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Reading Aloud: Evidence for Contextual Control Over Lexical Activation

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Can readers exert control (albeit unconsciously) over activation at particular loci in the reading system? The authors addressed this issue in 4 experiments in which participants read target words aloud and the factors of prime–target relation (semantic, repetition), context (related, unrelated), stimulus quality (bright, dim), and relatedness proportion (RP; high, low) were manipulated. In the high RP condition (RP = .5), an interaction between semantic context and stimulus quality was observed in which low stimulus quality slowed unrelated targets more than related ones, replicating previous work. In contrast, the low RP condition (RP = .25) yielded additive effects of semantic context and stimulus quality. However, when low RP was examined within the context of repetition priming, context and stimulus quality once again interacted. These results are discussed in the context of a widely endorsed framework with the addition of the central assumption that there is control over feedback between various levels.

Keywords: lexical activation, priming, contextual control, relatedness proportion

It is well established that the prior presentation of a word that is semantically related to a target word yields faster responses to the target relative to an unrelated prime in both lexical decision and reading aloud (see McNamara, 2005, for a review). Stolz and Besner (1996) provided an account of this semantic relatedness effect in the context of an interactive activation framework with three levels[1]: a letter level, an orthographic input lexicon (OIL), and a semantic level (see Figure 1). In their account, when a word is processed, appropriate letter level representations are activated and this activation feeds forward to localist representations at the word level, which in turn activates semantic representations of both the word and its associates. In addition to activation feeding from lower to higher levels, it also feeds back from the semantic level to the word level and from the word level to the letter level.

The Joint Effects of Semantic Context and Stimulus Quality

A number of factors have been shown to interact with the effect of semantic relatedness. Stimulus quality (often implemented as a reduction in contrast but sometimes implemented via masking or the superimposition of dots on the stimulus) is one such factor. In both lexical decision and reading aloud, related targets are less affected than unrelated targets by a reduction in stimulus quality (e.g., Meyer, Schvaneveldt, & Ruddy, 1975). One account, couched within the context of lexical decision, contends that this interaction arises because although the effect of stimulus quality does not extend beyond the OIL,[2] there is feedback from prime processing at the semantic level to semantically related representations at the lexical level. Accordingly, the related target requires less bottom-up activation because of this feedback from these associates of the prime. Unrelated targets do not receive any benefit from top-down influences and are therefore more impaired by low stimulus quality (Borowsky & Besner, 1993; Stolz & Neely, 1995).

Lexical Decision: Relatedness Proportion (RP) and the Interaction Between Semantic Context and Stimulus Quality

Stolz and Neely (1995) reported that in the context of lexical decision, the proportion of related word trials (RP) modulates the interaction between semantic context and stimulus quality for strong associates. When RP is high (.5), semantic context and stimulus quality interact, but when RP is low (.25), semantic context and stimulus quality have additive effects on reaction time (RT). Given the assumption that the effect of stimulus quality does not extend to the semantic level, Stolz and Neely argued that the three-way interaction between stimulus quality, RP, and context is the result of contextual control over feedback from the semantic system (SEM) to the OIL (via the SEM → OIL pathway in Figure 1). When RP is high, feedback from semantics to the word level (for the prime's associates) is operative, but when RP is low, this

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[1] For simplicity, we ignore the feature level (although it is obviously affected by stimulus quality).

[2] More current accounts suppose that in the context of lexical decision (but not reading aloud), stimulus quality affects feature and letter level processing, but not beyond (see M. Brown et al., 2006; O'Malley et al., 2007; Yap & Balota, 2007; Yap, Balota, Tse, & Besner, 2008).

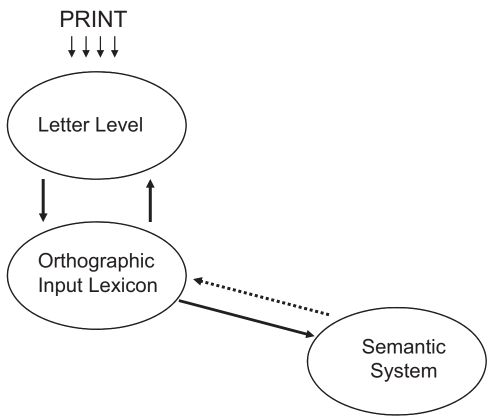

Figure 1. An interactive activation framework for lexical–semantic processing without phonology. The dotted line depicts the pathway modulated by relatedness proportion (i.e., blocked when relatedness proportion is low).

feedback is blocked. Stolz and Neely reasoned that feedback is blocked when RP is low because it is not a good use of limited capacity semantic activation given that on most trials this feedback will not assist target processing (see also M. Brown, Stolz, & Besner, 2006, for a replication in which stimulus quality and semantic priming are additive factors when RP is low and strong associates are used, along with an account in which feedback extends to the letter level).

