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The impact of bilingualism on working memory in pediatric epilepsy

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ABSTRACT

Impairments in executive skills broadly span across multiple childhood epilepsy syndromes and can adversely affect quality of life. Bilingualism has been previously shown to correlate with enhanced executive functioning in healthy individuals. This study sought to determine whether the bilingual advantage in executive functioning exists in the context of pediatric epilepsy. We retrospectively analyzed neuropsychological data in 52 children with epilepsy and compared executive function scores in monolingual versus bilingual children with epilepsy while controlling for socioeconomic status and ethnicity. Bilingual children performed significantly better on the Working Memory Index than did monolingual children. There were no significant differences on the remaining executive function variables. The bilingual advantage appears to persist for working memory in children with epilepsy. These findings suggest that bilingualism is potentially a protective variable in the face of epilepsy-related working memory dysfunction.

1. Introduction

Executive functions are a diverse but critical set of self-regulatory processes that include planning, initiating, and sustaining goal-directed behaviors, all critical to successful life performance [1,2]. Specifically, deficits in executive function are related to reduced quality of life [3], problems with psychosocial functioning, diminished educational achievement, and poor occupational outcomes [4]. Executive deficits do not appear to be syndrome-specific but instead are broadly affected in various epilepsy types [2,5]. Consequently, it has become increasingly important to examine the influence of individual characteristics on executive function [6].

Bilingualism is one such factor known to differentially impact executive functioning. Specifically, typically developing bilingual children perform better than their monolingual peers on executive functioning tasks [7,8] including inhibition of attention to distractor stimuli, selective attention to relevant information, mental switching between possible responses, and working memory [8–11]. It is theorized that certain areas of neurocognitive functioning within the executive domain are reinforced by processes related to bilingualism, resulting primarily from the practice of mentally switching between translations of two or more languages and selectively utilizing the language appropriate to the context while simultaneously inhibiting other known languages [12]. Children who know more than one language, therefore, become more adept at using these executive skills, resulting in stronger mental control.

Although executive dysfunction is a common deficit found in children with epilepsy, investigation of the bilingual advantage in executive functioning has not been extended to this population. Research to date suggests that bilingualism could serve as a protective factor against some neurodegenerative processes [13–15] and likely works through the recruitment of different brain regions during these cognitive tasks [16,17]. Therefore, this study sought to determine if the bilingual advantage in executive functioning persists in the context of a central nervous system (CNS) disease process that has broad negative effects on executive functioning. Specifically, we tested the hypothesis that bilingual children with epilepsy would perform significantly better on executive functioning tasks when compared to monolingual individuals with epilepsy.

2. Methods

2.1. Participants

A retrospective study identified 26 bilingual children between the ages of 6 and 18 with epilepsy who had completed a comprehensive neuropsychological evaluation between 2006 and 2015 at the Children's Hospital of Orange County. Board-certified pediatric epileptologists, with supportive information from routine and/or long-term video-EEG monitoring, confirmed all epilepsy diagnoses. Information regarding seizure foci/diagnosis was obtained from clinical notes and EEG reports located in the electronic medical record.

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Inclusion criteria for this study included a formal diagnosis of epilepsy, English language proficiency, and a General Ability Index (GAI) > 70. The control group consisted of 26 age-matched monolingual children who met inclusion criteria. Exclusion criteria for both groups included diagnosis of autism spectrum disorder. Participants selected for the control group were the closest age matches evaluated between 2006 and 2015. At the time of their evaluation, participants' ages ranged from 6.40 to 17.75 years (M = 12.62 years; SD = 3.31). Fifty-eight percent (n = 30) of the participants were female. Consistent with local demographics, the majority of the children were of Latino (42.3%) or European (30.8%) descent, with a smaller number of children of Asian (19.2%) or multiracial (7.7%) origins. Children were primarily right-hand dominant, with 8% (N = 2) of monolingual and 12% (N = 3) of bilingual children left-hand dominant.

2.2. Procedures

Study procedures were performed with the approval of the Institutional Review Board of the Children's Hospital of Orange County. The neuropsychological evaluation was performed as part of clinical care, and thus, the specific test battery varied. Domains assessed and included in this study were intellectual functioning, working memory, impulsivity, mental flexibility, and verbal fluency (Table 1). The General Ability Index (GAI) was used as a measure of intelligence, rather than full-scale IQ, because full-scale IQ includes working memory, a variable of interest in our study. All tasks were administered in English. Standard clinical care procedures included background questionnaires completed by parents. Data on parental education level and job type were obtained from this form to determine social economic status (SES) level using The Barratt Simplified Measure of Social Status [18].

