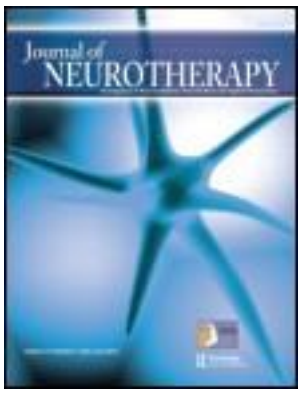

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Quantitative EEG Evidence of Increased Alpha Peak Frequency in Children with Precocious Reading Ability

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Quantitative EEG Evidence of Increased Alpha Peak Frequency in Children with Precocious Reading Ability

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ABSTRACT. *Background*. EEG research with specific clinical populations (e.g., Alzheimer's and mentally disabled) has confirmed that reduced alpha peak frequency often is associated with impaired cognitive functioning. However, research with high-functioning populations does not exist, and increased peak frequency in alpha has only been hypothesized to relate to advanced brain maturation.

Methods. This study compared peak frequency in the alpha band (8.0 to 12.0 Hz) of children with precocious reading ability to that of control groups. The experimental group consisted of 15 early readers (ER). One comparison sample included 15 age-level matched (ALM) children, similar to the ER group in terms of cognitive functioning and age, but reading at grade level. A second comparison group, composed of 15 reading-level matched (RLM) children, had intelligence and reading level scores equivalent to the ER group, but was 2.5 years older. Using

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The 2000 dissertation of Lynn A. Olson, PhD, "Quantitative EEG Features of Precociously Reading Children," provided the database for the analyses in the current study.

Lexicor NeuroSearch-24 equipment and v151 software, quantitative EEG (QEEG) data on each participant were obtained from 19 scalp electrode sites.

Results. As hypothesized, peak frequency in alpha differentiated the groups. Specifically, the ER group had significantly higher alpha peak frequency than the ALM group at 16 of the 19 electrode sites examined. The differences were consistent across all brain regions, as the mean alpha peak frequency at each site was between 9.0 and 9.3 Hz for members of the ER group and between 8.6 and 8.8 Hz for members of the ALM group. Peak frequency in alpha did not differ significantly between the ER and RLM sample.

Conclusions. Peak frequency in the alpha band is associated with precocious reading ability, and may be an indicator of advanced brain maturation.

KEYWORDS. Quantitative EEG, alpha, peak frequency, precocious readers, children

INTRODUCTION

Precocious readers represent a group of children who enter school with the ability to read far above expected, given their general intellectual abilities, histories of reading instruction and other home and educational experiences. While a great deal of scholarly work has attempted to identify the mechanisms that facilitate precocious reading ability, previous research has not incorporated understanding of the biological basis of brain and reading development to provide a more complete understanding of early reading skills.

Previous research suggests that the brain matures differently across stages of reading ability. Bakker (1979, 1983) posits that children in the early stages of reading rely more on right hemispheric functioning possibly due to visuospatial reliance. However, as readers become older and more fluent, left hemispheric language processing centers become more dominant. While neither hemisphere is completely inactive during a task, research with adult readers suggests that increased efficiency in reading is correlated with increased activation of the left hemisphere (Pugh et al., 1996, 1997). Thus, given the differences in brain activity between people of varying reading ability, quantitative electroencepha-

lography (QEEG) profiles observed in early readers (e.g., children) are likely to differ from those of adults.

Existing QEEG research suggests different patterns of brain maturation are associated with various developmental and reading levels. For example, Marosi et al.'s (1992, 1995, 1997) extensive investigations using QEEG coherence values to study reading differences has revealed that developmental patterns of poor readers are completely different from that of normal readers. Specifically, Marosi and colleagues (1992) found that coherence values of normal readers tend to increase with age in a symmetrical, Cz centered pattern, while children with reading difficulties show an asymmetrical maturation pattern, as well as a quantitative increase in theta and decrease in alpha coherence with age.

Research that has investigated peak frequency in the alpha rhythm band has been particularly useful in identifying differences in cognitive functioning and brain maturation. Of particular relevance to the present research, studies examining alpha peak frequency have revealed deviations from the norm in such clinical groups as Alzheimer's patients and children with mental retardation. Peak frequency refers here to the discrete frequency within the alpha band (8.0-12.0 Hz) that has the greatest amplitude.

