# Effects of Spatial Attention in Visual Word Recognition: Evidence from Hindi

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**Abstract**

Early literature on spatial attention and visual word recognition has often treated the two as independent processes (Stolz & McCann, 2000) and offered mixed opinions regarding their interaction. Existing theories argued for early or late interaction, or proposed moderation by familiarity of word targets (McCann et al., 1992). However, these results are mainly derived from investigations in English and their generalizability to languages written in different orthographies is not clear. The current study investigated the interaction between spatial attention and word recognition in Hindi language which is written in *Devanagari* orthography—a spatially dense abugida. Across two experiments, using a spatial-cueing paradigm, we found that cueing effect was robust for words but entirely absent for non-words. Within the word category, this effect remained stable regardless of word frequency, suggesting attention interacts only with lexical-status. Our results align with a late selection view for spatial attention and visual word recognition.

**Keywords:** Spatial Attention, Word Recognition, Devanagari orthography

## Introduction

Traditional models of visual word recognition (henceforth VWR) often treat it as an isolated linguistic process, ignoring how domain-general cognitive processes—specifically spatial attention—may interact with lexical access (Besner et al., 2016; Besner, 2022; McCann et al., 1992; Stolz & McCann, 2000; Montani et al., 2014). However, while some authors propose that VWR is an automatic process which is not mediated by attentional processing or capacity limitations (Rayner & Pollatsek, 1989; Augustinova & Ferrand, 2012); others argue for an important role of spatial attention in VWR (McCann et al., 1992; Stolz & McCann, 2000; Montani et al., 2014; Besner et al., 2016; Phénix et al., 2025).

Interestingly, the few studies that have explicitly investigated the role of spatial attention in VWR, present mixed evidence about whether it is relevant for lexical access, or the stage of lexical processing at which spatial attention plays its part in VWR. For instance, McCann et al., (1992) explicitly sought to investigate the effects of spatial attention on VWR using exogenous spatial cueing in a lexical decision task, and found additive effects of cueing benefits for both word frequency (high & low) and lexical status (words & nonwords). They concluded that spatial attention and lexical access operate independently and favoured the early selection models according to which attention plays an important role prior to the beginning of lexical access.

On the other hand, Stolz et al., (2000) combined spatial cueing and semantic priming to answer the same questions, and found similar cueing effects for words and nonwords but different cueing effects for related and unrelated words. They interpreted these findings as evidence for an interactive account, wherein they suggested that the process of VWR and spatial attention do not operate independently, but rather exhibit a functional overlap, i.e., spatial attention mediates the process of uptake of orthographic-lexical information.

An interesting recent study was conducted by Montani et al., (2014) in which they sought to investigate the effect of spatial cueing with words (high & low frequency) and pseudowords. They found cueing benefits for pseudowords, and to a certain extent for low frequency words but not for high frequency words. They conclude that spatial attention may interact differently with familiar (high frequency words) vs less/unfamiliar word targets (pseudowords or low frequency words). These results can be taken to be more in line with the interactive position as found by Stolz et al., (2000).

A few other studies (Sieroff & Posner, 1988; Auclair & Sieroff, 1992) report cueing benefits for nonwords more than words and support an early selection account, whereas others such as Stolz & Stevanovski (2004) and Risko et al. (2005) support the interactive account. However, it must be noted that across these studies different types of stimuli, tasks, and cueing locations have been used, which makes interpretation of these results rather difficult. Thereby, how attention and VWR interact still remains unclear. Furthermore, above results are mainly drawn from English and from the perspective of generalization of the models of VWR, it is not clear how these results might hold for the languages from other writing systems or orthographies such as Chinese, Japanese, Arabic, Thai, Hebrew or Hindi.

Importantly, Frost (2012) proposed that in order to develop a universal understanding of VWR, research about its fundamental processes must be conducted across different writing systems. Given, the suggestions from the interactive account (Stolz et al., 2000; 2004) and other studies that implicate spatial attention in orthographic and phonological decoding (Facoetti et al., 2006, 2010; Ruffiano et al., 2010) one might expect that orthographic differences in scripts, might lead to different findings than those already reported in English. With this background, in the current study we aimed to investigate the effects of spatial attention in visual word recognition in Hindi which is written in *Devanagari* script.

