Current psychology letters

Behaviour, brain & cognition

Vol. 26, Issue 1, 2010 | 2010

Varia

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Electronic version

URL: <http://journals.openedition.org/cpl/4984>

DOI: 10.4000/cpl.4984

ISSN: 1379-6100

Publisher

Centre PsyCLÉ

Electronic reference

Pamela Gobin and Stéphanie Mathey, « The influence of emotional orthographic neighbourhood in visual word recognition », *Current psychology letters* [Online], Vol. 26, Issue 1, 2010 | 2010, Online since 07 October 2010, connection on 08 September 2020. URL : <http://journals.openedition.org/cpl/4984> ; DOI : <https://doi.org/10.4000/cpl.4984>

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The influence of emotional orthographic neighbourhood in visual word recognition

Pamela Gobin and Stéphanie Mathey

We thank two anonymous reviewers for helpful comments and suggestions on an earlier version of this paper.

- 1 Does the emotional valence of orthographic neighbourhood influence visual word recognition? Orthographic neighbours are traditionally defined as words which only differ by one letter, the length and the letter positions being unchanged (Coltheart, Davelaar, Jonasson & Besner, 1977). In recent decades, the effect of orthographic neighbours on visual word recognition has been widely investigated (see Andrews, 1997; Mathey, 2001, for reviews). However, the possible impact of the affective content of the orthographic neighbours has remained unexplored. After a brief presentation of the orthographic neighbourhood issue, we present arguments for investigating the issue of emotional orthographic neighbourhood.
- 2 The inhibitory effect of higher-frequency neighbours was first shown in the standard lexical decision task (LDT) by comparing words without higher-frequency neighbours and words with at least one higher-frequency neighbour (Grainger, O'Regan, Jacobs & Segui, 1989). The recognition of words with at least one higher-frequency neighbour (*e.g.*, FOIN) was slowed down in comparison with that of words without a higher-frequency neighbour (*e.g.*, JUPE). In the Interactive-Activation (IA) model (McClelland & Rumelhart, 1981), this inhibitory effect can be attributed to lateral inhibition at the word level (Grainger et al., 1989). When a written word is presented, it activates its own representation and those of its orthographic neighbours. Because they are highly activated, high-frequency neighbours strongly compete with the other lexical representations, and therefore delay stimulus recognition.
- 3 The masked priming paradigm has also been widely used to investigate orthographic neighbourhood effects (see Davis, 2003; Robert, 2009, for reviews). Traditionally, a related or a control prime is briefly presented before the target word, which is the

subject of the task. In the LDT, target words (*e.g.*, *CHAR*) were recognized more slowly when they were preceded by a higher-frequency neighbour (*e.g.*, *chat*) than by a control prime during 60 ms (Segui & Grainger, 1990; see also Mathey, Robert & Zagar, 2004; Nakayama, Sears & Lupker, 2008). Within the IA framework (McClelland & Rumelhart, 1981), this inhibitory orthographic priming effect can be attributed to an increase in competitiveness between orthographic neighbour representations due to the pre-activation of the higher-frequency neighbour (Segui & Grainger, 1990). Similarly, in the LDT, when the prime was briefly presented but visible, a significant inhibitory effect was found again for a 200 ms-prime duration (Robert & Mathey, 2007) when neighbourhood distribution was manipulated. Recently, a significant inhibitory orthographic neighbourhood effect was also found with a 175 and a 350 ms-prime duration (Burt, 2009) when the frequency of primes and targets was manipulated. These results indicated that the visibility of the prime did not modify the effect of the higher-frequency neighbour. Moreover, according to Davis (2003), prime duration would increase the inhibitory orthographic priming effect in the IA model (McClelland & Rumelhart, 1981).

