

Word recognition is affected by the meaning of orthographic neighbours: Evidence from semantic decision tasks

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Many models of word recognition predict that neighbours of target words will be activated during word processing. Cascaded models can make the additional prediction that semantic features of those neighbours get activated before the target has been uniquely identified. In two semantic decision tasks neighbours that were congruent (i.e., from the same category) or incongruent (i.e., from the opposite category) were presented in a long-term priming paradigm. Performance to targets was better if they were primed by congruent neighbours than if they were primed by incongruent neighbours. The same effect was found for rhyming and nonrhyming primes. The results support cascaded models that allow semantic information to become activated before lexical selection has finished.

During word reading people must translate the word's orthography into a representation of its meaning. This translation process can be modelled in several ways. In all major models of word recognition a competition or selection process takes place between orthographically similar words. An important distinction can be made between serial (e.g., Forster & Hector, 2002) and cascaded models (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; McClelland, 1979; McClelland & Rumelhart, 1981; Grainger & Jacobs, 1996) of word recognition. Serial models assume that the word's lexical entry must first be selected among competitors. Only after the lexical

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entry is selected can activation of the word's meaning start. Cascaded models, on the other hand, assume that activation of meaning can start before a lexical entry is selected among competitors (Hino, Lupker, & Pexman, 2002). In the present study we provide evidence for the latter type of model by investigating the influence of orthographic neighbours in semantic decision tasks.

An orthographic neighbour is a word that differs only one letter from the target word; for example, *mouse* is an orthographic neighbour of *house*.¹ Several studies have investigated the influence of orthographic neighbours in lexical decision tasks and semantic categorisation tasks (Bowers, Damian, & Havelka, 2002; Carreiras, Perea, & Grainger, 1997; Forster & Hector, 2002; Forster & Shen, 1996; Pecher, Zeelenberg, & Wagenmakers, 2005; Rodd, 2004; Sears, Lupker, & Hino, 1999). Studies using the lexical decision task have consistently shown that orthographic neighbours facilitate the recognition of words (Andrews, 1997). This supports the idea that during word recognition not only the target word but also its orthographic neighbours are activated and can influence the responses to the targets. However, the competition process at the word level predicts that orthographic neighbours will *interfere* with word recognition rather than help. To explain the *facilitatory* effect of orthographic neighbours in lexical decisions researchers have proposed that lexical decisions might be based on global activation levels rather than unique word identification (Grainger & Jacobs, 1996). Thus, when a target word is presented its neighbours also become activated and contribute to the global activation level of the system. Target words with many neighbours have higher levels of global activation than target words with only few neighbours.

Because lexical decision might be inappropriate to study unique word identification, other tasks have been used. Semantic categorisation tasks seem good candidates because they rely on retrieval of the meaning of a word. Previous studies have assumed that a word has to be uniquely identified before its meaning can be retrieved (Forster & Shen, 1996; Sears et al., 1999). Thus, in order to classify a word in categories such as living or nonliving, lexical competition has to be resolved. Therefore, semantic decisions should be inhibited by orthographic neighbours of the target word because with more competitors the lexical selection process will take longer. Studies using the semantic categorisation task, however, obtained mixed results (Carreiras et al., 1997; Forster & Shen, 1996; Forster & Hector, 2002; Sears et al., 1999).

¹ There are other types of orthographic similarity such as subsets and letter exchanges (Bowers, Davis, & Hanley, 2005; Perea & Lupker, 2003, 2004) but for the present purposes we assume that these all behave in similar ways.

An explanation of these mixed results might be that the assumption that a word has to be uniquely identified before semantic information gets activated and the word can be classified is misguided. Rather, a word's semantics might start to become activated before the lexical competition between the target word and its neighbours has been resolved. As a result, semantic features of neighbours will also get activated and will affect the decision process. In fact, many models of word recognition assume cascaded processing of information, which allows semantic information to become available before orthographic processing has finished (e.g., Pecher, 2001; Pecher et al., 2005; Pexman & Lupker, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Van Orden & Goldinger, 1994). If a target word shares relevant semantic features with its neighbours, processing might be facilitated relative to target words that do not share relevant semantic features with their neighbours. The effect of neighbours will be a combination of competitive and facilitative processes, the net outcome of which depends on the particular details of the model.

Evidence for such a cascading semantics effect of orthographic neighbours has been obtained by Pecher et al. (2005) and Rodd (2004) (also see Bowers et al., 2005, for similar results with subset and superset neighbours, and Bourassa & Besner, 1998, for a short-term priming effect with nonword neighbours). Both studies used semantic categorisation tasks and made a distinction between congruent and incongruent neighbours. A congruent neighbour is an orthographic neighbour from the same category as the target (e.g., a living target and a living neighbour or a nonliving target and a nonliving neighbour in the living decision task). An incongruent neighbour is an orthographic neighbour from the opposite category (e.g., living target and nonliving neighbour or vice versa). For example in the living decision task, if the target word is *cat*, *rat* is a congruent neighbour and *mat* is an incongruent neighbour.