*Devanagari* script presents a unique opportunity to examine how spatial attention influences word recognition as it presents a spatially complex script in which words can be made both linearly and non-linearly (Vaid & Gupta, 2002;



In G. Boleda, I. Dautriche, M. Maldonado, C. Saldana and T. Torrent (Eds.), *Proceedings of the 48th Annual Conference of the Cognitive Science Society* 

Verma et al., 2021; Kumar et al., 2024). For example, in Hindi, a word can be made either by only consonant units (e.g., the word **'कलम'** (/k/+/l/+/m/; meaning, *pen*)), or via the help of diacritics (e.g., the word **कोमल;** (/k/ + o (marked as a diacritic above /k/) + /m/ + /l/) meaning, *soft*)). Words with only consonant units are similar to words in English, written linearly only with letters whereas words with one or more matra (diacritic) differ from English words in terms of visual characteristics and complexity.

Indeed, previous research suggests that the difficulty of word recognition may be directly influenced by these visual and structural intricacies and complexity (Chang et al., 2016; Ellis et al., 2004; Frost, 2012; Pae, 2022). Also, it has been suggested that orthographies with high visual density and non-linear structures may necessitate greater involvement of spatial attention for successful character-to-vowel binding (Di Bono & Zorzi, 2013; Pae, 2022; Rao & Singh, 2015). Similarly, recent findings by Kalra et al. (2025), and Singh & Rao (2014) suggest that the alphasyllabic nature of Devanagari imposes unique constraints on the visual-attentional system. Due to these unique constraints, selection via spatial attention may be expected to differ from the way it manifests in English language.

**The Present Study**

In the current study, we aimed to investigate the interaction between spatial attention and word recognition in Hindi, written in *Devanagari* script — a spatially dense abugida. In line with previous studies (McCann et al., 1992; Stolz et al., 2000) in experiment 1, we manipulated the lexical-status (word/nonword) and frequency (high, low) of Hindi words written in a linear fashion (without *matra*) like an alphabetic language, and aimed to directly compare the findings with previously observed findings of English language. However, in experiment 2, we increased orthographic complexity by introducing *matra* in word/nonword targets and tested whether the "gate" for attention is influenced by the visual density of the characters. In both these experiments we manipulated spatial attention via exogenous cues (valid/invalid) and conducted lexical decision task.

Given, that this is the first study of its kind in Hindi, we did not proceed with directional hypotheses, although in line with the interactional account, we expected differential effects according to lexical status (word/nonword) and frequency (high, low) of words. Further, we hypothesized for different findings in Exps 1 & 2, given that spatial complexity of words was increased in stimuli for Experiment 2.

## Experiment 1

### Method

**Participants.** Thirty-six participants (*M*: 23.38 years, *SD*: 4.21) participated in this study after providing informed consent. An a priori power analysis was conducted using G*Power 3.1 for a repeated-measures design assuming a medium interaction effect ($f$ = 0.20), $\alpha$ = .05, power = .80). All the participants had normal or corrected to normal vision. They all were native speakers of Hindi and had learned to read before the age of seven years. The study was approved by the Institutional Ethics Committee.

**Task, and stimuli.** The task was an exogenous spatial cueing task similar to the one previously used by McCann et al., (1992) and Montani et al. (2014) to investigate the effects of spatial attention on word processing in English language. The stimuli consisted of a set of 200 word targets and 200 pronounceable non-word targets. The words were chosen from a recently developed Hindi corpus called 'Shabd' (Verma et al., 2021), and the pronounceable non-words were made using a python code. Among words, 100 were high frequency words (3.01 - 6 Zipf), and 100 low frequency words (1 - 3 Zipf). Both words and non-words were 4-letter in length with no matra (e.g., 4-letter-0-matra word = अवसर; 4-letter-0-matra nonword = हकटत). Previous studies with these stimuli have shown reliable effects of word frequency in lexical decision task (Kumar et al., 2022). Cue-to-target validity was 50/50 for both word and non-word targets. That is, the cue could randomly appear either in the same position or the opposite position to the word/nonword targets. There were total 400 trials divided in two blocks of 200 trials each.