In summary, in the framework depicted in Figure 1, eliminating feedback from the SEM restricts the locus of the semantic priming effect to the SEM. To account for additive effects of semantic context and stimulus quality, the effect of stimulus quality must not extend to the SEM, which can be accomplished by thresholding the output from some previous process or by having cascaded processing that respects some constraints (McClelland, 1979; Roberts & Sternberg, 1993).

Reading Aloud: RP and the Interaction Between Semantic Context and Stimulus Quality

When RP = .5, there is an interaction between semantic context and stimulus quality in both lexical decision and reading aloud. However, we do not know what effect reducing RP has in the context of reading aloud.[3]

The answer to this question would tell us how deep into the word recognition system the effect of stimulus quality penetrates in the context of reading aloud. All we know at present is that the effect of stimulus quality penetrates farther into the system when reading aloud than in lexical decision. We know this because on the one hand, the joint effects of stimulus quality and word frequency are additive on RT in the context of lexical decision, consistent with the assumption that the effect of stimulus quality stops prior to the point at which word frequency exerts its effect (see O'Malley, Reynolds, & Besner, 2007, for a summary of such studies). On the other hand, stimulus quality and word frequency interact in the context of reading aloud, suggesting that the effect of stimulus quality extends to at least the level of the OIL on the common assumption that word frequency affects both the OIL and the phonological output lexicon (POL; O'Malley et al., 2007; Yap & Balota, 2007).

Does the effect of stimulus quality extend beyond the OIL to the level of the POL when reading aloud? If it does, then given a main effect of semantic context under low RP (see Neely, 1991, pp. 287–288), an interaction between semantic context and stimulus quality is expected because these two factors affect a common module (by assumption, the POL). If there is no interaction, then the strong inference is that the effect of stimulus quality does not extend to the POL.

The Stolz and Neely (1995) Account Is Incomplete

When considering the joint effects of semantic priming, stimulus quality, and RP, Stolz and Neely (1995) restricted themselves to a framework with only three components (i.e., letter level, orthographic word level, and semantic level), as in the scheme presented in Figure 1. However, when a more complete model of visual word recognition is considered, it is apparent that the Stolz and Neely account is incomplete in the context of lexical decision, as well as in its extension to reading aloud.

A well received localist framework (as attested to by its current citation count of more than 500) in the context of lexical decision and reading aloud is the dual route cascaded model (DRC) depicted in Figure 2 (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). This framework includes a POL, along with a phonemic buffer, and a routine that translates spelling into sound on the basis of sublexical spelling–sound correspondences.[4]

In this larger framework, it is clear that turning feedback off along the SEM → OIL pathway is no longer sufficient to prevent semantic information from activating the OIL. Activation in the SEM can also propagate back to the OIL via the SEM → POL and POL → OIL pathways.[5] Consequently, the account put forth by Stolz and Neely (1995) requires that, in addition to blocking the SEM → OIL pathway, low RP must also serve to block either the SEM → POL pathway or the POL → OIL pathway. Without postulating a block of one of these pathways when RP is low, activation from semantics would reach both the OIL and letter level, resulting in an interaction between semantic context and stimulus quality. Given that Stolz and Neely observed no interaction at a low RP, it follows that semantic activation must be insulated from modules where stimulus quality exerts its effect. It is currently unknown where this additional block arises under conditions of low RP. It could be the SEM → POL pathway, the POL → OIL pathway, or both pathways.

[3] P. Brown and Lupker (1993) reported that in reading aloud there was no interaction between stimulus quality and semantic priming when RP = .25. Unfortunately, this finding has never been published.

[4] Blais and Besner (2007) reviewed several findings suggesting that the effect of stimulus quality does not extend through the nonlexical route.

[5] The phonological level feeds back to the orthographic level in the DRC model. That said, the claim that such feedback is operative in skilled readers (see Stone, Vanhoy, & Van Orden, 1997) has been contested by Ziegler, Petrova, and Ferrrand (2008; at least in the context of lexical decision). Note that Perry, Ziegler, and Zorzi's (2007) CDP+ model has such feedback connections.