For example, research that examined 18 children with average cognitive functioning and 20 children with mental retardation during a state of mental activity found the sample without mental retardation had marked changes in peak frequency (specifically, shifts between alpha and beta rhythms in the frontal and temporal regions of the left hemisphere) while the group with cognitive impairment had lower peak frequencies and did not display comparable shifts of frequency in those regions (Fishman, Trush, & Markovskaya, 1983). Thus, information gleaned from EEG suggested that children with mental retardation have structurally and functionally immature brain activity in comparison to children with average cognitive functioning levels, as the sample with mental retardation exhibited an above average amount of low-frequency activity, as well as relatively diminished power and stability of alpha rhythm activity, and an atypical lack of regional differences in the alpha band.

Empirical studies of Alzheimer's patients have provided the most abundant evidence for an important role of alpha peak frequency in identifying clinical populations. A study conducted by Schreiter-Gasser, Gasser, and Ziegler (1993) compared QEEG profiles of 15 older adults with early onset Alzheimer's (EOA) to that of 15 age-matched controls with normal cognitive functioning. Occipital peak frequency in

the alpha band was significantly lower in the EOA sample (*M* = 9.0 HZ) than the control group (*M* = 9.7 Hz). Moreover, the authors noted that the low variability of this finding among the EOA sample indicated a uniform decrease in fast frequency power and degenerative regression. Other research comparing adults with and without Alzheimer's disease has confirmed the existence of significantly lower peak frequencies in the alpha band among Alzheimer's patients (Klimesch, Schimke, Ladurner, & Pfurtscheller, 1990; Passero, Rocchi, Vatti, Burgalassi, & Battistini, 1995).

A recent study that examined QEEG profiles of adults with various levels of cognitive abilities established that differences in alpha peak frequency distinguished between groups of different ages and degrees of cognitive impairment (d'Onofrio et al., 1996). Specifically, peak frequency in the alpha band was higher in a sample of 18 healthy middle-aged adults (*M* = 9.5 Hz) than in a group of 16 healthy elderly adults (*M* = 9.0 Hz). Both groups of healthy adults had higher peak frequencies in the alpha band than a sample of 45 adults with multi-infarct dementia (*M* = 8.5-9.0 Hz). Interestingly, QEEG readings from a group of 29 adults with dementia of Alzheimer's type also included in this study were characterized by absence of a definite peak frequency.

In sum, QEEG measures of adults with mental retardation and/or Alzheimer's disease are characterized by diminished peak frequency in the alpha band, suggesting that reduced alpha peak frequency is associated with cognitive impairment and/or deterioration. Correspondingly, researchers studying infants and children have established that *increased* levels of peak frequency in the alpha band are indicative of higher levels of brain maturation (Somsen, van't Klooster, van der Molen, van Leeuwen, & Licht, 1997; Stroganova, Orekhova, & Posikeras, 1999). For example, Stroganova et al. compared EEG rhythms of 77 infants ages 7.4 to 10 months to 70 infants ages 10.07 to 12.44 months. After establishing that "properties of the 5.2-9.6 Hz occipital rhythmic activity comply with the classical properties of alpha rhythm" (p. 997), this study found that alpha peak frequency increased significantly with age (*M* = 6.24 Hz at 8 months vs. *M* = 6.78 Hz at 11 months). Regression analyses indicated that age explained almost 40% of the total sample's variation in alpha peak frequency. Similarly, Somsen et al. studied 142 children, ages five through twelve years, and concluded "peak frequency increased with age . . . peak in the power spectrum shifted from fast Theta via slow Alpha to fast Alpha" (p. 187). Moreover, significant increases in alpha peak frequency between age levels appeared during both eyes closed (8.1 to 9.4 Hz) and eyes open (8.0 to 9.0 Hz) conditions.

In addition to providing useful information related to brain maturation, alpha peak frequency also can be conceptualized as an index of memory ability. Klimesch, Schimke, Ladurner, and Pfurtscheller (1990) conducted a two-part experiment to assess the relationship between alpha frequency and memory ability. Given the established relationship between Alzheimer's and diminished alpha peak frequency, experiment 1 explored differences in alpha peak frequency among 18 adults with Alzheimer's. As predicted, memory ability, assessed by the Wechsler Memory Scale (Wechsler, 1945) related to differences in QEEG profiles. Specifically, subjects with better Wechsler scores had higher alpha peak frequency (M = 8.14 Hz) than subjects with relatively worse memories (M = 7.02 Hz). Experiment 2 utilized a sample of 17 college students. Students with superior memory, as judged by a free-recall/recognition task, had significantly higher peak frequency in the alpha band (M = 11.39 Hz) than students with relatively poorer memory (M = 10.23 Hz) during both a resting condition and a memory recall task. Taken together, this line of research suggests that alpha peak frequency may be an attribute that relates to the rate information can be retrieved from memory.