**Procedure**. Each trial (Figure 1) began with a fixation sign (+) which appeared for 100 ms. Six hundred milliseconds later, a cue appeared for 50 ms. After a 50 ms delay, the letter string was presented for 100 ms either above or below the fixation. Cue-to-target validity was 50/50 for both word and non-word targets. The total time elapsed between the onset of the cue and the offset of the target was therefore 200 ms; brief enough to discourage eye movements. The intertrial interval, measured from the time the subject responded to the 100 ms blink of the fixation cross, was 1,200 ms. Participants were instructed to respond to the target as quickly as possible by pressing 'left arrow' key on the keyboard if the target was a word of Hindi language, or 'right arrow' key if the target was a nonword. The counterbalancing of keys was done. After the completion of the experiment, all the participants were compensated for their time with 100 Indian rupees. The overall experiment was designed, and stimuli were presented via PsychoPy version 2024.2.4 (Peirce et al., 2019).

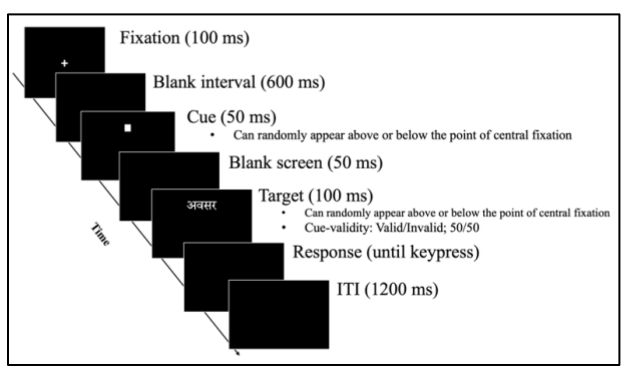


Figure 1. Trial structure of the task (experiment 1)

## Results

We used Linear mixed effects modelling (LMM) approach to analyze the reaction time (RT) data, and logistic mixed-effects regression to analyze the error data. For RT, we removed the data points which were 2 standard deviations above or below the mean for each participant for each condition. The RT data was log-transformed to best approximate a normal distribution, and to meet the assumption of the linear mixed effects model. All the analysis were done using R studio software (R Core Team, 2021) with the lme4 (Bates et al., 2015) and lmerTest packages (Kuznetsova et al., 2017). The degrees of freedom and the $p$ values were estimated using Satterthwaite's approximation as implemented in the lmerTest package (Kuznetsova et al., 2017).

### *RT analysis results*

1. Word/Non-word targets analysis. For this analysis, the model [lmer (logRT ~ Cue-validity*Lexical-status + (1|Subject) + (1|Item)] revealed a significant main effect of Cue-to-target Validity ($\beta$ = 0.07, $SE$ = 0.018, $t(411.41)$ = 3.80, $p$ < .001), indicating that reaction times were significantly faster for validly cued targets compared to invalidly cued ones. There was also a significant main effect of Lexical Status ($\beta$ = 0.14, $SE$ = 0.018, $t(378.45)$ = 7.86, p < .001), with faster reaction times for word targets compared to nonword targets. A significant interaction between Cue-to-target Validity and Lexical Status was also found ($\beta$ = -0.066, $SE$ = 0.025, $t(389.19)$ = -2.57, $p$ = .010). This interaction suggests that the impact of cue validity on reaction time differed depending on whether the target was a word or a non-word. A post-hoc simple effects analysis after Bonferroni correction using the emmeans package (Lenth, 2023) showed that for words, there was a significant effect of cue validity ($z$ = -3.80, $p$ < .001), where validly cued trials resulted in significant faster reaction time ($M$ = 6.65, $SE$ = 0.058) compared to invalidly cued trials ($M$ = 6.72, $SE$ = 0.058). In contrast, for nonwords, the effect of cue validity was not significant ($z$ = -0.23, $p$ = .821). Reaction time for validly cued trials ($M$ = 6.79, $SE$ = 0.058) did not differ significantly from invalidly cued trials ($M$ = 6.79, $SE$ = 0.058) for nonwords. To aid in interpretation, estimated marginal means were back-transformed from the log scale to the original millisecond (ms) scale. For word targets, validly cued trials (773 ms) resulted in a 56 ms faster response compared to invalidly cued trials (829 ms). For non-words, reaction times were nearly identical regardless of cue validity (889 ms for both). This indicates that the spatial cueing benefit was present only when the target allowed for lexical access.

