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Exploring the Interplay Between Lexical Context and Attentional Allocation in the Lexical Decision Task

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ABSTRACT. The lexical decision task, commonly used in psycholinguistic research, measures response speed and accuracy to word and nonword stimuli. Although evidence suggests that the task operates under strategic control, the role of lexical context—defined by the types of stimuli present—on this control remains elusive. Here we attempted to explore whether lexical context influences attentional allocation during the lexical decision task. In Experiment 1, the context included both words (high and low frequency) and orthographically illegal nonwords, where decisions could be made based on orthographic information. Results showed that focusing on orthography required minimal attentional resources, leaving room for interference from a superimposed, unattended tilted grating. In Experiment 2, we removed the orthographically illegal nonwords, increasing the task's attentional demands as decisions now required processing beyond orthography. This shift in demands eliminated interference from the tilted grating, suggesting that attentional resources were depleted. Importantly, word frequency information was accessed when attention was directed toward the lexical decision task but not when directed toward the tilted grating. Taken together, these findings indicate the dynamic interplay between lexical context and attentional allocation in the lexical decision task, highlighting the role of cognitive control in lexical processing.

Keywords: lexical context, attentional resource, cognitive control, lexical decision task, visual word recognition

The lexical decision task is a widely used experimental paradigm in psycholinguistics for investigating the cognitive processes underlying word recognition. In this task, participants are presented with a series of letter strings and must quickly decide whether each string forms a valid word (e.g., "book") or a nonword (e.g., "boko"). Response times (RTs) and accuracy are typically measured, with faster and more accurate responses to real words (compared to nonwords) reflecting the efficiency of lexical access. The lexical decision task is commonly used to examine various factors influencing word recognition and processing, such as word frequency, semantic priming, and attentional effects.

Lexical decisions rely on distinguishing words from nonwords based on orthographic, phonological, and semantic properties (Rubenstein et al., 1970). However, because words and nonwords differ across multiple dimensions, the basis for discrimination can vary. Previous work has shown that judgments of "wordness" are influenced by lexical context, with responses to real words being faster and more accurate when nonwords are orthographically illegal (e.g., "BRNT") compared to when they resemble real words, such as pseudowords (e.g., "LAIP") or pseudohomophones (e.g., "MEEN"; Evans et al., 2012; Ratcliff et al., 2004; Shulman & Davison, 1977). These findings suggest that lexical decision-making involves strategic control over processing (Stone & Van Orden, 1993).

Models of visual word recognition have considered the influence of context on lexical decision task performance (e.g., Coltheart, 1978; Paap & Noel, 1991; Rastle et al., 2003). The type of nonword used affects performance by shaping the optimal decision criteria, which in turn facilitates stimulus processing during the task (Seidenberg, 1990; Wagenmakers et al., 2008). For instance, orthographic information alone is sufficient to differentiate words and orthographically illegal nonwords (e.g., BRNT), whereas for words and pseudowords (e.g., LAIP), additional aspects of stimulus dimensions, such as semantic meaning, need to be considered for discrimination. Thus, the nature of nonwords determines which types of information are most relevant for optimizing task performance. At

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the same time, the rate at which information is accumulated for decision-making depends on the quality of information provided by the stimulus (Ratcliffe et al., 2004). As nonwords become more word-like (e.g., pseudohomophones), the increasing similarity between words and nonwords makes decision-making more challenging. This effectively reduces the signal-to-noise ratio in the decision process, leading to slower response times and decreased accuracy. Therefore, nonwords in a lexical decision task are not merely foils; they shape the decision context by influencing both the optimal stimulus dimensions and the overall signal strength of the decision.

When nonwords are orthographically illegal, orthographic regularity has been identified as the primary stimulus dimension for lexical decision-making (Grainger & Jacobs, 1996; Seidenberg & McClelland, 1989; Yap et al., 2006). This is supported by previous work showing that accurate lexical decisions can be made based solely on orthographic familiarity, with little or no involvement of phonological or semantic information (e.g., Edwards et al., 2005). Furthermore, when nonwords are distinctly separated from words in terms of orthographic composition, the signal-to noise ratio of the discrimination process is enhanced. As such, there are two important implications for the strategic control of processing within contexts containing orthographically illegal nonwords. First, evidence suggests that participants tend to adopt an overall response strategy that efficiently facilitates the processing of both words and nonwords (e.g., Edwards et al., 2004; Gibbs & Van Orden, 1998; Pexman et al., 2001). When nonwords can be distinguished from words based solely on orthographic features, participants engage in less extensive processing beyond the orthographic level, compared to contexts where additional stimulus dimensions must be considered. Second, visual word recognition occurs through a sequential activation process involving visual, orthographic, phonological, and semantic stages (e.g., Coltheart et al., 2001; Grainger & Holcomb, 2009). If the visual/orthographic stage is sufficient for word-nonword discrimination, completing the entire sequence of activation becomes unnecessary, again resulting in less extensive processing.

Less extensive processing implies that there is potentially more processing capacity left unused. Balota et al. (1999) proposed a flexible lexical processor in which local context drives attention to relevant processing dimensions. When the relevant dimension demands less extensive processing, as in the case of distinguishing words from orthographically illegal nonwords, greater attentional capacity remains unused. According to the perceptual load theory of attention (e.g., Lavie, 1995; Lavie & Tsal, 1994), stimuli are processed until perceptual capacity is exhausted. If a task does not exhaust this capacity, any remaining resources may be allocated to the perception of irrelevant stimuli, such as distractors. Therefore, we reason that the presence of orthographically illegal nonwords in a lexical decision task creates a context in which intrusion from irrelevant distractors becomes highly likely.

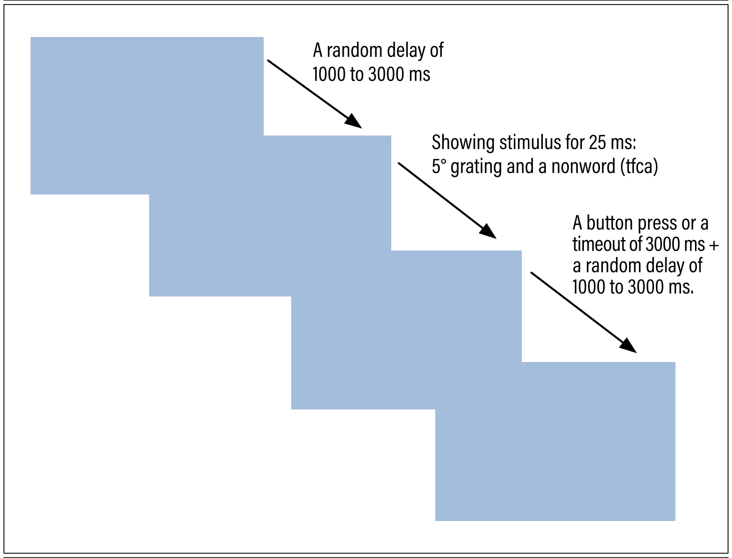
Previous studies have examined the attentional demands of lexical processing using a dual-task paradigm, where participants perform a lexical decision task and a concurrent task, for example, an auditory probe task (e.g., Becker, 1976; Herdman & Dobbs, 1989; Kellas et al., 1988). The underlying assumption is that if the lexical decision task requires attentional resources, fewer resources will be available for the concurrent task, leading to decreased performance on the probe task in a dual-task versus single-task condition. There are, however, several issues associated with assessing attentional demands with a dual-task paradigm. First, the paradigm requires engaging in two tasks at the same time, which incurs time-sharing costs and response competition. Second, actively monitoring both tasks requires additional attentional resources, which may interfere with performance on the primary lexical task. To address these issues, we propose an alternative approach that examines attentional influences within the lexical context using a more passive paradigm. Specifically, we seek evidence of unintentional distractor processing while participants naturally engage in the lexical decision task, without the need for a concurrent, secondary task.