Rodd (2004) compared semantic decision times to words with an animal neighbour and to words with a non-animal neighbour in animal decision. All target words were non-animals. She obtained an effect of congruency; decision times were slower to words that had an animal neighbour than to words that did not have an animal neighbour. In her second experiment she presented the same target words in a plant decision task (none were plant names). In this task no effect is expected, because animalness is not a relevant feature in the plant decision task. Decision times were only slightly slower to words that had an animal neighbour than to words that did not have an animal neighbour. More important, the interaction between task and type of neighbour was significant in her study, showing that the effect of neighbour congruency was task dependent.

Whereas these results are problematic for serial models of word recognition, Forster (2006; Forster & Hector, 2002) proposed an additional

mechanism, the Links model, to account for semantic congruency effects in category decision tasks. According to the Links model, the lexical entry for a word contains links to broad semantic fields to which the word belongs. For example, the word *mouse* could have a link to an *animal* field. These links are only rough indications of the fields a word is associated with, and do not activate any item-specific semantic information that would be needed to make a more detailed decision such as the object's size. During the initial stages of word processing when the orthography of the stimulus is compared to lexical entries these links between semantic fields and lexical entries are already available. The decision process can detect these links and direct further processing at lexical entries that have a link to the relevant semantic field. As a result, neighbours of the target word that are exemplars of the category receive more additional processing than neighbours that are not exemplars of the category. Thus, if a word has neighbours that are exemplars of the relevant category, processing is slowed down by additional processing. For example in the animacy decision task neighbours that have a link to the *animal* field (e.g., *mouse*) will be activated and may slow down the decision process for non-exemplar targets (e.g., *house*). This explanation was suggested by Forster (2006) as a solution for serial models of word processing to explain neighbour congruency effects.

The Links model predicts that neighbour congruency effects will be absent for decision tasks that require categorisation into ad hoc categories such as *bigger than a shoebox* (Forster, 2006). It is unlikely that semantic fields exist for such categories. In contrast, cascaded models can explain congruency effects in ad hoc categorisation. According to cascaded models of word processing (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Grainger & Jacobs, 1996; Masson, 1995; McClelland & Rumelhart, 1981; Pecher, 2001; Pexman & Lupker, 1999; Plaut et al., 1996; Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990) information from one level of processing (e.g., orthography) can serve as input for another level of processing (e.g., semantics) before processing has been completed. During word recognition the stimulus activates the orthography of both the target word and its neighbours. Before competition between these different orthographies has been resolved these orthographic representations start activating semantic representations. The decision process will be facilitated if the semantic features that are activated by neighbours are congruent to those of the target word with respect to the particular decision that is being made. The decision process will be slower or less accurate if the semantic features that are activated by neighbours are incongruent to those of the target word with respect to the particular decision that is being made.

Pecher et al. (2005) proposed that the decision process is based on the ratio of evidence for a *yes* response and evidence for a *no* response. Features of congruent neighbours will provide evidence for the same response as those

of the target. For example, the stimulus *monkey* activates the orthographic representations of *monkey* and *donkey*. Both representations activate semantic features that are evidence for an animate response (e.g., *climbs trees, has ears*).² Because there is a lot of evidence for a *yes* response, and little for a *no* response, a fast *yes* response will be made. In contrast, the stimulus *gibbon* activates the orthographic representations of *gibbon* and *ribbon*. In this case, the semantic features that are activated provide evidence for both a *yes* (e.g., *climbs trees*) and a *no* (e.g., *made of cloth*) response. Because there is evidence for both responses, the actual response will be slower and less accurate because the decision is based on the likelihood ratio for a response (see Wagenmakers et al., 2004, for a detailed model of such a mechanism applied to lexical decision). This mechanism does predict that semantic congruency effects will be obtained for both taxonomic category decisions and ad hoc category decisions.

Evidence for congruency effects in semantic decision tasks comes from studies that used animacy or animal decision (Forster & Hector, 2002; Pecher, Zeelenberg, & Wagenmakers, 2005; Rodd, 2004). In the present study, we extended these findings in order to collect more evidence that semantic decisions are affected by the semantics of neighbour words. We investigated whether the congruency effect would generalise to other semantic decision tasks. We were particularly interested in a task that cannot be performed with taxonomic category information. Therefore, we used a size decision task. In size decision, participants decide whether something is bigger than a given standard (in this case a *shoebox*). We assumed that performance in this task does not rely on taxonomic category information. Thus, a congruency effect in size decision would provide evidence for an explanation based on cascaded processing, but would be problematic for an explanation based on serial models of word recognition and the links model. To compare our result with previous studies, however, Experiment 1 used the living decision task that was also used by Pecher et al. (2005).

