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Cross-linguistic dissociations in Kannada-English bilingual persons with aphasia and alexia

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Abstract: Individuals with alexia manifest reading impairments comparable to spoken language impairments. With escalating dependency on communication through texts, emails, and other social media sources, these individuals express their interest in improving written language skills as well. Alexia in bilinguals in the Indian scenario is of special interest, owing to diverse geographical, cultural, traditional, and linguistic demarcations in India. Although substantial research is reported on bilingual aphasia, evidence on bilingual alexia is scarce. The study aimed to explore the cross-linguistic dissociations in Kannada-English bilingual individuals with alexia in post-stroke survivors. Thirteen Kannada-English bilingual individuals (10 males and 3 females) with reading and language impairments post ictus, above 18 years of age were recruited. Participants were subjected to neurobehavioral linguistic and reading tasks in both Kannada and English. The performance of linguistic tasks and reading tasks were analysed for cross-linguistic distinctions, linguistics versus reading, and correlation between linguistics and reading abilities. Results revealed evident cross-linguistic dissociations, wherein participants outperformed in Kannada (L1) in both linguistics and reading domains. All performed superior in the linguistics domain compared to reading. In both languages, semantic abilities were best performed within the linguistic domains. Oral reading abilities fared poor scores relative to reading comprehension. The correlation analysis revealed strong correlation between oral reading and semantics > phonology > syntax. Reading comprehension strongly correlated to syntax > phonology > semantics. The study proved convincing linguistic influences on reading abilities in Kannada- English bilingual context. Most investigations have predominantly centred on case observations, and have often lacked thorough pre- and post-rehabilitation assessments of linguistic and reading impairments using equivalent tests in a bilingual context. This study proves to be a preliminary attempt in this context. A much larger bilingual alexia cohort would aid in substantiating the reading impairments in a variant of subgrouping of aphasia.

Keywords: Bilingual aphasia; Alexia; Cross linguistic dissociations; Oral reading; Reading comprehension.

1.0 INTRODUCTION

Alexia is an acquired condition resulting in impaired abilities to comprehend and/or read written scripts aloud, secondary to brain lesions involved in reading processes (Goral, 2019). When disruptions occur in the processes essential for reading, such as visual recognition, phonological processing, lexical comprehension, and semantic processing, various forms of alexia may ensue (Crisp & Ralph, 2006; Madden et al., 2018). These acquired reading impairments often coincide with left hemispheric strokes, which are also associated with aphasia. Aphasia is a multifaceted condition in which persons with aphasia (PWAs) exhibit pervasive, multimodal language impairments featured by deficits in auditory comprehension, spoken production, reading, and writing, varying degrees. Most researchers and clinicians believe that the aphasia condition is not directly linked to loss of language (either vocabulary or rules) but leads to impaired processes necessary for comprehending, formulating, and producing spoken and written language (Brookshire et al., 2014).

Just as linguistic aspects are multifaceted in PWAs, reading impairments vary extensively across each PWA, depending on the type and nature of the language deficits. There is no predetermined relation between alexia classification and diagnostic categories of aphasia. Different types of aphasia may manifest the same reading impairment, and/or one type of aphasia can have different reading impairments (Hillis & Caramazza, 1992). Identification of impaired components of reading and writing is a crucial factor in remediating these deficits. Alexia in bilinguals in the Indian scenario is of special interest, owing to diverse geographical, cultural, traditional, and linguistic demarcations prevailing in India. Understanding the nature and processes involved in a multitude of languages and scripts through psycholinguistic paradigms among PWAs is an intriguing and highly relevant exploration of the Indian population.

The differences observed in the severity and characteristics of reading impairments among bilingual individuals with alexia are attributed to uneven language representations in the brain. Various languages with their respective writing system vary in how their orthography translates visual forms (graphemes) into language. Disparities arise in the direction of reading (e.g., right to left, left to right), the size of sound units corresponding to graphemes (e.g., phonemes, syllables), and the level of transparency and regularity in the relationship between written and spoken forms (Madden et al., 2018). Although there is substantial research reported on bilingual aphasia, evidence on bilingual alexia is scarce (e.g., Karanth, 1984).

Each language has its unique linguistic properties. Whether the impairment is in spoken or written form, the dissociations in either aspect across the linguistic distinctions are paramount. Aphasiologists have endeavoured to comprehensively grasp linguistic and reading impairments, predominantly among English speakers (e.g., Beaton & Davies, 2007). A plethora of research in cognitive neuroscience has concentrated on elucidating how native English stroke survivors are affected in both spoken and written communication. A more intricate inquiry arises from the necessity to comprehend linguistic dissociations in bilingual individuals with alexia.

Aphasiologists have attempted to explore alexia in bilingual stroke survivors through single-subject designs (e.g., Ohno et al., 2002; Senaha & Parente, 2012) to investigate the manifestation of variants of alexia across several orthographies. Multiple attempts were made to delineate the patterns of reading impairments in individuals with alexia through neurocomputational models. One of the most well-acknowledged models is the Distributed Route Cascaded (DRC) model by Coltheart and colleagues (2001).

DRC elucidates that languages featuring transparent orthographies, characterized by a clear and consistent relationship between written symbols (graphemes) and their corresponding sounds (phonemes), tend to encourage reliance on the Grapheme-Phoneme Correspondence (GPC) route. Additionally, skilled readers in transparent orthographies also employ the lexical route, which is presumed more efficient (Coltheart, 2006). Cross-linguistic studies are warranted to substantiate or refute the influence of orthography type on the degree of impairment in reading skills of bilingual individuals with alexia.

Ohno et al. (2002) reported a Japanese-English bilingual individual with pure alexia secondary to a left posterior cerebral artery (PCA) lesion. Post-stroke, the individual's language abilities were unimpaired. However, he could not read in either kana (a Japanese script with syllabic orthography) or kanji (a Japanese script with logographic orthography). The authors noted that kanji exhibited lesser impairment compared to kana. However, English showed superior performance compared to both, attributing to orthographic

disparities between English and Japanese. Interestingly, the most transparent orthographic script, kana, was found to be the most impaired. A parallel dissociation was reported by Hashimoto and Uno (2016) between kana and kanji scripts.

A contrary pattern was noted in a few case studies exploring bilingual speakers of Arabic-Hebrew (Ibrahim, 2009), Telugu-Kannada (Karanth, 1981), and Mongolian-Chinese (Weekes et al., 2007), wherein L1 was less impaired than L2 in all these instances. The authors attributed the dissociation in the language performance to the order of language acquisition in exploring the effect of orthography on reading impairment post ictus, wherein L1 was better than L2. Thus, native language (L1) was relatively spared compared to L2. Furthermore, a few case studies reported contrary effects of language acquisition. L2 was better preserved than L1, observed in bilingual individuals of Arabic-French (Beland & Mimouni, 2001) and Hindi–English (Karanth, 2002). Interestingly, the equipotent effect of language acquisition was noted in bilingual alexics of Spanish–English (Laganaro & Venet, 2001), Kannada- English (Ratnavalli et al., 2000) and, Welsh- English (Beaton & Davies, 2007).