- 4 To go further, one can also investigate whether the characteristics of orthographic neighbours influence visual word recognition. At a strictly orthographical level, it has been shown that the relationships of neighbours influence stimulus recognition in turn (*e.g.*, Mathey, 2001; Mathey et al., 2004). Beyond the effect of the orthographic characteristics of orthographic neighbours, little research has been devoted to the other characteristics of neighbours. However, a few studies reported that the semantic characteristics of orthographic neighbours influenced the semantic categorization of words or pseudowords (Forster & Hector, 2002; Pecher, Zeelenberg & Wagenmakers, 2005). Indeed, the time to reject a pseudoword in a semantic categorization task was slowed down when its orthographic neighbour was an exemplar of the semantic category (Forster & Hector, 2002). Moreover, words with semantically congruent orthographic neighbours (*i.e.*, neighbours that shared the same semantic category) were categorized both faster and more accurately than words with mostly semantically incongruent neighbours (Pecher et al., 2005). Therefore, the semantic properties of neighbours are involved at early stages in word processing (Forster & Hector, 2002) and even play a role before complete orthographic processing of the word (Pecher et al., 2005).
- 5 To go even further, the issue concerning the influence of the emotional characteristics of orthographic neighbours has never been investigated directly to our knowledge. However, a growing body of evidence indicates that visual word recognition is influenced by the emotional valence of the stimulus word. In the increasing and decreasing masking naming task, the threshold of conscious access for negative words was lower than for neutral ones, even if the contribution of low-level visual features was ruled out by using orthographic neighbours (Gaillard et al., 2006). Consistently, in event-related potential studies, early cortical responses were found for emotional words (*e.g.*, Kissler, Herbert, Peyk & Junghofer, 2007). Thus, on the one hand, negative words might be activated faster and more deeply than neutral ones. On the other hand, several LDT studies have shown that negative words are recognized more slowly than neutral ones (*e.g.*, Estes & Adelman, 2008). As a whole, everything happens as if the extraction of emotional valence occurs fast and early, which both explains ERP and

increasing-decreasing masking naming results, and accounts for why further inhibitory influences can develop and slow down lexical decision responses.

- 6 The priming paradigm has also been used to investigate the influence of emotional word processing. By using an affective priming paradigm in which prime and target words either shared only the same emotional valence or not, it was shown that negative words were recognized faster than neutral ones, notably when primes and targets shared the same emotional valence (Matthews, Pitcaithly & Mann, 1995). Moreover, the emotional valence of the words modulated the semantic priming effect (Rossell & Nobre, 2004). The semantic relatedness between prime and target traditionally facilitated the visual target recognition, and this effect tended to increase as a function of prime duration (from 66 to 166 ms; Perea & Rosa, 2002). By manipulating the emotional valence of semantic related words in the LDT, Rossell and Nobre (2004) pointed out that when primes and targets were neutral (*e.g.*, *baggy-glush*) or positive (*e.g.*, *elation-weaf*), the semantic priming effect was facilitatory whereas it was inhibitory for negative prime-target pairs (*e.g.*, *dismacy-silope*). The emotional valence of words might therefore modify linguistic processes. Thus, when the unique link between words is their negative emotional valence (Matthews et al., 1995), the emotional congruence could facilitate the visual recognition of words, whereas this negative emotional valence would disturb other effects of linguistic characteristics, like semantic relatedness (Rossell & Nobre, 2004).
- 7 Although the emotional valence of a word influences its identification, models of visual word recognition have paid little attention to the emotional component. Nevertheless, a bridge was built between linguistic and emotional characteristics to explain affective priming in the pronunciation task (Bargh, Chaiken, Raymond & Hymes, 1996; Ferrand, Ric, & Augustinova, 2006). Affective priming effects would arise from the existence of an affective system connected with the semantic one, itself linked with the orthographic lexicon (Ferrand et al., 2006). This affective system would be specifically assigned to affective processing, which seems to occur early and to influence following judgments (Bargh et al., 1996; Ferrand et al., 2006).
- 8 To summarize, visual recognition of written words is influenced by higher-frequency orthographic neighbours and also by the semantic content of these orthographic neighbours. Furthermore, the emotional valence of words modulates their processing and the effect of semantic relatedness. However, to our knowledge, the influence of the emotional valence of orthographic neighbours has never been tested. If the affective content is extracted early, we assume that the emotional valence of orthographic neighbours might play a role, as does their semantic content. Transposing the assumption of Bargh et al. (1996) and Ferrand et al. (2006) to visual word recognition and in accordance with the IA model (McClelland & Rumelhart, 1981), an effect of emotional orthographic neighbourhood would be expected (see Figure 1). When a written word is presented, it might activate its own representation and those of its orthographic neighbours in the orthographic lexicon, these representations then competing with each other until word recognition. The phonological lexicon, the semantic system and even the affective system might also be activated. If the orthographic neighbours are emotional, the affective system could influence word activation in the orthographic lexicon by top-down processes (see connection A on Figure 1). However, it remains to be established whether and how the activation spreads between the orthographic and the affective systems.

