pediatric stroke

Cognitive-linguistic profiles following childhood arterial ischemic stroke: A case-based exploration of bilingual assessment and interpretation

Kai Ian Leung[1,2], Nomazulu Dlamini[3], Robyn Westmacott[4], Elizabeth Rochon[1,2] & Monika Molnar[1,2]

[1]Department of Speech-Language Pathology, University of Toronto, Toronto, CANADA
Rehabilitation Sciences Institute, University of Toronto, Toronto, CANADA
[2]3Division of Neurology, The Hospital for Sick Children, Toronto, CANADA
[4]Department of Psychology, The Hospital for Sick Children, Toronto, CANADA

Word Count: 3565
Tables and Figures: None
Supplemental Digital Data: None
Previous publication: None

Author Note

Correspondence to Kai Ian Leung at Department of Speech-Language Pathology, University of Toronto, 500 University Avenue, Toronto, ON, Canada M5G 1V7. Tel: (416) 978-3353.

Email: kaiian.leung@mail.utoronto.ca.

Abstract

The evaluation of language and cognitive outcomes following childhood arterial ischemic stroke often relies on standardized assessments primarily developed for monolingual children. This case study presents longitudinal language and cognition scores following childhood stroke in two children from differing home language environments, a 7-year-old English monolingual child and an 8-year-old Tamil-English simultaneous bilingual child. Both children were assessed repeatedly using monolingual-normed tools. The aim

of this study is not to directly compare these two cases, but to illustrate how bilingual children's assessment outcomes can and should be interpreted when monolingual tools are used in clinical practice. Rather than only focusing on absolute scores at each time point, we report findings based on relative change over time, compared to the child's own baseline at initial assessment. This approach may offer a more meaningful interpretation, especially in the case of bilingual children. The cognitive-linguistic profile of the bilingual case is consistent with our prior research, supporting evidence of gradual improvements in select areas over time, despite some variability in scores. Specifically, the pattern of lower overall scores alongside relative strength in linguistic expression suggests that relying solely on monolingual-normed assessments and assessment in one language may underestimate the bilingual child's true linguistic abilities. These findings underscore the critical need for comprehensive evaluation to identify accurate profiles of bilingual children's strengths and difficulties, informing more linguistically responsive care.

Keywords: childhood stroke, bilingual, cognition, development, assessment, norms, case study

Introduction

Childhood arterial ischemic stroke (AIS) can have significant impacts on language and cognitive development, with considerable individual variability influenced by stroke-related factors like age at stroke onset and stroke subtype (Singh et al., 2024; Westmacott et al., 2010). AIS strokes often affect language processing regions, resulting in deficits in verbal comprehension, expressive language, verbal memory, and executive functions, though specific profiles vary considerably (Krivitzky et al., 2022). Beyond stroke characteristics, outcomes are shaped by a complex interplay of factors including stroke etiology, treatment, development, and environmental factors. Pediatric stroke is inherently heterogeneous, making prediction of individual outcomes challenging and necessitates careful, individualized assessment and interpretation.

Emerging evidence suggests that environmental influences, including monolingual versus bilingual exposure, may also play a role in shaping developmental post-stroke outcomes (Leung et al., 2023). Bilingualism is a global norm (Grosjean, 2010), with approximately 41% of Americans and 20% of Americans speaking more than one language (Dietrich & Hernandez, 2022; Statistics Canada, 2022). Given that a substantial portion of AIS patients grow up bilingual, understanding how language experience shapes stroke assessments and outcomes is clinically and theoretically crucial.

Current Assessment Practices and Their Limitations

When it comes to evaluating the linguistic and cognitive skills of bilingual pediatric stroke patients, two issues remain. First, it is common to use monolingual norms to evaluate bilinguals' abilities. While monolingual developmental norms are readily available, bilingual development lacks similarly clear-cut benchmarks, even for neurotypical children (Bhalloo & Molnar, 2023; Leung & Molnar, 2025a). Although bilingual children generally achieve language milestones concurrently with monolinguals, their progression is significantly influenced by the amount and timing of language exposure. Consequently, interpreting scores from monolingual-normed tests can be misleading when applied to bilingual children. In addition, even measures designed to minimize linguistic demands may contain cultural biases that affect performance

(Gonthier, 2022; Lozano-Ruiz et al., 2021; Rosselli & Ardila, 2003).

Second, it is common to evaluate bilinguals' abilities only in one of their languages (e.g., in English), despite the fact that several clinical guidelines state that only evaluation of both bilingual's languages provides a realistic snapshot of bilinguals' skills (American Speech-Language-Hearing Association, n.d., 2023; Speech-Language and Audiology Canada, 2024). As such, evaluating bilinguals in a single language can misrepresent their abilities. For instance, considering lexical development, single-language assessments like the Peabody Picture Vocabulary Test in English (Dunn & Dunn, 2007) often produce lower receptive vocabulary scores among bilinguals as compared to monolinguals (in English), even when matched for socioeconomic status (SES; Ben-Zeev, 1977; Umbel et al., 1992). In *single-language* vocabulary knowledge, a larger vocabulary is reported in monolinguals, as compared to bilingual children (Hoff et al., 2012; Poulin-Dubois et al., 2013). However, considering *total vocabulary* distributed across both languages, the opposite is true: bilinguals have a larger or similar total vocabulary compared to monolinguals (De Houwer et al., 2014).