2. Word targets analysis. A separate analysis on the word targets was done to examine the effect of spatial cueing depending on word-frequency (high, low) of the target. The model [lmer (logRT ~ Cue-validity*Word-frequency + (1|Subject) + (1|Item)] revealed a significant main effect of Cue-to-target Validity ($\beta$ = 0.09, $SE$ = 0.023, $t(179.39)$ = 3.91, $p$ < .001), validly cued trials resulting in faster reaction time compared to the invalidly cued trials. There was also a significant main effect of Word-frequency ($\beta$ = 0.049, $SE$ = 0.023, $t(169.34)$ = 2.14, $p$ = .033), showing that participants were faster to respond to high-frequency words compared to low-frequency words. However, the interaction between Cue-validity and Word-frequency was not statistically significant ($\beta$ = -0.03, $SE$ = 0.033, $t(185.31)$ = -0.92, $p$ = .361) indicating that the magnitude of the cueing effect did not differ significantly between high and low frequency words. To aid in interpretation, estimated marginal means were back-transformed from the log scale to the original millisecond (ms) scale. The analysis revealed that participants were 27 ms faster to respond to High-Frequency words ($M$ = 799.7 ms) compared to Low-Frequency words ($M$ = 826.7 ms). There was also a robust main effect of Cue-validity, with 60.88 ms faster responses for validly cued trials (782.75 ms) compared to invalidly cued trials (843.63). Taken together, these results suggest that the 'gate' for spatial attention is the lexical status (word/nonword) of the target rather than the ease of access (high/low frequency) to its specific lexical representation.

### *Error analysis results*

1. Word/Non-word targets analysis. For this analysis, the logit model [glmer (Error ~ Cue-validity*Lexical-status + (1|Subject) + (1|Item), family = binomial)] revealed a significant main effect of Lexical-status ($\beta$ = -0.38, $SE$ = 0.067, $z$ = -5.66, $p$ < .001), indicating that participants were significantly less likely to make errors on word targets compared to non-word targets. The main effect of Cue-validity was not significant ($\beta$ = 0.12, $SE$ = 0.068, $z$ = 1.70, $p$ = .09). However, there was an interaction between Cue-validity and Lexical-status ($\beta$ = 0.21, $SE$ = 0.096, $z$ = 2.15, $p$ = .031). This interaction suggests that the effect of spatial cueing on accuracy was modulated by whether the target was a word or a non-word. A post-hoc simple effects analysis after Bonferroni correction showed that for word targets, there was a robust and significant effect of cue-validity ($z$ = -4.81, $p$ < .001). Accuracy was significantly higher on validly cued trials (*Prob.* = .66, $SE$ = .014) compared to invalidly cued trials (*Prob.* = .58, $SE$ = .015). The odds of a correct response were 1.38 times higher when the cue was valid. In contrast, for nonword targets, the effect of cue validity was not significant ($z$ = -1.70, $p$ = .090). Accuracy for validly cued nonwords (*Prob.* = .70, $SE$ = .013) was not significantly different from invalidly cued nonwords (*Prob.* = .68, $SE$ = .013).