Figure 1

Figure 1. An IA model of visual word recognition extended to affective processing (adapted from McClelland & Rumelhart, 1981, and from Ferrand et al., 2006). Inhibitory connections are represented by dots. Facilitatory connections are represented by arrows. The A connection corresponds to a direct pathway between the orthographic word level and the affective system. The B connection represents response inhibition.

- 9 The present study therefore investigated the activation of the affective system mediated by the orthographic lexicon. Indeed, several results already demonstrated that the semantic properties of orthographic neighbours modify their influence on visual word recognition performances. However, while the semantic properties of orthographic neighbours have already been investigated, the affective characteristics of orthographic neighbours have been neglected. The semantic and affective systems would be distinct (Bargh et al., 1996; Ferrand et al., 2006) and the emotional valence of words was shown to influence both word recognition and the semantic priming effect. Could the emotional valence of orthographic neighbours also influence visual word recognition? To answer this question, we used neutral target words which had only one higher-frequency orthographic neighbour that was either negative or neutral. If negative words are processed faster and more deeply (e.g., Gaillard et al., 2006), negative neighbours would be harder to inhibit than neutral ones. Therefore, we predicted an inhibitory effect of emotional orthographic neighbourhood. In the LDT, target words with a negative higher-frequency neighbour would be recognized more slowly than those with a neutral higher-frequency neighbour. To investigate further the orthographic neighbourhood effect, an orthographic priming paradigm (Segui & Grainger, 1990) was used. Target words were preceded either by their orthographic neighbour or by a non-alphabetic control prime (Mathey et al., 2004). An inhibitory orthographic priming effect was expected: target words would be recognized more slowly when they are preceded by their orthographic neighbour than by a control prime. We also examined whether this effect could be increased by emotional orthographic neighbourhood and by prime duration by using the shortest and the longest conditions from Perea and Rosa's procedure (66 vs. 166 ms).

Method

Participants

- 10 Forty-four students from Bordeaux 2 University participated in the experiment and were randomly assigned to one of the two prime-duration groups (66 vs. 166 ms). All were native French speakers, reported having normal or corrected-to-normal vision, and had a neutral initial mood on the Brief Mood Introspection Scale (Mayer & Gaschke, 1988, French translation by Dalle & Niedenthal, 2003). Data from 9 additional students who had a negative initial mood were excluded from the analysis because negative mood affects processing of negative emotional words (Halberstadt, Niedenthal, & Kushner, 1995).

Stimuli

- 11 The main statistical characteristics of the materials are presented in Table 1. The 82 experimental word pairs involved five- to six-letter neutral target words (*e.g.*, *TENACE* [*tenacious*], *FUSEAU* [*spindle*]) and their higher-frequency orthographic neighbours that had either a negative or a neutral valence (*e.g.*, *menace* [*threat*], *museau* [*muzzle*]). The two sets of word pairs were selected from the French lexical database Lexique (New, Pallier, Ferrand & Matos, 2001) so that they were matched on target frequency and on the frequency difference between targets and primes ($t < 1$). The emotional valence of the words was rated in a pretest by 65 volunteers on a 7-point scale graded from « very negative » to « very positive » emotional valence (see Rossell & Nobre, 2004). The two sets of word targets were matched on their emotional valence ($t < 1$), whereas the higher frequency neighbours differed according to their emotional valence ($p < .01$). Subjective word frequency ratings were also collected from 72 participants on a 7-point scale graded from « very rare » to « very frequent », because emotional words are often more familiar than neutral ones (Calvo & Eysenck, 2008). The word targets were matched on subjective frequency ($t < 1$), as was the higher-frequency neighbours ($t < 1$). Other factors such as number of letters, number of syllables, syllable frequency, bigram and trigram frequencies, neighbourhood size, critical-letter position, consonant-vowel changes were also controlled from the Lexique database (all $p > .10$).
- 12 Two priming conditions were constructed. The target words were preceded by their higher-frequency neighbour in the orthographic priming condition (*e.g.*, *menace-TENACE*) or by a non-alphabetic string of the same length in the control condition (*e.g.*, *&&&&&-TENACE*). Eighty-two word-pseudoword pairs served as distractors. The pseudowords were created by changing one letter from real words, which were used as orthographic neighbour primes. In order to avoid strategies in the LDT, half of these pseudowords had a negative orthographic neighbour whereas the other half had a neutral one. All pseudowords were pronounceable and orthographically legal.