To circumvent the problem of having to deal with many nuisance variables, a design in which the same target words are used in all conditions is preferable. This is possible in a priming paradigm. Pecher et al. (2005) used a long-term priming paradigm and counterbalanced targets over conditions. The category of the decision task was living-nonliving. For each target (e.g., *cat*) there was a congruent prime (e.g., *rat*) or an incongruent prime (e.g., *mat*). In the first part of their experiments they presented either the congruent prime, the incongruent prime, or no prime. In the second part

² These features are given only as illustration. Of course, such a decision process may use more primitive features. At present, no word recognition model explicitly specifies what semantic features are used to represent meaning.

the target words were presented. Because the same target was used in all conditions (across subjects), the effect they found could only be attributed to the congruency of the prime. They obtained a clear effect of congruency. Reaction times were longer and error rates were higher if the incongruent prime had been presented earlier than if the congruent prime had been presented earlier.

As an additional variable, we investigated whether the effect of congruency was the same for rhyming and nonrhyming neighbours. In a study that investigated long-term neighbour priming effects in lexical decision, Bowers et al. (2002) obtained positive priming for target words that rhymed with previously presented neighbours (e.g., *howl-fowl*), but negative priming for target words that did not rhyme with previously presented neighbours (e.g., *bowl-fowl*) (see also Pexman, Trew, & Holyk, 2005). Therefore, we included the rhyme factor in the present experiments.

The priming paradigm was used under the assumption that prior presentation of the neighbour caused that neighbour to become a stronger competitor for the target word. Pecher et al.'s (2005) findings suggest that the effect of strengthening a neighbour can be either facilitating or interfering. They included a baseline condition in which no prime was presented. Performance in the congruent condition was better than baseline, whereas performance in the incongruent condition was worse than baseline. The question is, however, what counts as a proper baseline. In the baseline condition of Pecher et al. no orthographic neighbour was presented in the priming phase. However, neighbours are also assumed to play a role at the orthographic level of processing (Andrews, 1997). For example, in the Interactive Activation model the effect of orthographic neighbours is a combination of competition at the word level and facilitation due to feedback to the letter level. Thus, the baseline condition in the Pecher et al. (2005) study differs not only in the pattern of activation of semantic features, but also in the pattern of orthographic activation. Given these considerations, a proper baseline should consist of orthographic neighbours that do not have semantic features that are relevant to the task. Such primes cannot be presented in the same semantic decision task, however, which introduces another confounding. Therefore, we chose to exclude a baseline condition in the present study and to compare the congruent and incongruent conditions directly.

EXPERIMENT 1

In Experiment 1 we investigated the role of orthographic neighbours in a living decision task. In the first phase of the experiment participants made living decisions to prime words. These primes were orthographic neighbours

of the target words that were presented in the second phase of the experiment. Two variables were manipulated. The first was whether the prime was a member of the same semantic category as the target (congruent) or a member of the opposite category (incongruent). The second was whether the prime rhymed with the target or not.

Method

Participants. The 26 participants were psychology students at the Erasmus University Rotterdam. They received €3 for participating. All participants professed to be fluent in Dutch.

Stimuli. The target words were 46 Dutch nouns. For each target word two orthographic neighbours were selected. A neighbour was a word that differed only one letter from the target word. The neighbours were used as primes. One of the neighbours was congruent with the target, i.e., fell into the same category (living or nonliving). The other neighbour was incongruent with the target, i.e., fell into the opposite category. Living things were defined as animals, plants, humans, parts of living things, and groups of living things. Whether the neighbours rhymed with the target was manipulated between targets; 22 targets had rhyme neighbours (13 living and 9 nonliving) and 24 targets had nonrhyme neighbours (9 living and 15 nonliving).³ For example for the target word *snoep* (*candy*) the nonrhyme congruent neighbour *snoer* (*cord*) and the nonrhyme incongruent neighbour *snoek* (*pike*) were selected. No target word was a neighbour of any other target word, and each prime was a neighbour only of one target word. The stimuli are presented in Appendix A. Two additional words were selected to serve as examples, and ten additional words were used for practice. None of these were neighbours of any experimental word. No word was used more than once in the entire set of stimuli.

Two different experimental lists were made for counterbalancing. For each target the congruent prime was presented on one list, and the incongruent prime was presented on the other list. Each list had the same number of congruent and incongruent primes. Participants received only one list.

Procedure. Participants were tested individually using PCs. The instructions were presented on the computer monitors. Participants were told they had to decide if the referent of words that would be presented on the screen

³ With all the restrictions that were placed on item selection it was impossible to have the exact same number of items in each condition and still have a reasonable number of items. However, the critical comparisons (congruency and rhyme) have approximately equal numbers in each condition.

were living or nonliving things. Living things were defined as animals, plants, humans, parts of living things, and groups of living things. Two examples were provided. Participants were instructed to respond as fast and as accurately as possible.

Each trial began with a fixation stimulus (*****) in the centre of the screen for 500 ms. Immediately after the fixation stimulus a stimulus word appeared in the same position. The stimulus remained on the screen until a response was given or until 1800 ms elapsed. Participants responded by pressing the 'm' key if the referent of the stimulus was a living thing and the 'z' key if the referent of the stimulus was a nonliving thing. If the response was incorrect, the word 'Fout' (*error*) was displayed for 2000 ms slightly to the right and below the target position. If the response was slower than 1800 ms, the words 'Te laat' (*too late*) was displayed for 2000 ms to the right and below the target position. If the response was correct no feedback was given. After a blank screen of 500 ms the next trial started.

