The Effects of a Consumer-Oriented Multimedia Game on the Reading Disorders of Children with ADHD

Tammy McGraw
Intelligen, LLC
231 Capitol Street, Suite 305
Charleston, WV 25301
304-414-0100
tmcgraw@intelligen.net

Krista Burdette
Intelligen, LLC
231 Capitol Street, Suite 305
Charleston, WV 25301
304-414-0100
krista@burdette.net

Kristine Chadwick
Appalachia Educational Laboratory
Post Office Box 1348
Charleston, WV 25325
304-347-0400
chadwick@ael.org

ABSTRACT
Certain interventions that ameliorate impairments in reading and attention disorders operate on the physiological level and, therefore, lend themselves to technology-based applications. This study investigates the effects of *Dance Dance Revolution (DDR)*—a consumer-oriented, multimedia game—on the reading disorders of sixth-grade students with ADHD. It was hypothesized that by matching movements to visual and rhythmic auditory cues, *DDR* may strengthen neural networks involved in reading and attention and thereby improve student outcomes. Sixty-two students, randomly assigned to treatment and control groups, participated in the test-retest study using the Process Assessment of the Learner: Testing Battery for Reading and Writing as a measure of reading impairment. The results suggest that the treatment may have had an effect on participants' ability to perform on the Receptive Coding subtest. Furthermore, the results suggest a positive relationship between the number of treatment sessions a student completed and gains made on Receptive Coding and Finger Sense Recognition subtests.

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

Keywords
reading disorder, dyslexia, attention-deficit/hyperactivity disorder (ADHD), technology, video game, Dance Dance Revolution (DDR), random assignment, treatment group, control group, sixth-grade students, test-retest, Process Assessment of the Learner: Testing Battery for Reading and Writing (PAL-RW), receptive coding, finger sense recognition

INTRODUCTION

It is impossible to overstate the importance of effective interventions for addressing two highly prevalent and potentially devastating disorders affecting school-aged children—dyslexia and Attention-Deficit/Hyperactivity Disorder (ADHD). Both have been found to increase children's risk for underachievement, school failure, dropping out, suspension, expulsion, and delinquency [5, 7, 11, 12, 13, 16]. Furthermore, there is evidence that the disorders often coexist [16, 32], though the nature of this overlap is still not fully understood. While more and more children with learning deficits are being educated in regular classrooms, many of those teachers lack sufficient training to help them succeed. Moreover, the pressures placed on schools by high-stakes testing and accountability make it imperative to identify interventions that address learning deficits and maximize academic achievement.

REVIEW OF THE LITERATURE

Because of their potentially devastating effects on learning and behavior, dyslexia and ADHD pose a particular challenge to educators who must help struggling students meet performance goals. According to Pennington [21] dyslexia is "the most prevalent . . . learning disorder in childhood." It affects up to one in five students [29]. Similarly, ADHD is the "most common neurobehavioral disorder" and "one of the most prevalent chronic health conditions affecting school-aged children"—as many as 10% [1].

Dyslexia and ADHD frequently coexist [16, 32]. Studies have found that 25–40% of children with ADHD have a reading disorder; likewise, 15–26% of those with reading disorders and 30–50% of those with learning disabilities meet criteria for ADHD [8, 32].

Both disorders can impair higher order cognition and memory, possibly because language plays a key role in the development of executive functions and working memory [6, 21]. In addition, both are characterized by social skills deficits, coexisting psychiatric disorders, and motor difficulties [2, 3, 5, 7, 16, 25, 27, 32].

New thinking about the role of the cerebellum may help to explain the apparent connection between cognitive and motor impairment in dyslexia and ADHD. At one time thought to be connected only to functions of motor control and coordination, recent thinking posits that the cerebellum also plays important roles in perception, cognition, and behavior [9, 20, 23, 26].

Research Implications for Interventions
Knowledge of the brain's plasticity, or its ability to adapt to the environment [10, 14, 22, 24], has raised the possibility that interventions can directly target neural impairments underlying certain disorders [19]. Studies show certain interventions based on this principle—such as *Fast ForWord,* discussed later—are promising for ameliorating the impairment in reading and attention disorders. Because these interventions are intended to work on a physiological level, they lend themselves to technology-based applications.