Table 1 Characteristics of experimental pairs

Variables	Negative neighbour pairs	Neutral neighbour pairs	p-values
<i>Target word</i>			

Example	TENACE	FUSEAU	
Lexical frequency	0.06	0.11	ns
Emotional valence	4.1	4.2	ns
<i>Higher-frequency neighbour</i>			
Example	menace	museau	
Lexical frequency	0.82	0.84	ns
Emotional valence	2.4	4.5	p < .01
<i>Difference between the target word and its higher-frequency neighbour</i>			
Lexical frequency	p < .01	p < .01	ns
Emotional valence	p < .01	ns	p < .01

Note. Lexical frequency is given per million (in logarithms). Emotional valence scores were estimated on a seven-point scale.

Procedure

- 13 Participants performed an LDT individually. Stimuli were displayed in silver on a black background, in the center of a personal computer screen, using the E-Prime software (version 1.1). Each trial began with a 500 ms-hash mark mask (#####) matched in length with the prime-target pair, immediately followed by the prime in lowercase for 66 or 166 ms. Finally, targets appeared in uppercase until response or for 2500 ms. Participants had to decide as rapidly and as accurately as possible whether or not the target was a French word by pushing one of the two response keys. Each error or exceeding of the time limit was indicated by a visual feedback. The experiment started with a training session, followed by the stimuli presented in a different random order to each participant. Two lists of 82 word targets were constructed so that each target word appeared only once, preceded either by its orthographic neighbour or by a control prime. All the participants saw all the target words and the two priming conditions.

Results

- 14 Reaction times below 300 ms or above 1500 ms were excluded from the analyses (2.5% of the data). Eight items were removed because of a high error rate. The mean correct response latencies and error rates (see Table 2) were averaged separately for participants (F_1) and for items (F_2) with emotional valence of the higher-frequency neighbour (negative vs. neutral), prime type (control vs. orthographic), and prime duration (66 vs. 166 ms) as main factors.

Table 2 Mean reaction times (in ms) and percentage of errors for word targets (standard errors in parentheses)

	Reaction time		Percentage of errors	
Prime type	Higher-frequency neighbour	Control	Higher-frequency neighbour	Control
66 ms prime condition				
Negative neighbour	826 (18)	805 (22)	13.3 (1.4)	8.9 (1.7)
Neutral neighbour	808 (22)	798 (19)	8.2 (0.4)	9.2 (1.8)
166 ms prime condition				
Negative neighbour	886 (25)	819 (24)	9.3 (1.9)	10.8 (2.0)
Neutral neighbour	845 (24)	799 (23)	8.1 (2.0)	8.9 (1.2)

