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Special Attention and Word Frequency Effects onReading

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ABSTRACT

Word recognition researches have dichotomous opinion on attentional utility, where some studies establish the attentional utility and other researches pose the question on the requisitionof attention during reading, owing to the prevalent belief of automaticity inreading. Spatial attention has been attentional variant receiving mixed findings from lexical decision tasks andStroop tasks as being the prerequisite (Lachter, Forster, & Ruthruff, 2004) and not necessary (Brown, Gore, & Carr, 2002), respectively. Present study explored the attentional utility duringword reading through manipulation of the word frequency alongwith spatial attention through Posner's cueing paradigm to address the frequency-basedhypothesis of automaticity in reading. A 2 (Frequency: High and Low) × 3 (Cue: Valid, Invalid, Neutral) repeated measuredesign was applied. Thirty participants from 18 to 22 yrs contributed to the study. Two-way analysis of variance (ANOVA) revealed the better correct detection rate under valid cue conditions ($p = 0.00$). In addition, the incorrect detection rate was lowest for valid cue conditions ($p = 0.00$). Perceptual sensitivity and response criterion measures further supportedthe results. Findings have been explained in terms of activation- confusion model and mirror frequency effects.

Keywords: Reading, Word Frequency, Cue Validity.

Introduction

For long, the efficacy of spatial attention while processing visual word remained a vexed theme, often explored through the utility of selective attention, wherein words emerged as appropriate stimulus. Recently, a shift in this area emerged when the debate moved away from early selectionor late selection debate (Brown, Gore, & Carr, 2002) to tap the effect of attention on visual word recognition. The present investigation focuses the latter.

Visual word recognition

Reading skill is one of the finest accomplishments of the evolution of human culture and cognition. Through the pioneering and one of the earliest empirical cognitive works of Cattell (1886), the word identification became a significant subject of investigation wherein automatic processing vs. attentional need (Neely, 1977; Posner & Snyder, 1975; Fodor, 1983)saw a growingconcern. The prevalent assumption regarding the automaticity of word recognition is often posed up with questions. To address this, often the explanation ofautomatic refers to be happening withoutan attentional effect. Attention in such researches maintains the basic function of information selection and prioritization of the mental operations, although its different variants are studied. Brain studies and computational studiesof attention have revealed different neural systems for the variants of attention (Gazzaniga, Ivry, & Mangun, 1998; Pashler, 1998; Posner & Raichle, 1994).

Word identification has been studied with several paradigms, mostly in the realm of speed andaccuracy. These two measures have found evidence like the words encountered frequently take lesser time to be recognized, similarly, shorter words (Ferrand, L.,2000; Ferrand & New, 2003; New, Ferrand, Pallier, & Brysbaert, 2006) and words with a higher number of orthographic neighbours require lesser time and have higher accuracy rate (Andrews, 1997).

Word Frequency effects

Cattel (1886) found that the frequency at which any word appears in the givenlanguage can impact the word processing even at the most fundamental level, the recognition time and accuracy. The word-frequency effects further got generalized through Gorman (1961) and Schulman (1967). The three categories models of word recognition namely,logogen model, serial search model and activation-verification model each deal differently with frequency effects also several tasks have revealed different effects ranging from paradoxical reversal to mirror frequency effects. Word frequency effect has been used as a reconciling factor for the spatial attention utility in reading. Themost prominent element of the time exercised to process words is the frequency that it befalls with(Murray and Forster, 2004; Forster & Hector, 2002). Effects of word frequency were recorded in the lexical decision (Balota et al., 2004; Spieler &

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Balota, 2000; Yap, Balota, Sibley, & Ratcliff, 2010) alongside with numerable other functions considered to concern the orthographic

illustrations while perceptual identification (Broadbent, 1967)to eye fixations while word recognition(Inhoff and Rayner, 1986).