The Experiment began with 10 practice trials. After a short break the prime words were presented in two blocks. All 46 primes were presented once in random order in each block (i.e., each prime was presented twice in total). After another short break the 46 targets were presented in random order. The complete experiment took about 10 minutes.

Results and discussion

Only reaction times of correct responses within two standard deviations from each subject's mean were included in the subject analyses. The trimming procedure resulted in removal of 5.38% of the correct reaction times. The means and error rates are shown in Table 1.

Participants responded faster to targets in the congruent condition than to targets in the incongruent condition, $F_1(1, 25) = 4.56$, $MSE = 2619.5$, $p < .05$, $F_2(1, 44) = 3.48$, $MSE = 15451.8$, $p = .07$.⁴ The analysis by subjects shows that participants responded slower to targets in the rhyme condition than to targets in the nonrhyme condition, $F_1(1, 25) = 6.08$, $MSE = 2373.8$, $p < .05$, but this effect was not reliable in the item analysis, $F_2(1, 44) < 1$. There was no interaction effect between congruency and rhyme, $F_1 < 1$, $F_2 < 1$. Although accuracy seemed higher in the congruent condition than in the incongruent condition, this difference was not significant, $F_1(1, 25) = 1.73$, $MSE = 0.006$, $p > .15$, $F_2(1, 44) = 1.22$, $MSE = 0.010$, $p > .25$. According to the subject analysis participants responded less accurately, $F_1(1, 25) = 18.18$, $MSE = 0.008$, to targets that rhymed with the prime than to targets

⁴ Although item analyses are not required for counterbalanced designs (Raaijmakers, 2003; Raaijmakers, Schrijnemakers, & Gremmen, 1999) we provide the results of an additional ANOVA by items for the interested reader.

TABLE 1
 Mean and standard errors of reaction time (ms) and error rates in the animacy decision task in Experiment 1

	<i>Rhyme</i>				<i>Nonrhyme</i>			
	<i>RT</i>		<i>ER</i>		<i>RT</i>		<i>ER</i>	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Congruent	764	19	.18	.020	746	19	.09	.015
Incongruent	791	21	.19	.020	762	19	.13	.018

that did not rhyme with the prime, although this was not significant in the item analysis, $F_2(1, 44) = 2.17$, $MSE = 0.064$, $p > .10$. There was no interaction effect in the error rates, $F_1 < 1$, $F_2(1, 44) = 1.22$, $MSE = 0.010$, $p > .25$.

Thus in Experiment 1 we obtained a congruency effect in reaction times for living decision. Participants responded faster in the congruent condition than in the incongruent condition. This finding is predicted by cascaded models and is consistent with the results of Pecher et al. (2005). The main effect of rhyme obtained in the subject analysis may have been due to differences between the targets in the rhyme and nonrhyme conditions. Unfortunately the design placed too many restrictions on our stimulus materials to leave enough room for counterbalancing targets over rhyme conditions. Note that the targets were counterbalanced over congruency conditions. This made it possible to compare congruent with incongruent conditions within the rhyming and nonrhyming condition. Therefore, the interaction effect between rhyme and congruency is more interesting. We did not find such an interaction. We will return to this issue in the General Discussion.

EXPERIMENT 2

In the next experiment we investigated whether the neighbour congruency effect generalises to a different semantic decision task, size decision (i.e., *is it larger than a shoebox?*). As was discussed in the Introduction, a neighbour congruency effect in an ad hoc semantic decision task is predicted by cascaded models of word recognition, but problematic for the Links model. According to the Links model, some neighbour congruency effects can be explained by links from lexical entries to semantic fields. Although Forster (2006) does not specify exactly what semantic fields are, he provides the category *bigger than a brick* as an example of an ad hoc category for which no semantic field exists. Therefore, a neighbour congruency effect in a size

decision task would be problematic for the Links model and for serial models of word recognition in general.

Method

Participants. The 26 participants were psychology students at the Erasmus University Rotterdam. They received €3 for participating. All participants professed to be fluent in Dutch. None of the participants had participated in Experiment 1.

Stimuli. The target words were 50 Dutch nouns. For each target word two orthographic neighbours were selected. One of the neighbours was congruent with the target, i.e., fell into the same category (bigger or smaller than a shoebox). The other neighbour was incongruent with the target, i.e., fell into the opposite category. Rhyme was manipulated between targets, 26 targets had rhyme neighbours (16 bigger and 10 smaller) and 24 targets had nonrhyme neighbours (12 bigger and 12 smaller). No target word was a neighbour of any other target word, and each prime was a neighbour only of one target word. The stimuli are presented in Appendix B. Two additional words were selected to serve as examples, and ten additional words were used for practice. None of these were neighbours of any experimental word. No word was used more than once in the entire set of stimuli.

Two different experimental lists were made for counterbalancing. For each target the congruent prime was presented on one list, and the incongruent prime was presented on the other list. Each list had the same number of congruent and incongruent primes. Participants received only one list.

