Semantic and Phonological Priming in Children with Learning Disability: Word reading task

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Abstract

The purpose of the present investigation is to examine visual and auditory cross modal pattern processing at the lexical linguistic level. The study also aims at exploring the nature and level of breakdown in lexical processing in dyslexia due to the interfering primes resulting in lexical retrieval problems. Participants were 7 normal children age-matched to 7 children with learning disability (LD), ranging in age from 8; 0 to 15; 0(years; months). Procedures involved a computer-assisted word-naming task during which each participant was presented the same set of 30 words in each of the three different conditions: (a) no-prime condition in which no auditory stimulus was presented before word display; (b) related-prime condition in which a word, semantically related to the target word, was presented auditorily 500 ms before word display; and (c) unrelated prime condition in which a semantically unrelated word was presented auditorily 500 ms before word display. Results showed that children with LD performed poorly compared to the normal children on all the semantic and phonological priming tasks although larger semantic priming effects were seen in normal children as well as children with LD. The reaction time (RT) experiment showed that children with LD had longer RTs compared to normal children on all the three conditions and in both the tasks.

Key Words: dyslexia, cross modal priming, semantic priming, phonological priming, reaction time

Introduction

Reading is a crucial skill for academic and occupational success. Reading is the process of retrieving and comprehending some form of stored information or ideas. These ideas are usually some sort of representation of language as symbols to be examined by sight or by touch (for example Braille) (Keeney & Keeney, 1968). Reading is a process that requires coordination of a series of sub-functions which include visual functions, verbal functions and other cognitive functions like memory and attention (Kim & Davis, 2004). Reading can be impaired when any of these functions are affected. In simple terms reading failure in children, in spite of normal intellectual functioning, normal hearing, normal vision, adequate motor skills and adequate learning environment can lead to *'Learning disability' or 'Dyslexia'*. Learning Disabilities (LD) are most common in the general population. The definition according to the Learning Disabilities Association of America says that: "Learning disabilities are defined as neurologically-based processing problems. These processing problems can interfere with learning basic skills (Cossu,

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1999) such as reading (Stuart & Coltheart, 1988) writing, or math. They can also interfere with higher-level skills such as organization, time planning and abstract reasoning Learning disabilities are an 'umbrella' term describing a number of other more specific learning disabilities." The familiar term dyslexia which is a reading and language disorder is only one of the learning disabilities that fall under this large umbrella.

Individuals with LD fail to achieve normal reading skills despite adequate intelligence, educational opportunities and socioeconomic status (Shaywitz, Shaywitz, Fletcher & Escobar, 1990). The role played by a to-be-recognized word's semantic context or phonologic context is one such focus of the present study. In examining such effects during word recognition researchers often implement tasks where participants categorize a string of letters as a "word" or "non-word". During this lexical-decision task (LDT) word/non-word key-press reaction times (RTs) and accuracy serve as dependent measures. Generally a participant's speed and accuracy of response to a target vary depending on the relation of the prime item preceding it. Thus the target robin is recognized more quickly and accurately when preceded by the related prime BIRD than by the neutral prime XXX. This is termed facilitation whereas slower target response when reading BIRD...arm compared to the neutral prime condition (XXXX...arm) shows inhibition (Neely, 1977).

Priming is believed to occur without intention and is described as an automatic process. It also seems to occur without awareness and is therefore described as an unconscious process (McCarthy & Warrington, 1990; Posner & Snyder, 1975; Peereman & Content, 1995; Parkin, 1996 Harley, 2001). One of the original demonstrations (Meyer & Schvaneveldt, 1971) of priming occurred in a textual decision task in which a series of decisions is made about whether letter strings are words or not. Research by Ratcliff and McKoon (1981) showed that reaction times to target words primed with closely associated words were faster than target words primed with distantly associated words.

To date, however, there are very few published studies using an experimental semantic and phonological priming paradigm involving 8-15 years of children in Indian context. Hence the present investigation aims:

- To examine visual and auditory cross modal pattern processing at lexical-linguistic level.
- It also aims at exploring the nature and level of breakdown in lexical processing in dyslexia due to the interfering primes resulting in lexical retrieval problems. In other words it aims to study the nature of retrieval deficits in children with LD as the disorder is explored relatively lesser than any other clinical population in Indian context.