Apart from nonwords, an equally important component of lexical context is the presence of words. This leads us to our next question: Does a lexical context containing orthographically illegal nonwords influence the processing of words in a lexical decision task? Specifically, we aim to examine whether the attentional demands of our lexical context influence the processing of word frequency, defined as the frequency of a word's occurrence. Word frequency is a crucial source of lexical information that can shape how the mental lexicon is accessed. However, whether attention is required for processing word frequency remains a topic of debate (e.g., LaBerge & Samuels, 1974). Although some studies suggest that attention is necessary for lexical-semantic processing (Besner et al., 2005; Lachter et al., 2004; McCann et al., 1992; Waechter et al., 2011), others have demonstrated visual word recognition can occur automatically, independent of attentional control (e.g., Allen et al., 2002; Cleland et al., 2006; Lien et al., 2006; Rabovsky et al., 2008). This raises the question of whether the attention allocated to distinguishing words from orthographically illegal nonwords is sufficient to facilitate word frequency processing.

In this study, we aimed to explore the interaction between context and attention in the lexical decision task. Specifically, we focused on a context involving orthographically illegal nonwords and words, manipulating attention through task demands. Two optically superimposed stimuli were presented: a letter string and a tilted Gabor grating. Participants were instructed to either attend to the letter string and perform a lexical decision task, or to attend to the tilted Gabor grating and perform an orientation judgment task. In the first experiment, the letter strings were either words (both high frequency and low frequency) or orthographically illegal nonwords, providing a context in which focusing solely on the orthographic dimension was sufficient for making lexical decisions. We expected that this would leave unused attentional resources available for processing the tilted Gabor gratings, even when it was not the orientation judgment task. Additionally, comparing the processing of high- and low-frequency words in the lexical decision versus the orientation judgment tasks allowed us to explore how attention affects access to word frequency information. In the second experiment, we used the same experimental paradigm but removed orthographically illegal nonwords. We hypothesized that removing these nonwords would shift participants' focus from orthographic information to other dimensions of the stimulus, which would be more attentionally demanding. This strategic shift was expected to eliminate unintentional processing of distractors in the lexical decision task, and access to word frequency information would remain unaffected. Overall, our goal was to test how attention interacts context—an often-overlooked factor—in the lexical decision task, shedding light on how context influences the processing of lexical information.

FIGURE 1

Schematic Diagram of the Experimental Procedure (Two Trials Shown)



Note. Each trial begins with the onset of a grey circle surrounding a central fixation point on the computer screen. Following a random delay of 1000 to 3000 ms, a Gabor grating and a letter string, superimposed on each other, are presented within the circle. The participant is expected to respond as quickly and accurately as possible by pressing a button on the RT box, based on the task requirements for that block. The next trial begins either immediately after the response or after a 3000 ms timeout. The example trials shown belong to a high-frequency block with 5° tilted gratings: the first trial features an orthographically illegal nonword ("tfca") derived from a high-frequency word, and the second trial presents a high-frequency word ("seat").

Experiment 1

Method

Participants

With an a priori power analysis (Faul et al., 2007), we estimated that, for a medium effect size of $d = 0.50$, a total sample of 34 participants would be needed to achieve a power of .80. However, to account for potential technical issues or data loss, we recruited 50 undergraduate students (33 women; $M_{age} = 20.3$; $SD = 1.2$) via campus flyers at a university in the Eastern U.S. Each participant received a monetary compensation ($5.00) for their participation, which lasted between 45 minutes and an hour. Due to reported vision or reading difficulty, three participants were eliminated from data analysis, for a total of 47 participants. All participants were right-handed, with no history of neurological disorders. All participants provided informed consent and our University Research Ethics Committee approved the experimental procedures.

Materials

The experiment was conducted in a quiet, secluded lab space. Stimuli were programmed using PsychoToolBox in MATLAB (MathWorks Inc., MA), and delivered on an Apple iMac computer (2.5 GHz Intel Core i5 processor; 21.5-inch monitor; 1920 x 1080 resolution) with a connected Response Time box (RTbox, version 6; Li et al., 2010). The two buttons in the middle of the RTbox, symmetrical through the midline of the computer monitor, were used in this experiment. Participants were seated in a chair that was adjusted such that their eye gaze was at the same level as the center of the computer screen, at a viewing distance of one and a half feet. Participants responded to stimuli by pressing the RTbox buttons with their index finger (left button) and their middle finger (right button) on their right hand.

There were two types of visual stimuli: a Gabor patch with tilted grating and a string of letters. The two stimuli were always superimposed on each other and presented together during the experiment (see Figure 1).

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Each Gabor patch consisted of a 15 cycles-per-degree sinusoidal grating modulated by a Gaussian envelope with full width at half-maximum of 0.8°. The grating was either tilted to the left or to the right, with a tilted angle of either 5° or 30° from the vertical position.

Each string of letters contained four letters that made up either a word or a nonword. The words were either high-frequency or low-frequency in terms of their occurrence in the English language, selected from the SUBTLEX database (Brysbaert & New, 2009). The SUBTLEX database, which contains word-frequency counts based on the subtitles from American films and TV series, is thought to be a better index of the frequency of occurrence of words than widely used databases such as Kučera & Francis (1967) and Celex (Baayen et al., 1993; Balota et al., 2004; Zevin & Seidenberg, 2002). The selected high-frequency words each had a frequency count between 69 and 800 per million words, and the selected low-frequency words each had a frequency count between 1 and 1.6 per million words. To control for low-level linguistic and phonological features, only concrete nouns without homophones were included as word stimuli. In addition, the high- and low-frequency word stimuli were matched on the average neighborhood density (Goldinger et al., 1989). In contrast, the nonwords were created by pseudo-randomly mixing up the order of letters from the words (i.e., transposed-letter nonwords; Grainger, 2008), such that the generated nonwords were all orthographically illegal (e.g., name -> mnae).

There were 80 high-frequency words and 80 low-frequency words selected for this experiment, which generated 160 corresponding nonwords. The combination of words and nonwords accounted for the 320 experimental trials described below (i.e., none of the stimuli was repeated).

Procedure

Each trial began with a grey circle (diameter = 0.9 in) presented at the center of the computer screen, enclosing a fixation point directly in the middle (see Figure 1). After a random delay between 1000 to 3000 ms, a Gabor patch and a string of letters, superimposed on each other, were presented together within the circle for 25 ms. The choice of 25 ms was based on our pilot testing, suggesting that this duration would keep the task difficult enough that one would need to process the stimuli with focused attention. Participants were instructed to respond as quickly and accurately as possible to the presented stimuli, by pressing one of the two buttons on the response time box. The next trial began after a response had been made, or a timeout of 3000 ms.

There were two types of tasks: orientation judgment and lexical decision. For the orientation judgment task, participants were instructed to pay attention to the tilted Gabor grating while ignoring the string of letters. When the grating was tilted to the left, they should respond by pressing the left button of the response box. When the grating was tilted to the right, they should respond by pressing the right button of the response box. For the lexical decision task, participants were instructed to focus on the string of letters while ignoring the Gabor patch. When the string of letters was a word, they should respond by pressing the left button of the response box. When the string was a nonword, they should respond by pressing the right button. The orientation of the Gabor grating was counterbalanced with the lexicality of the letter strings to minimize the adaptation in response.

The experiment included 8 blocks of 40 trials each. The 8 blocks represented a 2x2x2 factorial design, involving within-participants factors of task (orientation judgment or lexical decision), angle of Gabor gratings (5° or 30°), and frequency (high frequency or low frequency). Note that for the factor of frequency, each block contained an equal number of words and nonwords (e.g., for a high-frequency block, there were 20 trials of high-frequency words and 20 trials of nonwords derived from the high-frequency words in the same block). The presentation order of blocks was randomly generated for each participant, and within each block, the trials were randomly permuted. Upon completion of a block, participants were encouraged to take a break and then continue onto their next block.

