Validation of *The Reading House* and Association With Cortical Thickness

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abstract

BACKGROUND AND OBJECTIVES: The American Academy of Pediatrics recommends literacy and school readiness promotion during well visits. *The Reading House* (TRH) is a children's book–based screener of emergent literacy skills in preschool-aged children. Vocabulary, rhyming, and rapid naming are core emergent skills, and reading abilities are associated with thicker cortex in the left hemisphere. Our objective was to expand validity of TRH relative to these skills and explore association with cortical thickness.

METHODS: Healthy preschool-aged children completed MRI including a T1-weighted anatomic scan. Before MRI, TRH and assessments of rapid naming (Comprehensive Test of Phonological Processing, Second Edition), rhyming (Pre-Reading Inventory of Phonological Awareness), vocabulary (Expressive Vocabulary Test, Second Edition), and emergent literacy (*Get Ready to Read!*) were administered. Analyses included Spearman-ρ correlations (r_ρ) accounting for age, sex, and socioeconomic status (SES). MRI analyses involved whole-brain measures of cortical thickness relative to TRH scores, accounting for covariates.

RESULTS: Seventy children completed assessments (36–63 months old; 36 female) and 52 completed MRI (37–63 months; 29 female). TRH scores were positively correlated with Comprehensive Test of Phonological Processing, Second Edition (r_ρ = 0.61), Expressive Vocabulary Test, Second Edition (r_ρ = 0.54), *Get Ready to Read!* (r_ρ = 0.87), and Pre-Reading Inventory of Phonological Awareness scores (r_ρ = 0.64; all $P < .001$). These correlations remained statistically significant across age, sex, and SES groups. TRH scores were correlated with greater thickness in left-sided language and visual cortex (*P*–family-wise error <.05), which were similar for higher SES yet more bilateral and frontal for low SES, reflecting a less mature pattern (*P*–family-wise error <.10).

CONCLUSIONS: These findings expand validation evidence for TRH as a screening tool for preschool-aged children, including associations with emergent skills and cortical thickness, and suggest important differences related to SES.

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Dr Hutton conceived, wrote, and coordinated publication of *The Reading House*, developed and collaborated in the refinement of the screening measure, designed all aspects of the study including the MRI protocol, collaborated in analyses, and drafted the initial manuscript and subsequent revisions; Dr Dudley collaborated in and oversaw the MRI acquisition protocol, conducted all MRI data analyses and interpretation, created all derivative tables and figures, and assisted with manuscript preparation and revisions; Ms Huang conducted all statistical analyses, created all figures and tables, and reviewed and revised the manuscript; Ms Horowitz-Kraus collaborated in study design, MRI protocol, and analyses and interpretation and reviewed and revised the manuscript and subsequent revisions; (Continued)

WHAT'S KNOWN ON THIS SUBJECT: Vocabulary, rhyming, and rapid naming are foundational emergent literacy skills, supported by defined brain networks. Reading abilities are associated with thicker cortex in the left hemisphere. *The Reading House* is a recently validated screener of emergent skills in preschool-aged children.

WHAT THIS STUDY ADDS: *The Reading House* scores were correlated with higher vocabulary, rhyming, and rapid naming abilities and thicker cortex in literacy-supporting areas. With our findings, we reinforce its validity as an early screening measure and provide brain-based correlates of emergent skills at a formative age.

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The American Academy of Pediatrics recommends literacy and school readiness promotion during well visits.[1–3] The National Center for Learning Disabilities cites improved screening and recognition of early signs of reading difficulties by health care providers as priorities.[4] Although developmental screening is a mainstay of pediatric practice,[5] there is no established standard to assess reading readiness and identify children at risk. Thus, many children arrive at kindergarten unprepared to learn to read, particularly from minority and economically disadvantaged backgrounds, the latter rate estimated at 50%.[6–9]

The Reading House (TRH) (blue manatee press) is a specially designed children's book and 9-item screening measure recently validated for preschool-aged children during well visits.[10] Screening generates an age-adjusted performance level to frame guidance, and the book is intended for the family to take home. TRH is grounded in the concept of emergent literacy,[11] a developmental continuum in which component skills accrue in typical age ranges beginning in infancy. Vocabulary, rhyming, and rapid automatized naming (RAN) are skills that emerge relatively early, predictive of reading success, and often implicated in reading difficulties.[12] Expressive vocabulary and rhyming are included in TRH, whereas RAN is less feasible for screening.