Procedure. The procedure was the same as that of Experiment 1, except that participants were instructed to press the 'm' key if the stimulus was bigger than a shoebox and the 'z' key if the stimulus was smaller than a shoebox.

Results and discussion

Only reaction times of correct responses within two standard deviations from each subject's mean were included in the subject analyses. The trimming procedure resulted in removal of 4.77% of the correct reaction times. The means and error rates are shown in Table 2.

Participants responded faster to targets in the congruent condition than to targets in the incongruent condition, $F_1(1, 25) = 7.69$, $MSE = 1771.5$, $p < .01$, $F_2(1, 48) = 4.16$, $MSE = 25163.9$, $p < .05$. There was no main effect of rhyme, $F_1(1, 25) = 1.14$, $MSE = 2604.0$, $p > .25$, $F_2(1, 48) = 1.05$, $MSE = 6563.2$, $p > .25$, nor an interaction effect, $F_1 < 1$, $F_2 < 1$. There was no congruency effect in the error rates, $F_1(1, 25) = 1.24$, $MSE = 0.012$, $p > .25$,

TABLE 2
Means and standard errors of reaction time (ms) and error rates in the size decision task in Experiment 2

	<i>Rhyme</i>				<i>Nonrhyme</i>			
	<i>RT</i>		<i>ER</i>		<i>RT</i>		<i>ER</i>	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Congruent	804	14	.09	.018	812	17	.08	.018
Incongruent	825	18	.13	.022	838	17	.08	.018

$F_2(1, 48) = 2.56$, $MSE = .014$, $p > .10$. The analysis by subjects suggested a marginal main effect of rhyme. Participants responded less accurately to nonrhyme targets than to rhyme targets, $F_1(1, 25) = 3.69$, $MSE = 0.008$, $p = .066$, but this effect was not reliable in the item analysis, $F_2(1, 48) = 1.21$, $MSE = .013$, $p > .25$. There was no interaction effect, $F_1 < 1$, $F_2(1, 48) = 1.33$, $MSE = .007$, $p > .25$.

Thus in Experiment 2 we obtained the congruency effect in size decision as in the living decision task in Experiment 1. Participants responded faster in the congruent condition than in the incongruent condition. There was no interaction with rhyme. There was a marginal effect of rhyme in the error responses (in the analysis by subjects), but this effect may have been due to differences between the target words themselves rather than to the prime condition because targets were not counterbalanced over rhyme conditions.

GENERAL DISCUSSION

In two experiments we obtained a consistent pattern of neighbour congruency effects in living decision and size decision. In both tasks targets primed with congruent orthographic neighbours were responded to faster than targets primed with incongruent neighbours. These results are consistent with word recognition models that assume cascaded processing and are problematic for serial models of word recognition.

Other studies also have shown an effect of neighbour congruency in semantic decision tasks (Bowers et al., 2005; Forster, 2006; Forster & Hector, 2002; Rodd, 2004). Whereas these previous studies compared different items (words or nonwords) in the congruent and incongruent conditions, the present study used the same procedure as Pecher et al. (2005). The target words were primed by either a congruent or an incongruent neighbour. This method of counterbalancing target words

over conditions gets rid of the effect of nuisance variables that may cause unwanted variance between words.

As we discussed in the Introduction, cascaded models of word recognition can explain the neighbour congruency effect. We assume that the stimulus activates both the target word and its orthographic neighbours. In cascaded models, activated orthographic patterns will lead to activation of semantic patterns as well. A congruent neighbour shares task-relevant semantic features with the target, whereas an incongruent neighbour causes a conflict in task-relevant semantic features. For example, if *louse* was the prime for *mouse*, higher activation of *louse* during processing of *mouse* activates *living* features, and activation of *mouse* also activates *living* features. This combined activation facilitates the decision process. If *house* was the prime for *mouse*, however, higher activation of *house* during processing of *mouse* activates *nonliving* features, and activation of *mouse* activates *living* features. This conflicting activation interferes with the decision process.

Whereas cascaded models can explain our findings, serial models of word recognition cannot. The Links model that was proposed as a solution (Forster, 2006; Forster & Hector, 2002) can only explain neighbour congruency effects in semantic decision tasks if the semantic decision refers to a taxonomic category such as *animals* but not if it refers to an ad hoc category such as *bigger than a shoebox*. The Links model explains neighbour congruency effects by assuming that when a link is detected between a candidate lexical entry and the relevant semantic field, that candidate receives further processing. Thus, processing is slower for words that have exemplar neighbours than for words that have no exemplar neighbours. This mechanism only works, however, if the semantic decision is based on an existing semantic field such as *animals*. Therefore, our finding of a neighbour congruency effect in an ad hoc category decision task is problematic for the Links model.