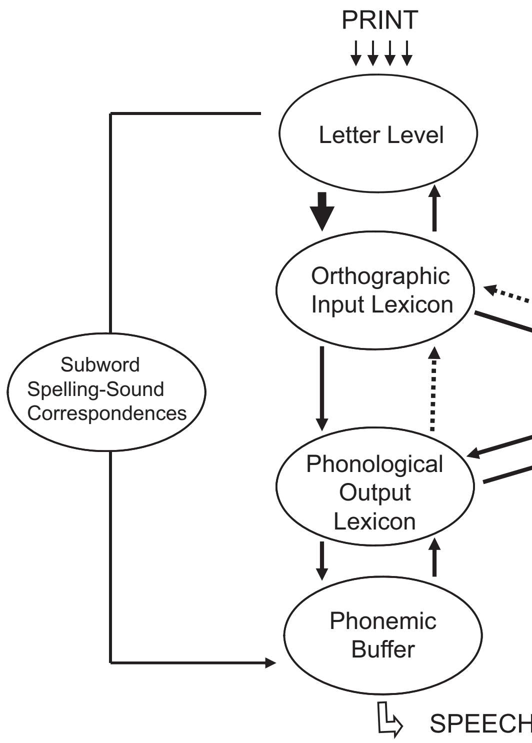

Figure 2. Coltheart and colleagues' (2001) interactive activation framework for lexical–semantic processing, which includes phonological influences. The dotted lines depict pathways modulated by relatedness proportion (i.e., blocked when relatedness proportion is low). The bold line depicts the only pathway affected by stimulus quality when reading aloud.

It is unclear how to address this issue in the context of lexical decision[6] because responses to the task have been argued to reflect the monitoring of activation at the semantic level (at least in healthy participants in cases in which the nonwords are orthographically legal; e.g., Borowsky & Besner, 1993; M. Brown & Besner 2002; M. Brown et al., 2006; Stolz & Neely, 1995; Stolz & Besner, 1996, 1998). Thus, phonological output processes are not necessarily engaged, obfuscating the role that they play in processing. However, unlike lexical decision, when reading aloud the participant must produce a phonological code in order to drive an utterance. Assuming that there is a main effect of semantic context at an RP of .25, it cannot be the case that it is the SEM → POL pathway that is blocked. This is because if both the SEM → OIL and the SEM → POL pathways are blocked, then there can be no means for the SEM to influence performance in this task. Any activation accruing within semantics would be functionally trapped within that module. Given that a response cannot be articulated within the SEM, it follows that the SEM would be unable to influence reading aloud. Therefore, assuming a main effect of semantic priming in the present experiment, it follows that all activation from semantics cannot be blocked. Activation must propagate from semantics to the POL. This would imply that the additional block that insulates orthographic processes from semantic activation must arise at the POL → OIL pathway rather than at the SEM → POL pathway.

In summary, a strong inference can be drawn if there are main effects of context and stimulus quality, but the joint effects of semantic context and stimulus quality are additive when RP is low and participants read aloud. This result would support the conclusion that the effect of stimulus quality does not extend beyond the OIL to the POL when reading aloud. It would also support the conclusion that semantic processing affects the POL but that (a) there is no feedback between SEM and the OIL and (b) there is no feedback between the POL and the OIL. To foretell the results, semantic context and stimulus quality are indeed additive when RP = .25, but the typically reported interaction is observed when RP = .5.

Experiment 1

Method

Participants. Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as a first language and all had normal or corrected-to-normal vision.

Design. A 2 (context: related vs. unrelated) × 2 (stimulus quality: clear vs. dim) repeated measures design was used. Both

[6] Although, if there is no feedback from the POL to the OIL as Ziegler et al. (2008) maintained, then the issue is not important in that context because blocking of the SEM → OIL pathway will suffice to prevent an interaction between stimulus quality and semantic priming when reading aloud, provided that the effect of stimulus quality does not extend beyond the OIL.

factors were within subject, and trials from all four conditions were randomly intermixed. There were an equal number of clear and dim trials; RP for both clear and degraded items was .25.

Stimulus materials and list construction. The stimuli consisted of the 96 related-word pairs used by Besner and Smith (1992); these items appear in the appendix to their article and are predominantly strongly associated. The first word of each pair was the prime and always appeared in clearly visible lowercase letters (Fixedsys Font Size 12). The second word was the target and appeared in lowercase letters that were clearly visible on half of the trials (RGB values: 200, 200, 200) and dim on the remaining ones (RGB values: 63, 63, 63). The 96 word pairs were used to form eight lists, such that each list consisted of 24 related-word pairs and 72 unrelated-word pairs (12 clear and 12 dim related-word pairs; 36 clear and 36 dim unrelated-word pairs). Each word in the experiment appeared only once for an individual participants.