Before the experiment, there were two practice sessions for each participant, one for each task. The practice sessions were exactly the same as the experimental blocks, except that there were only ten trials. In addition, the experimenter was sitting beside the participant during the practice to ensure that they could follow the instructions and properly respond to the stimuli based on the task. Participants were encouraged to conduct the practice sessions as many times as possible, until optimal comfort in both tasks was achieved.

Results

We examined the interplay between context and attention through both manipulating the presence of different stimuli and imposing task demands. The task demands refer to performing either orientation judgment of Gabor gratings or lexical decision of letter strings. For a more granular analysis, we arranged the frequency of letter strings into four categories, namely high-frequency words (HFW), low-frequency words (LFW), nonwords generated from high-frequency words (HFNW), and nonwords generated from low-frequency words (LFNW). To avoid confusion, this frequency factor was then renamed *lexicality*, because nonwords do not have "frequency." As a result, there were three factors in our analysis: task (orientation judgment vs. lexical decision), angle (5° vs. 30°), and lexicality (HFW, LFW, HFNW, LFNW).

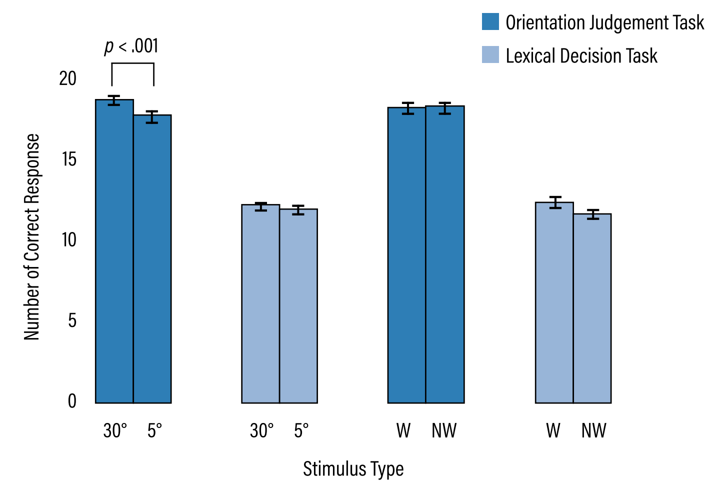
Accuracy

We first examined whether stimuli influenced accuracy of performance in either of the two tasks. For the orientation judgment task, a 2 (Angle) x 4 (Lexicality) ANOVA revealed a significant main effect of angle, $F(1, 46) = 18.76, p < .001, \eta_p^2 = .29$, with higher accuracy for 30° gratings (M = 18.68 or 93.4%, 95% CI [18.15, 19.21]) compared to 5° gratings (M = 17.68 or 88.4%, 95% CI [16.99, 18.37]). No significant interaction was observed, $F(3, 44) = 0.57, p = .641$. For the lexical decision task, however, a 2 (Angle) x 4 (Lexicality) ANOVA showed no significant main effects of lexicality, $F(3, 44) = 1.72, p = .177$ (Word: M = 12.34 or 62%, 95% CI [11.70, 12.96]; Nonword: M = 11.59 or 58%, 95% CI [10.90, 12.24]), or angle, $F(1, 46) = 1.67, p = .203$. Additionally, there was no significant interaction, $F(3, 44) = 0.02, p = .996$. It is worth noting that accuracy across all conditions in both tasks was significantly above the chance level (10 correct trials out of 20), as the 95% confidence intervals for all conditions were above 10 and did not include it.

These results suggest that participants were more accurate in judging wider-angle (30°) gratings during the orientation task, a pattern we refer to as the "grating angle effect" for simplicity. However, no evidence of an accuracy effect was observed for angle or lexicality in the lexical decision task (see Figure 2).

FIGURE 2

The Accuracy of Task Performance Shown as a Function of Stimulus Type



Note. The accuracy of task performance, measured as the number of correct responses (out of 20 per bar), is plotted against stimulus types for both tasks. In all conditions, performance was significantly above chance. The higher accuracy observed for larger-angle gratings (30°) in the orientation judgment task demonstrates the 'grating angle effect.' Because no such effect was found for letter stimuli, results for words and nonwords are presented without further differentiation. 30°: 30° tilted grating; 5°: 5° tilted grating; W: Word; NW: Nonword. Error bars represent standard errors.

Response Time

To examine whether there was any interference imposed by either Gabor gratings or letter strings that was indicative of unintentional processing, we focused on the participants' RT performance for evidence of an interaction between stimuli and task. We used a linear mixed-effects model to analyze RTs of correct trials, with both participants and items modeled as random effects (e.g., Baayen et al., 2008; Brysbaert, 2007). This analysis was based on single-trial data, thereby accounting for the nonindependence of observations within each participant and item. Random effects were introduced sequentially, and their effects on model fit were assessed based on likelihood tests. The final random structure model included participants and items as random intercepts, and angle, lexicality, and task as random slopes that were allowed to vary across participants (i.e., by-participants random slopes).

We found a main effect of task, $F(1, 58.51) = 70.57, p < .001$, and a main effect of lexicality, $F(3, 201.59) = 8.26, p < .001$, qualified by a Task x Lexicality interaction, $F(3, 194.42) = 13.44, p < .001$. We also found a Task x Angle interaction, $F(1, 194.58) = 18.12, p < .001$.

For the Task x Lexicality interaction (Figure 3a), post-hoc comparisons with Bonferroni corrections indicated that when the task was lexical decision, RTs were significantly shorter for high-frequency words (HFW: M = 658.99 ms, 95% CI [619.65, 698.33]) than for either low-frequency words (LFW: M = 762.31 ms, 95% CI [723.77, 800.86]) or nonwords created from low-frequency words (LFNW: M = 732.39 ms, 95% CI [693.39, 771.40]), $ps < .001$, demonstrating a robust word frequency effect (Rubenstein et al., 1970; Scarborough et al., 1977). In addition, RTs were longer for low-frequency words (LFW: M = 762.31 ms, 95% CI [723.77, 800.86]) than for nonwords created from high-frequency words (HFNW: M = 695.98 ms, 95% CI [656.46, 735.49]), $p < .001$, a finding consistent with some previous work supporting a longer search time for low-frequency words in mental lexicon (e.g., see Table 1 in Forster & Chambers, 1973). In contrast, when the task was orientation judgment, there was no evidence of a difference in RTs among words and nonwords (i.e., across levels of lexicality), $ps = 1$.

For the Task x Angle interaction (Figure 3b), post hoc comparisons with Bonferroni corrections indicated that RTs were shorter for 30° gratings (M = 560.02 ms, 95% CI [524.06, 595.98]) than for 5° gratings (M = 585.89 ms, 95% CI [549.89, 621.88]) during the orientation judgment task, $p = .022$. This corroborated the accuracy data in suggesting that judging the orientation of wider-angle gratings was indeed easier. However, the pattern was reversed for the lexical decision task, where RTs became longer with the presence of 30° gratings ($M = 728.16$ ms, 95% CI [691.33, 764.99]) than 5° gratings ($M = 696.68$ ms, 95% CI [659.82, 733.53]), $p = .013$, indicating greater interference associated with gratings of wider angle.