2. Word targets analysis. A separate analysis on the word targets was done to examine the effect of spatial cueing depending on word-frequency (high, low) of the target. the logit model [glmer (Error ~ Cue-validity*Word-frequency + (1|Subject) + (1|Item), family = binomial)] revealed a significant main effect of Cue-validity ($\beta$ = -0.40, $SE$ = 0.10, $z$ = -3.80, $p$ < .001). Participants were significantly more accurate on validly cued trials compared to invalidly cued trials. The main effect of Word-frequency was not significant

($\beta$ = -0.18, *SE* = 0.10, *z* = -1.74, *p* = .081). Crucially, the interaction between Cue-validity and Word-frequency was also not significant ($\beta$ = 0.11, *SE* = 0.15, *z* = 0.74, *p* = .457). This mirror's the reaction time results, indicating that while spatial attention significantly improves accuracy for words, this benefit does not vary significantly depending on the frequency of the word. The summary of the reaction time and accuracy are provided in Table 1 and Figure 2 (A, B) below.

Table 1. Mean reaction time and accuracy for different conditions in experiment 1.

| Cue-validity | Target-type | *Mean RT (and Accuracy)* |
|---|---|---|
| Valid | Non-word | 1052.34 (69.52) |
| | Word (*low freq.*) | 922.51 (63.94) |
| | Word (*high freq.*) | 879.59 (67.66) |
| Invalid | Non-word | 1042.42 (67.13) |
| | Word (*low freq.*) | 1015.09 (57.77) |
| | Word (*high freq.*) | 986.54 (59.38) |

A

B

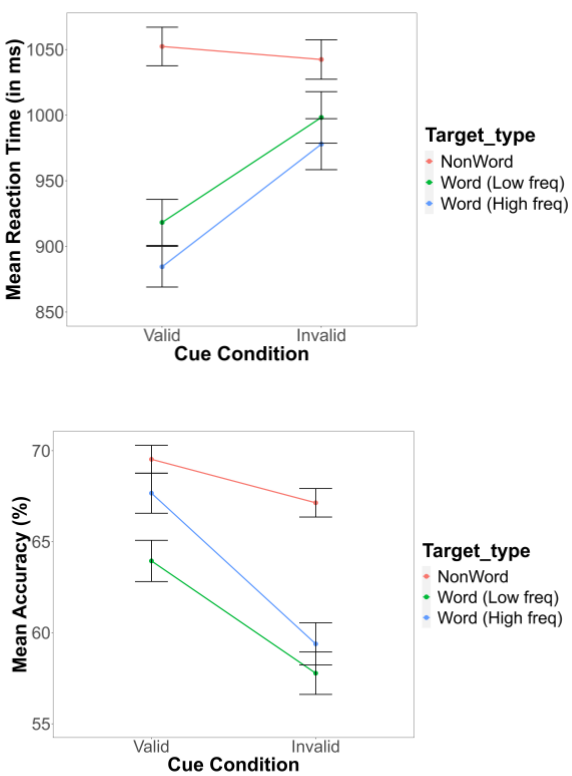


Figure 2. (A) Mean reaction time, and (B) accuracy for word/nonword targets in experiment 1. Error bars represent standard error of the means.

**Discussion**

We found an interaction of spatial attention with the lexical-status (word/nonword) of the target, but not with word frequency . These results are contrary to those from McCann et al., (1992), i.e., *early selection* but not identical to the ones that support *interaction* accounts of spatial attention and VWR as well. For instance, we find spatial cueing benefits for words but not for nonwords, moreover, these benefits are almost equivalent in case of high vs. low frequency words. If anything, our results may be reconciled with a version of the late-selection account (for a detailed discussion, see McCann et al., 1992) where spatial attention selectively enhances the processing of a target depending upon its lexical status. Possibly, spatial attention enhances the processing of words by strengthening the association between stages of orthographical/phonological decoding with lexical representations in the mental lexicon, which are absent in case of nonwords/pseudowords. It is notable that due to the transparent nature of its orthography, Hindi nonwords are pronounceable letter strings and hence can be seen to function as pseudowords for purposes of theoretical interpretation.