Method

While phonological and lexical/semantic priming have been extensively studied and reviewed relative to stuttering in children and adults (Conture, 1991; Ingham, 1998; Max & Caruso, 1997, 1998) and aphasics (Baum, 1997; Blumstein, Milberg & Shrier, 1982; Milberg & Blumstein, 1981) in American context, there appears to be growing sentiment that LD population also warrant similar considerations (Helenius, Salmelin & Connolly, 1999; Ben-Dror, Bentin & Frost 1995).

Participants

Seven participants ranging in age from 8.0 to 15.0 years, studying in English medium school participated in the study. None of the fourteen children had any known or reported hearing, neurological, developmental or emotional problems.

Inclusionary criteria for experimental group

- Children ranging in age from 8.0 to 15 years, studying in English medium school
- The mean age range of participants was 10 years.
- Children diagnosed as LD by a Speech Language Pathologist (SLP). Early Reading Skills (Loomba, 1991) was used as a tool to identify children with LD.
- All the LD participants were assessed by a clinical psychologist for their intelligence quotient (IQ) and reported to be average or above average.

Four children were in 7^{th} standard, one in 6^{th} standard and two in 3^{rd} standard. All participants were enrolled on a remediation program.

Inclusionary criteria for control group: Equal number of participants matched for the age, school grade, handedness and medium of instruction with learning disabled group participated in the study as control group.

Common inclusionary criteria for both the groups: Subjects with no significant history of any neurological, psychological and or sensory deficits

Test Material

Two sets of linguistic stimuli were prepared, one as target list and the other as prime list.

1. Target list consisted of 30 bisyllabic and 30 trisyllabic word lists taken from 3 semantic categories (10 in each) which were randomized before the administration of each task.
2. Prime list consisted of 2 sets of words with 30 words in each set.
   - First set consisted of 30 semantically related words to the target list with no overlapping phonemes in any position.
   - Second set consisted of 30 non-meaningful/pseudo-words with the same phoneme at initial word position as presented in target words
   - The target and prime were matched for syllable length, familiarity and semanticity

Speech-language pathologist assessed the selected stimuli for familiarity and semanticity. The stimuli with 90% familiarity and with high semanticity were included in the study

Tools

- The Screening Checklist for Auditory Processing (SCAP) (Yathiraj & Mascarenhas, 2002) was administered to screen for any central auditory processing disorder.
- Pentium 200 MHz computer with a 20" monitor and microphone with flat frequency response was used.

- *DMDX software (Version 3.0)

Instructions

Before placing the headphones the experimenter told the participants 'now you will hear words over the headphones while you name the words on the computer screen. Your job is to ignore the words as much as possible and to concentrate on reading (as fast as possible and in a loud voice) what you see and not what you hear'.

Recording and segmentation procedures for stimulus primes

A young adult male (23 years) with no known speech and hearing problems served as the speaker for recording the test stimuli .The stimuli were recorded in a quiet room with a high quality recorder and microphone positioned approximately 3 inch from the participant's mouth. The frequency response of the microphone was flat to about 20 KHz. Two repetitions of each stimulus were produced in a random order.

Procedure

In total there were three different conditions of 30 words each (90 words total) that were responded to by each child in one sitting with a brief (1-2 min) break between conditions to permit the preparation of the next condition.

The prime words were presented at stimulus onset asynchrony (SOA) of 250 ms. SOA was utilized to ensure that none of the auditorily presented primes would temporarily overlap the visual onset of the target words.

- Participants were seated in a comfortable position facing a desktop computer attached to a 20" monitor in a quite room.
- The responses were recorded with a high quality microphone placed at distance of 10 cm from the participant's mouth
- Testing was carried out in allay environment.

The priming experiment task was carried out in the following steps:

Step 1

The target words along with auditory prime were presented. The participants were instructed to ignore the auditory stimuli and respond only to the words appearing on the computer screen and the speech reaction time (in milliseconds) was recorded. Using DMDX software speech reaction time (SRT) were measured and analyzed in following 3 word-reading conditions which were employed in a counter-balanced order across participants.