Emergent literacy skills are supported by language and other brain regions that are gradually integrated into a functional reading network,[13,14] ideally in early childhood when plasticity is high.[15] Core areas described via MRI include inferior frontal (ie, Broca's), superior temporal (ie, Wernicke's), and occipital-temporal gyri, typically lateralized in the left hemisphere.[16–18] Print exposure and reading abilities have been associated with thicker gray matter cortex in reading-related brain areas in children and adults.[19] However, in no previous studies have researchers explored relationships between emergent literacy skills and cortical thickness before kindergarten. As fostering healthy brain development during early childhood is increasingly emphasized at clinical, program, and policy levels,[3,20,21] improved understanding of neurobiological correlates is vitally important.

Our objectives with this study were (1) to expand validation evidence for TRH, referenced to established measures of core skills typically emerging in the preschool age range that are predictive of reading outcomes (vocabulary, rhyming, RAN), and (2) to explore relationships between TRH and brain cortical thickness at this foundational stage of development. Our hypothesis was that TRH scores would be positively correlated with those for each component measure and would also map to thicker cortex in left-lateralized areas supporting an emerging reading network.

METHODS

TRH

TRH is a board-format book for young children that models early reading skills, described in the previous study (Supplemental Fig 3).[10] TRH assessment follows, yet is distinct from, the narrative and is intended to be administered to preschool-aged children (3–5 years old). Scoring involves 9 items, with the total score ranging from 0 to 14 points. Content includes phonological awareness (including rhyming) and expressive vocabulary.[10] Internal consistency, reliability, and concurrent validity referenced to the *Get Ready to Read!* (GRTR) standard were established previously.[10] The total score maps to age-adjusted performance levels for 36 to 47 months and 48+ months of age: below average (≤2, ≤4 points), average (3–5, 5–10 points), and above average (≥6, ≥11 points).

Language and Literacy Measures

Four assessments of emergent literacy abilities were administered before MRI: Expressive Vocabulary Test, Second Edition (EVT-2), Comprehensive Test of Phonological Processing, Second Edition (CTOPP-2) (rapid object naming subtest), GRTR, and the Pre-Reading Inventory of Phonological Awareness (PIPA) (rhyming subscale). The EVT-2 is a norm-referenced assessment of expressive vocabulary for ages 2.5 years and older.[22] The CTOPP-2 is a norm-referenced assessment of phonological abilities that are prerequisite to reading fluency.[23,24] The rapid object naming subtest is used to assess speed and accuracy of retrieval of verbal information from memory (broadly referred to as RAN) in young children, not requiring letter mastery. GRTR is a norm-referenced assessment of composite emergent literacy skills for children 3 to 6 years old, predictive of reading outcomes.[25] PIPA is a norm-referenced assessment of phonological abilities for ages 3 to 6 years old, with a rhyming subtest.[26]

Participants and Setting

Healthy children between 3 and 5 years old were recruited at an academic pediatric center and primary care clinics in a large Midwestern city. Eligibility criteria were (1) ≥36 weeks' gestation, (2) age 36 to 52 months, (3) no documented history of global developmental delay or neurobehavioral disorder, and (4) native English-speaking custodial parent. Written informed consent was obtained from a custodial parent, and families were provided with financial compensation. The study was approved by the center's institutional review board.

Screening and Assessments

Clinical research coordinators (CRCs) administered TRH and other assessments in a private room before MRI. TRH and GRTR were administered by using a randomized assignment list, followed by the other 3 assessments at the discretion of the CRC to keep the child engaged.

Statistical Analyses

Descriptive statistics were computed for all demographic and other variables specified in the study's statistical analysis plan. Spearman-ρ correlation coefficients (r_ρ) were then computed between TRH total scores and each cognitive measure. This approach was deemed most conservative given the modest sample size and nonnormative nature of several score distributions. Spearman correlations were then computed separately for older and younger children (36–47, 48+ months), boys and girls, and higher– and low–socioeconomic status (SES) households. SES was defined as a binary variable in terms of 2020 US poverty criteria by using the midpoint of income category relative to household size.[27] Finally, external criterion scores were computed and summarized by TRH performance level (below average, average, above average) for the combined sample and each age group. The criterion for statistical significance was $\alpha = .05$, unadjusted. Analyses were conducted by using SAS (SAS Institute, Inc, Cary, NC) version 9.4 software.