2.2.1. Assessment methods utilized

Neuropsychological tests consisted of standardized measures that have consistently demonstrated good reliability and validity [19]. Intellectual functioning was assessed using Wechsler Intelligence Scale for Children, 4th Edition (WISC-IV, [20]), Wechsler Abbreviated Intelligence Scale (WASI, [21]), or Wechsler Adult Intelligence Scale, 4th Edition (WAIS-IV, [22]). Working memory was measured using the Working Memory Index from WISC-IV or WAIS-IV. Within the executive functioning domain, several areas were assessed using multiple measures. Mental flexibility on nonverbal sequencing tasks was measured using either Trails B from the Trail Making Test or Condition 4 (Letter–Number Switching) from the Delis–Kaplan Executive Functioning System (D–KEFS) Trail Making Test [23]. Mental flexibility on verbal tasks was measured using Category Switching: Total Switching Accuracy from the D–KEFS Verbal Fluency Test [23]. Verbal fluency measures assessed both lexical and categorical word fluency. Lexical fluency was assessed using NEPSY-II Word Generation: Initial Letter Total Score, the FAS task from the Controlled Oral Word Association Test, and D–KEFS Verbal Fluency: Letter Fluency Total Correct. Categorical fluency was measured using the Animal Naming subtest from the Controlled Oral Word Association Test, D–KEFS Verbal Fluency: Categorical Fluency Total Correct, and NEPSY-II Word Generation: Semantic Total Score (Table 1; [19,23,24]). Data analyzed were age-based normative standard scores per standardized process associated with each measure.

2.3. Statistical analysis

Although not all participants completed all measures, missing data were determined to be missing at random. There were no outliers, and data were normally distributed. Data were assessed for possible covariates using one-way ANOVAs, revealing two covariates: SES and ethnicity. Multiple ANCOVAs were run to assess study hypotheses. Analyses were controlled for SES and ethnicity. Because of multiple analyses, the Bonferroni adjusted value of 0.01 was used for significance level.

3. Results

3.1. Participant characteristics

In this study, 84.6% of children were classified as having active epilepsy (i.e., one seizure within the past year) at the time of the evaluation. Furthermore, seizures in 71.2% of children were classified as pharmacoresistant, defined for this study as seizures that failed to respond to two or more antiepileptic medications. At the time of this evaluation, 8 children were seizure-free for 1 year, 13 had less than 1 seizure a month, 16 had between 1 and 3 seizures a month, 9 had 1 to 4 seizures a week, 5 had 5 to 10 seizures a week, and one child had daily seizures. Seizure frequency did not differ between the groups (χ^2 (2, N = 52) = 7.30, p = .19). In total, 80.8% of children had focal epilepsy, with 15.4% of these children also showing secondary generalization. The remaining 19.2% of children had generalized epilepsy. Planned analyses were run both with and without children with generalized epilepsy (Table 2) for all analyses expect Verbal Fluency: Category Switching Total Switching Accuracy, which failed to meet test assumptions. As expected, results did not differ, and thus, children with generalized epilepsy were retained in the sample for all analyses. Lateralization was not differentially distributed between the groups (χ^2 (2, N = 52) = 5.32, p = .07) nor was localization (χ^2 (4, N = 51) = 3.03, p = .55). Lateralization was trending toward a significant difference, with a greater number of children with left hemisphere focal epilepsy in the bilingual group. The majority of children in the study with focal epilepsy had seizure foci in the frontal (N = 12), temporal (N = 12), or frontal–temporal (N = 14) regions. Additionally, 2 children from each group had seizure foci in the parietal–occipital (N = 4) region. Approximately half of the subjects were receiving monotherapy (53.8%), with the remainder receiving polytherapy (44.2%) or no AEDs (1.9%). Handedness was not distributed differently between the two groups (χ^2 (2, N = 51) = 1.23, p = .55). All children

Table 1
Neuropsychological measures.

Instrument	Specific scale	Cognitive domain (subdomain)	n
Wechsler Intelligence Scale for Children, 4th Edition	Full-scale IQ	Intellectual functioning	n = 42
Wechsler Abbreviated Intelligence Scale			n = 2
Wechsler Adult Intelligence Scale, 4th Edition			n = 8
Delis–Kaplan Executive Functioning System	Verbal Fluency: Condition 1	Verbal fluency (lexical fluency)	n = 21
	Verbal Fluency: Condition 2	Verbal fluency (semantic fluency)	n = 21
NEPSY-II	Word Generation	Verbal fluency (lexical fluency)	n = 6
Controlled Oral Word Association	FAS	Verbal fluency (lexical fluency)	n = 25
	Animals	Verbal fluency (semantic fluency)	n = 25
Wechsler Intelligence Scale for Children, 4th Edition	Working Memory Index	Working memory	n = 44
Wechsler Adult Intelligence Scale, 4th Edition			n = 8
The Trail Making Test	Trails B	Executive functioning (nonverbal sequencing and set-shifting)	n = 20
Delis–Kaplan Executive Functioning System	Trail Making Test, Condition 4	Executive functioning (nonverbal sequencing and set-shifting)	n = 17
Delis–Kaplan Executive Functioning System	Verbal Fluency, Condition 4	Executive functioning (verbal mental flexibility)	n = 21