Technology-Based Games and Applications
Fast ForWord, an interactive computer game developed by neuroscientists Merzenich and Tallal, was designed to remedy rapid temporal processing deficits by artificially stretching or slowing the sounds in speech [17]. It has been shown to improve the reading achievement of children with language impairment and dyslexia by promoting the development of auditory discrimination and phonological awareness [18, 31].

Similarly, students with dyslexia who received audiovisual training with a computer game developed by Kujala et al. [15] improved their reading skills, even though the game was nonlinguistic. By matching sound patterns to graphic representations, the children improved auditory perception—a finding confirmed by electroencephalogram readings.

Attention Trainer and *Interactive Metronome* are computer programs that aim to ameliorate the symptoms of ADHD by strengthening pathways involved in attention, motor planning, and sequencing. *Attention Trainer* uses neurofeedback to evoke and reinforce a type of brainwave purportedly linked to attention, although rigorous research as to the program's effectiveness is lacking. Preliminary studies of *Interactive Metronome,* on the other hand, found that the program significantly improved attention and motor control, as well as language and reading skills [28].

The preceding examples are indicative of efforts to develop specialized, interactive, multimedia computer games to address disorders such as ADHD and dyslexia. *Dance Dance Revolution (DDR),* on the other hand, is designed solely for entertainment. The investigators contend that *DDR* may provide similar physiological benefits to those afforded by the previously discussed interventions.

METHOD

Participants
The pool of potential participants included 74 sixth-grade students who were identified by their parents or guardians as having been diagnosed with ADHD by a medical or psychological professional. Students attended four middle schools during three distinct project periods: Spring 2002, Spring/Summer 2004, and Fall 2004.

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

Procedure

Subsequent to acquiring parent approval, the 74 students diagnosed with ADHD were tested individually using the Process Assessment of the Learner: Test Battery for Reading and Writing (PAL-RW) to reveal the presence of reading impairment and to provide baseline data. For the purpose of this study, reading impairment was defined by the percentage of subtest scores in the Deficient and At-Risk categories compared to the percentage of subtest scores in the Proficient category.

The pretest yielded 62 students in four locations eligible to participate in the study. Students were sorted by class period availability and assigned to treatment, control, or exclusion groups using a table of random numbers. Eligible students were excluded in one location as dictated by availability (i.e., the number of eligible students exceeded the time available for intervention during their assigned elective class period). Students assigned to the control group did not participate in the intervention activity. Instead, they attended elective courses as normal and completed the posttest at the end of the treatment period.

DDR Disney Mix was the intervention used with the treatment group of this study. Game settings were adjusted to minimize background visual stimuli (i.e., background effects "off" and background brightness set to the lowest setting, "25%"). Participants followed onscreen cues to match rhythm and choreography. They stepped on arrows on the dance pad when corresponding arrows on the television screen indicated forward, back, left, and right. Students participated in pairs (matched randomly within their available class period), attending two 25-minute sessions each week for varying treatment periods (i.e., 4 weeks, 8 weeks, and 12 weeks). Sessions were monitored by a trained researcher or research assistant. Figure 1 depicts students using the DDR game and equipment.