Discussion

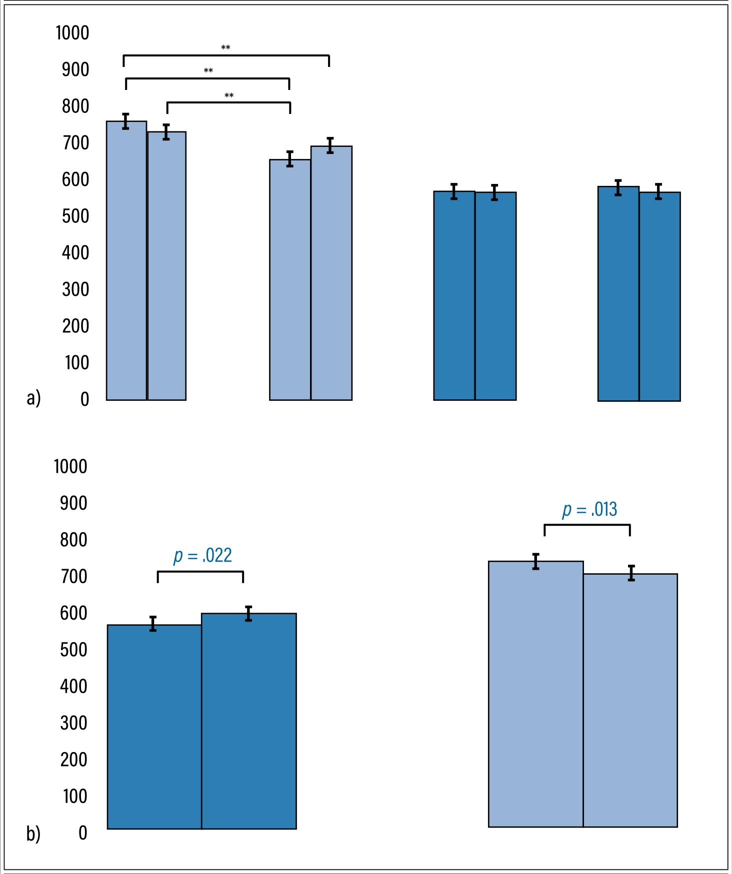
In this experiment, participants attended and responded to one of the two superimposed stimuli (tilted grating and letter string), as indicated by the task demand. Our results showed that task-guided attention influenced participants' responses to different stimuli. Specifically, when attending to the letter stimuli, participants exhibited the word frequency effect, but the grating angle effect emerged when attention was directed to the tilted grating. Furthermore, although we found no evidence of the word frequency effect interfering with the orientation judgment task, there was clear evidence of interference from the grating angle effect in the lexical decision task. This interference was reflected in longer response times due to the greater intrusion of the 300 gratings. Overall, the absence of interference from the word frequency effect during the orientation judgement task, coupled with the unintentional processing of the grating angle effect during the lexical decision task, provides support for the interplay between context and attention.

The findings highlight the lexical decision task as a valuable tool for exploring how task-guided attention interacts with contextual factors. In everyday situations, attention is often divided between multiple stimuli, such as when reading while processing peripheral visual cues. The lexical decision task simulates these divided attention scenarios, offering insights into how task demands and stimulus types influence cognitive processing. For example, our results showed that attention to letter stimuli elicited the word frequency effect, but attention to the tilted grating led to the grating angle effect, demonstrating how attentional shifts prioritize different information. However, our findings also reveal that attention does not always shield from distractions. When the lexical decision task was less demanding, the tilted gratings still interfered, suggesting that available attentional resources can still lead to distractions, even with the intention to focus. This highlights the importance of balancing cognitive load and available resources, with implications for multitasking, indicating that, even with focused effort, distractions may still intrude when cognitive resources are not fully taxed.

The letter stimuli used in our experiment consisted of both words and nonwords, with nonwords being derived from the words within the same block. To control for visual and orthographic confounds, words and nonwords within a block were matched on low-level visual features and character composition. This design ensured that any differences in responses to the stimuli could not be attributed to variations in visual features, as the same set of letters could appear as either a word or a nonword. Importantly, although we observed faster responses to high- words compared to low-frequency words in the lexical decision task, no difference in RTs were found for nonwords across the blocks, confirming the validity of our stimulus manipulation. As a result, the absence of interference from the letter stimuli during the orientation judgment task suggests that the observed difficulties in lexical access were driven by shifts in attention, rather than by inherent features of the stimuli.

FIGURE 3

Response Times Presented for the Performance of the Two Tasks



Note. (a) illustrates the task × lexicality interaction, where the word frequency effect was observed in the lexical decision task. LF Block refers to the low-frequency block, HF Block to the high-frequency block, W represents words, and NW represents nonwords. (b) depicts the Task × Angle interaction, showing that 30° gratings elicited faster responses than 5o gratings in the orientationjudgment task, and also caused greater interference during the lexical decision task. 30°: 30° tilted grating; 5°: 5° tilted grating. Error bars represent standard errors.

Hoffman & Nelson (1981) demonstrated that accurate detection of a target letter enhanced the discrimination of the orientation of a co-occurring symbol located in the same general area, suggesting that the spread of attention across space. Based on this, one might expect that attention would similarly spread over the letter stimuli during the orientation judgment task, potentially leading to interference from the word frequency effect. However, the RT data from the orientation judgment task showed no evidence of such interference. Importantly, this lack of interference is unlikely to be attributed to attentional overload during the task, as we observed no intrusion of the word frequency effect even in the easy condition (i.e., 30°, large-angle grating) of the orientation judgment task. These findings thus support the idea that activating the word frequency effect requires directed attention.

Previous research suggests that attention can modulate unconscious processing of task-irrelevant stimuli, such as orientation (e.g., Bahrami et al., 2008). In our lexical decision task, the attention required to process orthographic information for judging words and nonwords may have spilled over to the tilted grating stimuli, leading to unintended orientation processing. We argue that this orientation processing occurred because the lexical context (words and orthographically illegal nonwords) accentuated orthographic disparity. The lexical decision task's reliance on orthographic features required only limited attentional resources, which allowed the remaining resources to be diverted to the tilted gratings, thereby causing interference in the lexical decision task. This explains why the larger-angle grating (30°), which was easier to process during the orientation judgment task, also resulted in greater RT costs during the lexical decision task. Because the ignored tilted gratings influenced responses to the attended letter stimuli, we believe that these gratings were processed using the available attentional resources that were not fully allocated to the lexical decision task.

However, a trivial explanation for the results of Experiment 1 is that the 30° grating somehow made the letter stimuli more difficult to visually identify than the 5° grating, leading to slower responses during the lexical decision trials with the 30° gratings. If this were the case, we would expect the interference from tilted gratings to persist, even when the lexical context changes. This is because the trivial explanation focuses on low-level visual distraction, rather than attentional allocation linked to the lexical context, as the root cause of the interference. Altering the context (or the type of letter stimuli) would not change the fact that the 30° grating induces more visual interference than the 5° grating. On the other hand, if the interference was driven by the context itself, we would expect that shifting the context to increase the attentional demands of the lexical decision task could eliminate the interference from the tilted gratings, as fewer attentional resources would be available for the distractors. We tested this in Experiment 2.

Experiment 2

When lexical context requires more than just orthographic information for decision-making, additional stimulus dimensions need to be considered as well, increasing both processing load and attentional demand. This, in turn, reduces the likelihood of distractor interference. In Experiment 1, the presence of orthographically illegal nonwords contributed to an orthographic focus. Thus, the most straightforward way to eliminate this focus was to remove those nonwords altogether.

One alternative approach to increasing processing and attentional demand would have been to replace the orthographically illegal nonwords with other types of nonwords, such as pseudowords or orthographically legal nonwords. However, this substitution posed a challenge: pseudowords and orthographically legal nonwords may share varying degrees of orthographic similarity with the original illegal nonwords. Without additional measurements, we had no reliable way to assess how participants would judge "word-like" nonwords or how much additional attentional resource their processing might require.

Familiarity-based theories of lexical decision (e.g., Balota & Chumbley, 1984) suggest that lexical decisions rely on the strength of the match between a stimulus and stored memory representations. Introducing pseudowords or orthographically legal nonwords—stimuli that do not exist in memory but resemble real words—could create uncertainty in the judgment process, leading to variability across stimuli and participants. If attentional allocation is influenced not by a global feature (such as orthography) but by the characteristics of individual nonwords, it would be difficult to determine whether observed effects stem from attentional resources or merely stimulus-specific features.

Given these considerations, we opted to remove the orthographically illegal nonwords without substitution, retaining only high- and low-frequency words. Participants in Experiment 2 were still instructed to make a word vs. nonword decision. However, because the absence of nonwords does not align with the conventional definition of a lexical decision task, we referred to this modified paradigm as a "pseudo-lexical decision task" in the experiment description.