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* Note: DMDX software (Version 3.0) was developed by Kenneth I.Forster and Jonathan C.Forster at Monash University and at the University of Arizona. DMDX is Win 32-based display system used to measure reaction times to visual and auditory stimuli. Detailed information regarding this software is available at the following website:www.u.Arizona.edu/~kforster/dmdx/dmdx.htm

Stimulus Onset Asynchrony (SOA) is the time period from the onset of the auditory prime to the onset of the target word

Step 2

Semantic priming task

The priming task was carried out in the following three conditions:

- No prime condition in which no auditory stimulus were presented before word display
- Related prime condition in which a word semantically related (but not phonologically similar) to the target word was presented auditorily 500 ms before word display.
- Unrelated prime condition in which a word semantically unrelated (not phonologically similar) to the target word was presented auditorily 500 ms before word display.

Step 3

Phonological priming task

The priming task was carried out in the following three conditions,

- No prime condition
- Related prime condition- in which a non-meaningful phonologically similar (same initial syllable and syllable length) to the target word was presented auditorily 500 ms before word display.
- Unrelated-prime condition- in which a word phonologically unrelated (no similar syllable but same syllable length) to the target word was presented auditorily 500 ms before word display.

Errors

Word reading responses were considered in error and the associated speech reaction time was excluded from further analysis if the participant's response met any one of the following criteria:

a) Was preceded by or associated with any type of speech disfluencies
b) Was preceded by or associated with any type of extraneous noise or sound
c) Failed to trigger the gating switches on the voice-activated microphone
d) Generated a speech reaction time less than 250 ms or greater than 2000 ms

Results obtained were tabulated and appropriate statistical analysis was carried out to further understand the intrinsic details of the present study.

Results

The aim of the present study was to focus on the relative performance of children with LD in comparison to normal children on semantic and phonological priming tasks. Broadly two measurements were done and they were:

i. Accuracy of responses and

ii. Reaction time (RT) measurements

i. **Accuracy of responses**

Percentages of accurate responses within each task and in each condition for normal children and children with LD were listed separately in the following table. The maximum number of valid responses in each case was 210. The percentage of accurate responses is calculated using the following formula –

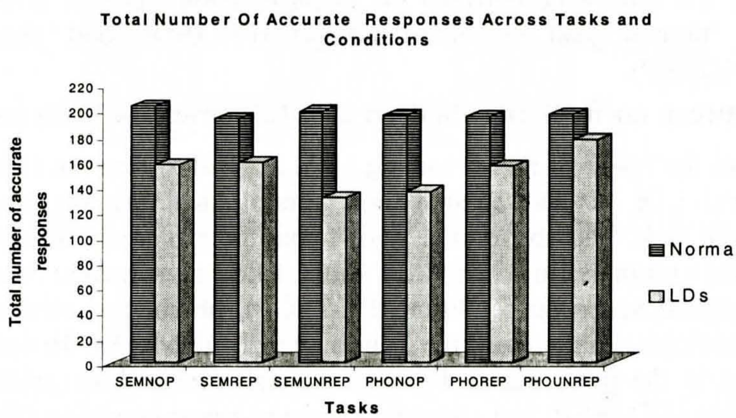
$$\frac{\text{Total number of accurate responses}}{\text{Total number of responses}} \times 100$$

Table 1: Percentage accurate responses across all the tasks and conditions in both the groups

Groups	Accurate Responses			
	Total number of accurate responses		Percent	
	Normals	LDs	Normals	LDs
PHONOP	196	136	92.5%	64.2%
PHOREP	195	156	92.0%	73.6%
PHOUNREP	197	177	92.9%	83.5%
SEMNOP	203	157	95.8%	74.1%
SEMREP	193	159	91.0%	75.0%
SEMUNREP	199	131	93.9%	61.8%

Note: SEMNOP = Semantic No-prime condition; SEMREP = Semantic Related-prime condition; SEMUNREP = Semantic Unrelated-prime condition.

