, $p < .001$; $F2(1, 17) = 26.64$, $MSE = 39{,}168$, $p < .001$, with overall latencies 19 ms faster in the related than in the unrelated condition. The factor type of relatedness was significant by participants, $F1(1, 27) = 6.15$, $MSE = 4609$, $p = .020$, but not by items, $F2 = 1.79$, $p = .198$. We also found a main effect of SOA, $F1(3, 81) = 10.44$, $MSE = 56{,}758$, $p < .001$; $F2(3, 51) = 45.04$, $MSE = 36{,}925$, $p < .001$. Crucially, we obtained a significant interaction between relatedness and type of relatedness, $F1(1, 27) = 8.29$, $MSE = 5354$, $p = .008$; $F2(1, 17) = 5.93$, $MSE = 3475$, $p = .026$, indicating that the form-related facilitation was modulated by the spelling of the distractor words. Simple effects of relatedness, conducted under each level of the factor type of relatedness, showed that for the PO condition, the 26 ms priming effect was highly significant, $F1(1, 27) = 44.11$, $MSE = 36{,}742$, $p < .001$; $F2(1, 17) = 28.76$, $MSE = 23{,}428$, $p < .001$. For the P condition, the numerically much smaller 12 ms effect was still significant, $F1(1, 27) = 6.68$, $MSE = 7779$, $p = .016$; $F2(1, 17) = 6.92$, $MSE = 4857$, $p = .018$. We additionally obtained an interaction between type of relatedness and SOA, $F1(3, 81) = 3.79$, $MSE = 2754$, $p = .013$; $F2(3, 51) = 2.93$, $MSE = 1639$, $p = .042$, and between relatedness and SOA, $F1(3, 81) = 3.14$, $MSE = 3123$, $p = .030$; $F2(3, 51) = 3.26$, $MSE = 1989$, $p = .029$, the latter interaction showing the expected sensitivity of the relatedness effect to the exact timing between picture and word. The three-way interaction between relatedness, type of relatedness, and SOA was not significant, $F1 < 1$, $p = .640$; $F2 < 1$, $p = .676$.

Similar ANOVAs performed on the error percentages showed a significant effect of relatedness, $F1(1, 27) = 8.56$, $MSE = 109.62$, $p = .007$; $F2(1, 17) = 5.12$, $MSE = 70.86$, $p = .037$, with lower error scores in the related (1.9%) than in the unrelated condition (2.9%). None of the other main effects or interactions reached statistical significance, all $F1 \leq 1.70$, $p \geq .173$; all $F2 \leq 1.80$, $p \geq .159$.

Discussion

For phonologically and orthographically related distractors, this experiment showed substantial form priming under all SOAs, ranging from −100 ms to + 200 ms. This pattern, as well as the size of the effects, is relatively typical, comparable to previously reported findings such as Damian and Martin (1999). The central finding, however, is that this priming effect was clearly modulated by the presence or absence of a concurrent orthographic relationship, as indicated by considerably reduced priming in the phonologically related, but orthographically unrelated, condition. Indeed, at SOA= − 100 ms, orthographic mismatch between picture and word eliminated form priming altogether. At SOA=0 ms, priming was reduced to about half in the P, relative to the PO condition, but at SOA= + 100 ms, both conditions showed comparable priming. Although we did not obtain a significant three-way interaction between relatedness, type of relatedness, and SOA, on a descriptive level our results indicate that whether or not orthographic match or mismatch exhibits an effect depends on the exact timing between picture and distractors. This finding allows us to resolve the discrepancy which emerged in the results of previous, similar experiments: As summarised in the introduction to this paper, Underwood and Briggs (1984) found that P distractors exhibit no (or only extremely small) priming, whereas Lupker (1982) reported numerically reduced, but still significant, priming for these distractors. By comparison, our results under SOA= − 100 ms would seem to agree with Underwood and Briggs' findings, whereas the results under SOA=0 ms are similar to Lupker's findings; the results under SOA= + 100 ms are incompatible with both previous studies. Whether or not a distractor shows an effect at any particular SOA is a result of a combination of picture, and word, processing time, hence it is problematic directly to compare effects across different studies. Nevertheless, our findings suggest that, had the earlier studies included a range of SOAs, they would have obtained results relatively similar to each other, with a considerable effect of orthographic overlap at more negative SOAs, but a reduced or eliminated effect at more positive SOAs.