TABLE 1 Demographics and Summary Scores

	n (%)	*n*	Mean ± SD	Minimum, Maximum
Total, *N* (%)	70 (100)	—	—	—
Child age, mo				
36–47	23 (33)	—	—	—
48+	47 (67)	—	—	—
Child sex				
Male	34 (49)	—	—	—
Female	36 (51)	—	—	—
Annual household income, $				
≤25 000	13 (19)	—	—	—
25 001–50 000	11 (16)	—	—	—
50 001–100 000	21 (30)	—	—	—
100 001–150 000	14 (20)	—	—	—
>150 000	11 (15)	—	—	—
Income[27] relative to needs				
At or under poverty threshold	16 (23)	—	—	—
Above poverty threshold	54 (77)	—	—	—
Maternal education				
High school or less	7 (10)	—	—	—
Some college	17 (24)	—	—	—
College graduate	24 (34)	—	—	—
More than college	22 (32)	—	—	—
TRH total score	—	70	7.3 ± 4.2	0, 14
CTOPP-2 rapid object naming scaled	—	50	9.0 ± 3.2	2, 15
EVT-2 scaled score	—	67	110.2 ± 15.3	87, 144
GRTR total score	—	70	16.4 ± 6.5	5, 25
PIPA rhyming score	—	69	4.8 ± 3.3	0, 12

—, not applicable.

MRI and Analyses

Details of play-based acclimatization techniques before MRI are described previously.[28] The protocol involved structural and functional MRI, but only structural scans were used for this study. Children were awake and nonsedated during MRI, which was conducted by using a 3.0T Philips Ingenia scanner with a 32-channel head coil. High-resolution, three-dimensional, T1-weighted anatomic images were acquired (repetition time/echo time = 8.1/3.7 millisecond; duration 5.25 minutes; field-of-view = 256 × 256 mm; matrix = 256 × 256; in-plane resolution = 1 × 1 mm; slice thickness = 1 mm; number of slices = 180, sagittal plane). Processing used the Computational Anatomy Toolbox (Structural Brain Mapping Group, Jena, Germany), which performs nonlinear transformations for voxel-based preprocessing and then computes surface-based morphometric (cortical thickness) measures. Those for individual subjects were mapped to a standard template space (~2-mm spacing) by using the Template-O-Matic 8 toolbox[29] for tissue segmentation, voxel-based spatial registration, and initial cortical surface creation, which was finalized by using the FreeSurfer FsAverage template and then smoothed along the surface with a 15-mm full-width half-maximum Gaussian kernel. Subjects with weighted image quality (calculated on the basis of resolution, signal-to-noise ratio, and bias field strength) of 2 or more SDs below the group mean and/or subjects with a mean correlation coefficient of cortical thickness 2 or more SDs below the group mean were excluded as outliers. Smoothed thickness maps for the remaining subjects were then fit to a multiple regression model to estimate the effect of TRH scores on cortical thickness across the whole brain, controlling for age. Analogous models were also employed for higher- and lower-SES subgroups. Sex was considered as a covariate but excluded because of empirically determined nonsignificance of association with thickness in the cohort. Threshold-free cluster enhancement was used to circumvent arbitrary threshold dependence of cluster identification, and 5000 random permutations of the design matrix were used to control family-wise error (FWE) rate at two-sided $\alpha = .05$ or .10.