In addition to differences in linguistic abilities, interpreting post-stroke outcomes in bilingual children is complicated by questions about how bilingualism affects neurocognitive development. Studies on typical bilingual development indicate potential cognitive advantages, particularly in areas of executive functioning (Bialystok & Craik, 2010; Carlson & Meltzoff, 2008; Gunnerud et al., 2020), though the consistency and extent of these advantages remain a topic of ongoing debate (Paap, 2019). Among other reasons, Arizmendi et al. (2018) noted poor task reliability as a contributor to variability in findings across studies, potentially obscuring true differences or similarities between groups. Moreover, emerging evidence in neurodivergent populations, including children with stroke (Leung et al., 2023), suggests that bilingualism does not inherently disadvantage language development and may even offer protective or facilitative effects in some domains, based on findings using the Pediatric Stroke Outcome Measure (Kitchen et al., 2012). Although

clinical assessments provide valuable data, it is important to acknowledge their potential limitations in fully capturing the nuanced cognitive profiles of bilinguals, as these tools may not always be sensitive to the advantages observed in research settings (MacLeod, 2014).

In summary, when monolingual-centered practices are applied to bilingual children following stroke, they introduce an additional layer of interpretive ambiguity into already complex clinical pictures. When a bilingual child's test scores are lower than expected, clinicians cannot easily distinguish whether this reflects neurological impairment, limited exposure or proficiency in the language of testing, test bias from using monolingual norms, or some combination of these factors. In already heterogeneous pediatric stroke cases, this represents a preventable source of uncertainty.

Study Purpose and Approach

This case study explores the language and cognitive development of two children with varying exposure to a second language who sustained a childhood AIS. To attenuate differences related to language balance (the relative proficiency and use of two languages), we report on a simultaneous bilingual (early dual language exposure from birth) and a monolingual child with additional language exposure to a second language in school settings only. With this approach we move away from a dichotomic monolingual vs. bilingual comparison and recognize that bilingualism exists on a spectrum (DeLuca et al., 2019; Gullifer & Titone, 2020; Kremin & Byers-Heinlein, 2021; Leung & Molnar, 2025b), with most individuals displaying diverse levels of proficiency and usage in each language.

In a typical clinical practice and as often seen in case studies, interpretation of the patients' scores often relies on a score obtained on an assessment at a single point in time, in one language only. However, the validity of directly evaluating individuals from different language environments using these scores is questionable. Neuropsychological tests are typically standardized based on monolingual populations with limited bilingual norms (Mueller Gathercole et al., 2008; Pedraza & Mungas, 2008), potentially yielding scores and benchmarks that may not accurately reflect bilinguals' abilities (Hemsley et al., 2014; Kohnert, 2010). Non-linguistic cognitive

measures, such as certain tests of visual-spatial reasoning or processing speed, have been presumed to be less mediated by an individual's language background compared to direct language assessments or verbal cognitive tasks. However, scores can still be influenced by linguistic and cultural biases that disproportionately affect bilingual individuals (Gonthier, 2022; Windsor et al., 2008). Consequently, monolingual-normed scores between monolingual and bilingual children can be misleading.

Given these complexities, this study focuses on individual trajectories rather than direct cross-case comparisons. While two cases are presented for contrast, the primary goal is not to compare the two individuals per se, but to demonstrate how each profile challenges the interpretation of standardized scores developed for monolingual populations. While the two cases presented differ across multiple dimensions that preclude causal attribution to any single factor, they offer valuable illustrations of assessment principles and interpretive challenges that clinicians commonly encounter when working with bilingual children following acquired brain injury. This may provide guidance for clinicians working with bilingual children affected by AIS and ultimately contribute towards more equitable assessment, score interpretation, and therapeutic approaches in pediatric neurorehabilitation, in line with current professional guidelines (American Psychological Association, 2020; American Speech-Language-Hearing Association, n.d.; Rivera Mindt et al., 2008; Speech-Language and Audiology Canada, 2024).

Case presentation

The selected cases were part of a larger study exploring language and cognitive outcomes in bilingual and monolingual AIS patients. Cases were considered for inclusion if patients had an AIS aged 0-17 years and had had at least two neuropsychological assessments. Those with presumed perinatal AIS or multiple diagnoses of stroke (e.g., recurrence) were excluded. The two cases were intentionally chosen to align on certain clinical variables (age at stroke onset, left hemisphere, middle cerebral artery territory) to allow for a more focused exploration of how

differences in language background may influence the interpretation of standardized assessment results. A review of the institutional stroke database and charts were used to collect information. Research ethics approval was obtained at the Hospital for Sick Children (Toronto, Canada). Neuroimaging could not be reproduced in this publication due to institutional privacy and research ethics restrictions. Detailed written descriptions of lesion location and affected structures are provided below for each case.

Patient M

Demographics and Social Context

Raised in an English-speaking household, she was introduced to French through an immersion program beginning in junior kindergarten, which she continued in following her stroke in early childhood. French exposure was limited to the school environment with no use at home or in community contexts, consistent with many Canadian children receiving second-language instruction. She was one of seven children from a two-parent family. Annual household income was between $50,001-100,000. Her mother held an undergraduate degree/diploma level and her father had completed some post-secondary education.

Medical History

Patient M was a Caucasian female who had an unremarkable perinatal history. She achieved age-appropriate language and motor developmental milestones. At 7 years and 7 months of age, Patient M presented with a supratentorial lesion involving the anterior circulation; specifically, a large left MCA stroke of the peri-sylvian cortex and basal ganglia, complicated by a contralateral right frontal intracerebral hemorrhage. She was also diagnosed with acute promyelocytic leukemia at this time, known to cause a prothrombotic state and systemic thrombosis. She was consequently treated with chemotherapy per AAML0631 and ended treatment in remission of her leukemia at 10 years 3 months of age.

