Shared Reading Quality and Brain Activation during Story Listening in Preschool-Age Children

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Objective To explore the relationship between maternal shared reading quality (verbal interactivity and engagement) and brain function during story listening in at-risk, preschool-age children, in the context of behavioral evidence and American Academy of Pediatrics, recommendations.

Study design In this cross-sectional study, 22 healthy, 4-year-old girls from low socioeconomic status households completed functional magnetic resonance imaging using an established story listening task, followed by videotaped observation of uncoached mother-daughter reading of the same, age-appropriate picture book. Shared reading quality was independently scored applying dialogic reading and other evidence-based criteria reflecting interactivity and engagement, and applied as a predictor of neural activation during the functional magnetic resonance imaging task, controlling for income and maternal education.

Results Shared reading quality scores were generally low and negatively correlated with maternal distraction by smartphones ($P < .05$). Scores were positively correlated with activation in left-sided brain areas supporting expressive and complex language, social-emotional integration, and working memory ($P < .05$, false discovery rate corrected).

Conclusions Maternal shared reading quality is positively correlated with brain activation supporting complex language, executive function, and social-emotional processing in at-risk, preschool-age children. These findings represent novel neural biomarkers of how this modifiable aspect of home reading environment may influence foundational emergent literacy skills, reinforce behavioral evidence and American Academy of Pediatrics, recommendations, and underscore the potential of dialogic reading interventions to promote healthy brain development, especially in at-risk households. *(J Pediatr 2017;191:204-11).*

The American Academy of Pediatrics recommends shared reading beginning as soon as possible after birth, citing enduring cognitive, social-emotional, and neurobiological benefits.[1] Interventions target home reading environment, a composite of quantitative and qualitative factors.[2] Positive association between quantitative factors (access to books and reading frequency) and brain activation supporting imagery and comprehension in preschool-age children was recently described, complementing behavioral evidence.[3] However, the influence of shared reading quality (verbal interactivity and engagement) on the developing brain has not been investigated.

Originally developed as an intervention to promote language development in low socioeconomic status (SES) children,[4] dialogic reading is a construct reflecting verbal interactivity and engagement during shared reading.[4] Through the use of specific types of prompts and responses, the caregiver encourages the child to participate in a reciprocal dialogue catalyzed by the story.[4,5] Behavioral evidence suggests that dialogic reading may confer moderate to large benefits,[6] including expressive language,[7,8] narrative comprehension,[5] and attention,[9] all foundational emergent literacy skills.[10] Social-emotional benefits are also cited, including increased parent-child bonding and enjoyment of reading.[11,12] Nurturing behaviors such as child-directed speech and lap sitting can also enhance shared reading quality and improve outcomes.[13] However, although highly variable, shared reading quality "dialogic-ness" tends to be low in low SES households.[7,14,15] Thus, programs such as Reach Out and Read targeted to low SES, at-risk families encourage providers to model dialogic reading during pediatric well-child visits.[2]

BOLD	Blood oxygen level dependent
CROWD	Completion, Recall, Open-ended questions, Wh- questions, Distancing
FDR	False discovery rate
fMRI	Functional MRI
IFG	Inferior frontal gyrus
MRI	Magnetic resonance imaging
PEER	Prompt, Evaluation, Expansion, Repetition
SES	Socioeconomic status

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As reading is an evolutionarily new, invented skill, there is no hardwired reading network in the brain. Instead, beginning in infancy, brain areas and networks adapted for other functions such as vision, language, and working memory are gradually integrated in response to reading exposure and practice.[16] This neurobiological process underlies emergent literacy, the skills, knowledge, and attitudes required to learn to read and write,[10] its foundation laid during the span of rapid brain growth between birth and age 5 years.[17] It is clear that neurobiological differences during this span predate[18] and can often predict behavioral differences, such as phonological awareness and vocabulary,[19,20] and long-term outcomes such as reading ability.[21] Less clear are questions regarding the potential to influence this neurobiological process via home reading practices, specific types of interventions, and dose-response thresholds thereof, during critical developmental stages. Neuroimaging is increasingly applied to provide mechanistic insights into such questions in the context of early home environment and child health outcomes.[3,22,23]