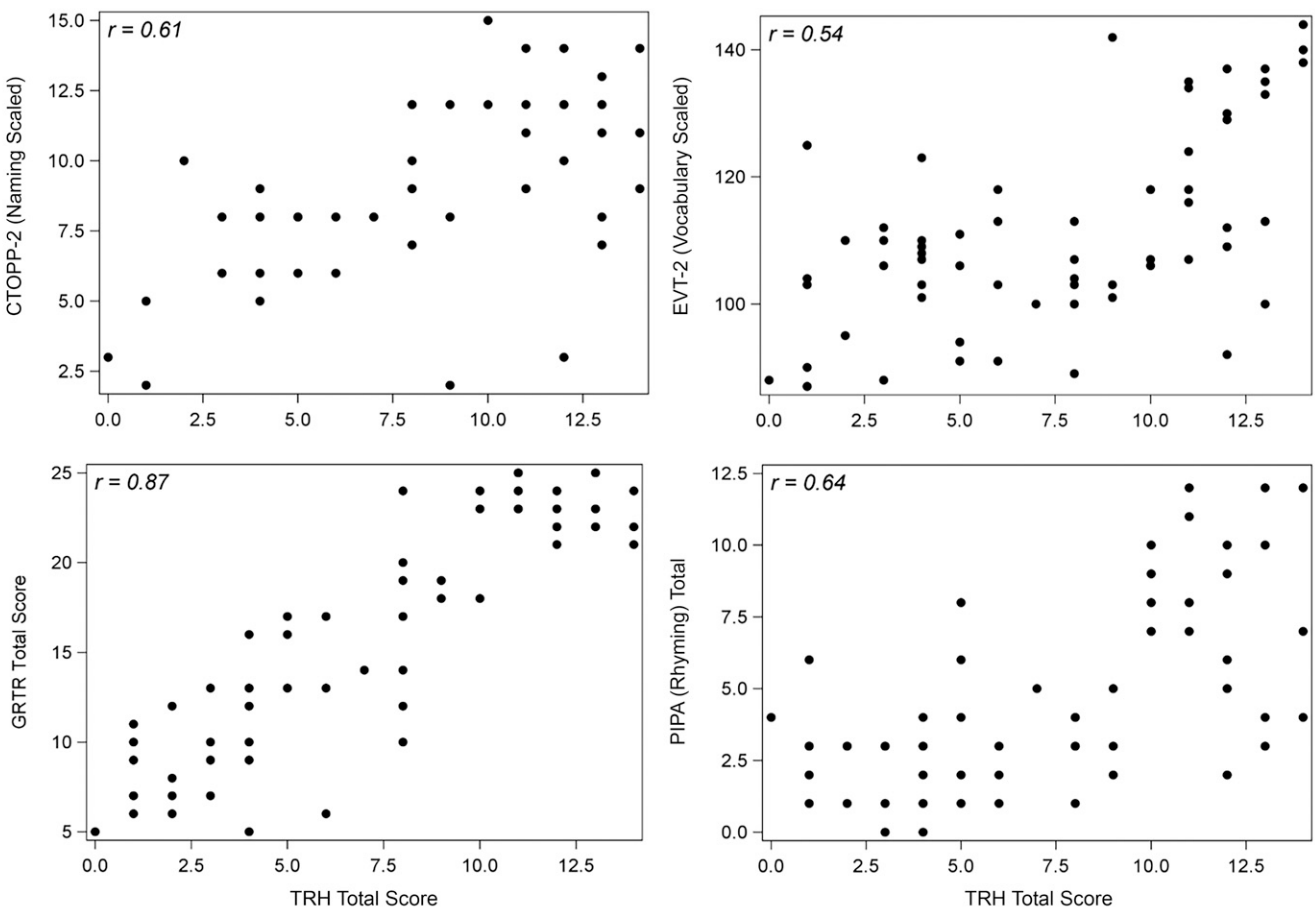

FIGURE 1
Scatter plots of TRH versus language and literacy scores. Shown are scatter plots of TRH versus (clockwise from top left) expressive vocabulary (EVT-2), rapid naming (CTOPP-2), rhyming (PIPA), and emergent literacy composite (GRTR scores for the entire sample (n = 70), with Spearman-ρ coefficients.

RESULTS

Sample Characteristics

A total of 70 children presented for MRI, with a mean age of 52 ± 8 months (range 36–63) with 34 boys and 35 girls. The mean TRH score was 7.3 ± 4.2 (0–14). Demographics and assessment scores are summarized in Table 1.

Cognitive Measure Analyses

TRH total scores were positively correlated with CTOPP-2 rapid naming scaled (r_ρ = 0.61), EVT-2 standard (r_ρ = 0.54), GRTR (r_ρ = 0.87), and PIPA total scores (r_ρ = 0.64; all $P < .01$). Scatter plots are shown in Fig 1. For children completing MRI with acceptable image quality (n = 52), these correlations were similar: CTOPP-2 (r_ρ = 0.61), EVT-2 (r_ρ = 0.47), GRTR (r_ρ = 0.84), and PIPA (r_ρ = 0.68; all $P < .01$).

For both the whole sample and those completing MRI, correlations between TRH and each of the 4 cognitive measures were essentially equivalent for boys and girls and remained highly significant for each age range (all $P < .01$), with the exception of PIPA for younger children. Correlations with GRTR were essentially equivalent for in-poverty and nonpoverty households (r_ρ = 0.84 and 0.83, respectively; $P < .01$), higher with EVT-2 for in-poverty households (r_ρ = 0.65 vs 0.47; $P < .01$) and higher with the other measures for nonpoverty households (CTOPP-2: r_ρ = 0.51, $P < .01$ versus r_ρ = 0.48, P = .14; PIPA: r_ρ = 0.68, $P < .01$ versus r_ρ = 0.36, P = .19).

Analyses of performance levels were conducted for TRH and are summarized in Table 2. Scores for each measure increased with increasing levels for both age groups, with the exception of PIPA for younger children.