The combinations of prime and target words were rotated across participants such that each target appeared equally often in clear and dim form and was preceded by both related and unrelated primes. The sequence of trials was randomized anew for each participant.

Procedure. Participants were tested individually and were seated approximately 57 cm from the computer monitor in a dimly lit room. They were instructed to respond as quickly and accurately as possible.

Stimuli were displayed on a standard 15-in. SVGA monitor controlled by E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) implemented on a Pentium-IV (1,800 MHz) computer. Response latencies to the nearest millisecond were collected using a Plantronics LS1 microphone headset (TWAcomm.com, Huntington Beach, CA) and a voice key assembly.

Each trial began with a fixation cross (+) at the center of the screen that was displayed for 750 ms. Following fixation, a prime appeared at fixation for 100 ms, followed by a blank interstimulus interval of 100 ms. A target was then presented at fixation until the participant read the target aloud. The experimenter coded responses as correct, incorrect, or spoiled.

Results

Spoiled trials accounted for fewer than 2% of the observations overall; their distribution can be seen in Table 1. Only correct responses to the target words were included in the analysis of the RT data (99.2% of the remaining trials in the experiment). These data were submitted to a recursive outlier analysis (Van Selst & Jolicoeur, 1994), which resulted in the further elimination of 3.0% of the data. Mean RTs, percentage errors, and percentage spoiled trials are presented in Table 1.

Table 1
Experiment 1: Mean Reaction Times (RTs), Percentage Error (%E), and Percentage Spoiled Trials (%ST) for Targets as a Function of Semantic Context and Stimulus Quality When the Relatedness Proportion Is .25

	Stimulus quality					
	Clear			Dim		
Prime context	RT (ms)	%E	%ST	RT (ms)	%E	%ST
Unrelated	534	.9	1.6	589	1.4	1.8
Related	524	.5	1.6	579	.5	1.0
Difference	10	.4		10	.9	

Mean RTs were submitted to a 2 × 2 within-subjects analysis of variance (ANOVA). The main effect of relatedness was significant, $F(1, 31) = 7.4$, $MSE = 436$, $p < .05$, $\eta_p^2 = .19$, as was the main effect of stimulus quality, $F(1, 31) = 30.7$, $MSE = 3{,}226$, $p < .05$, $\eta_p^2 = .49$. Critically, the interaction between relatedness and stimulus quality was not significant ($F < 1$, $\eta_p^2 = 0$). No formal analysis of the error data was conducted because there were too many cells with zero as an entry.

To assess the possibility that the null interaction was the result of a Type II error, we computed power using a $p < .05$, two-tailed *t* test, with procedures recommended by Cohen (1988, pp. 45–52). This power analysis was conducted using an effect size of 15 ms (which, to foreshadow, was the magnitude of the interaction observed in Experiment 2 using an RP of .5) and a correlation between the priming effects obtained for each participant for the bright and dim targets of $r = .864$. This yielded a d' of .69; the power of the two-tailed test was .78 (Stolz & Neely, 1995, used a one-tailed test to assess their null result and observed power of .695; a one-tailed test in the present context yields a power of .93).

Discussion

Semantic context and stimulus quality produced main effects in the context of reading aloud when RP was .25. Critically, there was no interaction between these two factors (0 ms). We discuss these findings after reporting the results of Experiment 2. In Experiment 2, we replicated the finding of an interaction between semantic context and stimulus quality when RP = .5 (see Besner & Smith, 1992; Meyer et al., 1975). Replicating this interaction in our lab at a high RP also allows us to formally test the three-way interaction.

Experiment 2

Method

Participants. Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as a first language and all had normal or corrected-to-normal vision.

Design. The same repeated measures design as in Experiment 1 was used, along with the same stimulus set. RP was .5 for both clear and degraded conditions.

Stimulus materials and list construction. The stimuli were the same as those used in Experiment 1. The 96 word pairs were used to form four lists, such that each list consisted of 48 related-word pairs and 48 unrelated-word pairs (24 clear and 24 dim in both related-word and unrelated-word pairs).