Thus, evidence from bilingual and biscriptal individuals with alexia suggests that the dissociations between the languages may be comparable or varied due to possible orthographic effects (transparent vs opaque scripts), age and language acquisition order, language proficiency, and other factors. Apart from these factors, another salient factor that may contribute to the differential impairments in the reading abilities of two languages post-stroke would be the extent of spoken language impairment, which is seldom attempted. The simultaneous occurrence of alexia in individuals with aphasia is now well documented. However, the disconnect or association between spoken language impairment and the subsequent effect of alexia characteristics is scarcely explored. Few spoken language models (e.g., Dell et al., 1997) ideally do not believe in the relevance of orthographic abilities.

Similarly, few written language or reading models (e.g., Coltheart et al., 2001) do not press the effect of spoken language skills on reading abilities or the possible core skills that allow language to be shared across modalities. Certain models, such as the one proposed by Rapcsak and Beeson (2000), explain processing for both spoken and written language. These models still describe spoken and written language depending on distinct components specific to each modality of language.

Hence, impairment in spoken language is believed to be the mainstay of reading impairment. Prodigious literature on aphasia research is on spoken language impairment, rendering subtle emphasis on written language or reading impairment (orthography dependent). The majority of PWAs are literate and own a professional background before stroke. Additionally, there is augmented dependence on written communication (like messaging, social media, etc). Individuals with acquired language impairments (PWAs) demonstrate a heightened desire to enhance their reading and writing abilities. However, challenges in these skills, combined with difficulties in spoken language, present obstacles to their active participation in the community. Literature support for understanding the relationship between the co-existing spoken language impairments and reading deficits in acquired language impairments is scarce. Specifically, in PWAs, the relationship between the extent of language components (phonology, semantics, and syntax) being affected and their subsequent effect on reading impairment is warranted to understand the processes involved and supplement the rehabilitation of individuals with alexia. The preponderance of reading and writing difficulties significantly centres on the script and orthographic characteristics of the specific language. The Western models fail to provide adequate explanations for reading and writing problems in Indian languages, which are transparent and alpha-syllabic (Karanth, 2003).

The comprehensive analysis of language and reading impairments concerning each is deemed crucial. These factors also facilitate estimation and apprehending the extent to which language and reading abilities are affected. Understanding the magnitude of deficits helps speech-language pathologists (SLPs) render the treatment based on the intact modality or based on the extent of profound impairments. Premorbid reading skills and current interest or need to read will dictate the extent of treatment required for these skills. Consequently, many factors should be considered when intervening in reading impairments in alexia, owing to the vast bilingual population in Indian states. It is essential to explore the reading impairments within the context of cross-linguistic influences, orthographic effects, and proficiency levels, and their connection to subsequent spoken language processing abilities (semantic, syntax, and phonology) between Kannada (a predominant language of the Dravidian family, spoken in South India) and English. This specific focus is of particular interest in the present study. Thus, the study aimed to explore the cross-linguistic dissociations

in Kannada- English bilingual individuals with alexia in post-stroke survivors. We specifically aimed to explore (a) the cross-linguistic variations in linguistics abilities across Kannada (L1) and English (L2); (b); the cross-linguistic variations in reading impairments across Kannada (L1) and English (L2) and (c) whether there is the influence of linguistic abilities (semantic, syntax & phonology) on reading abilities (oral reading & reading comprehension) solely in Kannada (L1) and English (L2) among Kannada- English bilingual post-stroke individuals.

2.0 MATERIALS AND METHODS

2.1 Participants

In the study, thirteen Kannada-English bilingual individuals with post-ictus language and reading impairments were recruited through purposive sampling. All were native speakers of Kannada (L1) and had acquired English (L2) during their schooling. All the participants enrolled in the study were assessed with the Kannada version of Western Aphasia Battery (WAB-K) (Shyamala et al., 2008) to ascertain the presence and type of aphasia. The study adhered to strict inclusion and exclusion criteria. PWAs with left cerebrovascular accident (CVA), with adequate auditory verbal comprehension abilities, who possessed right-handedness pre-morbidly, and who pursued at least secondary education in English medium were recruited in the study. Individuals with a history of developmental dyslexia or any other neurological ailments other than left hemisphere ictus and/or individuals with visual impairment or visual neglect were excluded from the study. All subjects in the study passed the Mini-Mental State Examination (MMSE; Folstein et al., 1975) with scores between 26 and 30 (Mean=28.2, *SD*=0.50). MMSE was administered to rule out the presence of cognitive linguistic impairments among these individuals. The final test population comprised 10 males and 3 females with an average age of 42.2 years (*SD*=15.58; range 20-68) and an average of 16 years of formal education (*SD*=1.77; range 12-18). Refer to **Table 1** for demographic details of the participants. All participants gave informed consent to take part in a multisession language assessment using the protocol approved by the Ethics Committee for Bio-Behavioral Research Projects involving Human Subjects at All India Institute of Speech and Hearing, University of Mysore, India (Ref no. DOR.9.1/PhD/AS/926/2021-22; dated 08.12.2022).

Table 1. Demographic details of thirteen participants with aphasia enrolled in the study.

Patient	Age	Gender	Education (years)	Qualification	MPO[1] (months)	MRI Findings	Aphasia Quotient
P1	22	Male	16	Graduation	26	Acute infarct in Basal Ganglia & occlusion in Lt MCA[2]	82.5
P2	46	Male	15	Graduation	45	Acute infarct in Lt MCA[2]	67.7
P3	20	Female	16	Discontinued graduation	12	Tempero partial haemorrhagic infarct	59.1
P4	32	Male	18	Post-graduation	10	Acute non haemorrhagic CVA[3] Lt Basal Ganglia	80.5
P5	34	Male	18	Post-graduation	17	Acute recurrent CVA[3] in Mt MCA[2]	75.8
P6	56	Female	18	Post-graduation	34	Haemorrhagic stroke Lt MCA[2]	86.2
P7	24	Male	14	Discontinued graduation	16	Complete thrombosis in Lt ICA/Lt MCA[2]	70.6
P8	48	Male	12	Higher secondary	9	Acute infarcts involving Left Fronto-Parietal lobe	45.6
P9	37	Male	15	Discontinued graduation	28	Tempero partial haemorrhagic infarct	66.3
P10	57	Male	16	Graduation	18	Acute Lt front parietal infarct	66.0
P11	59	Female	16	Graduation	40	Acute Lt MCA[2]	68.0
P12	48	Male	18	Post-graduation	23	Subacute infarct left fronto parietal lobe- subcortical regions	56.5
P13	68	Male	16	Post-graduation	17	Chronic infarct in Rt PCA[4]	87.4

Note: **1= Month post stroke Onset, **2**- Middle cerebral Artery, **3**- Cerebrovascular atrophy, **4**- Posterior Carotid Artery.