Initial presentation of the stroke was characterized by moderate neurological deficits including right hemiparesis/hemisensory deficit, altered mental status, hallucinations and confusion episodes, and speech-language deficit. Upon discharge, Patient M had mild fine-motor dexterity

and word-finding difficulties. Her Pediatric Stroke Outcome Measure results indicated a cognitive/behavioural subscale score of 1 (moderate deficit), attributed to poor math, spelling and anxiety-related issues. Post-stroke rehabilitation included speech-language, occupational, physical and psychological/psychiatric (anxiety) therapies.

Neuropsychology assessments were conducted at ages 9 years and 2 months, and again at 13 years and 6 months. During her initial assessment, it was noted that Patient M's extreme shyness and hesitation to participate may have led to a suspected underestimation of her neurocognitive abilities. By the follow-up assessment, she appeared notably more comfortable and engaged with the testing process.

Patient B

Demographics and Social Context

Patient B was a South Asian male of Sri Lankan descent, born in Canada. He was one of three children (third birth) from a two-parent family. Both parents were employed, mother as an assembly worker and father as a taxi driver. Specific details regarding parental education levels and household income were not available in the medical record. From birth, he was simultaneously exposed to the Tamil and English language, consistent with simultaneous bilingual acquisition. He was designated as an English-as-a-Second-Language student in school, a program for those whose first language is not English, and who have had educational opportunities to develop age-appropriate first language literacy skills.[1]

Medical History

Patient B had an unremarkable perinatal history aside from needing supplemental oxygen for respiratory support and low iron levels in the first week of life, both of which resolved without sequelae. He achieved age-appropriate motor and language developmental milestones in both Tamil and English prior to stroke.

At eight years of age, Patient B sustained a supratentorial stroke involving the anterior

[1] Tamil is a commonly spoken non-official language in Canada (Statistics Canada, 2025). Many Tamil families in Canada maintain strong heritage language use in home contexts while children acquire English through schooling and community exposure. This pattern was consistent with Patient B's language experience.

circulation, specifically a small, left-hemisphere middle cerebral artery stroke affecting his basal ganglia, complicated by ventriculitis and hydrocephalus. The cerebrovascular event occurred in the context of treatment for a pneumococcal meningitis infection. Initial presentation was characterized by abnormal level of consciousness, fever, vomiting, diarrhea, encephalopathy and sixth nerve palsy. At discharge, Patient B had a mild motor deficit and was discharged to a rehabilitation hospital, where he received speech-language, occupational, physical and psychological/psychiatric (for visual-auditory hallucinations, flat affect and anxiety) therapies. At follow-up, slight fine motor deficits and other deficits including cognitive, behavioural and hearing loss in the right ear, secondary to meningitis, were identified: abnormal study on right ear testing with brainstem auditory evoked response test, no Wave I; normal left ear.

Neuropsychological assessments were conducted at ages 9 years and 6 months, 13 years and 3 months and 17 years and 1 month.

Neuropsychological Assessments

Clinical neuropsychologists assessed both patients longitudinally as part of routine clinical care. The measures highlighted here were selected based on age-appropriateness and included *language-cognitive measures* (measures evaluating both language and cognition), *non-linguistic measures* (measures that use a minimal language in evaluating cognition), and a *parent questionnaire* (parental report of executive function; Table 1).

Table 1

Highlighted test battery by informant type and measure domain (language-cognitive, non-linguistic)

	Language-Cognitive Measures	**Non-Linguistic Measures**
Neuropsychological tests administered to children	WISC-IV/V (Wechsler, 2003, 2014): intellectual functioning Letter Fluency subtest of the D-KEFS (Delis et al., 2001) CVLT-C (Delis et al., 1994): memory and learning	Select subscales of the WISC-IV/V (Wechsler, 2003, 2014) • *Matrix Reasoning* • *Block Design* • *Coding*
Parent questionnaire	BRIEF Parent and BRIEF-2 Parent; (Gioia et al., 2000, 2015) executive function and self-regulation	

Note. BRIEF(-2), Behaviour Rating Inventory of Executive Function (-Second Edition); CVLT-C, California Verbal Learning Test-Children's Version; D-KEFS, Delis-Kaplan Executive Function System; WISC-IV/V, Wechsler Intelligence Scale for Children—Fourth Edition/ Fifth Edition

Neuropsychological performance is reported using standard scores and percentile rank for each patient and measure across two assessment timepoints, Visit 1 (initial assessment) and Visit 2 (follow-up assessment), as detailed in Table 2. Interpretation of scores follows the classification system of the American Academy of Clinical Neuropsychology (Guilmette et al., 2020), where lower percentile ranks reflect weaker performance, e.g., “Low Average” (9-24th percentile), “Below Average" (2-8th percentile), and "Exceptionally Low" (≤1st percentile). Performance is presented individually for each patient, emphasizing within-subject change over time.

Table 2

Patient M and B's performance profiles on repeated neuropsychological assessments

			M				
Index/Scale	Description	Visit	Score	Percentile	Classification	Score	Percentile
WISC-IV / WISC-V	**Cognitive abilities**						
Full Scale IQ	Overall intellectual abilities	*1*	86	18	Low Average	76	5
		2	92	30	Average	88	21
Verbal Comprehension Index	Index of verbal comprehension skills	*1*	89	23	Low Average	79	8
		2	92	30	Average	92	30
Working Memory Index	Index of attention and mental manipulation skills	*1*	91	27	Average	71	3
		2	96	40	Average	90	25
Processing Speed Index	Index of visuomotor processing speed	*1*	78	7	Below Average	83	13
		2	77	6	Below Average	106	66
CVLT-C	**Verbal list learning ability**						
List A Total Trials 1-5 *-T-score*	Memory for a list of words over 5 trials	*1*	50	50	Average	33	5
		2	59	82	High Average	38	13
List B Free Recall *-Z-score*	Memory for a second competing list of words after one presentation	*1*	1.5	94	Superior	0.5	68
		2	0.5	68	Average	-0.5	32
List A Short-Delay Free Recall *-Z-score*	Recalling a list of words after a brief delay	*1*	1	84	High Average	-1	16
		2	1	84	High Average	-1	16
List A Short-Delay Cued Recall-*Z-score*	Recalling words from the first list, by category	*1*	1	84	High Average	-2	2
		2	1.5	94	Above Average	-1	16