Results

Spoiled trials accounted for fewer than 4% of the observations overall. Only correct responses to the target words were included in the analysis of the RT data (98.1% of the total trials in the experiment). The remaining data were submitted to a recursive outlier analysis, which resulted in the further elimination of 3.9%

of the data. Mean RTs, percentage errors, and percentage spoiled trials are presented in Table 2.

The main effect of relatedness was significant, $F(1, 31) = 15.1$, $MSE = 512$, $p < .05$, $\eta_p^2 = .33$, as was the main effect of stimulus quality, $F(1, 31) = 86.5$, $MSE = 1{,}463$, $p < .05$, $\eta_p^2 = .74$. Critically, the interaction between relatedness and stimulus quality was significant, $F(1, 31) = 5.7$, $MSE = 310$, $p < .05$, $\eta_p^2 = .16$. No formal analysis of the error data was conducted because there were too many cells with zero as an entry.

A between-experiments analysis was also conducted to test the Stimulus Quality × Priming × RP interaction. A three-way interaction is expected given that P. Brown and Lupker (1993) reported additive effects of stimulus quality and semantic priming when reading aloud and RP = .25. This three-way interaction (i.e., the difference of the differences between related bright and related dim and unrelated bright and unrelated dim stimuli, for Experiment 2 relative to Experiment 1) was therefore tested with a one-tailed *t* test and proved to be significant, $t(62) = 1.82$, $p = .038$, $\eta_p^2 = .05$.

Discussion

When reading aloud, the joint effects of semantic context and stimulus quality were additive in Experiment 1 when RP was .25, but these same factors interacted in Experiment 2 when RP was .5.[7] This is consistent with the argument that, when RP is low, activation from semantics does not feed back to the OIL or letter levels, and the effect of stimulus quality does not extend to the level of the POL. Hence, there is no interaction. However, when RP = .5, there are no activation blocks, and feedback from SEM to OIL is responsible for the interaction given that stimulus quality affects the OIL. Demonstrating a context in which, under conditions of low RP, stimulus quality interacts with a source of increased activation in the word processing system would further bolster this argument because it would undermine the possibility that the additive effects reported in Experiment 1 were simply the result of weaker activation in general when RP is low.

In repetition priming, the prime and the target consist of the same word (e.g., Scarborough, Cortese, & Scarborough, 1977). Accordingly, in experiments in which the target immediately follows the prime (i.e., zero-lag repetition priming; see Besner, Dennis, & Davelaar, 1985; Humphreys, Besner, & Quinlan, 1988), feedback from semantics is not necessary to produce an interaction between context and stimulus quality because prime activation for the target persists at the letter and OIL levels. Accordingly, related targets should require less bottom-up activation, whereas unrelated targets do not receive the benefit of this activation and consequently are more impaired by low stimulus quality. Therefore, a test of the explanation provided for the results of Experiments 1 and 2 is to conduct an experiment, under conditions of low RP, using repetition priming rather than semantic priming. An interaction between context and stimulus quality would argue against the possibility that low RP merely weakens activation in general and that the additive effects found in Experiment 1 were simply a consequence of this attenuated activation.

In summary, the presence of an interaction between context and stimulus quality for repetition priming when RP = .25 combined with the absence of such an interaction for semantic priming when RP = .25 would support the hypothesis that the absence of the latter interaction at a low RP arises because activation from semantics does not feed back to influence orthographic processes.

Table 2
Experiment 2: Mean Reaction Times (RTs), Percentage Error (%E), and Percentage Spoiled Trials (%ST) for Targets as a Function of Semantic Context and Stimulus Quality When the Relatedness Proportion Is .5

	Stimulus quality					
	Clear			Dim		
Prime context	RT (ms)	%E	%ST	RT (ms)	%E	%ST
Unrelated	542	.8	3.8	613	3.5	3.3
Related	534	.8	3.7	590	2.2	4.7
Difference	8	0		23	1.3	

Experiment 3

Method

Participants. Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as a first language and all had normal or corrected-to-normal vision.

Design. The same repeated measures design as in Experiments 1 and 2 was used, along with the same target set. The only significant difference was that repetition priming rather than semantic priming was used. For both clear and degraded items, RP was .25.

Stimulus materials and list construction. The list construction and assignment of lists was the same as in Experiment 1 except for the substitution of the same word as both prime and target in the related condition. The prime was presented in lowercase letters, and the target was presented in uppercase letters.