The purpose of this study was to apply neuroimaging to explore the association between maternal shared reading quality, which behavioral evidence suggests can convey substantial benefits, and brain function supporting emergent literacy skills in a sample of 4-year-old girls from low SES households. We hypothesized that children whose mothers exhibited higher-quality shared reading behaviors would show greater activation in brain areas supporting expressive language,[24] social-emotional processing,[12] and attention.[25]

Methods

All participants in this cross-sectional study were enrolled in a longitudinal home injury prevention trial. That cohort consists of 650 mother-child dyads recruited in infancy from a home visiting program serving low-SES, first-time mothers.[26] Inclusion criteria for the present study were female sex, approximately 4 years old, full-term gestation, native English speaking household, no history of brain injury or developmental delay, and no contraindications to magnetic resonance imaging (MRI). Girls were exclusively sampled because of time/budget constraints, higher previous MRI success rates (67% vs 41% for boys),[27] and negligible sex differences in brain activation patterns for our story listening task at this age.[28] We identified 105 girls who would be approximately 4 years old during our study window (oldest in the cohort). Of these, 55 were unable to be contacted, 5 were excluded due to developmental delay, and 4 did not participate because of concerns about MRI. Of the 41 agreeing to participate, 32 arrived for their visit at which informed consent was obtained, including for video observation. Of these, 22 successfully completed the MRI and video tasks (69%). Families were compensated for time and travel, and our study was approved by our medical center's Institutional Review Board.

MRI was performed via a 3T Philips scanner (Achieva, Philips Healthcare, Best, The Netherlands) equipped with an Avotec audiovisual system. Details of play-based MRI acclimatization techniques are described by Vannest et al and[29] MRI acquisition specifications are detailed in Schmithorst et al.[30] For functional MRI (fMRI), blood oxygenation level dependent (BOLD)-weighted scans covering the entire brain with voxel size $3 \times 3 \times 4$ mm were acquired at 2-second intervals (repetition time = 2). Data preprocessing was performed using FSL software (fMRI-Brain Software Library, Oxford, United Kingdom), as described by Sroka et al.[20] All children were awake and not sedated during MRI.

Our fMRI story listening task consists of 10 alternating blocks of active and control conditions (5 each) of 32 seconds duration, for a total functional scanning time of 5 minutes 20 seconds. During the active condition, a series of 5 stories of 9-10 sentences each read in a female voice was presented via headphones. The stories were created by a speech pathologist with vocabulary, syntax, and content appropriate for preschool-age children (https://www.irc.cchmc.org/software/pedaudio.php).[3,31] The control condition consisted of tones in a range of frequencies simulating human speech. No visual stimulus was presented other than a blank screen.

Following MRI, the mother and child were directed to a private waiting room and encouraged to relax. A high-definition webcam was unobtrusively mounted, and arranged on a table were popular magazines, a sign with a WiFi password, and a children's picture book (*The Little Engine That Could*, Philomel, New York). If the mother or child did not spontaneously choose the book within 3 minutes, a research coordinator advised them that it was theirs to take home and encouraged them to read it together, with no further coaching. After approximately 15 minutes or when finished reading, the research coordinator entered to complete the visit.

Scoring for video-reading observations was adapted from a standardized form developed for dialogic reading training.[32] Categories were (1) introducing the book to build interest (1 point); (2) CROWD prompts (1 point per instance): sentence Completion, Recall of parts of the story, Open-ended questions, "Wh-" questions, and Distancing to relate the story to the child's life; (3) PEER responses to what the child says after the Prompt (1 point per instance): Evaluate, Expand, and/or Repeat; and (4) discussing the book after reading (1 point). Additional evidence-based behaviors[13] were also scored: proximity (0-2 points for distant, side-close, or on lap), child page turning (0-2 points for never, sometimes, often), and use of child-adjusted voice such as sound effects (0-2 points, for never, sometimes, often).

The principal investigator and 2 additional scorers (medical student and research coordinator) independently scored all videos, which were entered into a secure Research Electronic Data Capture database.[33] Scoring training lasted 4 hours, including a dialogic reading online module[32] and interactive role play sessions.[2]

fMRI Group Mean Analysis and Linear Regression with Maternal Reading Quality Scores

A biostatistician uninvolved with video scoring performed all fMRI analyses. Group mean analysis was conducted via the fMRI Expert Analysis Tool (FMRIB Software Library, Oxford, UK) modality of FSL software, generating contrast maps reflecting