Method

Participants

We recruited 50 undergraduate students (40 women; M_{age} = 20.6; *SD* = 1.3) via campus flyers at our university for this experiment. Each participant received a $5.00 monetary compensation for their participation, which lasted between 30 and 40 minutes. Due to reported vision difficulty and incompletion of the experiment, 8 participants were eliminated from data analysis, for a final sample size of 42. All participants were right-handed, with no history of neurological disorders. All participants provided informed consent and our University Research Ethics Committee approved the experimental procedures.

Experimental Procedures

The setting and paradigm were the same as Experiment 1, except that each block now contained 20 high-frequency and 20 low-frequency words that were randomly permuted (i.e., nonwords removed). There were 4 blocks of 40 trials, corresponding to a 2x2 factorial design, with within-participants factors of task (orientation judgment or pseudo-lexical decision) and angle of Gabor grating (5º v.s. 30º). In addition, a factor of lexicality was used to represent high- or low-frequency words in each block.

Results

Accuracy

We examined whether stimulus types influenced accuracy in two tasks (see Figure 4). In the orientation judgment task, a 2 (Angle) x 2 (Lexicality) ANOVA revealed a main effect of angle, $F(1, 41) = 8.61$, $p = .005$, $\eta_p^2 = .17$, where accuracy was higher for 30º gratings ($M = 18.80$, 95% CI [18.29, 19.31]) compared to 5º gratings ($M = 17.58$, 95% CI [16.75, 18.42]). For the lexical decision task, the 2 (Angle) x 2 (Lexicality) ANOVA showed no main effect of lexicality, $F(1, 41) = 2.22$, $p = .144$ (HF Word: $M = 11.71$, or 59%, 95% CI [11.22, 12.21]); LF Word: $M = 11.32$, or 57%, 95% CI [10.86, 11.79]), or angle $F(1, 41) = 0.02$, $p = .883$. Additionally, there was no significant interaction, $F(1, 41) = 0.09$, $p = .770$. We note that accuracy in all conditions across both tasks was significantly above chance level (10 out of 20), as none of the 95% confidence intervals included 10.

These results replicate the accuracy patterns from Experiment 1, confirming that the only accuracy effect occurred for tilted gratings in the orientation judgment task, or the "grating angle effect."

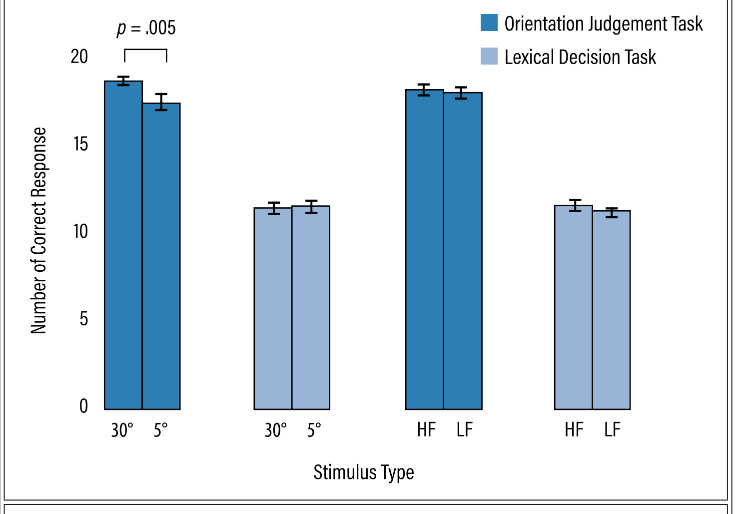
Response Time

We used a linear mixed-effects model to analyze RTs of correct trials, with participants and items modeled as random effects. Random effects were introduced sequentially, and their effects on model fit were assessed based on likelihood tests. Our final random structure model included participant and item as random intercepts, and angle, lexicality, and task as random slopes that were allowed to vary across participants.

We observed a main effect of task, $F(1, 59.82) = 25.59$, $p < .001$, and a main effect of lexicality, $F(1, 112.78) = 7.35$, $p = .008$, as well as a Task x Lexicality interaction, $F(1, 112.42) = 13.25$, $p < .001$. Post hoc

FIGURE 4

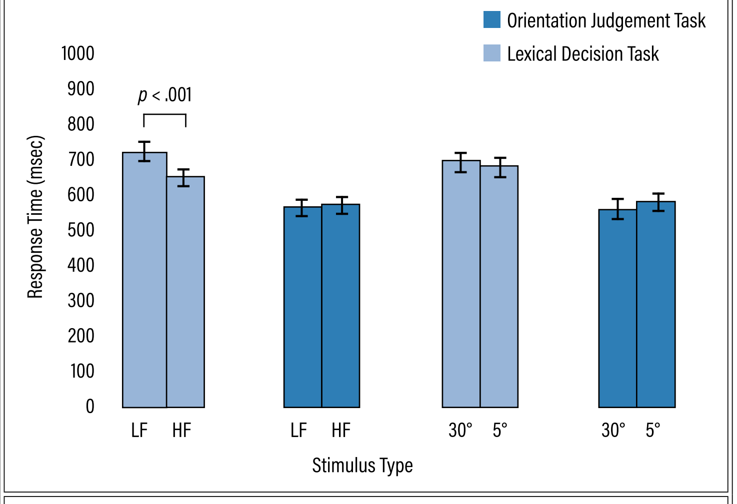
The Accuracy of Task Performance Shown as a Function of Stimulus Types



Note. The accuracy of task performance, represented by the number of correct responses (out of 20 for each bar), is plotted for each stimulus type across the two tasks. In all conditions, performance was significantly above the chance level. In the orientation judgment task, higher accuracy was observed for the 30° gratings compared to the 5° gratings, replicating the "grating angle effect." 30°: 30° tilted grating; 5°: 5° tilted grating; HF: high-frequency words; LF: low-frequency words. Error bars represent standard errors.

FIGURE 5

Response Times Are Displayed for the Performance of the Two Tasks



Note. High-frequency words elicited faster responses than low-frequency words during the pseudo-lexical decision task, replicating the word frequency effect. However, in contrast to Experiment 1, the 30° gratings no longer interfered with performance on the pseudo-lexical decision task. Error bars represent standard errors.

comparisons with Bonferroni corrections indicated that RTs were significantly longer for low-frequency words (*M* = 721.92 ms, 95% CI [674.50, 769.34]) than for high-frequency words (*M* = 648.97 ms, 95% CI [600.97, 696.96]) during the pseudo-lexical decision task, $p < .001$, demonstrating the word frequency effect (Figure 5). This effect vanished, however, when the task was orientation judgment (low-frequency words: *M* = 568.20 ms, 95% CI [521.73, 614.67]; high-frequency words: *M* = 575.73 ms, 95% CI [529.29, 622.18]), $p = .625$. Overall, these results are consistent with those of Experiment 1, indicating the presence of the word frequency effect when attending to the pseudo-lexical decision task but the absence of the effect when attending to the orientation judgment task.

In contrast, unlike Experiment 1, we failed to observe a Task x Angle interaction, $p = .11$, suggesting that there was no evidence of interference from the grating angle effect in the pseudo-lexical decision task. This is in line with our expectation that the new lexical context increased the processing load and attentional demand of the pseudo-lexical decision task, consequently making it harder for the tilted gratings to intrude.

Given the absence of nonwords in the pseudo-lexical decision task, one might argue that participants could quickly recognize all items as words and therefore simply press the "word" button throughout the experiment, with no decision at all. If this were the case, we would expect higher accuracy and much faster RTs in the current experiment, compared to Experiment 1. However, when comparing lexical decision task data across the two experiments, we found that the only significant difference in accuracy occurred in the low-frequency words with the 30° gratings condition, $t(87) = 2.25$, $p = .027$, where the accuracy in Experiment 1 was actually higher than in the current experiment, in the opposite direction of what would be expected. For RTs, no significant differences were found across all conditions in the lexical task between two experiments, $t(87) < 1.60$, $ps > .114$. Therefore, there was no evidence indicating that participants were simply responding by pressing the 'word' button throughout Exp 2 without engaging in cognitive processing. Furthermore, if participants had been simply performing the lexical task without mental processing, such as repeatedly pressing the same button, the task would have become trivial, increasing the likelihood of distractor interference. Given this, it seems counterintuitive that the grating interference in the lexical task would suddenly diminish under these conditions.