List A Long-Delay Free Recall-*Z-score*	Recalling a list of words after a long delay	*1*	1	84	High Average	-1.5	7
		2	1.5	94	Above Average	-1	16
List A Long-Delay Cued Recall-*Z-score*	Recalling words from the first list after a long delay, by category	*1*	1	84	High Average	-1.5	7
		2	1.5	94	Above Average	-1	16
Perseverations-*Z-score* †	Saying words from the list repeatedly	*1*	-1	16	Low Average	-0.5	32
		2	0	50	Average	3.5	>99
Total Intrusions-*Z-score* †	Saying words not from the given list	*1*	-1	16	Low Average	1.5	94
		2	-1	16	Low Average	1	84
Total Recognition Hits-*Z-score*	Recognition of words correctly identified as belonging to List A	*1*	1	84	High Average	0	50
		2	0.5	68	Average	-1.5	7
D-KEFS*	**Verbal fluency**						
Letter fluency -*Scaled Score*	Rapidly generating words that start with a particular letter	*1*	5	5	Below Average	7	16
		2	4	2	Below Average	9	37
BRIEF (-2) Parent*	**Executive functioning**						
Global Executive Composite -*T-score* ‡	Index of overall executive function	*1*	47	44	Average	53	69
		2	39	18	Low Average	58	79
Behavioural Regulation Index -*T-score* ‡	Index of abilities to shift cognitive set and modulate emotions and behavior via appropriate inhibitory control	*1*	47	46	Average	52	70
		2	37	11	Low Average	55	76

Note. BRIEF(-2), Behaviour Rating Inventory of Executive Function (-Second Edition); CVLT-C, California Verbal Learning Test-Children's Version; D-KEFS, Delis-Kaplan Executive Function System; WISC-IV/V, Wechsler Intelligence Scale for Children—Fourth Edition/ Fifth Edition; T1, Timepoint 1; T2, Timepoint 2. Performance is described according to classifications:
>98th percentile = "Exceptionally High "; 91-97th percentile = "Above Average"; 75-90th percentile = "High Average"; 25-74th percentile = "Average"; 9-24th percentile = "Low Average"; 2-8th percentile = "Below Average"; >1st percentile = "Exceptionally Low".
* Patient B's BRIEF-Parent and D-KEFS scores were obtained at age 13 and 17.
† For the error scores of the CVLT-C, higher *z*-scores suggest worse performance.
‡ For the BRIEF Index scores, higher t-scores suggest clinically elevated scores.

Patient M: Longitudinal Profile

Patient M completed neuropsychological assessments at 9.2 years of age (two years post-stroke; age at injury: 7) and again at 13.5 years of age (six years post-stroke) during or shortly after chemotherapy treatment for acute promyelocytic leukemia. As noted in Case Presentation, clinical staff documented extreme shyness and marked reluctance to engage during this first evaluation, raising concern that baseline scores might underestimate her true abilities due to reduced effort rather than capacity limitations.

Visit 1 (Age 9 years 2 months). Initial assessment revealed full-scale IQ in the low average range, with verbal comprehension and processing speed falling within the low average range and working memory falling within the average range. Her verbal learning and memory, inhibition, and parent-reported executive functioning were within the average range. However, she demonstrated difficulty with rapid word generation, performing in the below average to exceptionally low range. Additionally, perseverative errors on inhibition tasks were exceptionally elevated.

Visit 2 (Age 13 years 6 months). At follow-up assessment, Patient M's overall intellectual abilities remained stable in the low average range, though notable improvements were observed across several domains. Verbal comprehension and working memory strengthened to average range. Processing speed remained stable in the low average range. Her verbal learning and memory showed great improvement, advancing to the high average range. Parent-reported executive functioning remained stable within the average range. Perseverative errors normalized to the average range. However, rapid word generation remained a persistent challenge, continuing to fall in the below average to exceptionally low range.

Despite many improved neurocognitive functions, Patient M's profile continues to suggest challenges with rapid word generation and retrieval, though her verbal learning, memory and working memory capacities have strengthened over time.

Patient B: Longitudinal Profile

Patient B completed neuropsychological assessments at 9.5 years of age (approximately 1.5 years post-stroke; age at injury: 8), 13.3 years of age, and 17.3 years of age. Patient B's assessments were conducted exclusively in English, despite his simultaneous Tamil-English bilingual background with Tamil as the primary home language. No formal assessment of Tamil language skills was completed, and no objective measures of language dominance or proficiency were obtained, though he self-reported stronger English abilities. Additionally, Patient B sustained right-sided hearing loss secondary to meningitis; details regarding type, severity, and intervention (e.g., hearing aid use) were not available. While the left ear remained intact, hearing loss in one ear represents a potential confound for all auditory-verbal measures.

Visit 1 (Age 9 years 7 months). Initial assessment revealed full-scale IQ in the below average range, with verbal comprehension and working memory falling within the below average range and processing speed falling within the low average range. His verbal learning and memory and rapid word generation fell within the below average and low average ranges, respectively.