Graph 1 shows the total number of correct responses in both normal children and children with LD across both the tasks and across all the three conditions



Graph 1: Total number of accurate responses by normals and LDs across tasks and conditions

Both, Table 1 and Graph 1 clearly show that the total number/percentage of accurate responses are consistently more in normal children than in children with LD across all the three conditions i.e. no-prime, related-prime and unrelated-prime in both the tasks i.e. semantic and phonological. In the phonological priming task number of accurate responses in normal children for phonological no-prime condition (PHONP) was comparatively more than the phonological related-prime condition (PHOREP) and phonological unrelated-prime condition (PHOUNREP).

However the graph does not show any evident difference in the performance of these children among the above three conditions. Similarly on semantic priming task the performance of normal children across the three conditions was not so evident i.e., semantic no-prime condition (SEMNOP) was comparatively more than the semantic related-prime condition (SEMREP) and semantic unrelated-prime condition (SEMUNREP).

2. **Reaction Time Measurements**

a. Comparison between normals and children with LD on reaction time measurements

Independent sample t-test was done to compare the reaction time across normal children and children with LD across phonological priming and semantic priming tasks.

Table 2 shows that children with LD take relatively longer reaction time (RT) compared to normal children on both semantic priming and phonological priming task in all the conditions i.e. no-prime, related-prime and unrelated-prime condition.

Table 2: Mean and Standard Deviation for Normals and children with LD

Conditions	Normals		LD		t-value	Sig. (2-tailed
	MEAN	SD	MEAN	SD		
SEMNOP	587.871	67.701	937.066	344.630	2.631	.022*
SEMREP	655.809	102.791	790.119	230.070	1.410	.184
SEMUNREP	662.347	108.324	884.585	343.074	1.634	.128
PHONOP	677.780	90.163	1060.785	362.309	2.714	.019*
PHOREP	694.961	126.182	1027.014	352.369	2.347	.037*
PHOUNREP	714.647	112.635	967.804	254.395	2.407	.033*

*Significant at 0.05 level

Descriptively the difference between the mean reaction times of normals and children with LD is more in 'phonological no-prime condition' (PHONOP) and 'phonological related-prime condition' (PHOREP).

b. Comparison between normals and children with LD across the tasks and conditions

Table 2 shows the result of paired sample t-test applied to find the significant difference between normals and LDs across semantic and phonological priming task and respective conditions within each task. The above table shows that there is a significant difference in the performance between normals and children with LD on semantic no-prime condition (SEMNOP), phonological no-prime condition (PHONOP), phonologic related-prime condition (PHOREP) and phonologic unrelated-prime condition (PHOUNREP). However there was no significant difference in the performance between normals and children with LD on semantic related-prime condition (SEMREP) and semantic unrelated-prime condition (SEMUNREP).

The two groups i.e., normal children and children with LD underwent two tasks-phonological priming and semantic priming task. In turn each task subdivides into 3 conditions:

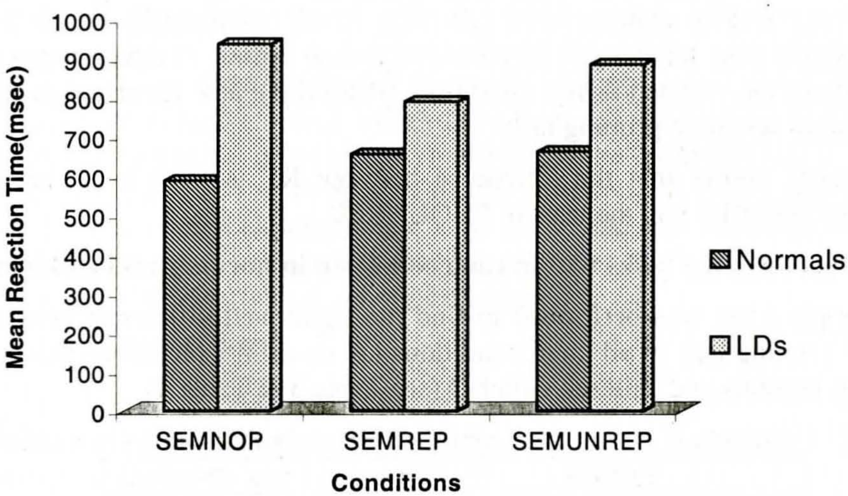
- No-prime condition
- Related prime condition
- Unrelated-prime condition

c. Comparison among three conditions within semantic priming task in normal children and children with LD

Repeated measures ANOVA were applied to see the difference among the three conditions i.e. no-prime, related-prime and unrelated-prime condition in normals within both semantic and phonological priming task.