MRI Analyses

A total of 58 children completed MRI, 52 of them with acceptable image quality (age 52.7 ± 7.7 months; 29 girls and 23 boys). Higher TRH scores were correlated with thicker cortex in temporal, inferior parietal, and inferior occipital areas in the left hemisphere, controlling for age (P-FWE <.05), shown in Fig 2A and described in Table 3. Thickness patterns were similar yet more extensive for children of higher SES (P-FWE <.10; Fig 2B, Table 3). These

TABLE 2 Summary Statistics for External Measure Outcome Scores by TRH Performance Level

External Measure (TRH Performance Level)	All Children		36–47 mo		48+ mo	
	N	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
EVT-2						
Below average	14	100.7 (11.7)	9	101.3 (12.6)	5	99.6 (11.1)
Average	28	103.7 (8.4)	7	109.4 (7.1)	21	101.8 (8.0)
Above average	25	122.8 (14.9)	5	118.3 (17.6)	21	123.6 (14.6)
CTOPP-2 (naming)						
Below average	6	5.2 (2.8)	4	5.8 (3.0)	2	4.0 (2.8)
Average	21	8.4 (2.8)	5	7.2 (1.6)	16	8.8 (3.0)
Above average	23	10.6 (2.6)	3	9.3 (2.3)	20	10.8 (2.7)
PIPA (rhyming)						
Below average	14	2.6 (1.5)	9	3.0 (1.5)	5	1.8 (1.3)
Average	29	3.7 (2.5)	8	2.1 (1.4)	21	4.3 (2.6)
Above average	26	7.2 (3.3)	5	5.2 (4.1)	21	7.7 (3.0)
GRTR total score (composite)						
Below average	15	8.5 (2.4)	10	8.1 (2.3)	5	9.2 (2.5)
Average	29	15.3 (5.1)	8	10.9 (3.4)	21	17.0 (4.7)
Above average	26	22.1 (3.2)	5	17.6 (4.8)	21	23.2 (1.3)

were markedly different for children of low SES, who had thinner cortex overall (Supplemental Fig 4), yet relatively thicker cortex correlated with higher TRH scores in cingulate, bilateral frontal, insular, and right-sided parietal areas (*P*-FWE <.10; Fig 2C, Table 3).

DISCUSSION

With trusted access to families during clinic visits, pediatric providers are poised to convey literacy guidance and align efforts with early childhood educators. However, there is no established approach to emergent literacy screening in pediatrics, particularly involving measures that directly engage the child. This reflects an important gap, as many children arrive at preschool and/or kindergarten with inadequate reading readiness, particularly those from disadvantaged backgrounds,[6,7] and then face outsized risk for reading difficulties.[7,30] TRH was developed to address this, providing efficient, enjoyable means to directly screen children proximal to recommended preschool entry and structure guidance complimenting existing programs.[31] Usability and concurrent validity were established previously,[10] and in this study, we expand this evidence by establishing relationships with core emergent skills that are predictive of reading outcomes.[32,33] We also map TRH scores to brain cortical thickness, which has also been linked to reading abilities,[19] providing a novel neural correlate at a formative age.[34]

TRH scores were highly correlated with those on the GRTR (r_ρ = 0.87), the gold standard composite used previously,[25,35] and moderately to highly so with scores for the other measures. This reinforces the potential of TRH as a composite screening tool able to differentiate performance in children with distinct trajectories (or deficits) in component skills, alerting clinicians or educators of a need for further investigation or support. Expressive language (EVT-2) is the basis for comprehension and often lags in children from disadvantaged home environments.[36] Early intervention programs such as Reach Out and Read (ROR) and Dolly Parton's Imagination Library help bridge the "word gap" experienced by such children[37] by encouraging book sharing at home.[38,39] Rhyming (PIPA) is among the earliest phonological abilities to emerge, typically explosively between 2.5 and 5 years old.[40] Low rhyme sensitivity can be an early sign of dyslexia[41] and can be improved via targeted practice, such as parent coaching,[42] dialogic reading,[43] and/or practice in quality preschool settings.[40] RAN (CTOPP-2) is a strong independent predictor of reading abilities[44,45] and measures the child's ability to process visual information and associate it with verbal representations.[46] In typically developing children, RAN first supports object recognition, followed by letters ("breaking the alphabet code") and words (fluency).[47,48] Low RAN can fuel reading difficulties alone or compound other deficits[49,50] and is relatively difficult to remediate, although school-based interventions have been described.[32]

Steady increases in scores for each of the component measures corresponding with higher TRH performance levels reinforce evidence of their reliability to differentiate abilities. Patterns for older and younger age groups reflecting component trajectories also provide useful insights. For example, lower TRH performance in younger children was most closely related to lower vocabulary and later emergence of rhyming abilities, each linked to language and reading exposure at home[36,51,52] and addressed by interventions such as Head Start,[53] Dolly Parton's Imagination Library,[39] and ROR.[38] By contrast, lower performance in older children was most closely related to lower RAN and phonological abilities, each linked to dyslexia,[54] and may warrant heightened surveillance and/or referral. However, these insights are preliminary, and longitudinal studies are needed to clarify risk profiles.