Also, as the cueing benefit is similar for both high & low frequency words, the findings may argue against the idea that cueing would benefit mainly unfamiliar words and that familiar (high frequency) words enjoy a special status (Montani et al., 2014; Sieroff & Posner, 1988; Auclair & Sieroff, 2002). Finally, while these results do serve as a contrast to known results from English, the exact locus of these effects is not clear. Whether, orthographic complexity is a factor is still unclear. To address this issue, we conducted experiment 2. In experiment 2, we manipulated orthographic complexity by introducing *matra* in the word/non-word targets. For the sake of simplicity, we introduced one matra only in the targets and investigated effects of spatial cueing on lexical processing.

## Experiment 2

### Method

**Participants**. Thirty-six participants (*M*: 21.75 years, *SD*: 2.29) participated in this experiment similar to experiment 1. All were native speakers of Hindi and had learned to read and write Hindi before seven years of age.

**Task, and stimuli.** Task in experiment 2 was the same as experiment 1. Stimuli differed from experiment 1 in terms of 1-*matra* in the target. Unlike experiment 1, each word/nonword target consisted of 1-*matra* in them. Number of targets were similar to experiment 1 (200 word targets and 200 non-word targets). Among words, 100 were high frequency words (3-6 Zipf), and 100 low frequency words (1-3 Zipf) selected from the 'Shabd' corpus (Verma et al., 2021). Apparatus and procedure were same as experiment 1.

## Results

Data cleaning and analysis protocol was similar to experiment 1.

***RT analysis results***

1. Word/Non-word targets analysis. For this analysis, the model [lmer (logRT ~ Cue-validity*Lexical-status + (1|Subject) + (1|Item)] revealed a significant main effect of Cue-validity ($\beta = 0.10$, $SE = 0.02$, $t(471.36) = 4.51$, $p < .001$), indicating that reaction times were significantly faster for validly cued targets compared to invalidly cued targets. There was also a significant main effect of Lexical-status ($\beta = 0.18$, $SE = 0.02$, $t(360.31) = 8.60$, p < .001), with faster reaction times for word targets compared to non-word targets. A significant interaction between Cue-validity and Lexical-status was also found ($\beta = -0.11$, $SE = 0.03$, $t(402.07) = -3.57$, $p < .001$) indicating that the impact of cue validity on reaction times differed depending on whether the target was a word or non-word. A post-hoc simple effects analysis after Bonferroni correction showed that for word targets, there was a significant effect of Cue-validity ($z = -4.51$, $p < .0001$), with validly cued words being processed significantly faster ($M = -0.27$, $SE = 0.08$) than invalidly cued words ($M = -0.17$, $SE = 0.08$). In contrast, for nonwords, the effect of cue validity was not significant ($z = 0.34$, $p = .738$). There was no statistical difference in reaction times between validly cued non-words ($M = -0.09$, $SE = 0.08$) and invalidly cued non-words ($M = -0.10$, $SE = 0.08$). To aid in interpretation, estimated marginal means were back-transformed from the log scale to the original millisecond (ms) scale. For words, validly cued targets (762 ms) resulted in 81 ms faster response compared to invalidly cued targets (829 ms). For nonwords, reaction times were nearly identical regardless of cue validity (~905 ms).

2. Word targets analysis. A separate analysis on the word targets was done to examine the effect of spatial cueing depending on word-frequency (high, low) of the target. The model [lmer (logRT ~ Cue-validity*Word-frequency + (1|Subject) + (1|Item)] revealed a significant main effect of Cue-validity ($\beta = 0.13$, $SE = 0.03$, $t(181.97) = 4.33$, p < .001), with validly cued trials resulting faster reaction time compared to invalidly cued trials. There was also a significant main effect of Word-frequency ($\beta = 0.11$, $SE = 0.03$, $t(153.66) = 2.14$, $p < .001$), showing that participants were faster to respond to high-frequency words compared to low-frequency words. However, the interaction between Cue-validity and Word-frequency was not statistically significant ($\beta = -0.01$, $SE = 0.04$, $t(192.50) = -0.34$, $p = .733$) showing that the magnitude of the cueing effect did not differ significantly between high-frequency and low-frequency words. To aid in interpretation, estimated marginal means were back-transformed from the log scale to the original millisecond (ms) scale. The analysis revealed that participants were 86.1ms faster to respond to high-frequency words ($M = 774.4$ ms) compared to low-frequency words ($M = 859.8$ ms). There was also a robust main effect of Cue-validity. Overall, participants were 91.1 ms faster on validly cued trials ($M = 768.3$ ms) compared to invalidly cued trials ($M = 865.9$ ms).