In Table 2, the mean reaction time was found to be lesser in SEMNOP condition compared to SEMREP and SEMUNREP. However no significant difference across these three conditions was found in normal children. Repeated measures ANOVA revealed that there is no significant difference observed between the three conditions in semantic priming task in normal children [$F(2, 12) = 2.055$, $p>0.05$].

As indicated in Table 2 the longest reaction time is in no-prime condition and the least in related-prime condition with unrelated-prime condition with the mid value. Descriptive statistics reveal that there is no significant difference observed between the three conditions in semantic priming task in LDs [$F(2,12) = 0.334$, $p>0.05$].



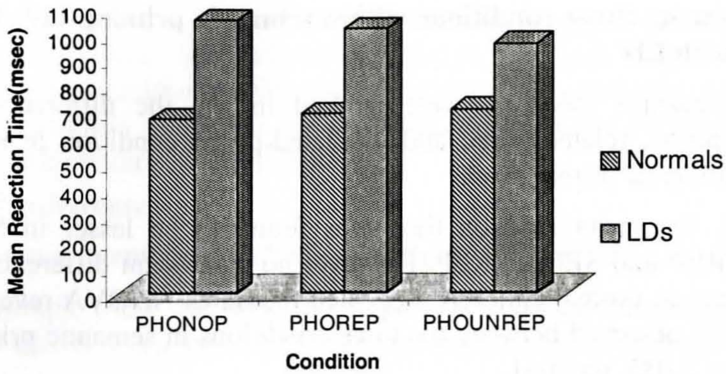
Graph 2: Mean Reaction Time (RT) of normals and children with LD in semantic priming task

Graph 2 shows obvious larger reaction time taken by children with learning disability (LD) than normal children across all the three conditions i.e.no-prime, related-prime and unrelated-prime, within semantic priming task.

d. Comparison among three conditions within phonological priming task in normal children and children with LD

Repeated measures ANOVA was applied to find out mean and standard deviation (SD) among the three conditions within phonological priming task in normal children.

Table 2 shows the similar trend as seen in semantic priming task i.e., gradual increase in mean reaction time from no-prime condition (PHONOP) to related-prime condition (PHOREP) to unrelated-prime condition (PHOUNREP). Results of ANOVA reveal that there is no significant difference observed between the three conditions in phonological priming task in normal children [$F(2, 12) = 0.736$, $p>0.05$].



Graph 3: Mean Reaction Time of normals and children with LD in phonological priming task

Table 2 also shows a gradual decrease in mean reaction time from no-prime condition to related-prime condition to unrelated-prime condition in children with LD. Descriptive statistics reveal that there is no significant difference observed between the three conditions in phonological priming task in children with LD [$F(2, 12)=0.163, p>0.05$]. Graph 3 also shows obvious larger reaction time taken by children with LD than normal children across all the three conditions i.e., no-prime, related-prime condition (PHOREP) and unrelated-prime condition (PHOUNREP) within semantic priming task.

It also clearly shows that the difference between RT is most in no-prime condition (PHONOP) than in PHOREP and the least in PHOUNREP.

e. Comparison between the tasks within each condition in normals and children with LD

Paired sample t-test was performed to find the significant difference between semantic and phonological priming task in all three conditions i.e. no-prime, related-prime and unrelated-prime condition in normals and children with LD (see Table 3 & Table 4).