Results

Spoiled trials accounted for fewer than 2% of the observations overall. Only correct responses to the target words were included in the analysis of the RT data (98.5% of the total trials in the experiment). The remaining data were submitted to a recursive outlier analysis that resulted in the further elimination of 2.7% of the data. Mean RTs, percentage errors, and percentage spoiled trials are presented in Table 3.

The main effect of relatedness was significant, $F(1, 31) = 86.5$, $MSE = 704$, $p < .05$, $\eta_p^2 = .74$, as was the main effect of stimulus quality, $F(1, 31) = 84.3$, $MSE = 1{,}427$, $p < .05$, $\eta_p^2 = .73$. Critically, the interaction between repetition and stimulus quality was significant, $F(1, 31) = 6.2$, $MSE = 1{,}164$, $p < .05$, $\eta_p^2 = .17$. No formal analysis of the error data was conducted because there were too many cells with zero as an entry. Finally, a between-experiments analysis of the RT data from Experiment 1 versus Experiment 3 yielded the three-way interaction that was expected on the current account, $F(1, 62) = 5.2$, $MSE = 708$, $p < .05$, $\eta_p^2 = .08$.

[7] It should be noted that there is no evidence here that RP affects target RTs under the bright condition (although this is a between-subjects comparison). If genuine, it remains to be explained.

Table 3
Experiment 3: Mean Reaction Times (RTs), Percentage Error (%E), and Percentage Spoiled Trials (%ST) for Targets as a Function of Repetition Context and Stimulus Quality When the Relatedness Proportion Is .25

	Stimulus quality					
	Clear			Dim		
Prime context	RT (ms)	%E	%ST	RT (ms)	%E	%ST
Unrelated	545	.8	1.6	622	2.8	2.1
Related	516	.5	1.3	563	.3	1.8
Difference	29	.3		59	2.5	

Discussion

Experiment 3 yielded an interaction between context and stimulus quality despite low RP. In repetition priming, feedback from semantics is not necessary to increase activation for the target at the letter and OIL levels. Thus the interaction is consistent with the assumption that both repetition and stimulus quality affect the letter level and OIL level when reading aloud. Furthermore, this result is consistent with the claim that the absence of the Semantic Priming × Stimulus Quality interaction at a low RP arises because activation from semantics does not feed back to the OIL or letter level.

An alternative account, advanced by an anonymous reviewer, is that in Experiments 2 and 3 responses were generated closer to asymptote. This, combined with a sigmoidal activation function, would generate greater priming effects because of the slower overall RTs in the unrelated condition in Experiments 2 and 3, relative to Experiment 1.[8] In other words, the argument is that irrespective of RP and type of priming, slower RTs (as in Experiments 2 and 3) lead to an interaction between context and stimulus quality, whereas faster RTs (as in Experiment 1) lead to additivity. Accordingly, the additive results found in Experiment 1 may have arisen because of factors other than contextual activation blocks.

To assess this possibility, we conducted a fourth experiment in which repetition and semantic priming were combined under conditions of low RP.[9] This experiment has the advantage of having only one unrelated condition (a baseline) with which to compare semantic and repetition priming. Accordingly, issues related to shifting baselines are no longer relevant. If Experiment 4, in which RP is low, yields additivity between context and stimulus quality for semantic priming but an interaction between repetition priming, then arguments predicated upon asymptote and the sigmoidal activation function cannot be correct. Instead, the results would provide further evidence for contextual control over lexical activation.

Experiment 4

Method

Participants. Thirty-two University of Waterloo undergraduate students took part in the experiment. All spoke English as a first language and all had normal or corrected-to-normal vision.

Design. A 3 (context: semantically related vs. repetition related vs. unrelated) × 2 (stimulus quality: clear vs. dim) repeated measures design was used. Both factors were within subject and trials from all six conditions were randomly intermixed. There were an equal number of clear and dim trials. The overall RP for both clear and degraded items was .25: 12.5% of the prime–target pairs were semantic prime–target pairs, 12.5% were repetition prime–target pairs, and 75% were unrelated prime–target pairs. Given the fact that repetition-related primes are, by definition, also semantically related, the overall RP for semantic priming was therefore .25, whereas the overall RP for identity priming was .125. The implementation of RP in this manner ensures that the overall semantic context is .25, which is important given that this was the RP at which additivity was observed in Experiment 1.

Stimulus materials and list construction. The stimuli consisted of the same 96 related-word pairs used in the previous experiments. The 93 word pairs were used to form 16 lists such that each list consisted of 12 semantically related word pairs, 12 repetition related word pairs, and 72 unrelated word pairs (6 clear and 6 dim semantically related word pairs; 6 clear and 6 dim repetition related word pairs; 36 clear and 36 dim unrelated word pairs). The prime was presented in lowercase letters, and the target was presented in uppercase letters. Each word in the experiment appeared only once for an individual participant.