In sum, previous research indicates alpha peak frequency increases with brain maturation and decreases with cognitive deterioration. Furthermore, alpha peak frequency differences among groups of similar age or clinical status may relate to certain aptitudes (e.g., memory). The purpose of this study was to examine relationships between peak frequency in the alpha band and the specific aptitude of precocious reading. Specifically, higher alpha peak frequency was predicted to discriminate children with precocious reading abilities from agemates reading at expected levels.

METHODS

Participants. Participants were 45 children, ages 4.7 to 12.7 (M = 7.1; SD = 1.6), recruited from preschools, local school districts, Montessori schools, and day care centers in a southeastern U.S. city. The sample included 18 females and 27 males. Most of the participants were Caucasian (n = 40; 88.9%); the remaining children were either African-American (n = 2; 4.4%) or of Indian decent (n = 3; 6.7%).

Participants were equally divided into three groups of fifteen: early readers (ER), age matched (AM) controls, and reading-level matched (RLM) controls. Inclusion of two control groups served to allow ob-

served differences between groups to be attributed to either developmental or skill level factors. Previous research has shown that changes in EEG functioning occur with age (Somsen et al., 1997; Stroganova et al., 1999), thus the AM group was incorporated in order to facilitate comparisons with same-age children who displayed typical academic achievement. The RLM control group allowed for comparisons to be made between samples with similar reading levels. Thus, the role of alpha peak frequency in indexing brain maturation (i.e., age) versus skill level (i.e., reading ability) was examined with the design of this study.

All members of the experimental sample read three or more grade levels above their current age-appropriate grade placement. Members of the AM sample were counterparts to the ER sample in terms of gender, age (within four months) and intelligence (within one standard error of measurement), but differed in terms of reading ability. Participants in the AM sample read at grade level or were not yet reading, but performed within normal limits on the Test of Early Reading Ability (TERA-2; Reid, Hresko, & Hammill, 1989), thus ruling out language delay. The RLM sample consisted of 15 children with IQ scores of at least 90 and who showed no evidence of reading or language delay. This group was matched to the ER sample on reading level (within one standard error of measurement) and averaged 2.5 years older than the ER sample.

Measures. Wechsler Individual Achievement Test (WIAT). The WIAT, a norm-referenced achievement test designed for children ages 5:0 (5 years, 0 months) to 19:11 (19 years, 11 months), was used in this study to operationalize participants' reading skills. Only Basic Reading and Reading Comprehension, the two subtests that comprise the Reading composite of the WIAT, were employed. Basic Reading assesses ability to decode and read words, while Reading Comprehension measures understanding of content of reading material. The WIAT reading subtests possess adequate levels of internal consistency, test-retest stability, and interrater scoring, as well as content and criterion validity (Psychological Corporation, 1992).

Test of Early Reading Ability: Second Edition (TERA-2). The TERA-2, a norm-referenced measure of early reading for children age 3:0 (3 years, 0 months) to 9:11 (9 years, 11 months), was employed in this study to screen subjects for reading or language delays. The TERA-2 has acceptable reliability and validity (Reid et al., 1989).

Kaufman Brief Intelligence Test (K-BIT). The K-BIT is an individualized assessment tool intended to provide a measure of verbal and nonverbal intelligence for people age 4:0 (4 years, 0 months) to 90+ in a

short administration period (Kaufman & Kaufman, 1990). It is comprised of two subtests, Vocabulary and Matrices. Vocabulary provides an index of crystallized intelligence by measuring one's verbal skills and concept formation, while Matrices measures fluid, nonverbal intelligence by requiring one to solve novel problems. The K-BIT possesses good internal consistency, stability, construct validity, and criterion-related validity (Kaufman & Kaufman, 1990).

Quantified Electroencephalography (QEEG). Lexicor NeuroSearch-24 equipment and v151 software, and an appropriately sized electrode cap from Electro Cap International, Inc. were used during data collection. QEEG recordings were obtained from nineteen scalp electrodes, placed according to the International 10-20 System, referenced to earlobes and grounded just forward of FZ.