Visit 2 (Age 13 years 3 months). At first follow-up assessment, Patient B's full-scale IQ improved to the low average range. Verbal comprehension advanced to the average range and working memory improved to the low average range. Processing speed remained stable in the low average range. His verbal learning and memory improved to the low average range, and rapid word generation showed notable gains, advancing to the average range. Inhibition and parent-reported

executive functioning were within the average range, while perseverative errors on inhibition tasks fell within the low average range.

Visit 3 (Age 17 years 1 month). At second follow-up assessment, parent-reported executive functioning shifted to the high average range.

Patient B's profile suggests persistent vulnerabilities in processing speed and working memory, emerging difficulties with perseverative errors and challenges with real-world executive functioning based on parent report. His gains in verbal comprehension and word generation are notable.

Discussion

This case study underscores the complexities that are inherent in assessing bilingual children using tools normed on monolingual populations. Both cases presented multiple complex factors, as all pediatric stroke cases do, including diverse medical etiologies, treatment exposures, sensory factors, and developmental contexts. Our key insight from these cases is about how assessment approach may shape interpretation. When tests are not designed for the population being assessed, we add preventable uncertainty to already complex clinical pictures.

Within-Subject Approach and Case Findings

To address limitations of monolingual-normed tools and single-language assessment, this study emphasized within-subject longitudinal analysis, tracking how each child's performance changes over time relative to their own baseline. By examining how each child's scores changed relative to their own baseline, rather than only directly comparing their scores at any single time point to benchmarks, we aim to mitigate the challenges of using monolingual-normed tests with children from differing language backgrounds and provide a more equitable understanding of their post-stroke language and cognitive development. This approach is particularly valuable for bilingual

children, for whom scores at single timepoints may not accurately reflect true abilities when compared to monolingual norms.

Patient B's case demonstrates limitations of single-language assessment for bilingual children. As a simultaneous Tamil-English bilingual, Patient B's linguistic knowledge is distributed across two languages, yet all assessments were conducted exclusively in English, despite clear clinical recommendations (American Speech-Language-Hearing Association, n.d.; Speech-Language and Audiology Canada, 2024). At initial assessment, his verbal performance was below average against monolingual English norms. Without comprehensive bilingual assessment, this could be misinterpreted as neurological impairment, when it is impossible to determine whether scores reflected true cognitive deficits, limited English proficiency, distributed linguistic knowledge, hearing-related difficulties, or some combination. Had comprehensive bilingual assessment been conducted—evaluating both languages with consideration of exposure, dominance, and proficiency— clinicians would have obtained a clearer picture of his true abilities. The notable improvements observed (verbal comprehension: 3rd to 27th percentile; letter fluency: 16th to 37th percentile) could reflect genuine recovery but might also partly reflect growth in the language of testing (English) relative to the primary home language (Tamil) only due to potential increased exposure to English in school-settings. To truly interpret this score, a language background measure should have been also conducted at each time point, to provide a context for score interpretations. The usage of such questionnaires is also recommended by clinical guidelines (American Speech-Language-Hearing Association, 2023; Speech-Language and Audiology Canada, 2024), and there are several available in the public domain (Leung & Molnar, 2025a).

While case heterogeneity precludes definitive conclusions about how bilingualism influences post-stroke trajectories, the patterns observed warrant consideration within the broader research context. Patient B's notable improvements, despite single-language assessment and hearing loss

challenges, are broadly consistent with emerging evidence that bilingual exposure does not inherently disadvantage cognitive and language development following acquired brain injury. This is important, as clinical practice has sometimes been guided by concerns that maintaining bilingual environments might impede development. Current cases, alongside recent research (Leung et al., 2023), do not support this concern. Leung and colleagues reported that bilingualism was not detrimental to language and cognitive outcomes in children with stroke, and in some instances, bilingual children demonstrated stronger language production skills. Research on bilingual children with epilepsy has shown mixed patterns, with benefits observed in mental flexibility and cognitive control though not consistently in working memory (Veenstra et al., 2016). Collectively, these findings highlight the need for further investigation into how bilingual exposure interacts with neurocognitive development, especially across different conditions and developmental stages.

As noted earlier, these findings may in part reflect the limitations of using psychometric norms developed for monolingual populations, which do not adequately capture bilingual children's cognitive and linguistic profiles. Absolute score comparisons can be misleading without considering the composition of the normative sample. Standardized tools developed for monolinguals may not account for bilingual children's distributed language knowledge and cross-linguistic influences. This case highlights a critical clinical imperative: the need for bilingual-appropriate assessment practices, including the development and use of norm-referenced tools validated on bilingual populations. Additionally, comprehensive evaluation should involve both of the bilingual child's languages to identify domain-specific strengths and vulnerabilities that can inform tailored intervention strategies (McLeod et al., 2017; Speech-Language and Audiology Canada, 2024).

Assessment considerations and limitations

This study has important limitations that must be acknowledged while also highlighting practical approaches that emerged from addressing these constraints. Case studies preclude causal inference because multiple variables are confounded. Given substantial differences in medical history and treatment exposures (chemotherapy-treated leukemia vs. meningitis), hearing status (typical vs. hearing loss), assessment approach (functionally monolingual vs. simultaneous bilingual assessed only in English), engagement at initial assessment, socioeconomic context (where available) and lesion characteristics, these patterns cannot be attributed primarily to any specific factor. Instead, they underscore the complexity of interpreting standardized neuropsychological assessments in heterogeneous pediatric stroke populations. Language experience exists on a continuum; despite her early French immersion, we considered Patient M to be closer to the monolingual end of the spectrum, with second language exposure occurring exclusively in school settings. In contrast, Patient B is a simultaneous heritage bilingual, which typically results in more integrated linguistic systems and positions him further along the bilingual side of the spectrum. While each represents a single linguistic profile, these cases were selected for their representativeness of language experiences in multilingual Canada. In this case, both children were assessed exclusively in English, and no objective measures of language dominance and proficiency were obtained, although it was recorded that the bilingual child self-reported stronger English abilities. While best-practice clinical guidelines in both neuropsychology and speech-language pathology emphasize the importance of culturally and linguistically appropriate assessments for bilingual children, speech-language pathology guidelines more specifically advocate assessment in all languages used by the child to gain a comprehensive understanding of their abilities and to differentiate between language differences and disorders. These guidelines highlight the need to consider the child's full linguistic repertoire for an accurate evaluation (American Speech-Language-Hearing Association, n.d.; Speech-Language and Audiology Canada, 2024).