2.2 Materials

The study protocol entailed two major domains, namely linguistics and reading. Each domain is further comprised of specific subdomains. The linguistic subdomains were semantics, syntax, and phonology. Likewise, the reading subdomains were oral reading and reading comprehension. A similar test protocol was followed in the study by Madden et al. (2018), wherein native speakers of English individuals with aphasia were assessed for linguistic and reading abilities to explore the effects of linguistics in post-stroke survivors. However, the present study aimed to explore linguistic effects on reading abilities in Kannada- English bilingual context in Indian scenario. Thus, all the tasks and the stimuli were compiled separately for both Kannada and English languages from various tasks of standardized test batteries, namely Western Aphasia Battery – Kannada (Shyamala et al., 2008) & English (Kertesz, 2006), Linguistic Profile Test- Kannada (LPT-K) (Karanth, 1997), Manual for Adult Non -Fluent Aphasia Therapy in

Kannada (MANAT-K) (Venugopal & Goswami, 2008), Manual for Adult Fluent Aphasia Therapy in Kannada (MAFAT-K) (Chaitra & Goswami, 2009), Manual for syntax processing activities for PWA (Deepak & Nagaraj, 2021), Dementia Assessment Battery (DAB) (Sunil & Shyamala, 2009), Manual for reading, writing and arithmetic for persons with aphasia in Kannada (MTR3A2- K) (Kruthi & Goswami, 2011)

2.3 Procedure

The Kannada and English stimuli set was subjected to validation by nine well-experienced (above 5 years) Kannada-English bilingual SLPs for appropriateness, stimulability, imageability, frequency, and sensitivity. Stimuli were rated based on a 3-point Likert scale, where 'zero' signified 'least relevant' and 'two' signified highly relevant. Final stimuli were compiled using a point-to-point comparison method, and the set that received scores above 80% on an average rating was considered for the final stimuli.

All assessments were carried out in a quiet room, and free from distractions. The study protocol entailed three primary investigations:

a) *Linguistic Tasks* specific to Kannada and English, including semantics, phonology, and syntax.
b) *Oral Reading Tasks* at single word level, specific to Kannada and English language, including real word reading, irregular word reading, and non-word reading.
c) *Oral Reading Comprehension* across single word, sentence, and paragraph levels in both Kannada and English.

The tasks and subtasks of linguistics and reading domains are depicted in **Table 2**. Task-specific instructions were given to every participant before administering each task (**Appendix A**). Also, trial stimuli were presented for every task to familiarize them. The written stimuli (black and bold, 42 font size), and coloured pictures were presented over the desk in printed format on an A4 size flash card. No specific cues were rendered while carrying out the tasks. A minimum of thirty seconds and a maximum of 2 minutes time limit was imposed for each stimulus while testing, and authors refrained from response-contingent feedback. The tasks were counterbalanced within the language and also across languages. One-half of the total participants were tested in the Kannada language (L1), and the rest were examined in English (L2). Likewise, one-half of the participants were subjected to linguistic tasks first and the other half to reading tasks. Counterbalancing was done to rule out the effect of stimuli complexity and the performance load on the participants.

Table 2. List of tasks and subtasks compiled in linguistic and reading domains.

Domains	Semantics	Phonology	Syntax
Linguistic	Picture Association	Minimal Pair judgement	Comprehension of Plural forms
	Picture Matching	Real word rhyme judgement	Comprehension of Tense Markers
	Auditory Comprehension	Non word judgement	Spoken sentence to picture matching
	Auditory judgement	Parsing/blending sounds	Sentence completion with locatives
Reading	**Oral reading**	**Reading comprehension**	
	Real word	Word level	
	Irregular word	Sentence level	
	Non word	Paragraph level	

2.4 Scoring

Each item on each task received a score of 'one' for correct response and 'zero' for erroneous response. Self-corrections were permitted, and the participant's final response was considered. The total raw score of each task was converted into percentile score (e.g., picture association percentile score average of total raw score/ total max score of the task* 100). This pattern of standardized scoring was ensured as the total items varied across subtasks and to rule out the effect of stimuli complexity on their performance.

In summary, the study administered two main domains: linguistics and reading. The overall linguistic scores were computed using the language quotient (LQ) and reading quotient (RQ) for all the participants' overall reading scores. Subsequently, an average percentile score for specific linguistic subdomains, namely semantics, syntax, and phonology, was computed. The average percentile scores for oral reading and reading comprehension were calculated within the reading domain. These scores were further subjected to specific and detailed statistical analysis.

3.0 RESULTS

The study had three main objectives. The first objective was to analyse (a) the cross-linguistic effects across Kannada (L1) and English (L2) in linguistics abilities; (b) the cross-linguistic variations in reading impairments across Kannada (L1) and English (L2) and (c) to understand the relationship between linguistic abilities (semantic, syntax & phonology) and reading abilities (oral reading & reading comprehension) solely in Kannada (L1) and English (L2) among Kannada- English bilingual alexia post stroke survivors.

The average percentage scores of domains and sub-domains of linguistics and reading were initially analysed for Descriptive statistics. The Mean (M) and Standard deviation (SD) were computed for measures of linguistics (Semantics, phonology, and syntax) and reading (Oral reading and Reading comprehension), in both Kannada and English-based tasks. The data was then subjected to Shapiro-Wilk's test for normality, and the data significantly followed a normal distribution (p>0.05). Therefore, the parametric Repeated Measures ANOVA was employed to see the main effect of Domains (Linguistics versus Reading), Languages (Kannada versus English), and the interaction effect between Domains*Language on the percentage scores.

Further, the repeated measure ANOVA was applied to the Linguistic domain to reveal the main effect of the subdomains (semantics, phonology & syntax), the main effect of language (Kannada & English), and the interaction effect between the subdomains * language. Similarly, the reading domain was subjected to repeated measure ANOVA to analyse the main effects of reading subdomains (oral reading and reading comprehension), the main effects of language (Kannada & English), and the interaction effect between the Subdomains * Language. When there was a significant influence (p<0.05) on scores observed, the Least Significant Difference (LSD) method was applied to analyse the pairwise significance between the variables.

Further, Karl Pearson's correlation analysis was employed to ascertain the relationship between language and reading tasks. The statistical significance value was compared with 0.05 or 0.01 level of significance. The entire statistical analysis was carried out using SPSS (version 23.0).

3.1 The Cross-linguistic Effects (Kannada vs English)

Overall linguistics abilities versus reading abilities

The effect of languages (Kannada vs English) on linguistic quotient (LQ) and reading quotient (RQ) was analysed through repeated measure ANOVA. The results showed a significant effect (p< 0.05) of languages on scores of linguistics and reading domains [F(1,9)=9.78, p=0.01] with a high effect size (re=0.52) (Norouzian & Plonsky, 2018) at α (power of test) = 0.79. Pronounced performance was noted in Kannada (L1) compared to English (L2) when observing the LQ (overall mean scores of linguistics) and RQ (overall mean scores of reading), as delineated in **Table 3**. Further, the interaction effect between the domain (linguistics and reading) * languages (L1 & L2) revealed no significance (p>0.05) (**Figure 1**). This suggested a similar trend in performance by Kannada English bilingual PWAs on both linguistics and reading domains, wherein performance in Kannada was better.