Spatial Attention

Visual spatial attention enables specific areas of the visual field to be defined for selective processing (Posner & Peterson, 1990). Several tasks have demonstrated that attending to a location where at the location of target, improves performance. The most prevalent estimate to evaluate the influence of spatial attention is the cueing paradigm by Posner (1980). Within this model, a spatial cue is followed by a target that points to the location of target as a valid trial or that points opposite of the target location as invalid trial. The difference in the performance of valid and invalid trial acts as the index concerning the impact of spatial attention. Literature describes that spatial attention in word processing has been examined through studies involving the cue validity manipulation combined with several word processing tasks (Besner, Risko, & Sklair, 2005; Hardyck, Chiarello, Dronkers, & Simpson, 1985; Lindell & Nicholls, 2003; Nicholls & Wood 1998; Nicholls, Wood, & Hayes, 2001; Stolz & McCann, 2001).

Spatial attention does have the characteristics resembling to the spotlight, the attention spotlight remains autonomous fixations of eyes and might assume various shapes. The central nature (LaBerge, 1995; Hoffman et. al., 1983) attentional spotlight has been proposed, also there are other studies that report the eye-independent movement of the spotlight (Sperling & Reeves 1980, Remington & Pierce 1984). Elaborate research regarding spatial attention and physical features has been performed by Triesman and colleagues, one of their research reported that, while the attention spotlight was focused the physical feature integration was better for stimulus as compared to the conditions where the area of spotlight was broader or unfocused (Treisman & Schmidt, 1982).

Methodology

Participants

Thirty-one participants with age range from 18 to 22 years from Banaras Hindu University participated in the study. Their visual acuity was checked for normal (6/6) or corrected to normal (6/9) level, also no known history of psychological and neuropsychological disorder was ensured. Thirty participants from Banaras Hindu University with normal or corrected to normal visual acuity, performed in the present study. A written consent was taken from all the participants after explaining the research study. The age of participants ranged from 19-21 years with mean age (M = 19.85 years; SD = 1.30). No known psychological or neurological issue was reported for the participants.

Tools and apparatus

Direct RT® v12.1 software was used to design the task and for obtaining the details of reaction time and correct and incorrect responses. A Dell Inspiron (Machine Inspiron 580s with Intel i3 processor) with 15 inch color monitor was used for the presentation of stimuli. Screening questionnaire was used to derive information about language acquaintance, knowledge and usage. A total of 180 stimuli categorized into words and non-words, were used. 160 of which was used in the experimental task, 20 was used for practice sessions.

Experimental Design

2 (Stimuli: Low and High Frequency words) × 3 (Cue type: Valid, Invalid and neutral cues) repeated measure design was used. A low event rate of 10 events per minute in each trial was maintained. The cue told about the probable location of the target. Cue validity was manipulated as valid, invalid and neutral cue. Word frequency and spatial attention were used as independent variables. Correct detection rates (accuracy), incorrect detection (false alarm) perceptual sensitivity (d") and response bias (c) were calculated on the basis of true scores of correct detection and incorrect detection was used as dependent measure in this study.

Experimental task

DirectRTv2012.4.0.166 software was used to design and run the task. Task was displayed using 14-inch color monitor, in 16- times new roman font. White letters against black background were used.

The task was designed to test the impact of the attention allocation on the identification of the words. Whereby, a spatially manipulated cue occurs before the target word Once the target stimuli was identified, a response had to be provided by distinguishing between the noise presented with the appropriate stimuli presented together on the response screen.

For each trial the experiment began with the fixation (+) that appeared at the centre of the screen and participants were instructed to fixate their visual focus at it. Fixation (+) was of 500 msec, followed by the spatial cue appearing for 50 milliseconds (ms). A delay of After 30 was presented that made the interval between cue and target to be of 80 msec, the target string was presented for 80 msec. The response screen then appeared with maximum 5000 msec time limit. Response screen had four options out of which one could be correct, the participant was required to choose the corresponding word, through the designated keys for responses. The ratio of the target and non-target was kept 20:80. A diamond shape made up with asterisk sign stimulus in white color was used as exogenous cue. Cue validity for

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valid, invalid, and neutral ratio was kept 60:20:20 across the blocks. The flow chart of experimental task is given in Figure1.