Results

Spoiled trials accounted for fewer than 5% of the observations overall; their distribution can be seen in Table 4. Only correct responses to the target words were included in the analysis of the RT data (99.6% of the remaining trials in the experiment). These data were submitted to a recursive outlier analysis, which resulted in the further elimination of 2.4% of the data. Mean RTs, percentage errors, and percentage spoiled trials are presented in Table 4.

The mean RTs were submitted to a 3 × 2 within-subjects ANOVA. The main effect of relatedness was significant, $F(2, 62) = 11.7$, $MSE = 1{,}282$, $p < .001$, $\eta_p^2 = .27$, as was the main effect of stimulus quality, $F(1, 31) = 18.3$, $MSE = 6{,}152$, $p < .001$, $\eta_p^2 = .37$. The interaction between relatedness and stimulus quality was also significant, $F(2, 62) = 7.5$, $MSE = 604$, $p < .001$, $\eta_p^2 = .20$. Follow-up 2 × 2 within-subjects ANOVAs were conducted to examine semantic and repetition priming separately. First, for the semantic primes condition, there was a main effect of relatedness, $F(1, 31) = 7.3$, $MSE = 823$, $p = .01$, $\eta_p^2 = .19$, and a main effect of stimulus quality, $F(1, 31) = 19.2$, $MSE = 5{,}597$, $p < .001$, $\eta_p^2 = .38$. Critically, the interaction between relatedness and stimulus quality was not significant ($F < 1$, $\eta_p^2 = .02$). For the repetition primes condition, there was a main effect of relatedness, $F(1, 31) = 22.2$, $MSE = 1{,}349$, $p < .001$, $\eta_p^2 = .42$, and a main effect of stimulus quality, $F(1, 31) = 16.5$, $MSE = 3{,}940$, $p < .001$, $\eta_p^2 = .35$. Critically, the interaction between relatedness and stimulus quality was significant, $F(1, 31) = 10.9$, $MSE = 734$, $p < .01$, $\eta_p^2 = .26$. No formal analysis of the error data was conducted because there were too many cells with zero as an entry.

[8] Note that Besner, Wartak, and Robidoux (2008) have challenged this account in the context of Plaut and Booth's (2000, 2006) computational model.

[9] We thank Jim Neely for suggesting this experiment.

Table 4

Experiment 4: Mean Reaction Times (RTs), Percentage Error (%E), and Percentage Spoiled Trials (%ST) for Targets as a Function of Semantic and Repetition Context and Stimulus Quality When the Relatedness Proportion Is .25

	Stimulus quality					
	Clear			Dim		
Context	RT (ms)	%E	%ST	RT (ms)	%E	%ST
Semantic						
Unrelated	555	.3	4.3	616	.8	4.6
Related	544	0	3.1	600	.5	1.6
Difference	11	.3		16	.3	
Repetition						
Unrelated	555	.3	4.3	616	.8	4.6
Related	541	0	4.1	570	0	3.1
Difference	14	.3		46	.8	

Discussion

The results of Experiment 4 demonstrate that under conditions of low RP, context and stimulus quality were additive factors when priming was semantic, whereas these factors interacted when priming was repetition based. This result is consistent with the claims that (a) at a low RP, activation from semantics does not feed back directly or via phonological processes to the OIL or letter level and (b) stimulus quality does not penetrate as far as the POL. In the case of immediate repetition, feedback from semantics is not necessary to produce an interaction between context and stimulus quality because activations for prime and target overlap at the letter and OIL levels.

General Discussion

Interpreting the Results Within an Interactive Activation Framework

As noted earlier, Stolz and Neely (1995; see also M. Brown et al., 2006) argued, in the context of lexical decision, that feedback between the semantic level and earlier levels is modulated by RP such that low RP leads to a block in this pathway. Given the assumption that stimulus quality does not extend its effects to the semantic level in the context of lexical decision, the presence of feedback will allow an interaction between stimulus quality and semantic context and its absence will prevent this interaction if no other processes are active (such as phonological processing). A parsimonious conclusion is that this same logic applies to reading aloud, in which phonological processing is necessarily involved, given that the joint effects of semantic context and stimulus quality produce the same outcome in lexical decision and reading aloud. That is, both SEM → OIL and POL → OIL feedback must be blocked when RP is low.