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

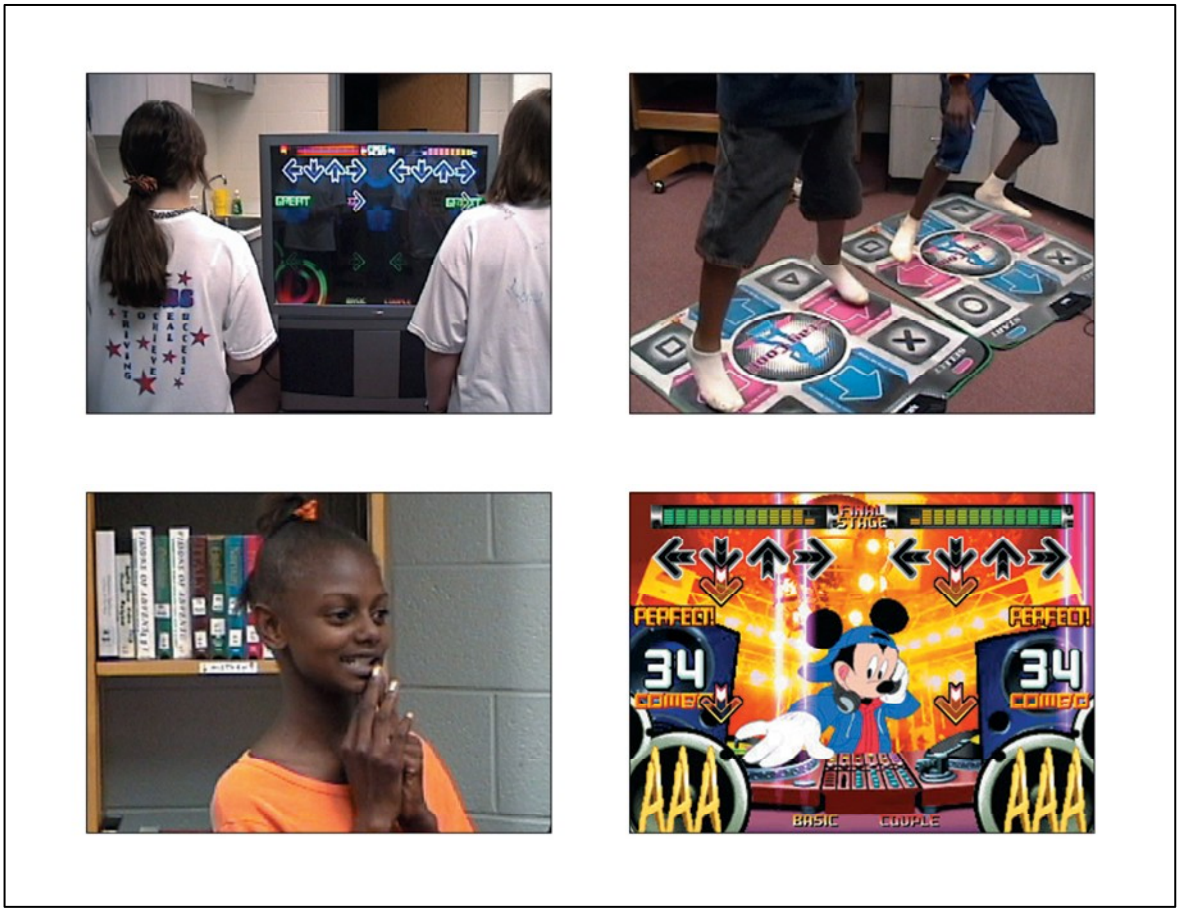

Figure 1: Students use the *Dance Dance Revolution* game and equipment. A standard large-screen television (upper left) and external dance pads (upper right) connect to a Sony PlayStation. The *DDR Disney Mix* is shown (lower right) without contrast and background effects adjusted to minimize visual stimuli.

As researchers anticipated, the number of completed treatment sessions varied by participant within the treatment group due to illness, weather-related school closings, school-wide events, and the like.

Following the treatment period, the PAL-RW was readministered. Posttest subtest raw scores were compared to pretest subtest raw scores.

RESULTS

The experiment was designed to test the hypothesis that students with ADHD who were involved in the intervention would exhibit less reading impairment (as measured by the PAL-RW) and would improve to a greater extent than would comparable students who were not exposed to the intervention. The pretest and posttest scores on the 24 subtests of the PAL-RW were used for comparison.

Participants in the treatment condition received between 5 and 23 treatment sessions. Treatment condition participants averaged 9.92 sessions each with a standard deviation of 5.06 sessions. Nearly half of the treatment group participants received 7 or 8 treatment sessions. In order to test for differences between the treatment and control groups, the general linear model for repeated measures was employed with treatment condition as the between-subjects factor, pretest/posttest as the within-subjects factor, and then each of the 24 subtests as the dependent variables. The main focus of these analyses was determining whether there was a significant difference between the treatment and control groups or an interaction between treatment assignment and pretest/posttest score.