Discussion

With the altered context, we replicated both the grating angle effect and the word frequency effect observed in Experiment 1. However, we found no evidence that either effect interfered with the performance on the opposite task. In particular, the absence of interference from the grating angle effect suggests that it was not the visual features of the tilted gratings causing the disruption. We argue that the increased attentional demand of performing lexical discrimination in the altered context led to the cessation of unintentional processing of irrelevant distractors.

These findings have important implications for everyday behavior, particularly in multitasking scenarios. They suggest that when a task requires more cognitive resources, the likelihood of being distracted by irrelevant stimuli decreases. This insight may inform strategies for optimizing focus in environments where attention must be selectively managed, such as reading in noising settings or working in visually cluttered spaces.

Despite the altered context, the word frequency effect persisted, aligning with our expectation that it would remain even after removing nonwords. In this context, lexical decisions could no longer rely solely on orthographic regularity but instead required access to additional stimulus dimensions, such as phonology and/or semantic meaning. This may have strengthened the word frequency effect, as it reflects lexical access and subsequent computations that are attentionally demanding (e.g., Balota & Chumbley, 1984; McCann et al., 1992). Furthermore, as in Experiment 1, the word frequency effect did not interfere with the orientation judgment task, reinforcing the idea that lexical access, particularly word frequency processing, requires attention.

The replication of the grating angle effect confirmed that judging the orientation of a large angle (30°) was easier than a small angle (5°). In the current experiment, however, judging the large angle was not necessarily faster than judging the small angle, suggesting reduced sensitivity in orientation processing. One possible explanation is the impact of orthographic focus on spatial processing. Orthographic representation integrates letter identity and order (e.g., Grainger, 2016), and models of orthographic processing (e.g., Davis, 1999; Whitney, 2001) emphasize letter position coding in word recognition. In Experiment 1, the emphasis on orthography may have enhanced spatial sensitivity, making it easier to judge tilted gratings. In contrast, Experiment 2's altered context de-emphasized orthographic processing, likely diminishing spatial sensitivity during the orientation judgment task.

The absence of interference from the grating angle effect in the pseudo-lexical decision task is consistent with the increased processing load and attentional demands in the altered context. As the optimal basis for lexical decisions shifted from orthography to a multi-dimensional approach, including phonology and semantic meaning, processing complexity increased, depleting attentional resources. With fewer resources available, the grating angle effect no longer caused interference.

General Discussion

We demonstrated that context in a lexical decision task influences attentional allocation, which in turn affects task performance. However, word frequency information was accessed regardless of context, as long as attention remained on the lexical decision task. Overall, these findings highlight the interplay between task context and attentional control in shaping performance in the lexical decision task.

Research on reading has long highlighted the crucial role of attention in processing whole-word phonology (e.g., Monsell et al., 1989; Rastle & Coltheart, 1999; Zevin & Balota, 2000). For instance, the dual-route model (Coltheart, 1978) distinguishes two pathways that allow readers to flexibly shift their reliance on word-specific information: words that do not follow regular rules of pronunciation (e.g., "steak") are processed through the lexical route, whereas nonwords not represented in the orthographic lexicon (e.g., "stik") are decoded through the non-lexical route. This exemplifies the important role of attention in selectively processing lexical information based on orthographic codes. Further evidence suggests that this attentional control is context-dependent (Monsell et al., 1989; Rastle & Coltheart, 1999), with naming performance differing between blocks that contain only one type of stimuli (i.e., pure blocks) and blocks with mixed types of stimuli (i.e., mixed blocks). Pure blocks require less attentional switching between pathways, making reading more efficient. In contrast, our study presents another case where context influences attention, but within the framework of a lexical decision task. Unlike reading, lexical decision only requires a judgment of "wordness", without the need to map orthography to phonology. In a context where words and nonwords differ sharply on a single dimension, the judgment can be made efficiently with minimal attentional resources, which then leads to the attentional spillover observed in our study. Reading, however, is a more complex task that likely involves dynamically changing contexts. Exploring whether and how readers strategically adjust their attention in response to these constantly changing contexts could deepen our understanding of the conditions under which reading becomes more susceptible to distractions.

Visual word recognition involves multiple, sequential stages of processing that differentiate between words and nonwords (e.g., Coltheart et al., 2001; Holcomb & Grainger, 2006). Evidence shows that word perception relies on multi-letter units of analysis based on orthographic/morphological structure (Prinzmetal et al., 1991; Prinzmetal & Millis-Wright, 1984), where monosyllabic words are processed holistically but nonwords are processed by single-letter units. Letters serve as discrete features, and attention plays a key role in accurately localizing and binding these features (Ashby et al, 1996), or in encoding the spatial ordering of features (Wolford, 1975). The proper coding of relative feature positioning becomes particularly relevant for distinguishing words from nonwords, due to the distinct modes of feature integration during recognition. In line with this, our findings in the lexical decision task support the notion that attention is biased toward the spatial integration of features. Specifically, in Exp 1, the presence of nonwords seemed to heighten spatial sensitivity for judging orientation, reflecting spatial coding. In contrast, in Exp 2, which did not include nonwords, showed no such sensitivity, likely due to the holistic processing of words. Taken together with existing models of visual word recognition, our results suggest that context can influence both the extent and the mode of attention deployed during the lexical decision task.

One might argue that the interference from the tilted gratings observed in Experiment 1 was due to perceptual grouping or object-based attention, where the tilted gratings and letter stimuli were integrated into a single object. According to existing evidence, when a distractor and target are part of the same object, increased processing of the target can actually enhance distractor interference (e.g., Chen, 2003; Murphy et al., 2016), as object-based attention overrides the conditions of perceptual load in allocating attentional resources (Cosman & Vecera, 2012). However, we believe this was not the case, because if the tilted gratings (distractor) and letter stimuli (target) were perceived as a single object, we would have expected significantly more interference in Experiment 2, given the higher processing demands of the letter stimuli. In other words, object-based attention would have led to simultaneous processing of the tilted gratings and the letter stimuli during the lexical task, which was not observed in Experiment 2. Therefore, the results from both experiments suggest that the tilted gratings and the letter stimuli were not perceptually grouped as a single object, but instead processed independently based on the demands of each task.

Previous research suggests that certain aspects of lexical access are sensitive to word frequency and require attention (e.g., Becker, 1976; Herdman, 1992). Dual-task paradigms involving a lexical decision task have shown that low-frequency words and nonwords incur greater performance costs than high-frequency words, indicating that lexical access demands more attention for less familiar words (Becker, 1976; Herdman & Dobbs, 1989). Additionally, studies that cue the location of attention reveal that processing low-frequency words and nonwords benefits from attention directed to their specific location, and identification of high-frequency words is generally facilitated by a broader attentional distribution across the stimulus space (Montani et al., 2014). Despite evidence that high-frequency words typically require less attentional demand, we did not observe interference from high-frequency words during the orientation judgment task. This could be because frequency-sensitive processes in lexical access demand more attentional resources than those available during the orientation judgment task, or because high-frequency words were processed in parallel with orientation processing, resulting in no measurable RT cost. Although our study does not resolve these competing explanations, future research could manipulate the characteristics of the secondary task to more directly examine the role of word frequency in lexical access in the absence of overt attention.