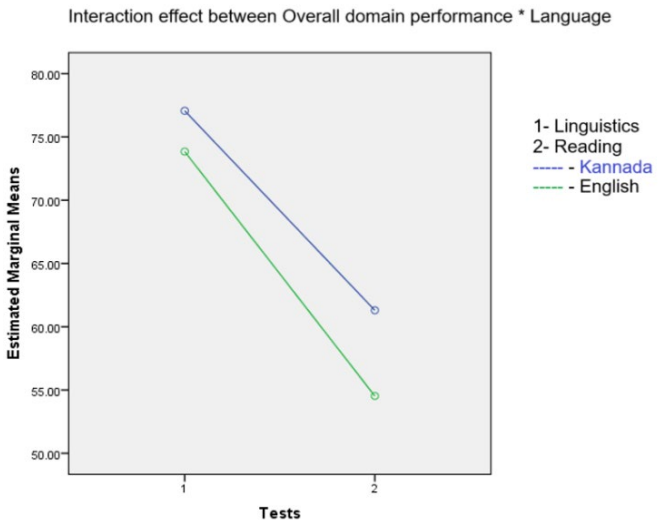

Figure 1. Interaction effect between Overall domain performance * Language

Subdomains of linguistics versus sub domains of reading

Further, repeated measure ANOVA was applied to reveal the cross-linguistic effects between Kannada and English on specific subdomains of linguistics, namely, semantics, syntax, and phonology. The results demonstrated no statistical significance (p>0.05) between the languages [F(1,9)=2.33, p=0.16]. As illustrated in **Table 3**, the participants performed uniformly on all subdomains of linguistics across Kannada and English languages.

However, on manifesting the effect of language (Kannada vs English) on subdomains of reading (oral reading & reading comprehension) through repeated measure ANOVA, the results revealed a significant impact of language (p< 0.05) on subdomains of reading

[F(1,9)=7.28, p=0.02] with high effect size (re=0.45) (Norouzian & Plonsky, 2018) at power of test, α=0.67. The results suggested that language affects subdomains of reading. Specifically, it was observed that participants outperformed in Kannada (L1) compared to English (L2) in subdomains of reading (See **Table 3**). Further, no significant interaction effect was observed (p>0.05) between language and reading subdomains [F(1,9)=0.02, p=0.88] (**Figure 2**). This suggests that the trend in performance on both oral reading and reading comprehension remained the same (Kannada better than English) among Kannada English bilingual alexia.

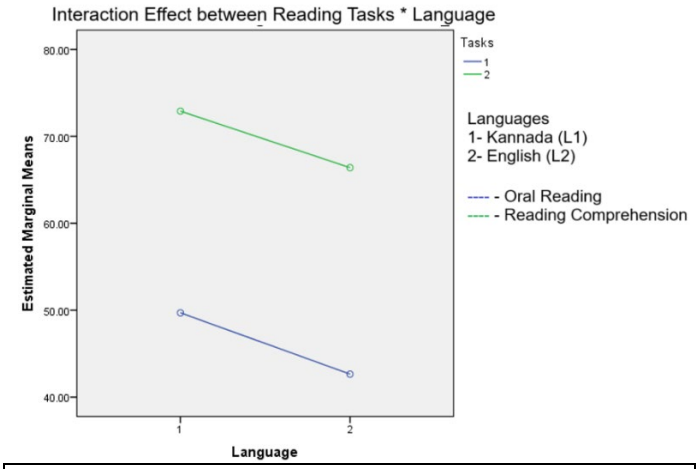

Figure 2. Interaction effect between Reading tasks * Language.

Table 3. Descriptive measures of tasks of linguistic across Kannada (L1) and English (L2).

Tasks	Kannada (L1)		English (L2)	
	Mean	SD	Mean	SD
Linguistic Domain				
Semantics	87.84	11.53	86.53	14.18
Phonology	59.07	26.42	55.48	27.09
Syntax	74.15	18.37	67.30	18.42
Language Quotient	**77.07**	**18.08**	**73.84**	**19.31**
Reading Domain				
Oral reading	38.46	37.59	33.73	35.25
Reading comprehension	72.84	25.60	68.00	25.57
Reading Quotient	**61.32**	**27.85**	**54.53**	**28.41**

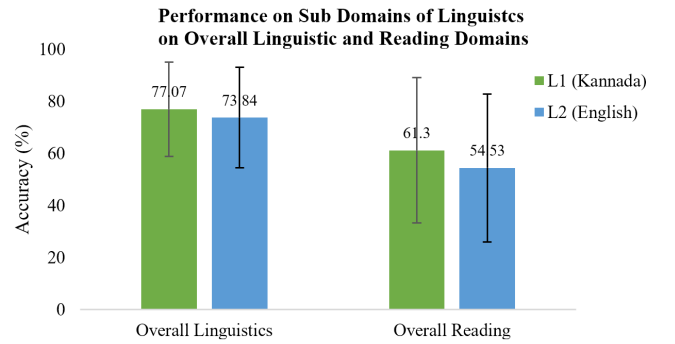

Figure 3. Descriptive measures of Overall Linguistic and Reading domains in Kannada (L1) and English (L2).

3.2 Performance in linguistic and reading abilities

Performance in overall linguistic versus reading abilities in Kannada and English

The effect of domain-specific performance on overall linguistic versus reading was compared individually in Kannada and English through repeated measure ANOVA. The results revealed a significant effect of overall performance (p<0.05) on domains of linguistics and reading [F(1,9)=5.96, p=0.03] with a high effect size (re=0.39) (Norouzian & Plonsky, 2018) at (power of test) α=0.58, suggesting that there is variability in overall performance across linguistic and reading domains.

Specifically, it was witnessed that PWAs outperformed in linguistics compared to reading (**Figure 1**). Further, the interaction effect between overall performance in domains (linguistics and reading) * languages (Kannada and English) was analysed. The results manifested no significant interaction effect (p>0.05) between domains and languages [F(1,9)=1.11, p=0.31], implying that the trend in performance in Kannada and English remained the same (Linguistic better than reading) among Kannada English bilingual persons with alexia (**Figure 1 & 3**).

Performance in semantics, syntax, and phonology in Kannada and English

The effect of subdomain performance of linguistics across semantics, phonology, and syntax were compared individually in Kannada and English through repeated measure ANOVA. The results revealed a significant effect of performance (p<0.05) on subdomains of linguistics [F(2,18)=18.33, p=0.00] with a larger effect size (re=0.67) (Norouzian & Plonsky, 2018) at (power of test) α=0.99, suggesting that there is variability in performance across semantics, syntax, and phonology. Subsequently, the post hoc pairwise analysis was applied through the Least significant difference (LSD) method, and results showed significant differences among semantics, syntax, and phonology, as shown in **Table 4**.