***Error analysis results***

1. Word/Non-word targets analysis. For this analysis, the logit model [glmer (Error ~ Cue-validity*Lexical-status + (1|Subject) + (1|Item), family = binomial)] revealed a significant main effect of Lexical-status ($\beta = -1.13$, $SE = 0.08$, $z = -12.75$, $p < .001$), indicating that participants were significantly less likely to make errors on word targets compared to non-word targets. The main effect of Cue-validity was also significant ($\beta = 0.27$, $SE = 0.09$, $z = 2.84$, $p < .05$) indicating that participants were more accurate on valid trials. Furthermore, there was an interaction between Cue-validity and Lexical-status ($\beta = 0.49$, $SE = 0.12$, $z = 3.82$, $p < .001$) showing that the effect of spatial cueing on accuracy was modulated by whether the target was a word or a non-word. A post-hoc simple effects analysis after Bonferroni correction showed that for the word targets, there was a robust and significant effect of Cue-validity ($z = -8.85$, $p < .001$). Accuracy was significantly higher on validly cued trials (*Prob.* = .69, $SE = .019$) compared to invalidly cued trials (*Prob.* = .51, $SE = .022$). The odds of a correct response were 2.25 times higher when the cue was valid. In contrast, for nonword targets, the effect of cue validity was found significant ($z = -2.84$, $p < .05$). Accuracy for validly cued non-words (*Prob.* = .81, $SE = .014$) was significantly higher than invalidly cued non-words (*Prob.* = .76, $SE = .016$).

2. Word targets analysis. A separate analysis on the word targets was done to examine the effect of spatial cueing depending on word-frequency (high, low) of the target. the logit model [glmer (Error ~ Cue-validity*Word-frequency + (1|Subject) + (1|Item), family = binomial)] revealed a significant main effect of Cue-validity ($\beta = -0.71$, $SE = 0.13$, $z = -5.47$, $p < .001$). Participants were significantly more accurate on validly cued trials compared to invalidly cued trials. The main effect of Word-frequency was not significant ($\beta = -0.16$, $SE = 0.13$, $z = -1.22$, $p = .22$). Crucially, the interaction between Cue-validity and Word-frequency was not significant ($\beta = -0.14$, $SE = 0.18$, $z = 0.76$, $p = .44$). Overall summary of the reaction time and accuracy are provided in Table 2 and Figure 3 (A, B) below.

Table 2. Mean reaction time and accuracy for different conditions in experiment 2.

| Cue-validity | Target-type | *Mean RT (and Accuracy)* |
|---|---|---|
| Valid | Non-word | 1089.73 (67.77) |
| | Word (*low freq.*) | 876.36 (69.33) |
| | Word (*high freq.*) | 823.24 (73.61) |
| Invalid | Non-word | 797.32 (64.13) |
| | Word (*low freq.*) | 613.28 (55.94) |
| | Word (*high freq.*) | 634.00 (62.72) |