EXPERIMENT 2

As noted in the introduction to this paper, the finding that the orthographic properties of the visual word distractors influence performance in the PWI task could be explained with the assumption that the lexical representations activated during picture naming are at least partially constrained by orthographic variables, an interpretation originally suggested by Lupker (1982). In this sense, production of the phonological code for a picture name would genuinely involve orthographic factors, much like what has been claimed for access to phonological codes in spoken comprehension (e.g., Seidenberg & Tanenhaus, 1979). Alternatively, it could be that the orthographic effects mainly reflect input processing of the distractor word (e.g., the written word "pool" activating the orthographic form "stool", which in turns activates the phonological form of the to-be-named picture "stool"). Indeed, some models of PWI, e.g., Starreveld and La Heij (1996), predict exactly such an effect. In this case, the results should not be taken as positive evidence for the role of orthography in spoken production per se, but rather arise as a consequence of the fact that processing of visual distractors necessarily involves an orthographic element.

In the second experiment, we used distractors that were auditorily presented. Under these circumstances, if orthography had an effect on form priming, it would provide striking further evidence that both auditory word processing or picture naming involve the automatic activation of orthographic codes. On the other hand, if facilitation is mainly constrained by phonological, but not by orthographic, factors, we would conclude that the role of orthography in word production is rather subtle.

Method

Participants. Twenty-eight undergraduate students at the University of Bristol, none of whom had taken part in the first experiment, participated in this experiment for course credit. All were native speakers and had normal or corrected-to-normal vision.

Materials, design, apparatus, and procedure. These were identical to Experiment 1. However, distractor words were recorded by a male speaker and digitised with a sampling frequency of 16 kHz. The durations of the distractors, measured in a sound-editor and displayed in Table 1, were matched across the conditions ($F < 1$).

In the experiment, distractor words were presented to participants at a comfortable volume level over Sennheiser mb40 headphones at the appropriate time interval relative to picture onset; response latencies were measured relative to picture onset.

Results

Responses judged to be incorrect by the experimenter for the reasons described previously were excluded from the response latency analysis (2.1%). Latencies faster than 250 ms or slower than 1500 ms were considered outliers and eliminated (1.1%). Table 3 presents the mean latencies and error percentages, varied by relatedness, type of relatedness, and SOA. In this experiment, priming effects emerged under SOAs ranging from –100 ms to + 100 ms, with both PO and P distractors exhibiting substantial, and similar, priming relative to the unrelated baseline.

ANOVAs conducted on the response latency means showed a main effect of relatedness, $F1(1, 27) = 46.85$, $MSE = 35{,}342$, $p < .001$; $F2(1, 17) = 13.04$, $MSE = 22{,}599$, $p = .002$, with overall latencies 18 ms faster in the related than in the unrelated condition. The factor type of relatedness was not significant, $F1 = 1.34$, $p = .257$; $F2 < 1$, $p = .484$. The factor SOA was not significant by participants, $F1 = 1.33$, $p = .271$, but by items, $F2(3, 51) = 4.43$, $MSE = 2741$, $p = .008$. Crucially, and in contrast to the results from the first experiment, relatedness and type of relatedness did not significantly interact, $F1 < 1$, $p = .347$; $F2 < 1$, $p = .723$, suggesting that the presence or absence of orthographic overlap was irrelevant to the form-related priming effect. We found a significant interaction between type of relatedness and SOA, $F1(3, 81) = 3.18$, $MSE = 3863$, $p = .028$; $F2(3, 51) = 8.07$, $MSE = 2861$, $p < .001$. The interaction between relatedness and SOA was not significant, $F1 = 2.05$, $p = .113$; $F2 = 1.63$, $p = .193$, and neither was the three-way interaction between relatedness, type of relatedness, and SOA, $F1 < 1$, $p = .750$; $F2 < 1$, $p = .864$.

TABLE 3
Experiment 2: Auditory distractors: Mean response latencies (in ms) and mean error proportions (in parentheses), varied by picture–word stimulus–onset asynchrony and relatedness

	SOA (ms)				
Condition	*–100*	*0*	*+100*	*+200*	*Overall*
PO	565 (2.0)	567 (2.0)	582 (1.4)	591 (1.6)	576 (1.7)
U	584 (2.0)	595 (2.2)	602 (2.0)	602 (3.4)	596 (2.4)
Effect	+19 (0.0)	+28 (+0.2)	+20 (+0.6)	+11 (+1.8)	+20 (+0.7)
P	581 (1.6)	576 (1.4)	588 (1.8)	581 (2.6)	581 (1.8)
U	597 (2.0)	596 (1.8)	612 (2.2)	585 (3.2)	597 (2.3)
Effect	+18 (+0.4)	+20 (+0.4)	+24 (+0.4)	+4 (+0.6)	+16 (+0.5)

SOA = stimulus–onset asynchrony; PO = phonologically and orthographically related; P = phonologically related; U = unrelated.