Procedure. Data collection occurred in three phases. First, several private preschools and kindergartens in the area were contacted and invited to submit names of early reading children. Parents of nominated children were contacted and the research was explained to them. Following obtainment of parental consent, children who agreed to participate were administered the K-BIT, TERA-2, and WIAT to determine whether each met the study criteria for early reader. Once members of this group had been established and, therefore, the matching criteria known, potential average reading and reading-level-matched controls were selected through a comparable screening process involving student and parental consent and completion of the standardized test battery. Age matched control participants were selected from the same schools as the experimental group, while reading matched subjects were selected primarily from a local public school.

The third phase of data collection involved gathering EEG samples from participants. EEG recordings were conducted during school hours, within one to 14 days following psychometric evaluations. Three four-minute samples of brain wave activity were collected for each subject during resting, eyes closed condition. The EEG was digitized at 128 Hz with 32K gain and high pass filter off. Scalp electrode sites were prepared until impedance for each channel was at or below 5000 ohms. Participants were seated in a comfortable chair and requested to sit as still as possible, relax, keep eyes closed and remain motionless. The raw EEG was observed via computer monitor and instructions were given to participants until eye and other movement artifacts were minimized.

After data collection, the third author, a certified QEEG technician, inspected waveforms visually and removed artifacts prior to data analysis. While three samples of brain activity were collected from each par-

ticipant, only the sample with the largest number of retained epochs (range: 32-172 epochs) was employed in data analysis. All two-second consecutive epochs free from artifacts then were processed by a Fast Fourier Transform and obtained values averaged across all epochs to obtain a mean peak frequency for each channel. Peak frequency values in the alpha (8.0-12.0 Hz) band were used for quantitative analysis. For each of the 19 sites examined, a one-way between subjects ANOVA was performed to test for evidence of a main effect of group membership on alpha peak frequency. Following a significant F-test, alpha peak frequency levels of the precocious readers were compared to that of both control groups via a series of post hoc comparisons of means using least significant difference (LSD) tests.

RESULTS

Sample Characteristics. Nine males and six females comprised each of the three groups. The sample of early readers, ages 4.7 to 6.9 (*M* = 6.2; *SD* = .68), had WIAT reading scores that ranged from 1:2 (grade: month) to 7:3 (*M* = 3:9; *SD* = 1.6) and K-BIT full scale IQs that ranged from 99 to 147 (*M* = 118.5; *SD* = 11.1). The age matched control group, ages 5.0 to 6.8 (*M* = 6.2; *SD* = .59), had WIAT reading scores that ranged from K:9 to 2:2 (*M* = 1:2; *SD* = .37) and K-BIT full scale IQs that ranged from 92 to 138 (*M* = 113.2; *SD* = 11.7). Last, the reading-level matched control group, ages 6.2 to 12.7 (*M* = 8.7; *SD* = 1.6), had WIAT reading scores that ranged from 1:0 to 8:3 (*M* = 3:9; *SD* = 1.8) and K-BIT full scale IQs that ranged from 97 to 125 (*M* = 113.8; *SD* = 7.0). There were no statistically significant group differences related to the matching criteria; thus, the three groups were adequately matched on all targeted variables.

Relationship Between Alpha Peak Frequency and Group Membership. Means and standard deviations for the samples' peak frequency in alpha at each site are presented in Table 1. Results of the one-way between subjects ANOVAs indicated statistically significant group mean differences relative to alpha peak frequency at each of the 19 sites examined, $F(2, 42) = 3.78\text{-}10.22$, $p = .0002\text{-}.0310$. In an effort to identify which group differences were driving this effect, two sequences of post hoc comparisons of means were conducted. An alpha level of .05 was used for all analyses. First, LSD tests revealed that the experimental sample of early readers had significantly higher alpha peak frequencies at 16 of the 19 sites than the AM sample. Only differ-

TABLE 1. Mean Peak Frequency of Alpha Band in Early Readers, Age Matched Controls, and Reading-Level Matched Controls