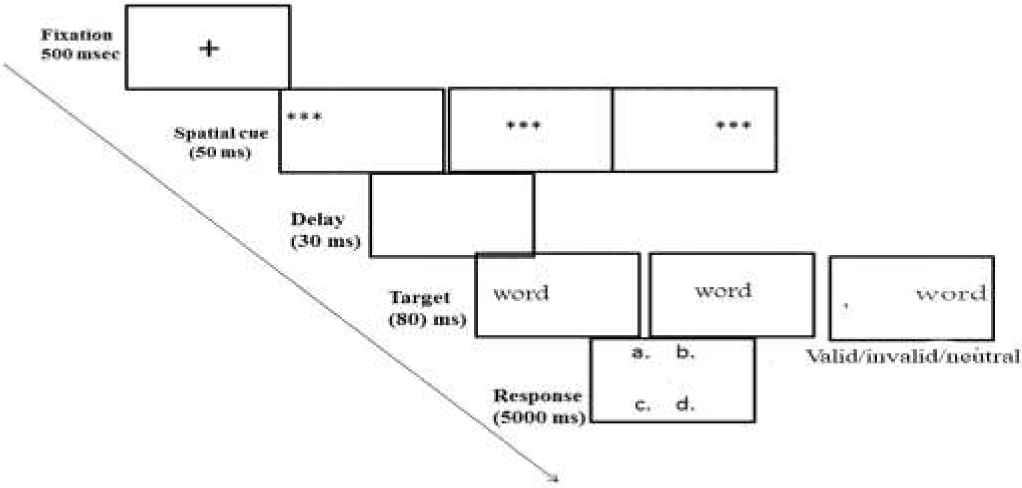

Figure 1: flow chart of the experiment

Procedure

The participants were first rendered at ease with the Laboratory environment. They were then presented with a screening questionnaire to obtain the specifics of language competence and acquaintance. After clearing the participant's concerns and questions relating to the experiment consent form were signed and biographical

details were obtained from the participant. During the Experiment, participants received the 2 min. demonstration and then 2min. practice followed by final session of 6 min. of the experimental task. Four participants could not meet the performance criteria and were thus eliminated from the experiment.

Data Analyses

A 2 (Stimuli: High Frequency, Low Frequency words) × 3 (Cue type: Valid, Invalid and Neutral cue). Two-way repeated measure ANOVA was computed for comparing the correct detection and incorrect detection scores of the participants.

Experimental Design

A low event rate of 10 events per minute in each trial was used. The time duration for experimental task was of 6-min. word frequency was defined as independent variable manipulated in terms of word frequencies, namely high and low. Performance measures. The participants were instructed to press one of designated keys to perform their response.

Results

For valid cue condition correct detection for high frequency words was higher (M= 92.74; SD= 14.71) in comparison with words of lower frequency (M= 75.00; SD= 20.41). Whereas in invalid cue condition correct detection for words with low frequency was higher (M= 33.87; SD= 35.08) than that for the words being high in frequency (M= 29.03; SD= 28.20). For neutral condition correct detection was higher for low frequency words (M= 70.96; SD= 33.60) than high frequency words (M= 45.16; SD= 23.64). The mean results under different frequency and cue conditions are presented in table 1 and graphically represented in figure 2. For word frequency there was significant main effect $F(1, 30) = 26.95$; $p = 0.000$ along with the main effect obtained for the cue validity being foundsignificant as well $F(2, 60) = 40.35$; $p = 0.000$.Also, a significant $F(2, 60) = 23.04$; $p = 0.000$.interaction effect was found for cue validity and word frequencies.