Although word frequency is a reliable source of the word frequency effect in lexical decision tasks (Gardner et al., 1987), previous work suggests that it is the decision-related processes in these tasks that amplify the effect (Balota & Chumbley, 1984); When the focus is on the concept or meaning of a word, as in the category verification task (e.g., verifying whether the word “robin” belongs to the category “bird”), the word frequency effect is minimal. This suggests that attention alone does not necessarily induce the word frequency effect. Conversely, when attention is directed toward task-irrelevant stimuli, such as the tilted gratings in our study, the word frequency effect does not emerge, even when the word stimuli are easily accessible. This indicates that the word frequency effect does not occur without attention (e.g., Lien et al., 2006). Overall, it appears that attention is a necessary but not sufficient condition for the word frequency effect in lexical decision tasks.

There are several caveats to consider when interpreting our results. First, accuracy in our lexical tasks was generally lower than in typical lexical decision tasks, likely due to dual-task interference and, primarily, the short stimulus presentation duration (25 msec). When selecting this duration, our goal was twofold: to minimize interference from the secondary task and to maintain a level of difficulty that required participants to stay fully engaged. If the task were too easy, the attentional demands central to our study would be undermined. At the same time, we aimed to ensure that the presentation was long enough to avoid unconscious or subliminal perception. Additionally, in Experiment 2, the brief stimulus duration may have led participants to perceive the presence of nonwords, thereby treating the pseudo-lexical decision task as valid.

Given these considerations, we determined that 25 ms was an optimal stimulus duration - ensuring participants actively attended to and consciously processed the stimuli (e.g., see Schräder et al., 2023). Indeed, the significantly above-chance accuracy levels confirmed the appropriateness of this choice. However, 25 msec is considerably shorter than the stimulus presentation times in most classic lexical decision tasks, so the observed lower accuracy was expected. Although we do not anticipate this lower accuracy compromising the validity of our findings, the extent of its impact remains an open question for future research.

Another limitation is that our data was collected from undergraduate students at a U.S. university without race/ethnicity information. This omission makes it difficult to assess the generalizability of our findings and potential cognitive differences across racial groups (e.g., Rouse, 2021). Given accumulating evidence that participant demographics can influence cognitive processes, future research should address this gap.

Conclusion

The lexical decision task, like other tasks in visual word recognition and reading, involves conscious processing of individual stimuli over time. The lexical context created by these stimuli can have a significant impact on task performance, influenced by factors such as the number, order, and neighborhood of the stimuli. The arrangement of stimuli triggers strategic control during task execution, optimizing the outcome. In the current study, we demonstrated that the context, specifically the mixture of different stimulus types, affected attentional allocation, which in turn influenced task performance in the lexical decision task. In contrast, the access to word frequency information remained unaffected despite the varying patterns of attention deployed across contexts. Our findings highlight the complexity of the interaction between contextual factors and cognitive control in lexical decision tasks, underscoring the need for future research to provide a more nuanced understanding of this interplay.

References

Allen, P. A., Smith, A. F., Groth, K. E., Pickle, J. L., Grabbe, J. W., & Madden, D. J. (2002). Differential age effects for case and hue mixing in visual word recognition. *Psychology and Aging*, *17*(4), 622–635. https://doi.org/10.1037/0882-7974.17.4.622

Ashby, F. G., Prinzmetal, W., Ivry, R., & Maddox, T. (1996). A formal theory of illusory conjunctions. *Psychological Review, 103, 165–192.* https://doi.org/10.1037/0033-295X.103.1.165

Baayen, R., Davidson, D., & Bates, D. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412. https://doi.org/10.1016/j.jml.2007.12.005

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). The CELEX Lexical Database (CD-

ROM), Linguistic Data Consortium, University of Pennsylvania, Philadelphia.

Bahrami, B., Carmel, D., Walsh, V., Rees, G., & Lavie, N. (2008). Spatial attention can modulate unconscious orientation processing. *Perception, 37*, 1520–1528. https://doi.org/10.1068/p6045

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. J. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General, 133*, 283–316. https://doi.org/10.1037/0096-3445.133.2.283

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 340–357. https://doi.org/10.1037/0096-1523.10.3.340

Balota, D. A., Paul, S., & Spieler, D. H. (1999). Attentional control of lexical processing pathways during word recognition and reading. In S. Garrod & M. Pickering (Eds.), *Language Processing* (pp. 15–57). Psychology Press.

Becker, C. A. (1976). Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 2*(5), 556–566. https://doi.org/10.1037/0096-1523.2.5.556

Besner, D., Risko, E. F., & Sklair, N. (2005). Spatial attention as a necessary preliminary to early processes in reading. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale, 59*(2), 99–108. https://doi.org/10.1037/h0087460

Brysbaert, M. (2007). "The language-as-fixed-effect fallacy": Some simple SPSS solutions to a complex problem (Version 2.0). Royal Holloway, University of London.

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41*(4), 977–990. https://doi.org/10.3758/BRM.41.4.977

Chen, Z. (2003). Attentional focus, processing load, and Stroop interference. *Perception & Psychophysics, 65*(5), 888–900. https://doi.org/10.3758/BF03194818

Cleland, A. A., Gaskell, M. G., Quinlan, P. T., & Tamminen, J. (2006). Frequency effects in spoken and visual word recognition: Evidence from dual-task methodologies. *Journal of Experimental Psychology: Human Perception and Performance, 32*(1), 104–119. https://doi.org/10.1037/0096-1523.32.1.104

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of Information Processing* (pp. 151–216). Academic Press.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108*(1), 204–256. https://doi.org/10.1037/0033-295X.108.1.204

Cosman, J. D., & Vecera, S. P. (2012). Object-based attention overrides perceptual load to modulate visual distraction. *Journal of Experimental Psychology: Human Perception and Performance, 38*(3), 576–579. https://doi.org/10.1037/a0027406

Davis, C. J. (1999). The self-organizing lexical acquisition and recognition (SOLAR) model of visual word recognition. [Doctoral dissertation, University of New South Wales].

Edwards, J. D., Pexman, P. M., Goodyear, B. G., & Chambers, C. G. (2005). An fMRI investigation of strategies for word recognition. *Cognitive Brain Research, 24*(3), 648–662. https://doi.org/10.1016/j.cogbrainres.2005.03.007

Edwards, J. D., Pexman, P. M., & Hudson, C. E. (2004). Exploring the dynamics of the visual word recognition system: Homophone effects in lexical decision and naming. *Language and Cognitive Processes, 19*(4), 503–532. https://doi.org/10.1080/01690960444000070

Evans, G. A. L., Ralph, M. A. L., & Woollams, A. M. (2012). What's in a word? A parametric study of semantic influences on visual word recognition. *Psychonomic Bulletin & Review, 19*(2), 325–331. https://doi.org/10.3758/s13423-011-0213-7

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Forster, K. I., & Chambers, S. M. (1973). Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior, 12*(6), 627–635. https://doi.org/10.1016/S0022-5371(73)80042-8

Gardner, M. K., Rothkopf, E. Z., Lapan, R., & Lafferty, T. (1987). The word frequency effect in lexical decision: Finding a frequency-based component. *Memory & Cognition, 15*(1), 24–28. https://doi.org/10.3758/BF03197709

Gibbs, P., & Van Orden, G. C. (1998). Pathway selection's utility for control of word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 24*(4), 1162–1187. https://doi.org/10.1037/0096-1523.24.4.1162

Goldinger, S. D., Luce, P. A., & Pisoni, D. B. (1989). Priming lexical neighbors of spoken words: Effects of competition and inhibition. *Journal of Memory and Language, 28*(5), 501–518. https://doi.org/10.1016/0749-596X(89)90009-0

Grainger, J. (2008). Cracking the orthographic code: An introduction. *Language and Cognitive Processes, 23*(1), 1–35. https://doi.org/10.1080/01690960701578013

Grainger, J. (2016). Orthographic processing and reading. *Visible Language, 50*(2), 132–153. https://doi.org/10.1177/2327586216650501

Grainger, J., & Holcomb, P. J. (2009). Watching the word go by: On the time-course of component processes in visual word recognition. *Language and Linguistics Compass, 3*(1), 128–156. https://doi.org/10.1111/j.1749-818X.2008.00121.x