Similar ANOVAs performed on the error percentages showed an effect of relatedness that was marginally significant by participants, $F1(1, 27) = 4.04$, $MSE = 30.38$, $p = .055$, but not by items, $F2 = 1.92$, $p = .183$, with slightly lower error scores in the related (1.8%) than in the unrelated condition (2.3%). None of the other main effects or interactions reached statistical significance, all $F1 \leq 1.12$, $p \geq .347$; all $F2 \leq 1.93$, $p \geq .136$.

The design of the experiment may be criticised on the basis that each target is named several times, and indeed is presented in conjunction with the same distractor four times, once for each SOA. If it is assumed that orthographic effects in spoken production exist but are relatively subtle, one could argue that our design obscured them. Due to severe constraints on stimulus selection, it is less than straightforward to avoid this problem by expanding the stimulus set. We therefore performed an additional analysis in which we restricted our analysis to the first half, i.e., the first two experimental blocks on which each participant was tested. Again, we failed to find an interaction between relatedness and type of relatedness in response times, $F1 = 1.47$, $p = .236$; $F2 = 0.82$, $p = .378$ (23 and 24 ms facilitation effects for the PO and P condition, respectively), and in errors, $F1 = 0.39$, $p = .537$; $F2 = 0.16$, $p = .692$ (0.0 and +0.4% effects for the PO and P condition, respectively). When we restricted our analysis to just the first quarter (i.e., the first block on which each participant was tested), we found the same results, $F1 = 0.79$, $p = .381$; $F2 = 0.44$, $p = .515$ for response times (20 and 16 ms facilitation effects for the PO and P condition, respectively), and $F1 = 2.36$, $p = .136$; $F2 = 1.55$, $p = .231$ for error rates (–0.4 and +0.8% effects for the PO and P condition, respectively). These additional findings argue against the possibility that an alternative design in which each target was named fewer times, or perhaps only once, would have unearthed orthographic effects that are absent from the results of Experiment 2.

Discussion

We obtained substantial form-based priming with SOAs ranging from −100 ms to +100 ms, with relatively less priming at SOA = +200 ms. This finding is generally congruent with some previous studies; e.g., Jescheniak and Schriefers (2001) and Starreveld (2000) found priming with SOAs ranging from −300 ms to +150 ms. On the other hand, Schriefers et al. (1990) found phonological effects only with SOAs of 0 ms or longer, and Damian and Martin (1999) obtained priming with SOAs ranging from −100 ms to +200 ms, with the effect peaking at SOA = +100 ms. Clearly, the strength of form-based priming at any particular SOA depends on a number of factors, such as overall response latencies, the length of the distractor words, whether SOAs are varied within or between participants, and possibly the presence and absence of semantic distractors (see Starreveld, 2000, for a discussion). The particular SOA at which form-based priming peaks is, however, of only minor interest for our present study.

More importantly, the presence or absence of an orthographic relationship between distractor and picture did not modulate the form-based priming effect; indeed, priming effects in the PO and the P condition, when collapsed across SOAs, were very similar (20 and 16 ms, respectively). We conclude that, as opposed to distractor words that are visually presented, with auditorily presented distractors orthographic match or mismatch between distractor and object name does not affect response latencies.

GENERAL DISCUSSION

Two experiments were conducted that set out to test the relative contributions of phonological and orthographic overlap between picture labels and distractor words in the picture–word interference paradigm. In the first experiment, using visually presented distractors we replicated the main pattern from earlier studies: Distractors that rhymed with the picture name but were spelled differently (train–cane) showed a reduced priming effect relative to rhyming distractors that were spelled similarly (train–brain). This effect was robust and extended to a range of SOAs. The second experiment used the same materials and design, but distractors were auditorily presented. Here, we found no effect of orthographic overlap—form priming was exclusively determined by the presence of phonological overlap between picture and word.