Of the 24 repeated measures analyses, two will be discussed because the results support possible effects of the intervention. The participants who underwent the intervention gained approximately two points more from pretest to posttest on the RAN Digit subtest than did those students in the control group. Table 1 displays the ANOVA results. Although the magnitude of the effect appears to be small, there may be some practical significance to the association between subtest gain (pretest to posttest) and treatment effect.

Table 1. Summary of the Analysis of RAN Digit Subtest

Source	Sum of Squares	df	Mean Square	F	Significance	Partial Eta Squared
Treatment Condition	8.168	1	8.168	.033	.856	.001
Error (Treatment)	11063.747	45	245.861			
Pre/Post	147.768	1	147.768	10.269	.002	.186
Pre/Post * Treatment	105.257	1	105.257	7.315	.01	.14
Error (Pre/Post)	647.552	45	14.390			

There is also some evidence that the intervention may have had an effect on participants' ability to perform on the Receptive Coding subtest. Participants in the treatment condition gained approximately two points from pretest to posttest, compared to a gain of less than one point among the controls. In addition, there was less variance among the treatment group's scores than among those in the control group. Table 2 presents the ANOVA results. Again, the magnitude of the effect was small.

Table 2. Summary of the Analysis of Receptive Coding Subtest

Source	Sum of Squares	df	Mean Square	F	Significance	Partial Eta Squared
Treatment Condition	65.261	1	65.261	3.374	.073	.068
Error (Treatment)	889.697	46	19.341			
Pre/Post	48.606	1	48.606	11.123	.002	.195
Pre/Post * Treatment	15.939	1	15.939	3.647	.062	.073

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

Error (Pre/Post)	201.019	46	4.370			

Following the repeated measures analyses, a closer examination was made of the effects of differing levels of the intervention. Regression analyses were performed using number of treatment sessions as the predictor variable and the difference score (posttest minus pretest) from each of the 24 subtests as the criterion variable. Again, only the results from those subtests where the number of treatment sessions did have an effect on the difference score are presented.

The number of treatment sessions had a positive effect on the gains made by treatment group participants in two subtest areas. In other words, the more sessions of *DDR* a participant completed, the greater gain he or she made from pretest to posttest on the Receptive Coding and Finger Sense Recognition subtests. See Table 3 and Figures 2 and 3 that follow.

Table 3. Regression Analysis Summary for Number of Treatment Sessions Predicting Change in Receptive Coding Scores from Pretest to Posttest

Predictor Variable	Criterion (Subtest) Variables	B	$Error_B$	β	R^2	Significance
Number of Treatment Sessions	Receptive Coding	.252	.100	.464	.215	.02
	Finger Sense Recognition	.111	.054	.392	.154	.05

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

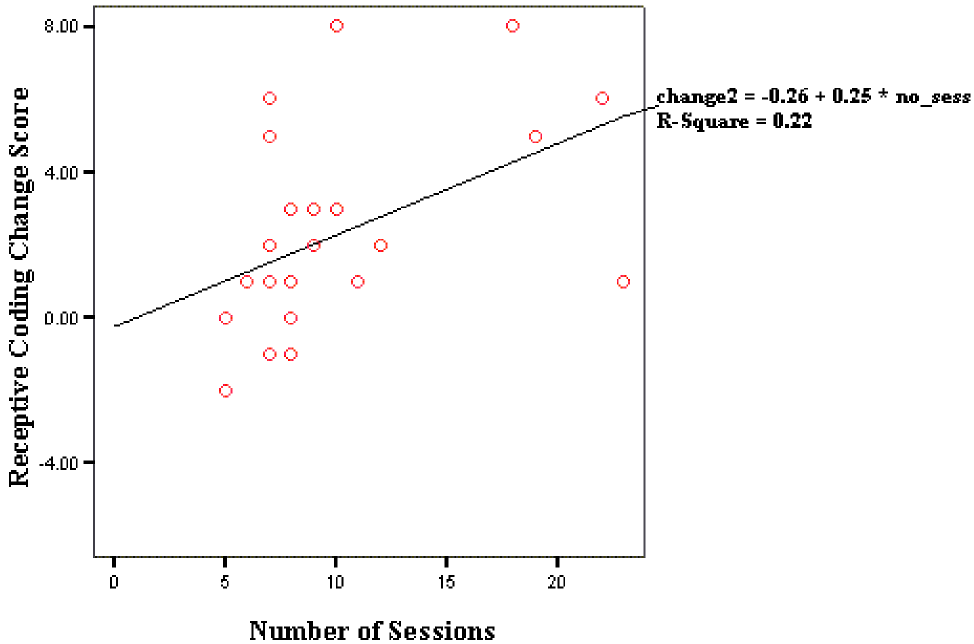

Figure 2: Scatterplot with regression line showing change in Receptive Coding scores by number of treatment sessions.