Table 3: Comparison within each condition across both the tasks in normals

TASKS	t-value	Sig. (2-tailed)
SEMNOP - PHONOP	3.128	.020*
SEMREP - PHOREP	1.187	.280
SEMUNREP - PHOUNREP	1.490	.187

* Significant at 0.05 level

Table 4: Comparison within each condition across both the tasks in LDs

TASKS	t-value	Sig. (2-tailed)
SEMNOP - PHONOP	.591	.576
SEMREP - PHOREP	1.532	.176
SEMUNREP – PHOUNREP	.414	.693

The results obtained in no-prime condition for normal children indicated a significant difference between semantic no-prime condition (SEMNOP) and phonological no-prime condition (PHONOP). On the contrary there is no significant difference obtained in the other two conditions i.e. related-prime condition (PHOREP) and unrelated-prime condition (PHOUNREP) in normal children (see Table 3). The results obtained for children with LD showed no significant difference between semantic and phonological priming tasks in all the three conditions (See Table4).

Discussion

The aim of the present study was to focus on the relative performance of children with LD in comparison to normal children on semantic and phonological priming tasks. Broadly two measurements were done and they were:

i. Accuracy of responses and

ii. Reaction time measurements

i. **Accuracy of responses**

The results in Table 1 and Graph 1 shows that the total number/percentage of accurate responses are consistently more in normal children than in children with LD across all the three conditions i.e. no-prime, related-prime and unrelated-prime in both the tasks i.e. semantic and phonological. The poor performance of children with LD on tasks of visual word recognition is generally attributed to the deficit in language processing abilities which further affects their reading ability too (Lahey, Edwards & Munson, 2001). Graph 1 showed a remarkable difference in the performance of normal children and children with LD across both the tasks (i.e. semantic priming task and phonological priming tasks) and across the three conditions i.e. for PHONOP, PHOREP, PHOUNREP, SEMNOP, SEMREP and SEMUNREP. This result supports research which has shown that normal children are able to utilize both semantic and phonological routes in order to decode a string of letters while reading. However children with LD do not use both or either of the routes as efficiently as the normal children.

ii. **Reaction time measurements**

The results obtained on RT measurements are discussed in the following sub-sections:

a) Comparison between normal children and children with LD on reaction time measurements across semantic and phonological priming tasks and across conditions.
b) Comparison between normal children and children with LD across both the tasks and across the three conditions in each task
c) Comparison between both the tasks within each condition in normal children and children with LD

a) **Comparison between normal children and children with LD on reaction time measurements across semantic and phonological priming tasks.**

Overall the results in Table 2 showed that children with LD took relatively longer reaction time compared to normal children on both semantic priming and phonological priming tasks across all the conditions i.e. no-prime, related-prime and unrelated-prime condition (Ferrand & Grainger,1993). The results yielded evidence of a general temporal processing deficit seen in children with LD found by various researchers who studied processing abilities in children with LD (Shapiro, Ogden & Lind-Blad, 1991; Heim, Freeman, Eulitz & Elbert (2001). Thus our hypothesis supports the findings that children with LD present with temporal processing deficit in the visual modality.

b) Comparison between normal children and children with LD across both the tasks and across the three conditions in each task

Results in Table 2 showed a significant difference for reaction time measurements between the performance of normal children and children with LD on phonological priming tasks across all the three conditions (i.e. PHONOP, PHOREP & PHOUNREP). Table 2 also showed that children with LD have longer RT compared to normal children on all the three conditions in phonological priming task. This could be because normal children have a well established sub-lexical or phonological or grapheme-phoneme-conversion (GPC) route for word recognition compared to children with LD. The inability to read words faster in children with LD indicates that these children utilize the GPC route less efficiently when compared to normal children (Beauvois & Derouesne, 1979). However normal children process the strings of letters in words much faster either through the semantic (lexical) or phonological (GPC) route. Thus the results of the present study is in consonance with other research findings (Coltheart, 1987; Ellis & Young, 1988) who argued that reading takes place either via the semantic system or by GPC.

Results on semantic priming tasks for reaction time measurements between the performance of normal children and children with LD showed that children with LD have longer RT compared to normal children on all the three conditions. However, a statistically significant difference was found only in one condition i.e. SEMNOP (see Table 2). In SEMNOP condition the children under study were not primed for word reading and hence there was no cueing that helped these children in recognition. Normal children could however utilize either of the two routes i.e. lexical or GPC route to decode the target words and read them. But children with LD took longer time to decode the target words compared to the normal children. This difference could be due to slower lexical or semantic processing abilities in children with LD on semantic tasks.