	Early Readers		Age Matched		Reading-Level Matched	
Site	M	(SD)	M	(SD)	M	(SD)
F1	9.16	(.35)**	8.73	(.37)**	9.28	(.33)
F2	9.15	(.38)*	8.80	(.42)*	9.25	(.33)
F7	9.22	(.37)**	8.81	(.33)**	9.34	(.31)
F8	9.21	(.44)*	8.84	(.36)*	9.31	(.33)
F3	9.13	(.43)*	8.77	(.43)*	9.21	(.35)
F4	9.13	(.40)*	8.76	(.42)*	9.23	(.32)
T3	9.24	(.45)*	8.84	(.36)*	9.42	(.48)
T4	9.17	(.56)*	8.80	(.37)*	9.36	(.40)
C3	9.29	(.51)**	8.83	(.40)**	9.38	(.44)
C4	9.20	(.56)	8.87	(.41)	9.43	(.44)
T5	9.10	(.58)*	8.69	(.42)*	9.37	(.43)
T6	9.07	(.59)*	8.69	(.36)*	9.33	(.51)
P3	9.08	(.53)*	8.66	(.38)*	9.27	(.43)
P4	9.04	(.57)*	8.64	(.34)*	9.28	(.38)
O1	9.10	(.62)*	8.65	(.38)*	9.39	(.31)
O2	9.02	(.58)	8.69	(.38)	9.36	(.42)
FZ	9.09	(.48)*	8.74	(.41)*	9.15	(.37)
CZ	9.02	(.50)	8.72	(.36)	9.16	(.44)
PZ	9.09	(.52)*	8.64	(.37)*	9.27	(.45)

Note 1. For statistical comparisons between the ER and AM samples, * $p < .05$, **$p < .01$ (LSD tests for independent samples).
Note 2. For statistical comparisons between the ER and RLM samples, $p > .05$ at all sites.
Note 3. For statistical comparisons between the AM and RLM samples, $p < .01$ at all sites.

ences in alpha peak frequencies at sites C4, O2, and CZ did not reach statistically significant levels. Peak frequencies of alpha from the ER sample ranged from 9.04 Hz to 9.29 Hz (M = 9.13 Hz), while values for the AM group ranged from 8.64 Hz to 8.87 Hz (M = 8.75 Hz). Second, comparisons of means indicated that there were no significant differences in alpha peak frequency values between precocious readers and the reading-level matched control group. Peak frequency in the alpha band ranged from 9.15 Hz to 9.43 Hz (M = 9.30Hz) in the RLM group.

In sum, alpha peak frequency of the early readers is significantly different from that of their age-matched counterparts and remarkably similar to that of the sample of older children.

DISCUSSION

Findings indicate children of various ages differ in terms of peak frequency in the EEG alpha band. The present finding of higher values in older children with typical reading abilities relative to younger children with normal reading levels is consistent with previous research indicating that peak frequency in alpha reflects brain maturation due to age (Somsen et al., 1997; Stroganova et al., 1999).

However, this study serves to modify the notion that age is the only force responsible for variations in alpha peak frequency. In light of earlier research that exposed the link between alpha peak frequency and specific aptitudes such as memory (Klimesch et al., 1990), it was hypothesized that precocious readers would display levels of alpha peak frequency different from children of the same age with normal reading abilities as a function of their reading aptitude. Results provided evidence supporting this hypothesis. Moreover, the remarkable similarity in alpha peak frequency between precocious readers and older children with average reading skills necessitates a reexamination of the definition of "brain maturation." Brain development appears to be related to factors other than biological age and general intellectual development. Specifically, early reading aptitude, distinct from general intelligence, may be uniquely related to peak frequency of EEG alpha rhythm.

The results of this study suggest that QEEG profiles of children may be helpful assessment tools when exploring reading achievement potential. Although similar research with reading disabled populations is needed, findings suggest that practitioners should be mindful of the relationship of alpha peak frequency with reading skills when treating clients with reading troubles. For example, interventions designed to increase alpha peak frequency (e.g., specific types of neurofeedback training) may serve to maximize and/or expedite brain development, as well as increase desirable aptitudes such as reading ability. Future researchers should attempt to incorporate the finding that elevated alpha peak frequency in children with precocious reading ability is a topographically widespread phenomenon into conceptual models of brain function related to reading ability.

Although a significant relationship between exceptional reading skills and alpha peak frequency was found, it is important to keep in mind that the determinants of brain activity are manifold. Increased peak frequency in the alpha band is a correlate of precocious reading ability; however, longitudinal research is needed to determine the extent to which increased alpha peak frequency facilitates reading skills development as compared to reading practice facilitating increased peak frequency (i.e., actually producing accelerated maturation of brain processes). In addition, these findings require replication in larger samples that include a variety of ages. Furthermore, future research could examine the opposite end of the reading spectrum and study alpha peak frequency in children with dyslexia or other learning disabilities related to impaired reading. Evidence of diminished alpha peak frequency in these populations could provide further support for the important role of quantitative EEG readings in identifying and treating special populations.