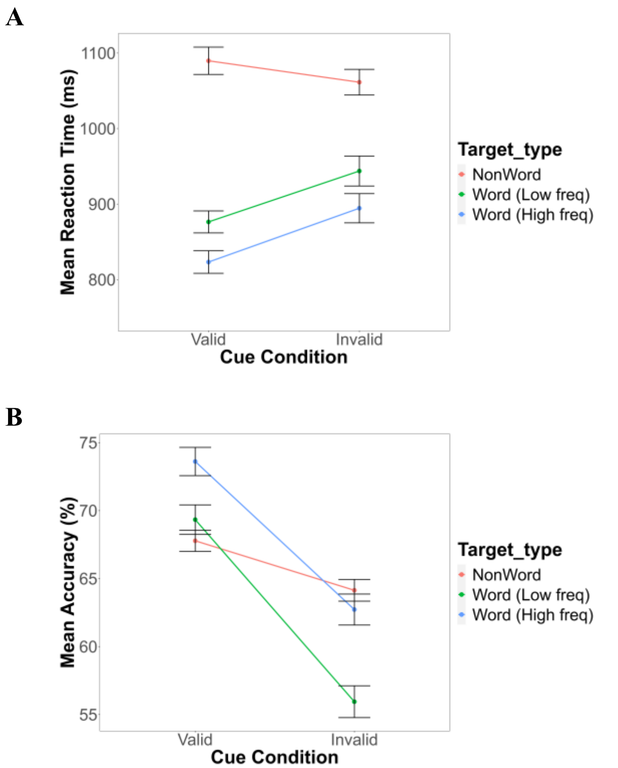


Figure 3. (A) Mean reaction time, and (B) accuracy for word/nonword targets in experiment 2. Error bars represent standard error of the means.

**Discussion**

The findings from Experiment 2 are in line with those of experiment 1, implying that orthographic complexity does not impact the interaction of spatial attention and VWR. More precisely, it seems that even when visual complexity is increased by adding a matra in a targets, word recognition is modulated by attention only at the level of lexical-status and not at the word-frequency level similar to experiment 1. This could be taken to suggest that the "gate" for spatial attention is the lexical status of the target—requiring a match with a known entry in the mental lexicon—rather than the ease of access (frequency) to that specific representation even when non-linearity is there in the lexical items in the form of a *matra*.

It is important to mention that in the current experiment we manipulated orthographic complexity in the form of adding one *matra* in the targets. It is possible that complexity can be increased more depending on more *matras* in the targets. How attention interacts with VWR when more than one matra is present in the targets is the issue still unanswered and should be investigated in future studies.

## General Discussion

We conducted the current study with the aim to investigate the role of spatial attention in visual word recognition (VWR), with a focus on Hindi language which is written in *Devanagari* orthography. The findings of this study provide evidence for a late interaction between spatial attention and VWR (McCann et al., 1992) showing that spatial attention partakes during the process of lexical access and hence differentially enhances the processing of words as compared to nonwords. These findings contradict the previous proposals for early selection by McCann et al. (1992) and Montani et al. (2014), as well as that of interaction proposed by Stolz et al. (2000).

Our findings are broadly in line with a 'late selection' account, discussed in detail by McCann et al., (1992). Late selection account (La Berge & Samuels, 1974) suggests that spatial attention may operate after stimulus identification and/or semantic processing and hence selectively enhance lexical access for words compared to nonwords. Also, as Hindi nonwords are essentially pronounceable pseudowords, to some extent, our findings might also be accounted for by the assumptions of the CDP+ model (Perry et al., 2007; as discussed in Montani et al., 2014). CDP+ model suggests that spatial attention at a pre-cued location may benefit the processes of orthographic and phonological decoding and matching the same with representations in the mental lexicon. Finally, the expected null effect of increased orthographic complexity in experiment 2 needs more investigation since other experiments in our lab (currently unpublished) have suggested that orthographic complexity, when increased in a graded fashion with increasing number of matras (2-3 matra onwards) have a significant impact on lexical access.

A more detailed discussion of the possible mechanisms underlying our results is beyond the scope of the current paper format. Nonetheless, these novel findings present an intriguing opportunity to researchers interested in the role of spatial attention and VWR (across different writing systems & scripts). Also, more detailed experiments are needed in Hindi to investigate the direction of spatial cueing (top/down vs. left/right or congruent/incongruent to the direction of reading), timing of cues (50-100 ms vs 200 ms or more), the type and length of letter strings, the type of cueing (partial vs. whole word cueing). Only these detailed systematic investigations will shed more light on how spatial attention interacts with VWR. Finally, we hope that the reported results encourage more researchers to take up investigations regarding the role of attention in general and spatial attention in particular, along with other domain-general cognitive functions in visual word recognition to develop more generalizable and complete models of visual word recognition.

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