An important question is how semantic decisions are made. Carreiras et al. (1997) and Forster and Hector (2002) proposed that semantic decisions are based on the activation of a relevant semantic feature (e.g., *animalness*) that is present in exemplars, and absent in non-exemplars. If the activation of this feature exceeds a threshold, a *yes* decision is made. If the activation of this feature does not reach threshold before a deadline, a *no* response is made. A further assumption is that the deadline is extended when there is some activation of the relevant feature, as might be the case if the target has an exemplar neighbour. This is consistent with the finding that *no* responses are slowed down for targets that have an exemplar neighbour (Bowers et al., 2005; Forster & Hector, 2002; Rodd, 2004). According to Forster and Hector, there should be no effect, however, of non-exemplar neighbours on *yes* responses. Contrary to this prediction, Pecher et al. (2005) did show such an effect of non-exemplar neighbours. These results are problematic for the

semantic feature plus deadline model for animacy decision. A second problem for the semantic feature plus deadline model is our present finding of a neighbour congruency effect in size decision. In our size decision task, subjects judge the relative size of objects. The reference object (a *shoebox*) had an arbitrary size, and the same task can be performed with many different types of reference objects. It seems unlikely that the language system has features for each possible size comparison. Thus, the idea that semantic decisions are based on monitoring the activation of one relevant semantic feature in combination with a response deadline is not supported by the data.

An alternative mechanism was proposed by Pecher et al. (2005). They proposed that rather than monitoring a single task relevant feature, the decision process is based on weighing all the evidence for a *yes* decision and all the evidence for a *no* decision, based on many features. In a cascaded model (Grainger & Jacobs, 1996; Masson, 1995; McClelland & Rumelhart, 1981; Pecher, 2001; Pexman & Lupker, 1999; Plaut et al., 1996; Van Orden & Goldinger, 1994; Van Orden et al., 1990) relevant features would also be active for neighbours of the target before lexical competition is resolved. It is assumed that evidence for a response is based on semantic information of the target and the neighbours and accumulates as processing of semantic information progresses. The resulting decision will be based on the likelihood ratio for a response (Wagenmakers et al., 2004).

A somewhat surprising result in the present study was the absence of an interaction between rhyme and congruency. In a long-term priming paradigm, Bowers et al. (2002) found facilitation for targets that had been primed by a rhyme neighbour, but no effect for targets that had been primed by a nonrhyme neighbour. In their study, targets were presented in lexical decision, and only the words (*yes* responses) had been primed by a neighbour. Based on their results we expected the congruency effect in our experiments to be larger in the rhyme than in the nonrhyme condition, but we did not obtain such an effect. There are several differences between our experiment and those of Bowers et al., however. The first important difference is that they used lexical decision whereas we used semantic decision tasks. It is possible that phonology mainly affects lexical competition processes at the lexical level and therefore this competition does not play such an important role in semantic decision tasks as it does in lexical decision. If that were the case, however, then overlap in orthography should also not have such an effect in semantic decision tasks. There is no clear reason why orthography should play a role in both tasks and phonology only in lexical decision.

The second important difference between our study and that of Bowers et al. (2002) lies in the stimuli. Careful examination revealed two notable differences between their stimuli and ours. First, Bowers et al.'s neighbours

differed from the target words in the first letter of the word, whereas in our stimuli the nonrhyme neighbours differed from the targets mostly in a letter in the body of the word. For example, in the study by Bowers et al., the rhyme neighbour for the target *bear* was *pear*, whereas the nonrhyme neighbour was *rear*. Because Dutch has a more regular grapheme-phoneme overlap there are hardly any neighbours that differ in the first letter and do not rhyme (Martensen, Maris, & Dijkstra, 2003). Therefore, in order to create nonrhyming pairs, we had to select target-neighbour pairs that differed at a letter position in the body of the word.

Second, as a consequence of differences between English and Dutch in regularity of grapheme-phoneme overlap, there was also a difference in the amount of phonological overlap. In the Bowers et al. (2002) study the rhyming neighbour shared more phonemes with the target than the nonrhyming neighbour, and part of the shared orthography between the nonrhyming neighbour and the target (e.g., *ea* in *rear* and *bear*) even had conflicting orthography-phonology mappings. In our experiments, however, rhyme and nonrhyme neighbours did not differ much in the amount of overlap in phonology. Because Dutch has a much more regular grapheme-phoneme mapping in most cases changing one letter in a word changes only one phoneme. For example, the nonrhyming neighbours for the target *boef* were *boer* and *boek*. These words all have the same grapheme-phoneme mapping for *boe*. That is, the pronunciation of *boe* is very similar in all three words. This was the case for the majority of our stimuli. Thus, our stimuli did not have the type of phonological competition that Bowers et al.'s stimuli had (see also Andrews, 1997; van Heuven, Dijkstra, & Grainger, 1998 for a similar argument). This suggests that the difference between the rhyme and nonrhyme condition in the Bowers et al. study was the result of conflicting phonology (as was concluded by Bowers et al.) rather than of differences in rhyme per se.

In sum, the present study shows that performance for target words in a semantic categorisation task is affected by the semantics of orthographic neighbours. Performance was enhanced if a neighbour from the same category (a congruent neighbour) was primed. Performance was decreased if a neighbour from the opposite category (an incongruent prime) was primed. Furthermore, this congruency effect was unaffected by rhyming. These results are problematic for serial models of word recognition and provide support for cascaded models. Furthermore, our finding that similar effects occurred in living decision and size decision suggest that rather than a single semantic unit a more complex semantic representation directs the decision process.