Table 4. Linguistic subdomains pairwise comparison.

Pairs	Mean difference	*p*-value
Semantic vs Phonetics	24.135*	0.00**
Semantic vs Syntax	13.800*	0.00**
Phonetics vs Syntax	-10.335*	0.03*

**p<0.01, *p< 0.05.

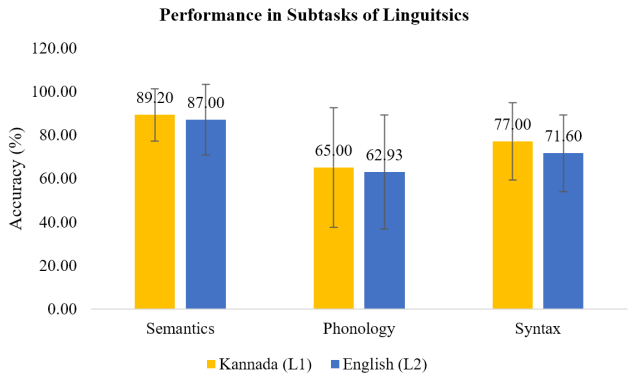

Figure 4. Descriptive measures of sub domains of linguistic in Kannada (L1) and English (L2).

As illustrated in **Figure 4**, participants outperformed in semantics, followed by syntax, and performed poorest in phonology in both Kannada and English. This was evident through analysis of the interaction effect between performance in subdomains of linguistics and language (Kannada and English). The results manifested no significant interaction effect (p>0.05) between semantics, syntax, and phonology and languages [F(2,18)=17.78, p=0.54], suggesting that their linguistic aspects were best in semantics > syntax > phonology in both languages.

Performance in oral reading and reading comprehension in Kannada and English

Repeated measure ANOVA was applied to observe the main effects on the performance of reading subdomains (oral reading and reading comprehension) in both Kannada and English languages. The results showed a significant difference (p<0.05), suggesting there is a significant effect of performance on subdomains of reading [F(1,9)=6.65, p=0.03] with high effect size (re=0.42) (Norouzian & Plonsky, 2018) at (power of test) α=0.63. It was noticed that reading comprehension was better than oral reading in both Kannada and English. The variability in languages was verified through interaction effects that indicated no significant difference (p>0.05) between subdomains of reading (oral reading and reading comprehension), and languages (Kannada and English) [F(1,9)=0.02, p=0.88] as illustrated in **Figure 5**.

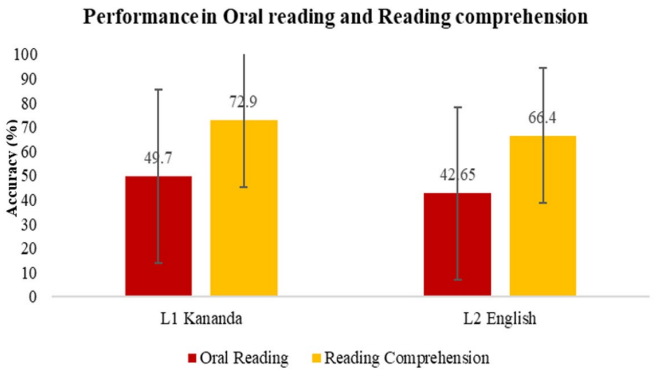

Figure 5. Descriptive measures of Sub domains of reading across Kannada (L1) and English (L2).

3.3 Influence of linguistic abilities on reading abilities

The study attempted to investigate the relationship between linguistic subdomains and reading subdomains on the raw scores of the participant's performances. Karl Pearson's correlation test revealed a positive correlation among all the linguistic subdomains, namely semantics, phonology, and syntax, with oral reading and reading comprehension subdomains of reading in both Kannada and English languages (**Table 5** & **Table 6**).

Further, it is remarkable to note the positive correlation between semantics, syntax, and phonology with oral reading in Kannada to delineate the specific relation between the subdomains. Wherein semantics was highly correlated with oral reading (r=0.734, p<0.05), followed by phonology (r=0.395, p>0.05) and syntax (r=0.377, p>0.05). Therefore, the trend suggests that oral reading is directly compared to semantic > phonology > syntax in Kannada (**Table 5**). Similarly, the same trend was noted in the English language, wherein oral reading was highly correlated with semantics (r=0.733, p<0.05) > phonology (r=0.499, p<0.05) > syntax (r=0.392, p>0.05) (**Table 6**).

Correspondingly, the reading comprehension abilities were correlated with linguistic subdomains. Reading comprehension in Kannada was highly positively correlated with syntax (r=0.600, p>0.05), followed by phonology (r=0.540, p>0.05) and semantics (r=0.528, p>0.05). Semantics was marginally correlated with phonology. Similarly, in English, reading comprehension positively correlated with semantics (r=0.682, p<0.05), syntax (r=0.672, p<0.05), and phonology (r=0.519, p<0.05). It was noted that the correlation between reading comprehension with

semantics and syntax differed marginally. Also, all relations manifested significant differences (**Table 6**). The correlation trend with reading comprehension in English was semantics ≥ syntax > phonology.

Table 5. Correlation analysis of linguistic sub domains with reading sub domains in Kannada (L1).

	Semantics	Phonology	Syntax	Oral reading
Semantics				
Phonology	0.724*			
Syntax	0.788**	0.900**		
Oral reading	0.734*	0.395	0.377	
Reading Comprehension	0.528	0.540	0.600*	0.93

**p<0.01, *p< 0.05.

Table 6. Correlation analysis of linguistic sub domains with reading sub domains in English (L2).

	Semantics	Phonology	Syntax	Oral reading
Semantics				
Phonology	0.888**			
Syntax	0.816**	0.943**		
Oral reading	0.733*	0.499*	0.392	
Reading Comprehension	0.682*	0.519*	0.672*	0.487

**p<0.01, *p< 0.05.

4.0 DISCUSSION

4.1 Cross-linguistic effects of Kannada (L1) and English (L2) on linguistic and reading abilities.

The study discerned cross-linguistics effects on linguistics and reading tasks in two folds. First, the overall performance in linguistics (LQ) and overall reading (RQ) were compared across Kannada (L1) and English (L2). Significant influence of language was noticed in both the domains, wherein all the participants outperformed in Kannada (L1) than in English (L2). Secondly, the study further investigated the cross-linguistics effects on subdomains of linguistics (semantics, syntax, and phonology) and reading (oral reading and reading comprehension). The participants performed equipotent on subdomains of linguistics in both Kannada and English languages. However, the performance of PWAs was superior in Kannada (L1) relative to English (L2) on all the subdomains of reading, and the effect was significant.