To address limitations (i.e., monolingual-normed tools and assessment in one language only) and allow for a fairer comparison of developmental trajectories, this case study emphasized the evaluation of *relative change* in scores across time (i.e., change from initial assessment to follow-up). By examining how each child's scores changed relative to their own baseline, rather than only directly comparing their absolute scores at any single time point, we aim to mitigate the challenges of using monolingual-normed tests with children from differing language backgrounds and provide a more equitable understanding of their post-stroke language and cognitive development. This approach contrasts with typical clinical practice, which often evaluates patients' performance at one timepoint, based on interpreting absolute scores against monolingual norms. While we acknowledge the limitations in applying monolingual norms and a single language approach with bilingual populations, we also acknowledge the reality that the current clinical landscape often necessitates the use of these scores.

Our findings also underscore the importance of integrating patient psychosocial and demographic variables into clinical assessment and interpretation. Childhood stroke presents considerable heterogeneity; and in this study, differences in cultural background, socioeconomic status and medical histories, including comorbid neurological and psychological conditions, were evident across the two cases. Clinical evaluation and intervention should therefore adopt an individualized approach, with particular attention to linguistic and cultural context (Arce Rentería et al., 2023; Canas et al., 2020; Cardenas et al., 2017; Fujii, 2018). A more comprehensive understanding of bilingual developmental trajectories is essential to providing culturally sensitive and equitable care. For bilingual children, this requires: assessment in all regularly used languages; consideration of exposure patterns, dominance, and proficiency (see Leung & Molnar, 2025 for a critical review of language history measures for bilingual children); careful interpretation of standardized scores; emphasis on within-subject change; collaboration with speech-language

pathologists; and consideration of contextual factors (hearing status, treatment history, engagement). Bilingual assessment should not be viewed as optional but as necessary for accurate clinical practice that reduces interpretive uncertainty.

Conclusion

This case study reinforces the importance of considering bilingualism as a relevant factor, and not just a risk factor in clinical assessment. Notable gains in language functioning suggest that bilingual exposure may support aspects of development, which are not apparent relying on absolute scores only. Although limited by a small sample and incomplete language background data, this study aims not to compare the two children directly, but to highlight how standardized assessments normed on monolingual populations may underestimate bilingual children's abilities when used without consideration of language background. This study underscores the need for clinicians to go beyond normative score comparisons and consider the linguistic background of bilingual clients when using monolingual assessment tools. Developing culturally sensitive, linguistically informed assessment protocols that reflect the complexities of bilingualism including language exposure, dominance, and proficiency, is essential for equitable clinical care. More broadly, this study contributes to a growing call for more inclusive, individualized approaches to post-stroke evaluation and intervention in children from diverse backgrounds.

Acknowledgments

We are grateful to the families of the patients for their participation in this research. This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) through a Discovery Grant (RGPIN-2019-06523) to M.M. and a Canada Graduate Scholarship – Master's (CGS-M) to K.I.L and The Auxilium Foundation funding to N.D.

Author Contributions

KIL: Conceptualization, Methodology, Data collection, Analysis, Writing – original draft, Funding acquisition. **ND:** Conceptualization, Methodology, Supervision, Writing – review & editing. **RW:** Conceptualization, Methodology, Data collection, Supervision, Writing – review & editing. **ER**: Conceptualization, Methodology, Supervision, Writing – review & editing. **MM:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

Conflicts of Interest Statement

The authors declare no conflicts of interest.

References

American Psychological Association. (2020). APA guidelines for psychological assessment and evaluation. In *American Psychological Association: Washington, DC, USA*.

American Speech-Language-Hearing Association. (n.d.). *Multilingual service delivery in audiology and speech-language pathology [Practice Portal]*. Retrieved October 7, 2024, from https://www.asha.org/Practice-Portal/Professional-Issues/Bilingual-Service-Delivery/

American Speech-Language-Hearing Association. (2023). *Ad Hoc Committee on Bilingual Service Delivery: Competencies, expectations, and recommendations for multilingual service delivery*. https://www.asha.org/siteassets/reports/ahc-bilingual-service-delivery-final-report.pdf

Arce Rentería, M., Avila, J. F., Vonk, J. M. J., & Manly, J. J. (2023). Centering social forces and cultural experiences in neuropsychological assessment. In G. G. Brown, B. Crosson, K. Y. Haaland, & T. Z. King (Eds.), *APA handbook of neuropsychology, Volume 2: Neuroscience and neuromethods (Vol. 2).* (pp. 199–231). American Psychological Association. https://doi.org/10.1037/0000308-010

Arizmendi, G. D., Alt, M., Gray, S., Hogan, T. P., Green, S., & Cowan, N. (2018). Do bilingual children have an executive function advantage? Results from inhibition, shifting, and updating tasks. *Language, Speech, and Hearing Services in Schools*, *49*(3). https://doi.org/10.1044/2018_LSHSS-17-0107

Ben-Zeev, S. (1977). The Influence of Bilingualism on Cognitive Strategy and Cognitive Development. *Child Development*, *48*(3), 1009–1018. https://doi.org/10.2307/1128353