- 15 Analysis on reaction times showed an inhibitory effect of the emotional valence of the higher-frequency neighbour, which was significant in both the participant and item analyses, $F_1(1, 42) = 16.40$, $p < .01$; $F_2(1, 69) = 3.97$, $p = .05$. Words with a negative neighbour were recognized more slowly (834 ms) than those with a neutral one (812 ms). The inhibitory effect of prime type was also significant, $F_1(1, 42) = 37.19$, $p < .01$; $F_2(1, 69) = 10.40$, $p < .01$. Target words preceded by an orthographic neighbour were responded to more slowly (841 ms) than those preceded by a control prime (805 ms). The prime duration effect was significant for items, $F_2(1, 69) = 37.79$, $p < .01$, but not for participants, $F_1 < 1$. Reaction times were faster for a 66-ms prime duration (809 ms) than for a 166-ms duration (837 ms). The prime type x prime duration interaction was significant, $F_1(1, 42) = 11.81$, $p < .01$; $F_2(1, 69) = 12.33$, $p < .01$. The inhibitory orthographic priming effect was greater for the 166 ms prime duration (56 ms) than for the 66 ms prime duration (16 ms). No other interactions were significant.
- 16 Analyses on the error rates indicated an inhibitory effect of emotional valence of the neighbour for participants, $F_1(1, 42) = 5.34$, $p < .05$; $F_2 < 1$. Error rates were greater when the neighbour was negative (10.6%) rather than neutral (8.6%). No other effects were significant.

Discussion

- 17 The most important finding of this study is that words with a negative higher-frequency neighbour were recognized more slowly than those with a neutral one. In an IA model of visual word recognition (McClelland & Rumelhart, 1981) adapted to affective processing (Bargh et al., 1996; Ferrand et al., 2006), this inhibitory effect of

emotional orthographic neighbourhood can be accounted for by the activation of the emotional valence of the neighbour in the affective system through the orthographic lexicon (see Figure 1, connection A). In such a theoretical framework, we assume that when the higher-frequency orthographic neighbour is activated by the presentation of target words, the activation of the orthographic lexicon spreads to the affective system. The lexical representation of the neighbour is then associated with affective information, which may in turn consolidate activation of its lexical representation. Negative neighbours would receive additional activation from the affective system by top-down processes. This would produce a faster and deeper activation of the negative words, which is consistent with their lower threshold of conscious access (Gaillard et al., 2006) and early cortical responses (Kissler et al., 2007). In our emotional orthographic neighbourhood framework, activation of the lexical representation of the negative higher-frequency neighbour would generate greater inhibition toward the target, which would delay the moment when the identification threshold of the target is reached. The negative valence of higher-frequency neighbours, like their semantic content (Forster & Hector, 2002; Pecher et al., 2005), would therefore be extracted early enough to influence orthographic processing automatically.

- 18 Another finding of this experiment is the inhibitory orthographic priming effect, which was increased by prime duration. At short prime duration (around 60 ms), the inhibitory orthographic priming effect can be attributed to an increase in the competitiveness between the orthographic neighbours due to the presentation of the higher-frequency neighbour as a prime (Segui & Grainger, 1990; see also Mathey et al., 2004; Nakayama et al., 2008). The higher-frequency neighbour would be pre-activated before the presentation of the target word, thereby reinforcing its inhibitory flow because of a previous start and of a higher level of activation. Therefore, the higher-frequency neighbour is more competitive when the target word appears. This orthographic priming effect also increased with prime duration (66 vs. 166 ms), which is consistent with IA model (McClelland & Rumelhart, 1981) predictions (see Davis, 2003). For a 66 ms-prime duration, the inhibition from this orthographic neighbour might not be maximal, while it would have time to fully develop with a 166 ms-prime duration. The inhibitory priming found in the 166-ms condition is also consistent with recent findings from Burt (2009) with a 175-ms prime duration and Robert and Mathey (2007) with a 200-ms prime duration. In the latter cases, the higher-frequency neighbour prime was totally visible, so its lexical representation was likely activated completely. As a whole, it can be assumed that when prime duration is sufficiently brief to avoid the establishment of an episodic and/or strategic component (Forster, 1998), orthographic priming effects are not qualitatively different (Burt, 2009; Robert & Mathey, 2007). They can even be quantitatively increased by prime duration.
- 19 Finally, the inhibitory orthographic priming effect was not influenced by the effect of emotional orthographic neighbourhood. An initial explanation is that the emotional valence of the words is strongly activated so early that the emotional orthographic neighbourhood effect emerges completely from the moment that the target words are processed and is not sensitive to pre-activation of the neighbour. Activation of the affective system through the orthographic lexicon, and consolidation of the activated representation in turn by top-down processes (see Figure 1 connection A), might therefore occur during the early stages of orthographic processing. This is consistent with the hypothesis that semantic properties are involved very early in processing,