Differential effects of language, specifically L1 being better preserved or better-recovered post-stroke, may be attributed to general Kannada (L1) language dominancy and proficiency factors. Wherein, English being the second and a less dominant language with less proficiency in the premorbid state of the PWAs, was more impaired post-stroke. This phenomenon is well theorized through Green's Model of language inhibition (Green, 2005). The model states that L2 tends to be more constrained than L1 following stroke, resulting in greater impairment in the second language. In this scenario, all participants being unbalanced bilinguals, switching from a weaker to a more dominant language is more taxing than the other way around, resulting in asymmetric inhibitory patterns (Weekes et al., 2007).

In specific relevance to linguistics, dissociations noted in the study (L1 better than L2) may be ascribed to Pitres' rule. Pitres theorized that the recovery of two languages they spoke among the bilingual post-stroke survivors relies on the familiarity of language in the premorbid condition. The language that is most familiar or proficient recovers first. In the study, the majority of the PWAs (> 80%) were more proficient in Kannada (L1) compared to (L2) English (Pitres, 1985). This is significant as language use and exposure also impact the performance of linguistics abilities.

Additionally, other factors that may contribute to the cross-linguistic dissociations may be individual variability, owing to factors like aphasia type, severity, and site of lesion among the PWAs who performed in the study (Kiran & Roberts, 2012; Peñaloza & Kiran, 2019). Though the study made extensive efforts to minimize the heterogeneity in the population sample, there were few inevitable individual differences noted. A few hidden and uncontrollable variables could be language exposure and language usage post-stroke, limited language rehabilitation received in both languages and other social limitations. Consequently, all these factors may result in cross-linguistic dissociations post-stroke in linguistic domains.

Specific reference to reading abilities being well preserved or regained in L1 (Kannada), depends on the mechanisms involved in learning to read the second language. According to the assimilation hypothesis, the neural connections involved in learning to read the second language (L2) exclusively rely on networks of reading processed for learning to the first (L1). Contrarily, the accommodation hypothesis states that a new network is solely generated for learning to read a second language (e.g., Goral, 2019; Perfetti, 2017). These mechanisms partially depend on the degree of variability between L1 and L2 orthographies (Goral, 2019). Specific to the present study, Kannada (L1) being more transparent compared to English (L2), it may be presumed that an additional neural network is

processed for English (L2), as English is distinctly opaque compared to Kannada script. A similar distinction was observed between L1 and L2 reading impairments in studies of Liu and Cao (2016) and Tan et al. (2003).

Yet another reason that could be attributed to the dissociation across languages in reading is the orthographic differences. Kannada, being alpha-syllabic, necessitates reading through direct phonologic correspondence as the language is more transparent than English. English is known as alphabetic, and there is no direct correlation between alphabets and phonemes in most instances, owing to its opaqueness. Comparably, differential impairment was noted in Mongolian-Chinese bilingual alexics, wherein Mongolian (L1) was less impaired than Chinese (L2) (Weekes et al., 2007). Equivalent observations were evinced by a few other case studies exploring bilingual speakers of Arabic Hebrew (Ibrahim, 2009), Telugu-Kannada (Karanth, 1981), and Mongolian-Chinese (Weekes et al., 2007). In all these cases, the native language (L1) was relatively well preserved compared to L2. Thus, cross-linguistic dissociations in reading may be ascribed to the differential neural networking for different languages and the orthographic variability. However, model-specific explanations are much warranted in the Indian context, owing to India's multilingual population and diverse scripts.

4.2 Performance in linguistic and reading abilities

The study attempted to explore the task-specific variabilities in performance across linguistic and reading tasks among bilingual PWAs. The objective was analysed in three ways: (a) overall linguistic and reading domain performance, (b) comparison of performance in specific subdomains of linguistics, and (c) comparison of performance in specific subdomains of reading.

At the outset, the results of the main effects on performance in the overall linguistic domain versus the reading domain in specific languages, Kannada and English, discerned significant differences (p<0.05). This suggested that a task affects performance. Specifically, when observing the descriptive mean scores, all PWAs performed superior in the overall linguistic domain (on LQ scores) compared to reading (RQ). This finding was similar in Kannada and English linguistic and reading domains, as no interaction effect was noted (p>0.05).

This distinction between linguistic and reading abilities may be due to the most fundamental basis of the nature of perceptual input. The neurological bases for oral language and reading are exclusive to each other. In spoken language, auditory information travels from the medial geniculate nucleus in the thalamus to both primary cortical areas (BA) and secondary areas (BA 42) in the superior temporal gyrus, with the latter potentially housing the auditory representations of words (Binder et al., 1994). Wernicke's area presents activation peaks in language tasks when connected with Broca's area via the arcuate fasciculus (Thierry et al., 1999).

For written language, the visual region of the fusiform gyrus (BA 37) may constitute orthographic representations of words (Fujimaki et al., 1999; Herbster et al., 1997; Nobre et al., 1994), and the superior parietal lobe (BA 7) could play a role in spatial attention aspects of reading. Wernicke's area (BA 22) and its adjacent areas, including the angular gyrus and supramarginal gyrus (BA 39, 40), are multimodal areas possibly responsible for integrating spoken and written word forms, along with their associated meanings or semantics (Mesulam, 2007). Additionally, the variabilities in the neural networks across tasks may be presumed as a consequence of contrasts in the degree to which semantic, phonologic, syntactic, or orthographic processes are retrieved, which may be mirrored due to minute distinctions in the brain activation (Booth et al., 2001).

The dominance in performance on linguistic tasks in the study over the reading tasks may be attributed to extensive usage and exposure to spoken language mode. The majority of the time, in the human daily routine, the mode of communication is through spoken language. Reading or literacy skills are used in daily chores unless the adult is involved in desk work or academic work or to read daily affairs through newspapers, social media, etc. Besides, the individual's preference to read and write differs on social aspects (e.g., interests, literacy, socio-economic status, family, and occupation) (Parr, 1992). Variability among individuals may also stem from the inherent differences in reading significance and reading preferences (Webster et al., 2023). Undoubtedly, spoken language or linguistic processing tends to be well-preserved or well-recovered post-stroke comparing their reading abilities.

The supremacy in performance in linguistics over reading among PWAs may be ascribed to the variability in the complexity of tasks. In the study, some PWAs exhibited no challenges in basic linguistic assessments but showed difficulties with written language tasks. For these individuals, challenges at the text level might stem

from heightened cognitive demands associated with text processing. Also, deficits in working memory, attention allocation, and executive function, which are crucial for processing written material, could affect their overall performance in reading abilities. The finding is comparable with the study by Chesneau and Ska (2015).

Further, the study investigated the dissociations in performance across the subdomains of linguistics, namely between semantics, syntax, and phonology. The analysis revealed that they all performed significantly better in semantics, followed by syntax and phonology. Aphasia leads to deficits in the processing of semantics, syntax, and/or phonological aspects, each involving multiple functions. However, the severity of these deficits varies depending on the nature and severity of lesions among PWAs.