Bhalloo, I., & Molnar, M. (2023). Early Precursors of Reading Development in Simultaneous Bilinguals: A Systematic Review and Meta-Analysis. *Perspectives of the ASHA Special Interest Groups*, *8*(5). https://doi.org/10.1044/2023_persp-23-00041

Bialystok, E., & Craik, F. I. M. (2010). Cognitive and linguistic processing in the bilingual mind. *Current Directions in Psychological Science*, *19*(1). https://doi.org/10.1177/0963721409358571

Canas, A., Bordes Edgar, V., & Neumann, J. (2020). Practical Considerations in the Neuropsychological Assessment of Bilingual (Spanish-English) Children in the United States: Literature Review and Case Series. *Developmental Neuropsychology*, *45*(4). https://doi.org/10.1080/87565641.2020.1746314

Cardenas, A., Villavicencio, L., & Pavuluri, M. (2017). Considerations in the Neuropsychological Evaluation and Treatment of Children with Limited English Proficiency. *The Permanente Journal*, *21*. https://doi.org/10.7812/TPP/16-149

Carlson, S. M., & Meltzoff, A. N. (2008). Paper: Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2). https://doi.org/10.1111/j.1467-7687.2008.00675.x

De Houwer, A., Bornstein, M. H., & Putnick, D. L. (2014). A bilingual-monolingual comparison of young children's vocabulary size: Evidence from comprehension and production. *Applied Psycholinguistics*, *35*(6). https://doi.org/10.1017/S0142716412000744

DeLuca, V., Rothman, J., Bialystok, E., & Pliatsikas, C. (2019). Redefining bilingualism as a spectrum of experiences that differentially affects brain structure and function. *Proceedings of the*

National Academy of Sciences, *116*(15), 7565–7574. https://doi.org/10.1073/pnas.1811513116

Dietrich, S., & Hernandez, E. (2022). *Language Use in the United States: 2019*. United States Census Bureau. https://www.census.gov/library/publications/2022/acs/acs-50.html

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test—Fourth Edition*. Pearson Education. https://doi.org/10.1037/t15145-000

Fujii, D. E. M. (2018). Developing a cultural context for conducting a neuropsychological evaluation with a culturally diverse client: The ECLECTIC framework*. *Clinical Neuropsychologist*, *32*(8). https://doi.org/10.1080/13854046.2018.1435826

Gonthier, C. (2022). Cross-cultural differences in visuo-spatial processing and the culture-fairness of visuo-spatial intelligence tests: An integrative review and a model for matrices tasks. *Cognitive Research: Principles and Implications*, *7*(1), 11. https://doi.org/10.1186/s41235-021-00350-w

Grosjean, F. (2010). Myths about bilingualism. *Myths about Bilingualism*.

Guilmette, T. J., Sweet, J. J., Hebben, N., Koltai, D., Mahone, E. M., Spiegler, B. J., Stucky, K., & Westerveld, M. (2020). American Academy of Clinical Neuropsychology consensus conference statement on uniform labeling of performance test scores. *The Clinical Neuropsychologist*, *34*(3), 437–453. https://doi.org/10.1080/13854046.2020.1722244

Gullifer, J. W., & Titone, D. (2020). Characterizing the social diversity of bilingualism using language entropy. *Bilingualism: Language and Cognition*, *23*(2), 283–294. https://doi.org/10.1017/S1366728919000026

Gunnerud, H. L., ten Braak, D., Reikerås, E. K. L., Donolato, E., & Melby-Lervåg, M. (2020). Is bilingualism related to a cognitive advantage in children? A systematic review and meta-analysis. *Psychological Bulletin*, *146*(12). https://doi.org/10.1037/bul0000301

Hemsley, G., Holm, A., & Dodd, B. (2014). Identifying language difference versus disorder in bilingual children. *Speech, Language and Hearing*, *17*(2), 101–115. https://doi.org/10.1179/2050572813Y.0000000027

Hoff, E., Core, C., Place, S., Rumiche, R., Señor, M., & Parra, M. (2012). Dual language exposure and early bilingual development. *Journal of Child Language*, *39*(1). https://doi.org/10.1017/S0305000910000759

Kitchen, L., Westmacott, R., Friefeld, S., MacGregor, D., Curtis, R., Allen, A., Yau, I., Askalan, R., Moharir, M., & Domi, T. (2012). The pediatric stroke outcome measure: A validation and reliability study. *Stroke*, *43*(6), 1602–1608. https://doi.org/10.1161/STROKEAHA.111.639583

Kohnert, K. (2010). Bilingual children with primary language impairment: Issues, evidence and implications for clinical actions. *Journal of Communication Disorders*, *43*(6), 456–473. https://doi.org/10.1016/J.JCOMDIS.2010.02.002

Kremin, L. V., & Byers-Heinlein, K. (2021). Why not both? Rethinking categorical and continuous approaches to bilingualism. *International Journal of Bilingualism*, *25*(6), 1560–1575. https://doi.org/10.1177/13670069211031986

Krivitzky, L. S., Westmacott, R., Boada, R., Sepeta, L., Reppert, L., & Mrakotsky, C. (2022). Recent Advances in Neuropsychological Outcomes and Intervention in Pediatric Stroke. *Stroke*, *53*(12), 3780–3789. https://doi.org/10.1161/STROKEAHA.122.037294

Leung, K. I., Dlamini, N., Westmacott, R., & Molnar, M. (2023). Language and Cognitive Outcomes Following Ischemic Stroke in Children With Monolingual and Bilingual Exposure. *Journal of Child Neurology*, *38*(6–7). https://doi.org/10.1177/08830738231171466