Although correlation between TRH and GRTR composite scores was nearly equivalent across SES levels, there were important differences in relationships with scores on component measures. Notably, TRH scores were more strongly correlated

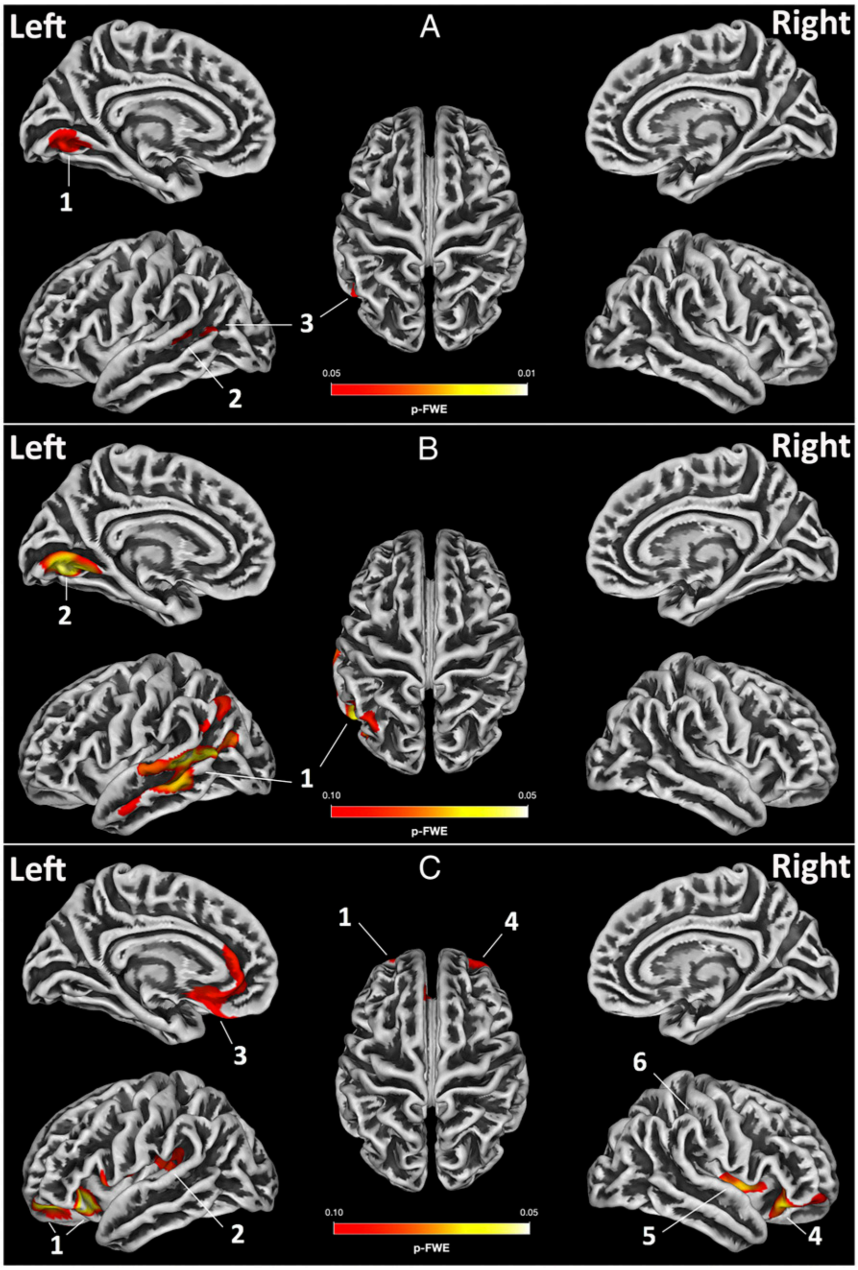

FIGURE 2
Cortical thickness maps showing correlation with TRH scores. Three-dimensional maps reveal correlations between TRH total scores and gray matter cortical thickness for the total sample (A) (*P*-FWE <.05), children from higher-SES households (B) (*P*-FWE <.10), and children from lower-SES households (C) (*P*-FWE <.10), controlling for age. Areas with significant positive association (thicker) are shown in red hues. For each, upper views are medial, lower views are lateral, and the central view is superior. Numbered cortical regions are detailed in Table 3.

with vocabulary (EVT-2) for children of low SES and with phonological abilities (PIPA) for those of higher SES. This suggests that higher TRH scores in children of low SES may be fueled by more basic skills and those for children of higher SES may be fueled by more advanced skills. This is consistent with the impact of early adversity on language abilities and resulting lag in reading readiness.[55–57] Surprisingly, correlation with RAN (CTOPP-2) was only marginally lower for lower-SES children, which may reflect less dependence of RAN on SES at this age or the untimed nature of TRH items. Regardless, these findings suggest that support for children from impoverished backgrounds who score low on TRH should be broadly based, addressing vocabulary as well as phonological and other skills, whereas support for children from higher-SES backgrounds may be more targeted.