The study showed that PWAs performed much better on semantic than phonological tasks. The findings aligned with the perspective that accessing the semantic system precedes the processing of phonological information, suggesting that there are greater chances for phonological access impairment than semantic access (Meier et al., 2016; Howard & Gatehouse, 2006).

These outcomes were likely shaped by the interaction of two primary components in cognitive-linguistic processing: the impact of the cognitive systems facilitating lexical processing and how the varied tasks taxed these systems. Certainly, cognitive functioning among PWAs is compromised and, thus, affects lexical processing. Additionally, there is inherent task variability across semantic and phonology subdomains. Tasks like minimal pair judgment (rhyming and non-rhyming), blending, and segmentation require higher efforts and multiple processing. These tasks are more taxing than the semantic association, picture association, and auditory sentence comprehension tasks, which are all based on simple semantic judgment tasks. Segmentation and blending are inherent phonological tasks and are much more challenging (Meier et al., 2016).

Another reason for phonology being affected maximally is due to the neural distinctions. The phonological processes like phonological awareness, phonological short-term memory, and speech production are all established through the dorsal pathway in the perisylvian region (Beeson et al., 2022; Hickok & Poeppel, 2007; Saur et al., 2008). However, the semantic processing is broadly distributed through the left anterior inferior frontal gyrus (par orbitalis) and angular gyrus. These regions are within the left middle cerebral artery, some even from the right hemisphere (Beeson et al., 2022; Binder et al., 2009). Thus, semantic processing is supported by much broader regions in the brain than phonology processing. Subsequently, the severity and probability of phonology being affected is higher and more severe than semantics, which is compensated through other intact pathways.

Phonological deficits inherently affect syntactic processing. These findings are reflected in a few recent treatment studies positing that enhancing the phonological skills ameliorated correct information units in discourse (Silkes et al., 2021) and enriched the grammatical/morphological structure of sentences (Beeson et al., 2022). Sentence processing is a more complex mechanism wherein the readers or listener has to recognize the sentence structure and process involved to comprehend the meaning of the entire sentence within a time frame. Most PWAs, especially the non-fluent variants of aphasia, are known to have agrammatic features at their peak. These include difficulty understanding sentence structures, detecting sentence structure violations, and difficulty in comprehending sentences with violations in noun-verb phrases (Bhat & Chengappa, 2003). Thus, in the study, syntactic abilities were also compromised relative to phonological skills.

The results further suggested no effect or variability with performance across languages on the linguistic tasks, wherein in both Kannada and English, the trend in performance was comparable (semantics > syntax > phonology). The tasks employed in the linguistic subdomains were less taxing (**Table 2**) in both languages, and the participants had to respond merely based on pointing or lexical decision or judgment yes/ no responses. Thus, their performances were equipotent in both languages in the linguistic domain.

Similar to the exploration of the effect of linguistics subdomains, the study observed the effect of subdomains of reading in Kannada and English languages. The analysis revealed a significant difference between oral reading task performance and reading comprehension task, wherein PWAs performed the reading comprehension tasks better. This pattern was identical in both Kannada and English, as no interaction effect between reading tasks and languages was evinced.

Regarding the nature of the task, oral reading demands active central phonological processing, visual perceptual, and peripheral sensorimotor processing for the verbal output. In contrast, the reading comprehension obviates the need for verbal output. Definitive interactive processes (visual perceptual, decoding graphemes, working memory, attention, and metacognitive abilities) are involved while comprehending the written script (Webster et al., 2023; Meteyard et al., 2015). However, the cognitive load is comparatively less than oral reading output. Specifically, the study included tasks like single-word comprehension, sentence comprehension, and paragraph comprehension involving written word-picture matching, sentence-picture matching, paragraph to picture matching, respectively

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4.3 Correlation between linguistics and reading impairment

The study uncovered the relationship between linguistic subdomains and reading subdomains on the raw scores of the participants' performance. The correlation test revealed a positive correlation among all the linguistic subdomains, namely semantic, phonology, and syntax, with oral reading and reading comprehension subdomains. This finding was consistent with a study by Webster et al. (2021), who also found a strong positive correlation between language impairment and reading impairment through administering the Porch Index of Communicative Ability.

Specifically, semantics and phonology were more positively correlated to the oral reading task, suggesting that semantics and phonology are good predictors of oral reading abilities. If semantics and phonology are affected, oral reading abilities will be compromised, and vice versa. Several studies support this finding well through priming paradigms. Results suggested larger semantic priming effects for poor readers compared to good readers when reading target words were presented after a single word or sequential priming context (Scwantes, 1985, 1991; Simpson & Lorsbach, 1987; West & Stanovich, 1978). Speech production, semantics, and phonological skill strongly predicted oral reading performance, as Booth et al. (2000) demonstrated, who also found a significant positive correlation between orthographic and phonologic priming with naming accuracy and age. A recent study also suggested that semantics, phonological ability, and speech production emerged as robust predictors of spoken naming and oral reading performance (Beeson et al., 2022).

Few authors have proposed neurocomputational models of language processing depicting dissociations in linguistics aspects and their influence on reading. According to Plaut and Booth (2000), inherent individualistic semantic processing differences noticed in poor readers hampered grapheme-phoneme connections. Subsequently, the semantic connections influence the reduced speed of word recognition processes. Few prominent computational models in current reading-aloud literature presuppose that interactive activation serves as the predominant mode of processing dynamics, particularly within the lexical system (e.g., Plaut et al., 1996; Coltheart et al., 2001, 2010; Perry et al., 2010).

Specifically, semantics and phonology share some inherent neural pathways in oral reading tasks. These shreds of evidence were reflected by comparing the reading profiles of phonological alexia and surface alexia (Rapcsak et al., 2009; Henry et al., 2012, 2016; Rapcsak & Beeson, 2015). Researchers stated that the reading deficits in these conditions reflect variations in the language's central phonological and semantic systems, which invariably rely on neural networks. A dorsal pathway is firmly established to aid phonology, speech production, phonological short-term memory and awareness (Hickok & Poeppel, 2007; Saur et al., 2008). Additionally, the semantic network is widely distributed, involving contributions from regions like the left anterior inferior frontal gyrus (pars orbitalis) and angular gyrus within the left middle cerebral artery distribution, alongside certain regions in the right hemisphere (Binder et al., 2009). Thus, semantics and phonological processing are crucial and mutually exclusive in the oral reading process.

Based on the explanations of the Primary System Hypothesis (PSH) (Patterson & Ralph, 1999), and the Parallel Distributed Processing (PDP) model of reading (Plaut et al., 1996), both typical and atypical reading patterns are secondary to the strong interaction between semantics and phonological systems (Crisp & Ralph, 2006). Impairment in reading abilities would reflect a combination of deficits in these systems. The reading deficiencies may arise in phonological and semantic routes and rely on the status of general cognitive systems (Crisp & Ralph, 2006). Wherein these systems are not specific to reading. In particular, the present study also focused on the influence of non-reading abilities (linguistic tasks) on reading abilities to delineate the same and suggested interaction between linguistic modalities is inherent in reading abilities.