Table 1. Mean and standard deviations on correct detection as a function of word frequency and cue validity

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Cue Conditions	Word Frequency	
	High Frequency	Low Frequency
Valid	92.74 ± 14.71	75.00 ± 20.41
Invalid	29.03 ± 28.20	33.87 ± 35.08
Neutral	45.16 ± 23.64	70.96 ± 33.60

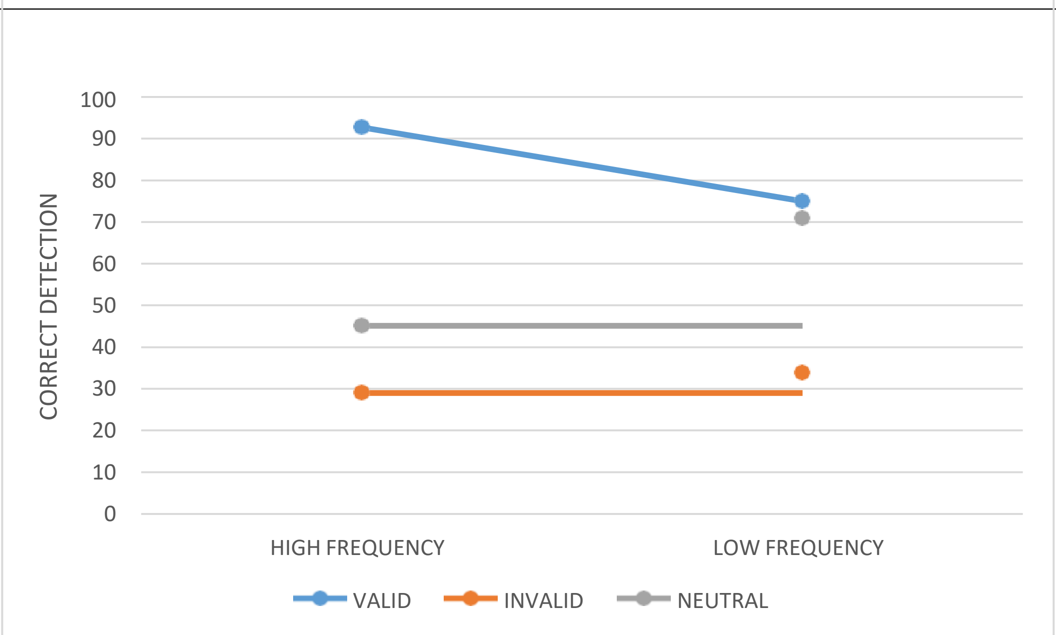

Figure 2: Correct detection as a function of word frequency and cue validity

Incorrect detection rate for valid cue conditions was considerably lower for high frequency words (M= 7.25; SD= 13.21) compared to low frequency words (M= 20.96; SD= 20.51). In invalid cue conditions incorrect detection rate reported to low frequency words was lower (M= 61.29; SD= 38.10) than that reported for high frequency words (M= 67.74; SD= 27.53). For neutral condition the words with low frequency (M= 27.41; SD= 31.19) had lower incorrect detection rate than the words with high frequency (M= 51.61; SD= 31.19). The main effect of word frequency was not found significant F(1,30)= 2.79; p = 0.10. However, cue validity was found to have significant main effect F(2,60)= 48.26; p= 0.00. The results for mean values under different frequency and cue conditions are presented I n table 2 and graphically represented in figure 3. Moreover, the interaction effect of spatial attention i.e., cue validity and word frequencies was also found significant F (2, 60) = 11.18; p= 0.00. *Table2. Mean and standard deviations on incorrect detection as a function of word frequencyand the cue validity.*

Cue Conditions	Word Frequency	
	High Frequency	Low Frequency
Valid	7.25 ± 13.21	20.96 ± 20.51
Invalid	67.74 ± 27.53	61.29 ± 38.10
Neutral	51.61 ± 24.09	27.41 ± 31.19