even before orthographic processing is finished (Forster & Hector, 2002; Pecher et al., 2005). A second explanation can be formulated in terms of response inhibition (see Figure 1 connection B), related to automatic vigilance (see Estes & Adelman, 2008). When a word is activated, it would be evaluated as negative or positive in the affective system. When it is negative, responses to other characteristics of the stimulus, like orthographic aspects, could be delayed and slowed. When it is positive, the opposite could occur, by means of the facilitatory connection. In our study, although the interaction between prime type and emotional valence of the neighbour was not significant at any prime duration, a small trend was observed for each prime duration (11 ms for the 66-ms one and 20 ms for the 166-ms one). Based on the effect size, we performed power analyses using the GPOWER 3 software (Faul, Erdfelder, Lang & Buchner, 2007) to estimate the sample size required to make this interaction significant for each prime duration. With a statistical power of .90 ($\alpha = .05$), it was found that 136 participants would be required at the 66-ms prime duration (i.e., an unusually large sample), while 47 participants would be required at the 166-ms prime duration. Altogether, these further analyses suggest that the influence of the affective system could occur in two ways. First, the influence of the negative valence mediated by the orthographic lexicon could be attributed to early processes, with no reliable difference between the priming conditions for non-visible primes. Second, when the activation of the neighbour has time to develop further (e.g., for visible primes), the affective system could strengthen lateral processes between neighbours in the orthographic lexicon by top-down processes. Thereafter, affective processing would predominate and slow down the LDT response. Further experiments should be designed to investigate this issue.

- 20 To conclude, this study provides new evidence for indirect activation of the affective system via the orthographic lexicon, by means of emotional orthographic neighbourhood. The findings strongly suggest that the activation of the affective system through the orthographic lexicon occurs early in visual word recognition processes, and might also influence further stages of the primed LDT, at least for long prime durations. Further studies should be conducted in order to specify the conditions in which activation and inhibition occur between and within the orthographic lexicon and the affective system.

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ABSTRACTS

The aim was to investigate the activation spread between the orthographic lexicon and the affective system by means of emotional orthographic neighbourhood. Target words with a neutral emotional valence (*e.g.*, *tenace*, *fuseau*) were selected so that they had only one higher-frequency orthographic neighbour with either a negative valence (*e.g.*, *menace*) or a neutral valence (*e.g.*, *fuseau*). All target words were presented in a primed lexical decision task, either preceded by their neighbour or by a control prime during 66 or 166 ms. The main finding was the inhibitory effect of negative emotional orthographic neighbourhood. Target word responses were delayed when the valence of the neighbour was negative rather than neutral. The data also indicated an inhibitory orthographic neighbourhood priming effect that was enhanced by prime duration. The results are discussed within an interactive-activation framework of visual word recognition adapted to affective processing.

L'objectif est d'étudier la propagation de l'activation entre le lexique orthographique et le système affectif au moyen du voisinage orthographique émotionnel. Les mots cibles sélectionnés étaient émotionnellement neutres (*e.g.*, *tenace*, *fuseau*) et possédaient un seul voisin orthographique plus fréquent, négatif (*e.g.*, *menace*) ou neutre (*e.g.*, *museau*). Ces mots cibles étaient présentés dans une tâche de décision lexicale amorcée, précédés par leur voisin ou par une amorce contrôle durant 66 ou 166 ms. Le résultat principal est l'effet inhibiteur du voisinage orthographique émotionnel négatif. Les temps de réponse aux mots cibles étaient ralentis lorsque leur voisin orthographique était négatif plutôt que neutre. De plus, les résultats indiquent un effet inhibiteur d'amorçage orthographique, accru par la durée de présentation de l'amorce. Les données sont discutées dans le cadre d'un modèle d'activation-interactive pour la reconnaissance visuelle des mots, adapté au traitement affectif.

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Keywords: emotional valence, orthographic neighbourhood, visual word recognition

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