Leung, K. I., & Molnar, M. (2025a). Bilingualism measures in children: A critical review of content overlap, development, and pragmatic quality. *International Journal of Speech-Language Pathology*. https://doi.org/10.1080/17549507.2025.2532787

Leung, K. I., & Molnar, M. (2025b). Examining Neurodiversity in Bilingual Development Research: Recent Insights Through an Equity, Diversity, and Inclusion Lens. *International Journal of Language & Communication Disorders*, *60*(5), e70100. https://doi.org/10.1111/1460-6984.70100

Lozano-Ruiz, A., Fasfous, A. F., Ibanez-Casas, I., Cruz-Quintana, F., Perez-Garcia, M., & Pérez-Marfil, M. N. (2021). Cultural Bias in Intelligence Assessment Using a Culture-Free Test in Moroccan Children. *Archives of Clinical Neuropsychology: The Official Journal of the National Academy of Neuropsychologists*, *36*(8), 1502–1510. https://doi.org/10.1093/arclin/acab005

MacLeod, A. A. N. (2014). On extending experimental findings to clinical application: Never too late? An advantage on tests of auditory attention extends to late bilinguals. *Frontiers in Psychology*, *5*(DEC). https://doi.org/10.3389/fpsyg.2014.01367

McLeod, S., Verdon, S., & The International Expert Panel on Multilingual Children's Speech. (2017). Tutorial: Speech assessment for multilingual children who do not speak the same language(s) as the speech-language pathologist. *American Journal of Speech-Language Pathology*, *26*(3). https://doi.org/10.1044/2017_AJSLP-15-0161

Mueller Gathercole, V. C., Mon Thomas, E., & Hughes, E. (2008). Designing a Normed Receptive Vocabulary Test for Bilingual Populations: A Model from Welsh. *International Journal of Bilingual Education and Bilingualism*, *11*(6), 678–720. https://doi.org/10.1080/13670050802149283

Paap, K. (2019). The Bilingual Advantage Debate. *The Handbook of the Neuroscience of Multilingualism*, 701–735. https://doi.org/10.1002/9781119387725.CH34

Pedraza, O., & Mungas, D. (2008). Measurement in Cross-Cultural Neuropsychology. *Neuropsychology Review*, *18*(3), 184–193. https://doi.org/10.1007/s11065-008-9067-9

Poulin-Dubois, D., Bialystok, E., Blaye, A., Polonia, A., & Yott, J. (2013). Lexical access and vocabulary development in very young bilinguals. *International Journal of Bilingualism*, *17*(1), 57–70. https://doi.org/10.1177/1367006911431198

Rivera Mindt, M., Arentoft, A., Kubo Germano, K., D'Aquila, E., Scheiner, D., Pizzirusso, M., Sandoval, T. C., & Gollan, T. H. (2008). Neuropsychological, Cognitive, and Theoretical Considerations for Evaluation of Bilingual Individuals. *Neuropsychology Review*, *18*(3), 255–268. https://doi.org/10.1007/s11065-008-9069-7

Rosselli, M., & Ardila, A. (2003). The impact of culture and education on non-verbal neuropsychological measurements: A critical review. *Brain and Cognition*, *52*(3), 326–333. https://doi.org/10.1016/S0278-2626(03)00170-2

Singh, J., Slim, M., Moharir, M., Westmacott, R., Krishnan, P., MacGregor, D., Dlamini, N., Parthasarathy, S., Musaphir, S., & Domi, T. (2024). Long-Term Neurologic Outcomes in

Pediatric Arterial Ischemic Stroke: The Impact of Age and Lesion Location. *Stroke*, *55*(11), 2622–2631.

Speech-Language and Audiology Canada. (2024). *SAC Position Paper on School-Based Speech-Language Pathology Services in the Context of Multilingualism*. https://www.sac-oac.ca/wp-content/uploads/2024/02/2024-Multilingualism-in-Schools_Final-EN.pdf

Statistics Canada. (2022). *While English and French are still the main languages spoken in Canada, the country's linguistic diversity continues to grow* (The Daily). https://www150.statcan.gc.ca/n1/daily-quotidien/220817/dq220817a-eng.htm

Statistics Canada. (2025, January 22). *Language diversity in Canada*. Statistics Canada Catalogue No. 11-627-M. https://www150.statcan.gc.ca/n1/en/pub/11-627-m/11-627-m2025007-eng.pdf?st=BYDbxYdf

Umbel, V. M., Pearson, B. Z., Fernández, M. C., & Oller, D. K. (1992). Measuring Bilingual Children's Receptive Vocabularies. *Child Development*, *63*(4), 1012–1020. https://doi.org/10.1111/j.1467-8624.1992.tb01678.x

Veenstra, A. L., Riley, J. D., Barrett, L. E., Muhonen, M. G., Zupanc, M., Romain, J. E., Lin, J. J., & Mucci, G. (2016). The impact of bilingualism on working memory in pediatric epilepsy. *Epilepsy & Behavior : E&B*, *55*(100892858), 6–10. https://doi.org/10.1016/j.yebeh.2015.11.025

Westmacott, R., Askalan, R., Macgregor, D., Anderson, P., & Deveber, G. (2010). Cognitive outcome following unilateral arterial ischaemic stroke in childhood: Effects of age at stroke and lesion

location. *Developmental Medicine & Child Neurology*, *52*(4), 386–393. https://doi.org/10.1111/j.1469-8749.2009.03403.x

Windsor, J., Kohnert, K., Loxtercamp, A. L., & Kan, P.-F. (2008). Performance on nonlinguistic visual tasks by children with language impairment. *Applied Psycholinguistics*, *29*(2), 237–268. https://doi.org/10.1017/S0142716407080113