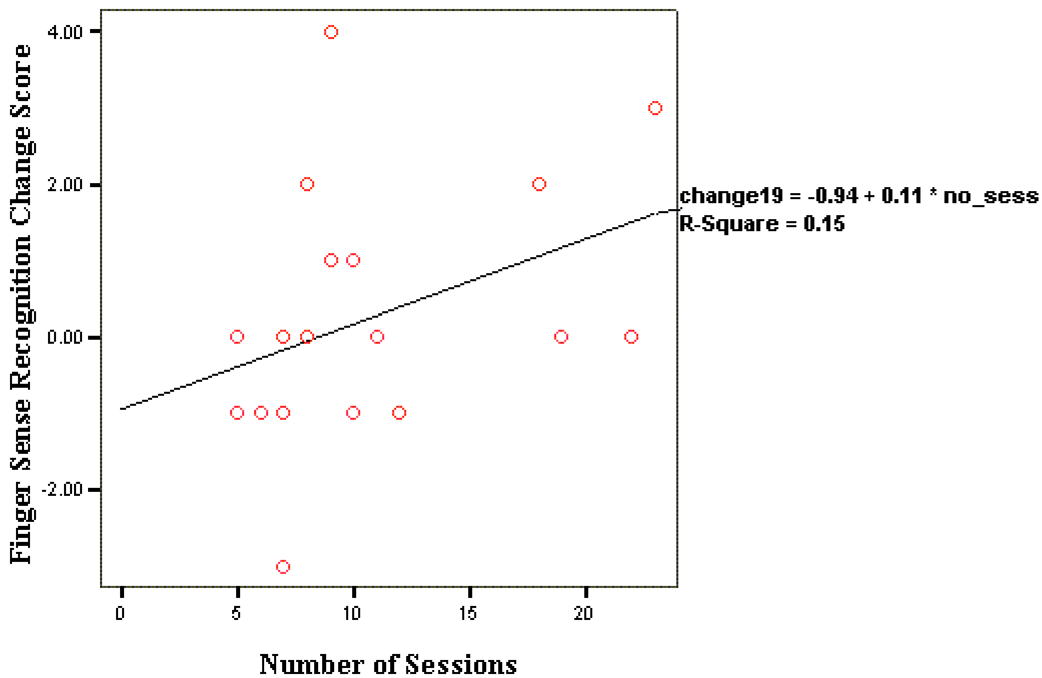

Figure 3: Scatterplot with regression line showing change in Finger Sense Recognition scores by number of treatment sessions.

DISCUSSION AND CONCLUSIONS

Regression analyses revealed a positive relationship between the number of treatment sessions completed and the gains made on Receptive Coding and Finger Sense Recognition subtests. This supports the need for further research and provides guidance for it (e.g., longer intervention periods, increased treatments during the intervention period, and targeted PAL-RW testing versus full administration).

A perplexing result was that of an apparent decrease in performance (i.e., greater response times) by the treatment group on the RAN Digits subtest, according to the repeated measures analyses. One possible explanation is that, with the small sample size, the poorer performance of just a few students skewed the results. Another possible explanation is that the intervention does, in some way, result in poorer performance on this measure. Regardless, the ambiguity of findings points to the need for additional research.

Results from the general linear model for repeated measures indicate that the treatment may have had an effect on participants' ability to perform on the Receptive Coding subtest. For a sixth-grade student, this subtest requires (a) looking at a target word for only one second before viewing a page with letters and determining if they were or were not in the previous word in the correct order and (b) looking at a target word for only one second before viewing a page with a letter and determining if it was or was not in the previous word. The student may not look at the word again and must try to remember what was seen. The subtest measures the child's ability to "code whole written words into short-term memory and then to segment each word into units of different size" [4]. Furthermore, attention is vital, as the target word is presented only briefly.