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103*(3), 518–565. https://doi.org/10.1037/0033-295X.103.3.518

Herdman, C. M. (1992). Attentional resource demands of visual word recognition in naming and lexical decisions. *Journal of Experimental Psychology: Human Perception and Performance, 18*(2), 460–470. https://doi.org/10.1037/0096-1523.18.2.460

Herdman, C. M., & Dobbs, A. R. (1989). Attentional demands of visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 15*(1), 124–132. https://doi.org/10.1037/0096-1523.15.1.124

Hoffman, J. E., & Nelson, B. (1981). Spatial selectivity in visual search. *Perception & Psychophysics, 30*(3), 283–290. https://doi.org/10.3758/BF03214286

Holcomb, P. J., & Grainger, J. (2006). On the time course of visual word recognition: An event-related potential investigation using masked repetition priming. *Journal of Cognitive Neuroscience, 18*(10), 1631–1643. https://doi.org/10.1162/jocn.2006.18.10.1631

Schräder, J., Habel, U., Jo, H.-G., Walter, F., & Wagels, L. (2023). Identifying the duration of emotional stimulus presentation for conscious versus subconscious perception via hierarchical drift diffusion models. *Consciousness and Cognition, 110*, 103493. https://doi.org/10.1016/j.concog.2023.103493

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the time course of attentional allocation in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 14*(4), 601–609. https://doi.org/10.1037/0096-1523.14.4.601

Kučera, H., & Francis, W. N. (1967). Computational analysis of present-day American English. Brown University Press.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6*(2), 293–323. https://doi.org/10.1016/0010-0285(74)90015-2

Lachter, J., Forster, K. I., & Ruthruff, E. (2004). Forty-five years after Broadbent (1958): Still no identification without attention. *Psychological Review, 111*(4), 880–913. https://doi.org/10.1037/0033-295X.111.4.880

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 451–468. https://doi.org/10.1037/0096-1523.21.3.451

Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics, 56*(2), 183–197. https://doi.org/10.3758/BF03213897

Lien, M.-C., Allen, P. A., Ruthruff, E., Grabbe, J., McCann, R. S., & Remington, R. W. (2006). Visual word recognition without central attention: Evidence for greater automaticity with advancing age. *Psychology and Aging, 21*(3), 431–447. https://doi.org/10.1037/0882-7974.21.3.431

Li, X., Liang, Z., Kleiner, M., & Lu, Z.-L. (2010). RTbox: A device for highly accurate response time measurements. *Behavior Research Methods, 42*(1), 212–225. https://doi.org/10.3758/BRM.42.1.212

McCann, R. S., Folk, C. L., & Johnston, J. C. (1992). The role of spatial attention in visual word processing. *Journal of Experimental Psychology: Human Perception and Performance, 18*(4), 1015–1029. https://doi.org/10.1037/0096-1523.18.4.1015

Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General, 118*(1), 43–71. https://doi.org/10.1037/0096-3445.118.1.43

Montani, V., Facoetti, A., & Zorzi, M. (2014). Spatial attention in written word perception. *Frontiers in Human Neuroscience, 8*(42). https://doi.org/10.3389/fnhum.2014.00042

Murphy, G., Groeger, J. A., & Greene, C. M. (2016). Twenty years of load theory—

Where are we now, and where should we go next? *Psychonomic Bulletin & Review, 23*(5), 1316–1340. https://doi.org/10.3758/s13423-015-0982-5
Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research, 53*(1), 13–24. https://doi.org/10.1007/BF00867328
Pexman, P. M., Lupker, S. J., & Jared, D. (2001). Homophone effects in lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(1), 139–156. https://doi.org/10.1037/0278-7393.27.1.139
Prinzmetal, W., Hoffman, H., & Vest, K. (1991). Automatic processes in word perception: An analysis from illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance, 17*(4), 902–923. https://doi.org/10.1037/0096-1523.17.4.902
Prinzmetal, W., & Millis-Wright, M. (1984). Cognitive and linguistic factors affect visual feature integration. *Cognitive Psychology, 16*(3), 305–340. https://doi.org/10.1016/0010-0285(84)90011-6
Rabovsky, M., Álvarez, C. J., Hohlfeld, A., & Sommer, W. (2008). Is lexical access autonomous? Evidence from combining overlapping tasks with recording event-related brain potentials. *Brain Research, 1222*, 156–165. https://doi.org/10.1016/j.brainres.2008.05.032
Rastle, K., & Coltheart, M. (1999). Serial and strategic effects in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 25*(2), 482–503. https://doi.org/10.1037/0096-1523.25.2.482
Rastle, K., Kinoshita, S., Lupker, S. J., & Coltheart, M. (2003). Cross-task strategic effects. *Memory & Cognition, 31*(6), 867–876. https://doi.org/10.3758/BF03196439
Ratcliff, R., Gomez, P., & McKoon, G. (2004). A diffusion model account of the lexical decision task. *Psychological Review, 111*(1), 159–182. https://doi.org/10.1037/0033-295X.111.1.159
Rouse, S. V. (2021). Increasing the representation of diversity in the Psi Chi Journal. *Psi Chi Journal of Psychological Research, 26*(4), 360–362. https://doi.org/10.24839/2325-7342.JN26.4.360
Rubenstein, H. A., Garfield, L. A., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 9*(5), 487–494. https://doi.org/10.1016/S0022-5371(70)80091-3
Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance, 3*(1), 1–17. https://doi.org/10.1037/0096-1523.3.1.1
Seidenberg, M. S. (1990). Lexical access: Another theoretical soupstone? In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 33–72). Erlbaum.
Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*(4), 523–568. https://doi.org/10.1037/0033-295X.96.4.523
Shulman, H. G., & Davidson, T. C. (1977). Control properties of semantic coding in a lexical decision task. *Journal of Verbal Learning and Verbal Behavior, 16*(1), 91–98. https://doi.org/10.1016/S0022-5371(77)80009-4
Stone, G. O., & Van Orden, G. C. (1993). Strategic control of processing in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 19*(4), 744–774. https://doi.org/10.1037/0096-1523.19.4.744
Waechter, S., Besner, D., & Stolz, J. A. (2011). Basic processes in reading: Spatial attention as a necessary preliminary to orthographic and semantic processing. *Visual Cognition, 19*(1), 171–202. https://doi.org/10.1080/13506285.2010.528249
Wagenmakers, E. J., Ratcliff, R., Gomez, P., & McKoon, G. (2008). A diffusion model account of criterion shifts in the lexical decision task. *Journal of Memory and Language, 58*(1), 140–159. https://doi.org/10.1016/j.jml.2007.04.001
Whitney, C. (2001). How the brain encodes the order of letters in a printed word: The SERIOL model and selective literature review. *Psychonomic Bulletin & Review, 8*(2), 221–243. https://doi.org/10.3758/BF03196158
Wolford, G. (1975). Perturbation model for letter identification. *Psychological Review, 82*(3), 184–199. https://doi.org/10.1037/h0076476
Yap, M. J., Balota, D. A., Cortese, M. J., & Watson, J. M. (2006). Single- versus dual-process models of lexical decision performance: Insights from response time distributional analysis. *Journal of Experimental Psychology: Human Perception and Performance, 32*(6), 1324–1344. https://doi.org/10.1037/0096-1523.32.6.1324
Zevin, J. D., & Balota, D. A. (2000). Priming and attentional control of lexical and sublexical pathways during naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(1), 121–135. https://doi.org/10.1037/0278-7393.26.1.121
Zevin, J. D., & Seidenberg, M. S. (2002). Age of acquisition effects in word reading and other tasks. *Journal of Memory and Language, 47*(1), 1–29. https://doi.org/10.1006/jmla.2001.2834

Author Note

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Authors are willing to share their data, analytics methods, and study materials with other researchers. The material and data that support the findings of this study are available from the corresponding author, upon reasonable request.

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