The neurobiological basis of emergent literacy is increasingly well described, involving left-lateralized cortical areas synchronized into a functional "reading network."[58,59] Maps of cortical thickness correlated with higher TRH scores (Fig 2A) align with this model and also align with evidence involving stronger reading abilities in older children and adults.[19] The temporal-parietal areas support receptive language[16] and visual-language association (eg, imagery) during story listening or reading.[60] The occipital-temporal (lingual) gyrus supports visual memory encoding, RAN, and complex visual processing, notably letter recognition.[61,62] It is adjacent to the visual word form area, a core of the typical reading network that supports lexical processing, encoding, and reading fluency.[61,63] Because cortical thickness in the left visual word form area in older children is associated with reading abilities,[19] it is possible that increased thickness in the lingual gyrus with higher emergent skills (TRH) may be a neural correlate of more basic processes at an earlier stage of development.

Altogether, relationships between higher TRH scores and cortical thickness were consistent with those for the cognitive measures. However, akin to cognitive findings, subgroup MRI analyses by SES reveal notable differences. Whereas thickness patterns for children of higher SES were left lateralized, consistent with a typical emerging reading network (Fig 2B), those for children of low SES

TABLE 3 Extent and Description of Cortical Areas With Higher Thickness Correlated With TRH Scores, Including Subgroups by Poverty (SES) Status

Sample	Hemisphere (Label)	No. Vertices	Overlap, %	Atlas Region	Major Function
Combined (n = 52)	Left (1)	175	100	Lingual gyrus	Visual processing (shapes, letter and word forms), imagery, semantic memory and retrieval
	Left (2)	102	100	Superior temporal sulcus	Receptive language, audiovisual integration, social cognition
	Left (3)	75	51	Inferior parietal lobule	Semantic language and association
	—	—	33	Superior temporal sulcus	Receptive language, audiovisual integration, social cognition, empathy
	—	—	16	Middle temporal gyrus	Semantic language
Higher SES (nonpoverty) (n = 43)	Left (1)	1589	34	Inferior parietal lobule	Semantic language and association
	—	—	26	Superior temporal sulcus	Receptive language, audiovisual integration, social cognition
	—	—	22	Middle temporal gyrus	Semantic language
	—	—	12	Superior temporal gyrus	Receptive language
	—	—	4	Supramarginal gyrus	Phonological processing, association
	Left (2)	364	96	Lingual gyrus	Visual processing (shapes, letter and word forms), imagery, semantic memory and retrieval
	—	—	4	Pericalcarine gyrus	Visual processing, imagery
Low SES (poverty) (n = 9)	Left (1)	561	73	Lateral orbitofrontal gyrus	Executive functions, limbic association
	—	—	12	Pars orbitalis	Language
	—	—	10	Rostral middle frontal gyrus	Language
	—	—	4	Insula	Social cognition
	—	—	1	Pars triangularis	Expressive language
	Left (2)	668	25	Supramarginal gyrus	Phonological processing, association
	—	—	21	Precentral gyrus	Primary motor
	—	—	16	Pars opercularis	Language processing
	—	—	15	Insula	Social cognition
	—	—	9	Postcentral gyrus	Primary sensory
	—	—	9	Superior temporal gyrus	Receptive language
	—	—	6	Transverse temporal gyrus	Primary auditory
	Left (3)	325	58	Anterior cingulate gyrus	Executive functions, emotional control
	—	—	42	Medial orbitofrontal gyrus	Executive functions, goal directed
	Right (4)	501	34	Lateral orbitofrontal gyrus	Executive functions, sensory and limbic integration, decision-making
	—	—	32	Pars orbitalis	Attention, executive, imagery
	—	—	23	Pars triangularis	Attention, executive, imagery
	—	—	12	Rostral middle frontal gyrus	Ventral attention, reorienting
	Right (5)	314	82	Insula	Social cognition, self-awareness, salience
	—	—	16	Superior temporal gyrus	Language, social perception
	—	—	2	Transverse temporal gyrus	Primary auditory
	Right (6)	35	100	Supramarginal	Social cognition, proprioception