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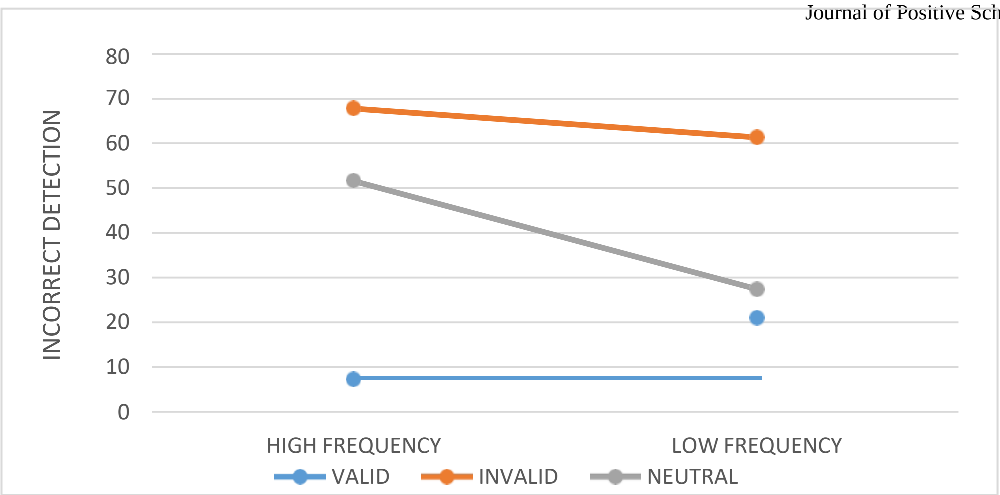

Figure 3: Incorrect detection as a function of word frequency and the cue validity

Perceptual sensitivity index (d')

The sensitivity index or d' is a statistic that provides the separation between the means of signal and the noise distribution, being compared against the standard deviation of the signal or noise distribution. The mean scores and standard deviations of perceptual sensitivitywere calculated on the basis of the correct detection and incorrect detection performance measures. A paired-samples t-test was conducted to compare perceptual sensitivity for high frequency and low frequency words. There was a significant difference in the scores for high frequency words (M=0.15, SD=0.47) and low frequency words (M= 1.09, SD= 0.47) conditions; t (29) =-7.42, p = 0.00. These results suggest that perceptual sensitivity is affectedby word frequency.

Specifically, results suggest that when the words with varying frequency are encountered, the low frequency words are perceived better as the sensitivity for their perception is higher.

Table 1: *Mean scores and standard deviations (in parenthesis) on perceptual sensitivity index(d') performance as a function of familiarity.*

Familiarity	Perceptual Sensitivity (d')
High Frequency	0.15 (0.47)
Low Frequency	1.09 (0.47)

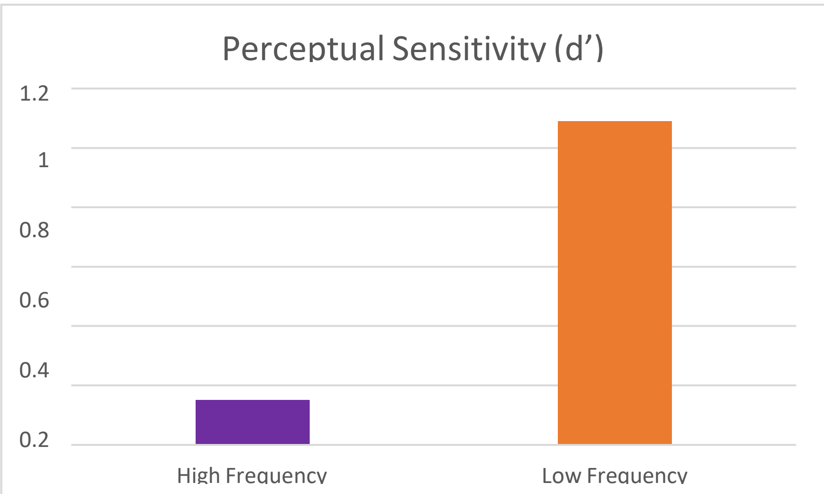

Figure 1. Perceptual Sensitivity as a function of word frequency.