The findings of this study seem noteworthy for three reasons. First, they emphasize the utility of quantitative EEG readings in the assessment and identification of special populations. Second, they confirm the connection between alpha peak frequency and age in children with average achievement. Third, early reading ability, an aptitude previously unstudied with regard to QEEG profiles, is established as a correlate of increased alpha peak frequency.

REFERENCES

Bakker, D. J. (1979). Perceptual asymmetries and reading proficiency. In M. Bortner (Ed.), *Cognitive growth and development* (pp. 134-152). New York: Brunner/Mazel.

Bakker, D. J. (1983). Hemispheric specialization and specific reading retardation. In M. Rutter (Ed.), *Developmental neuropsychiatry* (pp. 498-506). New York: Guilford Press.

d'Onofrio, G., Salvia, S., Petretta, V., Bonavita, V., Rodriguez, G., & Tedeschi, G. (1996). Quantified-EEG in normal aging and dementias. *Acta Neurologica Scandinavica*, *93*, 336-345.

Fishman, M. N., Trush, V. D., & Markovskaya, I. F. (1983). Spectral correlation analysis of the EEG in normal and mentally retarded children. *Human Physiology*, *9* (1), 43-49.

Kaufman, A. S. & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test: Manual*. Circle Pines, MN: American Guidance Service.

Klimesch, H., Schimke, H., Ladurner, G., & Pfurtscheller, G. (1990). Alpha frequency and memory performance. *Journal of Psychophysiology*, *4*, 381-390.

Marosi, E., Harmony, T., Becker, J., Reyes, A., Bernal, J., Fernandez, T., Rodriguez, M., Silva, J., & Guerrero, V. (1995). Electroencephalographic coherences discrimi-

nate between children with different pedagogical evaluations. *International Journal of Psychophysiology*, *19*, 23-32.

Marosi, E., Harmony, T., Reyes, A., Bernal, J., Fernandez, T., Guerrero, V., Rodriguez, M., Silva, J., Yanez, G., & Rodriguez, H. (1997). A follow-up study of EEG coherences in children with different pedagogical evaluations. *International Journal of Psychophysiology*, *25*, 227-235.

Marosi, E., Harmony, T., Sanchez, L., Becker, J., Bernal, J., Reyes, A., Diaz de Leion, A., Rodriguez, M., & Fernandez, T. (1992). Maturation of the coherence of EEG activity in normal and learning disabled children. *Electroencephalography and Clinical Neurophysiology*, *83*, 350-357.

Passero, S., Rocchi, R., Vatti, G., Burgalassi, L., & Battistini, N. (1995). Quantitative EEG mapping, regional cerebral blood flow, and neuropsychological function in Alzheimer's disease. *Dementia*, *6*, 148-156.

The Psychological Corporation. (1992). *Wechsler Individual Achievement Test*: *Manual*. San Antonio, TX: Author.

Pugh, K., Shaywitz, B., Shaywitz, S., Constable, T., Skudlarski, P., Fulbright, R., Bronen, R., Shankweiler, D., Katz, L., Fletcher, J., & Gore, J. (1996). Cerebral organization of component processes in reading. *Brain*, *119*, 1221-1238.

Pugh, K., Shaywitz, B., Shaywitz, S., Shankweiler, D., Katz, L., Fletcher, J., Skudlarski, P., Fulbright, R., Constable, T., Bronen, R., Lacadie, C., & Gore, J. (1997). Predicting reading performance from neuroimaging profiles: The cerebral basis of phonological effects in printed work identification. *Journal of Experimental Psychology: Human Perception and Performance*, *23*, 299-318.

Reid, D., Hresko, W., & Hammill, D. (1989). *The test of early reading ability, second edition: Manual*. Austin, TX: PRO-ED.

Schreiter-Gasser, U., Gasser, T., & Ziegler, P. (1993). Quantitative EEG analysis in early onset Alzheimer's disease: A controlled study. *Electroencephalography and Clinical Neurophysiology*, *86*, 15-22.

Somsen, R. J. M., van't Klooster, B. J., van der Molen, M. W., van Leeuwen, H. M. P., & Licht, R. (1997). Growth spurts in brain maturation during middle childhood as indexed by EEG power spectra. *Biological Psychology*, *44*, 187-209.

Stroganova, T. A., Orekhova, E. V., & Posikera, I. N. (1999). EEG alpha rhythm in infants. *Clinical Neurophysiology*, *110*, 997-1012.

Wechsler, D. A. (1945). A standardized memory scale for clinical use. *Journal of Psychology*, *19*, 87-95.

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