Experiments 3 and 4 provide converging results in that an interaction between repetition priming and stimulus quality is observed despite low RP. This interaction can be explained on the assumption that both repetition and stimulus quality affect the letter level and the OIL. No feedback from semantics needs to be invoked. Hence, the presence of this interaction supports the argument that the absence of the Semantic Priming × Stimulus Quality interaction at a low RP arises because activation from semantics does not feed back to the OIL or letter level.

The dotted lines in the larger framework of Figure 2 depict pathways blocked by low RP. When reading aloud, there is no "decision" about "wordness" (in contrast to what occurs in lexical decision), but there is a semantic context effect in both tasks. Given that feedback from semantics to the OIL is denied (i.e., the SEM → OIL pathway is blocked), the effect of semantic context must arise elsewhere when reading aloud. We suppose it arises via prime processing leading to semantic activation that in turn activates associated lexical entries in the POL (via the SEM → POL pathway). In order to avoid an interaction between semantic context and stimulus quality, the effect of low stimulus quality must not extend to the POL.

Given the assumption that stimulus quality affects the OIL when reading aloud (stimulus quality and word frequency interact in reading aloud; O'Malley et al., 2007; Yap & Balota, 2007), it must be assumed that feedback between the POL and the OIL (the POL → OIL pathway) is also blocked under conditions of low RP (or else does not normally occur as Ziegler, Petrova, & Ferrrand, 2008 maintain). If this was not the case, then an interaction between semantic context and stimulus quality would be expected (given a main effect of semantic priming) on the assumption that context exerts its influence on the POL via semantic activation and the consequent feedback to the OIL.

The account provided here is obviously complex. First, we emphasize that the general framework in which it is situated has been widely adopted in the literature. Second, the associated computational DRC model has been very successful in being able to simulate a large number of benchmarks. Third, no new pathways have been invoked to explain the present data. Fourth, the main idea invoked here (control over feedback) has previously been used to explain the effects of RP on semantic priming in lexical decision (Stolz & Neely, 1995; M. Brown et al., 2006) and feedback in other tasks (e.g., Smith & Besner, 2001). Finally, no alternative account has been proposed to date.

This account is thus consistent with a variety of previous results, and it extends the Stolz and Neely (1995) account so as to encompass the joint effects of semantic context, RP, and stimulus quality when reading aloud. It remains to be seen whether this interpretation can be realized in the context of a computational model, or whether an alternative account can be provided that also explains all of the other benchmark phenomena on the table and can be implemented in a computational model.

Alternative Implemented Accounts

Few formal models have attempted to address any part of the data reported in Stolz and Neely (1995). A notable exception is Plaut and Booth's (2000, 2006) parallel distributed processing model of lexical processing. This model purports to simulate semantic context effects, and particularly the Stimulus Quality × Priming interaction reported many times in the context of lexical decision. Notably, these authors make no attempt to simulate the additive effects observed when relatedness proportion is .25 (indeed, Plaut & Booth, 2006, appear to doubt this particular result, p. 199). It would be an important milestone if Plaut and Booth's model could simulate the three-way interaction between semantic context, RP, and stimulus quality in lexical decision and reading aloud, as well as the dissociation between semantic and repetition priming as a function of RP.

Conclusions

The results of the present experiments demonstrate that in reading aloud, RP modulates the interaction between semantic context and stimulus quality. When RP is high, there is an interaction between semantic context and stimulus quality, whereas when RP is low, there is not. The elimination of this interaction at a low RP can be accommodated by the following assumptions:

1. Activation for the prime at the letter level feeds to the OIL through to the SEM and then to associated entries in the POL. Activation for the prime may also feed forward from the OIL directly to the POL (via the OIL → POL pathway), then to the semantic system (via the POL → SEM pathway), and then to associates in the phonological lexicon (via the SEM → POL pathway).

2. Feedback from the SEM to the OIL is blocked.

3. Feedback from the POL to the OIL is blocked.

4. The effect of low stimulus quality for the target cascades through the letter level to the OIL, but its effect ends there.

Whether the theoretical account offered here will prove to be as fruitful in the future as it has in the past remains to be seen. Whatever the answer, any viable theory of semantic (and repetition) relatedness effects will need to accommodate all the findings discussed here. Finally, the data (in both lexical decision and reading aloud) appear stable enough that they qualify as benchmarks that computational models of lexical-semantic processing should address.

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