Table 2 also shows no significant difference between the performance of these two groups on SEMREP and SEMUNREP conditions. This could be because children with LD are performing almost like the normal children as they are aided by priming cues on word reading tasks. From the above results we can infer that cueing can aid poor readers or children with LD to perform equally well as the normal children. Thus the present study implicates the need to utilize the priming cues in remedying children exhibiting various reading disorders as well as children with LD.

c) Comparison between both the tasks within each condition in normal children and children with LD

The results obtained in no-prime condition for normal children showed longer RT for phonological no-prime (PHONOP) condition compared to semantic no-prime (SEMNOP) condition and this difference was found to be statistically significant (see Table 3). This could be because normal children are able to make use of both the semantic and phonological cues in order to decode the target words faster. However no significant difference was found across the above two conditions in children with LD probably because of the absence of priming cues in these children. This hypothesis refutes studies which have shown larger semantic priming effects for children with LD than for good readers (Schwantes, 1985, 1991; Elbro & Arnbak, 1996; Nunes &

Bindham, 1998; Booth & MacWhinney, 1999). Plaut and Booth (2000) suggest that good readers show small semantic priming effects as their well developed spelling sound mapping allows them to decode words rapidly thereby reducing the effects of semantics on word recognition. Poor readers in children with LD show more semantic priming because their underdeveloped GPC connections allow semantic information to compensate for their slow word recognition.

From the above findings of the present study we note that children with LD have performed poorly compared to normal children on all the semantic and phonological priming tasks. However larger semantic priming effects are seen in normal children as well as children with LD. These results do not agree with the above quoted studies wherein the subjects include those children in the western countries whose native language as well as medium of instruction is the same i.e. English. English is an alphabetic language and by nature has poor grapheme to phoneme mapping (Kolers, 1966; Mackey, 1968; Albert & Obler, 1978; Altenberg & Cairns, 1983; Nas, 1983; Kirsner, Smith, Lockhart, King & Jain, 1984; Thirumalai & Chengappa, 1986; Beauvillain,1992; Keatley, Spinks & DeGelder, 1994; Brysbaert,1998; Thomas & Allport, 2000; Beland & Mimouni, 2001;). These children master the regularities and irregularities of English over a period of exposure. Hence these normal children show larger phonological priming effects in word reading paradigms (Grainger, 1993; Grosjean, 1998; Green, 1998b; Kotz, 2001;) However, this may not be true for Indian languages (like Hindi, Kannada, etc.) which are considered as semi-alphabetic languages and which have good grapheme to phoneme mapping. Thus Indian children would probably show lesser phonological priming effects in comparison to the western children due to the differences in language orthographic structures learnt at school (like Kannada and English). Indian children would learn an alphabetic language like English use the semantic route more efficiently than the western children who learn to read English through the phonological route.

The present investigation aimed at exploring semantic and phonological prime/cue processing at lexical linguistic level in children with LD. In turn the study focused on the nature of recognition deficits and levels of breakdown in lexical processing in learning disability due to the interfering primes while reading a string of letters.

Statistical analysis of the data revealed that on accuracy measurements children with LD took relatively longer reaction time compared to normal children on both semantic priming and phonological priming tasks across all the conditions yielding evidence of a general temporal processing deficit in children with LD. The inability to read words faster in children with LD indicated that these children utilize the GPC route less efficiently when compared to normal children (Beauvois & Derouesne, 1979).

Results on semantic priming tasks for reaction time measurements between the performance of normal children and children with LD also showed that children with LD have longer RT compared to normal children on all the three conditions and in both the tasks.

Conclusions

To conclude from the above findings of the present study we note that children with LD perform poorly compared to normal children on all the semantic and phonological priming tasks. However larger semantic priming effects are seen in normal children as well as children with LD which is not in consonance with the earlier findings of studies done in western population. Indian children would probably show lesser phonological priming effects in comparison to the western children due to the differences in language orthographic structures learnt at school (like Kannada and English). Thus this makes way for a need for future research in Indian languages and research on second language influence on Indian languages in children who encounter learning problems. In the present study similar pattern of differences is seen in children with LD, however, with larger temporal processing deficit in comparison to normal children.

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