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APPENDIX A

Targets and primes with English equivalents used in Experiment 1 in the animacy decision task

		<i>Target</i>		<i>Congruent</i>		<i>Incongruent</i>
Rhyme	pint	<i>beer</i>	lint	<i>ribbon</i>	sint	<i>santa</i>
	mast	<i>mast</i>	kast	<i>closet</i>	gast	<i>guest</i>
	kade	<i>quayside</i>	lade	<i>drawer</i>	made	<i>maggot</i>
	rad	<i>wheel</i>	bad	<i>bath</i>	rat	<i>rat</i>
	woning	<i>residence</i>	honing	<i>honey</i>	koning	<i>king</i>
	pand	<i>building</i>	mand	<i>basket</i>	hand	<i>hand</i>
	tent	<i>tent</i>	cent	<i>cent</i>	vent	<i>fellow</i>
	veld	<i>field</i>	geld	<i>money</i>	held	<i>hero</i>
	dar	<i>drone</i>	nar	<i>jester</i>	kar	<i>cart</i>
	hoeder	<i>shepherd</i>	moeder	<i>mother</i>	poeder	<i>powder</i>
	roker	<i>smoker</i>	joker	<i>fool</i>	koker	<i>tube</i>
	tor	<i>beetle</i>	oor	<i>ear</i>	nor	<i>jail</i>
	gen	<i>gene</i>	den	<i>pine</i>	pen	<i>pen</i>
	kruid	<i>herb</i>	bruid	<i>bride</i>	kruit	<i>gunpowder</i>
	perk	<i>flowerbed</i>	berk	<i>birch</i>	kerk	<i>church</i>
	peul	<i>legume</i>	beul	<i>brute</i>	geul	<i>trench</i>
	peen	<i>carrot</i>	teen	<i>toe</i>	veen	<i>peat-soil</i>
	vink	<i>finch</i>	bink	<i>he-man</i>	zink	<i>zinc</i>
	lam	<i>lamb</i>	mam	<i>mum</i>	kam	<i>comb</i>
	luis	<i>louse</i>	muis	<i>mouse</i>	huis	<i>house</i>
heer	<i>gentleman</i>	beer	<i>bear</i>	teer	<i>tar</i>	
waard	<i>landlord</i>	paard	<i>horse</i>	haard	<i>fireplace</i>	
Nonrhyme	snoep	<i>candy</i>	snoer	<i>cord</i>	snoek	<i>pike</i>
	plus	<i>plus</i>	plas	<i>puddle</i>	paus	<i>pope</i>
	zool	<i>sole</i>	zoom	<i>seam</i>	zoon	<i>son</i>
	lijm	<i>glue</i>	lijn	<i>line</i>	lijf	<i>body</i>
	bon	<i>receipt</i>	bom	<i>bomb</i>	boa	<i>boa</i>
	vork	<i>fork</i>	vonk	<i>sparkle</i>	volk	<i>nation</i>
	boot	<i>boat</i>	boor	<i>drill</i>	boom	<i>tree</i>
	harp	<i>harp</i>	hark	<i>rake</i>	hart	<i>heart</i>
	kras	<i>scratch</i>	krat	<i>crate</i>	krab	<i>crab</i>
	kraal	<i>bead</i>	kraag	<i>collar</i>	kraai	<i>crow</i>
	tang	<i>pliers</i>	tank	<i>tank</i>	tong	<i>tongue</i>
	schaar	<i>scissors</i>	schaal	<i>dish</i>	schaap	<i>sheep</i>
	anker	<i>anchor</i>	akker	<i>field</i>	anjer	<i>carnation</i>
	rok	<i>skirt</i>	rol	<i>roll</i>	ros	<i>steed</i>
	knot	<i>bun</i>	knop	<i>key</i>	knol	<i>tuber</i>
	aal	<i>eel</i>	aap	<i>monkey</i>	hal	<i>hall</i>
	boef	<i>scoundrel</i>	boer	<i>farmer</i>	boek	<i>book</i>
	mus	<i>sparrow</i>	mug	<i>mosquito</i>	jus	<i>gravy</i>
	graaf	<i>count</i>	graan	<i>grain</i>	graad	<i>degree</i>
	gezel	<i>companion</i>	wezel	<i>weasel</i>	vezel	<i>fibre</i>
haag	<i>hedge</i>	haai	<i>shark</i>	haak	<i>hook</i>	
mees	<i>titmouse</i>	mens	<i>human</i>	meel	<i>flour</i>	
duif	<i>pigeon</i>	duim	<i>thumb</i>	duit	<i>coin</i>	
pols	<i>wrist</i>	poes	<i>cat</i>	pils	<i>beer</i>	

Note: The English equivalents do not always overlap the meaning of Dutch words exactly.