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Response Criterion index (c)

The response criterion index or c refers to the critical output of the sensory process in terms of decision criterion while undergoing a decision- making process. Decision criterion used by an observer can vary with different tasks, it is also affected by temporal factors. A p aired-samples t-test was conducted to compare response criterion for high frequency andlow frequency words. There was a significant difference in the scores for high frequency words (M=0.18, SD=0.06) and low frequency words (M= 0.28, SD= 0.06) conditions; t (29) =-6.63, p = 0.00. These results suggest that response criterion is affected by word frequency. Specifically,results suggest that when the words with varying frequency are encountered, the low frequency words are processed more meticulously.

Table 2. *Mean scores and standard deviations (in parenthesis) on response criterion index*

(c) performance as a function of familiarity.

Familiarity	Response Criterion(C)
High Frequency	0.18 (0.06)
Low Frequency	0.28 (0.06)

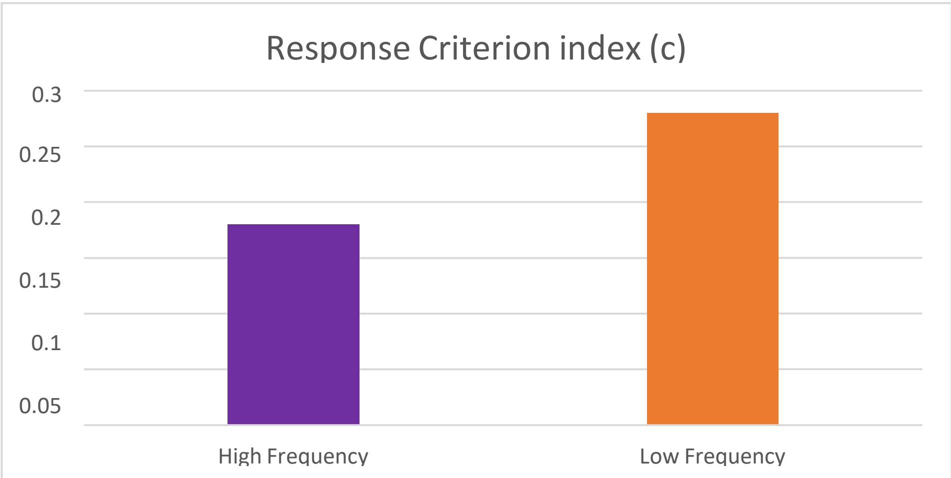

Figure2. Response Criterion as a function of word frequency

Discussion

Posner and Boies in 1971 suggested the mental work and selective processing as essential definitions of attention which is well followed by the phenomenon of spatial attention, these features help the selective processing of the multielement presentation, by connoting location. The present study intended to explore the utility of spatial attention in word recognition through cue manipulation and with varied frequency measures. Familiarity hypothesis implies to consider that increasing familiarity level marks a decrease in the requirement for the spatial attention, for which the study chose two frequencies to operate upon, namely high and low frequency. Also, the target word when presented at the response screen has noise stimulus along, from which it had to be identified if the target word was present. The hypothesis proposed in the study suggested that the spatial utility irrespective of word frequency will remain significant to the word recognition, which was verified by the findings of the experiment. The measures chosen were correct detection and incorrect detection referring to correct hits and false alarm. The correct detection was found to be higher and incorrect detection to be lower for low frequency conditions for invalid conditions, where the attentional cue was not congruent to the target stimulus. Similarly, for neutral condition where the cue revealed no information about the probable position of the target, the correct detection was better for low frequency words. Inversely to this, we found that the performance of correct detection and committing lesser incorrect detection occurred for the valid cue condition and correctly determined the stimulus location. High frequency words had a better performance during valid cue conditions but not during invalid and neutralconditions. This difference indicates the effect of spatial attention, the overall correct detection along with lesser false alarm was found invalid cue conditions, also supports the previous findings suggesting improved word recognition in the presence of valid spatial cues (Ducrot & Grainger, 2007; Gatheron, & Siéroff, 1999; Mondor & Bryden, 1992). The findings remain in line