Taken together, these results do not provide evidence in support of the claim that orthographic effects arise in spoken production. If orthographic codes were strongly activated in the normal course of speech perception and production, it might have been predicted that the effects we obtained from written distractors should have extended to the spoken distractors as well. At the same time, our failure to obtain orthographic effects from spoken distractors does not necessarily imply that there are no orthographic effects in verbal language tasks in general and, indeed, a variety of studies reviewed in the introduction to this paper suggest such effects in both speech perception and production. But the failure to observe such effects in the PWI task with spoken distractors highlights that the effects may be somewhat subtle. It is worth noting that the PWI task is a version of the Stroop task that is considered to assess relatively automatic processes, whereas many of the previous studies that have obtained evidence for orthographic influences in perception and production may be more subject to strategic influence. Thus, the present finding also raises the possibility that previous evidence in support of orthographic effects was in fact artefactual and task specific. Future research on this issue is clearly warranted.

In the introduction to the first experiment, we highlighted the fact that English pronunciation and spelling cannot easily be dissociated. In our experiments we assessed priming for phonologically and orthographically related distractors, compared to priming from distractors that were phonologically equally similar, but orthographically less similar (but not entirely unrelated). As outlined, this approach possibly underestimates the potential contribution of spelling. In Chinese, by contrast, spelling and sound are virtually unrelated, and hence a possible further study would be to conduct a PWI study with auditorily presented distractors on Chinese speakers. Unfortunately, the exceptionally frequent occurrence of homophones in Chinese (e.g., MacNaughton, 1999) makes it nearly impossible to identify suitable stimuli, because a given auditory distractor word will typically exhibit multiple possible spellings.

Although the current findings provide no evidence for orthographic effects in spoken production, the findings do provide evidence for cascaded processing in reading. In particular, in our view the most parsimonious account of orthographic priming effects obtained with visual distractors is one that assumes that a written distractor word activates a set of form-related items (or "neighbours") in the orthographic lexicon, a claim supported by various empirical findings in visual word recognition (e.g., Andrews, 1997; Carreiras, Perea, & Grainger, 1997). Candidates in this set in turn may coactivate their corresponding lexical–phonological (lexeme) or lexical–semantic (lemma) representations through cascaded processing. For example, when naming a picture of a "stool", the written word distractor "pool" may activate the lexical–orthographic codes for "pool" and "stool", and this in turn could coactivate the lexical semantic and lexical phonological codes of "pool" and "stool". It is the activation of the target stool in semantics or phonology based on the written word pool that can explain the orthographic priming effects from written distractors. On the other hand, the phonologically related, but orthographically dissimilar, distractor "rule" will activate a different set of orthographically similar items (mule, yule, pule). When these activate their corresponding phonological and semantic entries the target "stool" will not be among them, and no (or little) facilitation will result. This lends support to a number of recent studies that have also reported evidence for cascaded processing from orthography to semantics (Bowers, Davis, & Hanley, 2005; Rodd, 2004). Cascaded processing in visual word identification is widely assumed (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), but until recently, little evidence for this claim has been reported. The pictured scenario essentially attributes the orthographic facilitation effect to direct priming of the target candidate; but of course, additional priming could take place at the segmental level. In the previous examples, both "pool" and "rule" share phonological segments with the target picture name "stool"; activation of this subset of the target phonemes via phonological priming from both types of distractors would then account for the facilitation effect obtained in the P condition in which there is no orthographic overlap between word and picture.

On a methodological level, our findings indicate that in the PWI task with visually presented distractors, both orthographic and phonological overlap between picture and distractor are variables that need to be carefully controlled. By contrast, when distractors are auditorily presented, priming is exclusively determined by phonological overlap, and the degree of orthographic match or mismatch between picture names and distractor words can be safely ignored. This should be of comfort to researchers using this version of the task who have to date not considered potential effects of orthographic overlap.

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APPENDIX

Stimuli used in Experiment 1 and 2

Target	*Phonologically and orthographically related*	*Phonologically and orthographically unrelated*	*Phonologically related*	*Phonologically unrelated*
bear	swear	pool	share	view
bread	head	foe	shed	snow
broom	doom	scale	plume	share
chain	drain	beer	lane	rule
deer	beer	brain	gear	shed
door	floor	brew	snore	plume
drum	slum	swear	crumb	jail
hair	chair	slum	square	crumb
kite	white	trail	fight	plea
mole	dole	drain	goal	gear
plane	crane	floor	stain	fight
screw	brew	white	view	goal
snail	trail	fee	gale	cane
stool	pool	head	rule	lane
toe	foe	chair	snow	gale
train	brain	dole	cane	square
tree	fee	crane	plea	stain
whale	scale	doom	jail	snore