APPENDIX B

Targets and primes with English equivalents used in Experiment 2 in the size decision task

	<i>Target</i>		<i>Congruent</i>		<i>Incongruent</i>	
Rhyme	rafel	<i>fray</i>	wafel	<i>waffle</i>	tafel	<i>table</i>
	rozijn	<i>raisin</i>	robijn	<i>ruby</i>	kozijn	<i>window frame</i>
	kever	<i>beetle</i>	lever	<i>liver</i>	wever	<i>weaver</i>
	pink	<i>little finger</i>	vink	<i>finch</i>	bink	<i>he-man</i>
	long	<i>lung</i>	tong	<i>tongue</i>	gong	<i>gong</i>
	hoeder	<i>shepherd</i>	moeder	<i>mother</i>	poeder	<i>powder</i>
	roker	<i>smoker</i>	moker	<i>sledge</i>	joker	<i>joker</i>
	lam	<i>lamb</i>	dam	<i>dam</i>	kam	<i>comb</i>
	polder	<i>polder</i>	zolder	<i>attic</i>	folder	<i>brochure</i>
	kade	<i>quayside</i>	lade	<i>drawer</i>	made	<i>maggot</i>
	heer	<i>gentleman</i>	beer	<i>bear</i>	veer	<i>feather</i>
	held	<i>hero</i>	veld	<i>field</i>	geld	<i>money</i>
	woning	<i>residence</i>	koning	<i>king</i>	honing	<i>honey</i>
	peen	<i>carrot</i>	teen	<i>toe</i>	been	<i>leg</i>
	kras	<i>scratch</i>	gras	<i>grass</i>	klas	<i>class</i>
	luis	<i>louse</i>	muis	<i>mouse</i>	huis	<i>house</i>
	pen	<i>pen</i>	gen	<i>gene</i>	den	<i>pine</i>
	kruid	<i>herb</i>	kruit	<i>powder</i>	bruid	<i>bride</i>
	nar	<i>jester</i>	bar	<i>bar</i>	dar	<i>drone</i>
	slee	<i>sleigh</i>	plee	<i>loo</i>	snee	<i>cut</i>
	sluis	<i>lock (ship)</i>	kluis	<i>safe</i>	pluis	<i>fluff</i>
	vos	<i>fox</i>	bos	<i>forest</i>	mos	<i>moss</i>
	haard	<i>fireplace</i>	paard	<i>horse</i>	baard	<i>beard</i>
	tent	<i>tent</i>	vent	<i>fellow</i>	cent	<i>cent</i>
	zon	<i>sun</i>	non	<i>nun</i>	ion	<i>ion</i>
	boot	<i>boat</i>	goot	<i>gutter</i>	noot	<i>nut</i>
Nonrhyme	aal	<i>eel</i>	gal	<i>gall</i>	hal	<i>hall</i>
	snot	<i>snot</i>	snor	<i>moustache</i>	snob	<i>snob</i>
	snoep	<i>candy</i>	snoer	<i>cord</i>	snoek	<i>pike</i>
	vlok	<i>flake</i>	vlek	<i>spot</i>	vlot	<i>raft</i>
	zool	<i>sole</i>	zoom	<i>seam</i>	zoon	<i>son</i>
	duif	<i>pigeon</i>	duim	<i>thumb</i>	duin	<i>dune</i>
	sik	<i>goatee</i>	sok	<i>sock</i>	eik	<i>oak</i>
	jus	<i>gravy</i>	mus	<i>sparrow</i>	bus	<i>bus</i>
	rits	<i>zipper</i>	riks	<i>coin</i>	rots	<i>boulder</i>
	kraal	<i>bead</i>	kraag	<i>collar</i>	kraam	<i>stand</i>
	mees	<i>titmouse</i>	meel	<i>meal</i>	mens	<i>human</i>
	tand	<i>tooth</i>	tang	<i>pliers</i>	tank	<i>tank</i>
	hark	<i>rake</i>	harp	<i>harp</i>	hart	<i>heart</i>
	boef	<i>scoundrel</i>	boer	<i>farmer</i>	boek	<i>book</i>
	lans	<i>lance</i>	land	<i>land</i>	lens	<i>lens</i>
	staf	<i>staff</i>	stad	<i>city</i>	stof	<i>dust</i>
	werker	<i>worker</i>	werper	<i>pitcher</i>	wekker	<i>alarm clock</i>
	kast	<i>closet</i>	kust	<i>coast</i>	kaft	<i>cover</i>

(continued)

APPENDIX B (*Continued*)

<i>Target</i>		<i>Congruent</i>		<i>Incongruent</i>	
mams	<i>mum</i>	maas	<i>mesh</i>	mais	<i>corn</i>
perk	<i>flowerbed</i>	park	<i>park</i>	peuk	<i>cigarette</i>
anker	<i>anchor</i>	akker	<i>field</i>	anjer	<i>carnation</i>
hek	<i>fence</i>	heg	<i>hedge</i>	hak	<i>heel</i>
cafe	<i>café</i>	cape	<i>cape</i>	cake	<i>cake</i>
oom	<i>uncle</i>	olm	<i>elm</i>	oor	<i>ear</i>

Note: The English equivalents do not always overlap the meaning of Dutch words exactly.