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with the researches suggesting that attention allocation facilitates the recognition of unattended stimulus (McCann, Folk, & Johnston, 1992). The better performance for low frequency words in invalid and no cue conditions does not follow the frequency hypothesis that predicts better performance for high frequency hypothesis. It can be explained on the grounds of semantic interference and the similarity between target and noise. Present task used meaningful target and noise words along with similar looking words used as noise stimulus. Semantic interference is the obstruction induced delayed response effect caused by irrelevant stimuli in the visual field concerning the pertinent stimuli. This interference although is contingent upon the strength of association between the semantic of target and noise words, yet it tends to reduce suddenly when the pertinent stimulus receives a preceding focus of the attentional spotlight (Underwood, 1976; Allport et. al., 1985). Also, the differed finding may be explained by the feature integration hypothesis, suggesting the similarity between the noise and target to be causing the difference in recognition. This is further relevant in explaining the improved accuracy of target detection in valid cue conditions, i.e. with the attentional focus, therecognition rate was more accurate with lower false alarm, reducing the chance responses. Whether these factors cause the better performance in low frequency words in interaction or one remains independent of the other, remains a question for further investigation.

The word frequency effects define the superior processing of high frequency words in terms of accurate and speeded response. Recently, an interesting debate has emerged in the literature, which questions exactly how our experience with words is encoded into the orthographic representations supporting visual word recognition. The earlier researches account the frequency as a good estimate of the word occurrence within the language and thusexplained the influences on the time required for recognition processes (Forster & Chambers, 1973). These bases these estimates of frequency is the expanded corpora displayed by adult texts, where the individual words are counted for their occurrences (Baayen et al., 1993; Kucera and Francis, 1967; Zeno et al., 1995). Nevertheless recent advances reflect the age of acquisition as another determinant of significance for an individual's experience with different words (Brysbaert et al., 2000; Morrison and Ellis,1995; Gerhand & Barry, 1999). The present study included the identification of words with high and low frequency when embedded between similar looking words. The results revealedbetter processing of low frequency words, with higher perceptual sensitivity for words havinglow frequency as compared to the high frequency words. Single process theories utilise the account of their unique representations (letter features or semantic features) due to the specialcharacteristics of low-frequency words to explain this effect in contrast with the high- frequency words, thus making them easily prominent for correct recognition less prospective for the fallacious recognition (Auclair & Siéroff, 2006; McClelland & Chappell, 1998; Shiffrin & Steyvers, 1997). According to the dualprocess theory, of memory, the model that is accountable for mirror frequency effect is Source of activation confusion, which reducesthe ability to differentiate between activation regulated through recent exposures in contrast to the effects of prior exposures (Reder et al., 2000). Therefore, based on the findings and above noted theories we can say that the sensory processdefined by the sensitivity parameter and the decision process depicted by a response criterion parameter, were both better for low frequency words. This negates the word frequency effect, indicating towards non automaticor attention-based perception of words.

Conclusion

Understanding word recognition is important to make the breakthrough from "learning to read" to "reading to learn". Reading and word recognition are complex, with extensions ranging to clinical conditions of learning disorders, dyslexia, ADHD and further limiting issues. Often, unrealized factor remains attention, therefore the present study attempted to depict the attentional utility in word recognition, which is essential component of reading. Findings suggest improved word recognition with the preceding attention allocation on spatial location of the target word. Study finds its implication in bringing the attentional rehabilitation strategies for reading related disorders; it also extends the research opportunities for further investigations in terms of characteristics of noise and its effect on target detection along with further orthographies that might be studied to verify the universality of spatial attention usage in word recognition.

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Conflict of interests

The authors declare no conflict of interest.

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