Extent, atlas labels, and major function of clusters with greater thickness correlated with higher TRH scores controlling for child age, shown in Fig 2A (combined sample, FWE-corrected two-sided $P < .05$), Fig 2B (higher-SES backgrounds), and Fig 2C (low-SES background; each FWE-corrected two-sided $P < .10$). The number in parentheses corresponds to the respective image label in the designated hemisphere. Vertices are points on the cortical surface comprising each numbered cluster. Overlap is the proportion of a given cluster that falls within the noted atlas region.

were markedly bilateral, concentrated in inferior frontal areas (Fig 2C). This has been interpreted as a less efficient (or "strain") pattern in children with lower language and reading abilities.[64,65] Although preliminary in a small subsample, this suggests a neural correlate of low reading readiness in children from impoverished backgrounds, aligning with the finding of lower scores on TRH fueled by more basic component skills. It is also notable that these children had significantly thinner cortices in general, consistent with MRI-based studies of early adversity.[66,67] Research is needed to better understand factors fostering neural-cognitive resilience to improve outcomes.

This study has limitations. Although these findings expand validation evidence for TRH, including neurobiological correlates, predictive validity has yet to be established, which requires a longitudinal design. TRH was administered by CRCs during an MRI visit and it is possible that results would not generalize to other settings. The sample was largely of higher SES (67% nonpoverty) and results might be different with greater diversity. Conservative Spearman correlations were used instead of regression models for cognitive analyses, yet these generated robust results accounting for subgroups of age, sex, and SES. Reduced sample sizes for SES subgroups in MRI analyses did not survive at FWE $P < .05$ yet did for FWE $P < .10$, and in each case, stringent correction and two-sided approach reduced the likelihood of false-positives. Differences in MRI and cognitive results related to SES may be considered a strength because these align in terms of quantifying reading readiness (ie, lower TRH scores and less efficient thickness pattern for the low-SES group), suggest adversity-informed approaches to guidance, and raise questions for further research.[56]

This study also has strengths. The cognitive measures used are well established and assess distinct core skills that typically emerge in the preschool age range and are predictive of reading abilities. Scores aligned with TRH performance levels, reinforcing validity as a screening measure, suggesting major drivers of performance at younger and older ages, and approaches to guidance and interventions. MRI analyses involved a whole-brain approach accounting for subject motion and multiple comparisons, reducing the likelihood of false-positive results. These suggest novel biomarkers of emergent skills at a formative age, involving more typical areas in children of higher SES[58,59] and a less mature pattern for children in poverty.[64,65] The findings translate into pediatric or preschool use, addressing opportunities to improve surveillance and guidance, complimenting existing programs such as ROR. Future studies involving administration of TRH by clinicians or educators, integration into workflows with fidelity, and refined approaches to guidance are needed. Training materials including a manual and demonstration video have been developed[68] and pilot studies including test-retest reliability and administration by clinic staff have been promising. Altogether, with this study, we expand evidence supporting TRH as a valid and engaging approach to emergent literacy screening in preschool-aged children consistent with American Academy of Pediatrics literacy and school readiness recommendations[1,3] and suggest novel neural correlates of abilities at a formative age.

CONCLUSIONS

In this study involving preschool-aged children, higher scores on TRH were correlated with stronger vocabulary, rhyming, and rapid naming abilities accounting for age and sex, with differences in magnitude related to SES. Higher scores were also correlated with thicker gray matter cortex in left-sided areas supporting language and literacy, although less mature patterns were found for children of low SES. These findings expand evidence of validity of TRH as an engaging approach to emergent literacy screening and guidance at a formative age, particularly for children from impoverished backgrounds. Longitudinal studies are needed to establish predictive validity and to assess performance when administered by providers.

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APPENDIX

For more information about TRH, including the administration and scoring form, technical manual, and demonstration video, or to order for research or clinical use, visit http://www.bluemanateepress.com/nonprofit/ or e-mail press@bluemanateebooks.com or john1.hutton@cchmc.org.

ABBREVIATIONS

CRC: clinical research coordinator
CTOPP-2: Comprehensive Test of Phonological Processing, Second Edition
EVT-2: Expressive Vocabulary Test, Second Edition
FWE: family-wise error
GRTR: *Get Ready to Read!*
PIPA: Pre-Reading Inventory of Phonological Awareness
RAN: rapid automatized naming
ROR: Reach Out and Read
SES: socioeconomic status
TRH: *The Reading House*

Dr DeWitt provided guidance on study design, analyses, and clinical application and reviewed and revised the manuscript; Dr Ittenbach directed and supervised statistical data analyses for this study, collaborated with Dr Hutton in development of *The Reading House* screening instrument, and reviewed and revised the manuscript; Mr Holland provided guidance on study design, helped develop and oversaw the MRI acquisition protocol, collaborated in analyses and interpretation, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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