Further, the reading comprehension abilities were correlated with linguistic subdomains. Results evinced reading comprehension strongly correlated with syntax (r=0.600, p>0.05), followed by phonology (r=0.540, p>0.05) and semantics (r=0.528, p>0.05), wherein semantics was marginally less correlated compared to phonology. These results substantiate the belief that shared syntactic, phonological, and semantic processing contribute to the comprehension of both spoken and written sentences (Madden et al., 2018). Also, as reading comprehension tasks encompassed reading word, sentence, and paragraph levels, they necessitated syntactic knowledge and processing invariably to comprehend the text at the sentence level. After syntactic processing through syntax verification/judgment, semantic processing becomes vital to judge the appropriateness of the meaning of the text to comprehend the sentences completely. Hence, syntax and semantic performance strongly correlate with reading comprehension in the study.

Phonology strongly correlates to reading comprehension after syntax, which may seem paradoxical. Nevertheless, as many sentences include functional, abstract, or unfamiliar vocabulary that relies less on semantic understanding, it is plausible that orthographic-phonological knowledge, along with syntactic context, aids in decoding and comprehending these words at the sentence level. In short, syntax could be a much more sensitive and stronger linguistic predictor of reading comprehension, followed by phonology and semantics.

To recapitulate, the findings of the study demonstrated that impaired reading performance post an acquired brain lesion is the result of comparable linguistic impairments in both languages among bilingual individuals with alexia. These dissociations also depend on specific orthographic features of each writing system (Goral, 2019; Senaha & Parente, 2012; Meguro et al., 2003). The study first evinced the crossed-linguistic effect on linguistic and reading abilities, which reflected clear domination of the Kannada language on all the aspects of linguistics and reading compared to English. The authors attribute these findings to (a) high exposure and proficiency effect in L1 (Kannada) during the premorbid stage, (b) lexical organization is better for native language (Kannada in this case), (c) other factors like post-stroke language usage, aphasia severity, education background, language-focused while rendering therapy contribute for the same. All these aspects are deemed to be contributing factors to ameliorated performance in the Kannada language in the linguistics or spoken language domain. A comparable effect was noted in reading domains, wherein all PWAs performed superior in Kannada in all reading tasks. This was suggestive of the assimilation and accommodation process while reading. The former process refers to learning to read the second language exclusively relying on networks of reading processes for learning the first. Thus, Kannada, being the native and first language, manifested better reading profiles. The explanation of the accommodation hypothesis supports that there is a new network generated exclusively for learning to read a second language (English), as English comprises a more opaque writing system than transparent Kannada script. The cross-linguistic dissociation in reading was ascribed to the alpha-syllabic nature of the Kannada language, which directly relates to the phonological rules of the language compared to the alphabetic script of English (indirect grapheme-phoneme correspondence). Thus, these explanations made reading profiles prominent in Kannada relative to English in our Kannada English bilingual persons with alexia in the study.

The study further discovered pronounced performance in linguistic abilities compared to reading abilities in investigating the domain/ task variability in the performance of PWAs. The authors of the study opined that the distinction between linguistic and reading abilities may be (a) due to the exclusive neurological bases for oral language and reading, wherein for reading, the neurological bases are much more widespread and complex. Thus, recovery to these neurological bases may be challenging and long-lasting; (b) dominance in performance on linguistic tasks in the study over the reading tasks may be attributed to extensive usage and exposure to spoken language mode; (c) lastly, the task variability was attributed to the higher cognitive load bound in reading tasks compared to linguistic tasks.

As the third objective, the study investigated the correlation between linguistic and reading abilities. The results revealed a highly positive and significant correlation between overall linguistic and reading abilities, suggesting that impairment in the linguistic domain is the mainstay of reading impairment. Specifically, semantics strongly correlated to oral reading tasks followed by phonology and syntax in both Kannada and English. This assures that semantics and phonology could be strong predictors of oral reading abilities as semantics and phonology share some inherent neural pathways in oral reading tasks. This finding also supports the theory of primary system

hypothesis, which proves the existence of a strong interaction between semantics and phonology in the oral reading process. Comparatively, the reading comprehension abilities also strongly correlated with linguistics tasks, wherein syntax was strongest, followed by phonology and semantics. The strong correlation of syntax with reading comprehension was attributed to the nature of the task.

5.0 CONCLUSIONS

Reading impairments are most prevalent observed in post-stroke survivors, resulting in oral reading and reading comprehension problems with reduced reading speed (Knollman-Porter et al., 2015). Reading is a neuropsychological phenomenon entailing sensory, semantic, morpho-syntactic, and phonological processing. The results of this study provide support to a unified model of language, both spoken and written, which underscores the interplay among semantics, phonology, and orthography. These findings hold significance not only for neuropsychological frameworks but also for investigations seeking to elucidate the neural underpinnings of language.

Owing to the multilingual environment in the Indian context, the cross-linguistic dissociations among acquired reading-impaired individuals post-stroke become crucial. The routine speech-language assessments for persons with aphasia target only one language. Consequently, rehabilitation is typically focused only on one language. If two languages were to be rehabilitated simultaneously, definitive answers regarding the language selection criteria would be lacking. Some researchers suggest prioritizing the mother tongue, while others argue to treat the least impaired language. Conversely, some suggest targeting the most severely affected language for rehabilitation.

Owing to these dilemmas, the study proposed the need to evaluate language and reading impairments among post-stroke survivors comprehensively. Research on language and reading rehabilitation in bilingual aphasics remains budding. Most investigations have predominantly centred on individual cases and have often lacked thorough pre- and post-rehabilitation assessments of linguistic and reading impairments using equivalent tests in both languages. The study has effectively attempted to explore the linguistics and reading components in bilingual post-stroke survivors and also ascertained the importance of analysing the cross-linguistic variabilities in bilingual contexts. Consequently, conclusions drawn from the study need to be interpreted with caution owing to a small sample.

5.1 Limitations of the study

The study attempted to mark the importance of understanding the relationship between reading and linguistic abilities through a more comprehensive protocol. However, the study had a few shortcomings. Though the study made extensive efforts to minimize the heterogeneity in the population sample, there were few inevitable individual differences noted. These few hidden and uncontrollable variables could be, language exposure, language usage post-stroke, limited language rehabilitation received in both languages, and other social limitations. The study could have been described based on sub-grouping the variants of aphasia and then exclusively exploring the extent of reading impairment across these subgroups. A larger sample size would also aid in better understanding the sub-grouping variations and give us a clear distinction of correlation analysis on their linguistic and reading impairment per se.

Supplementary Materials: Appendix A - Task specific instructions and details is available at https://neuroscirn.org/ojs/index.php/nrnotes/article/view/356.

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