DDR requires the ability to attend to a stimulus (moving arrows on a screen) and decode the meaning (direction) of those arrows. It also requires responding to the sequence and timing necessary to progress in the game as well as monitoring reinforcement (rank, combo score, energy level, and per-step visual feedback such as "perfect," "good," or "miss"). Because of demonstrated improvement in the Receptive Coding subtests, the known links among ADHD and dyslexia, motor timing deficits [33], and memory impairments [6, 21] and their relevance in this context are of particular interest. Is it that the game has a positive effect on short-term memory—requiring participants to attend to various visual and auditory cues simultaneously while fluidly storing information and accessing it in their short-term memory—or is it a function of learning and replicating a pattern? Is it possible to understand this distinction using this game? While no overall discernable pattern exists in the game play, certain combinations appear in some songs. One option available in the game, though not used in the present study, is training that allows participants to learn and practice entire songs or certain dance steps within a song. This option could possibly facilitate recognizing, learning, and mimicking patterns. The relationship of the auditory cues/rhythmic component is also unclear and might warrant removing the auditory cues in future research to better understand this distinction.

Limitations

Sample size and intervention period were considered to be limitations. Time constraints, in particular, severely limited the sample size. Arranging to conduct quasi-experimental research in a school setting was difficult and investigators contacted a total of 15 school systems in four states to identify participating schools.

Though highly recommended by reading specialists to the investigators, several issues related to the PAL-RW were viewed as limitations. First, the test does not yield a composite score, necessitating analyses on 24 separate subtest scores. Second, raw scores are converted to decile scores, meaning the standard scores yield only the *tenth* of the distribution in which the child's performance falls. Third, the limited number of items in the upper level of certain subtests (as required for students in Grade 6) makes interpretation more difficult. Last, test-retest comparison of subtests produced reliability coefficients ranging from .61 to .92, with 5 of 24 subtests below the acceptable level of .70; however, consultation with experts and a thorough review of test reviews led researchers to conclude that the PAL-RW was, at the time of the study, the best assessment of reading and writing processes.

Future Directions

There may be value in replicating this study and limiting participation to those students who have been identified with only ADHD or dyslexia, not both. Future investigations might also benefit from other measures such as Achenbach's Child Behavior Checklist or Conners' Ratings Scales (Teacher and Parent) to document changes in ADHD/behavior. The Wide Range Assessment of Memory and Learning (WRAML) might also be appropriate in future studies more narrowly focused on memory. The extent to which other tests measuring receptive coding abilities exist will also be explored. It is likely that other video games will be examined as possible treatments to determine if they produce similar results.

With Sony PlayStation One consoles being found in more than one of every three U.S. households [30], video games have indeed developed into a pervasive technology. Further research may support the use of recreational games such as *DDR* to supplement traditional classroom interventions for addressing these disorders, offering educators and families alike a low-cost, readily available child-focused option that is neither pedagogical nor pharmacological.

REFERENCES

1. American Academy of Pediatrics. "Clinical practice guideline: Diagnosis and evaluation of the child with Attention-Deficit/Hyperactivity Disorder" in *Pediatrics* vol. 105, no. 5 (2000), pp. 1158–1170.

2. Bagwell, C., Molina, B., Pelham, W., & Hoza, B. "Attention-deficit hyperactivity disorder and problems in peer relations: predictions from childhood to adolescence" in *Journal of the American Academy for Child and Adolescent Psychiatry* vol. 40, no. 11 (2001), pp. 1285–1292.

3. Barkley, R. *ADHD and the Nature of Self-Control.* The Guilford Press, New York, 1997.

4. Berninger, V. *Process Assessment of the Learner (PAL) Test Battery for Reading and Writing.* The Psychological Corporation, San Antonio, TX, 2001.

5. Crawford, D. Review of research on learning disabilities and juvenile delinquency. In *Learning Disabilities: Lifelong Issues,* S. Cramer & W. Ellis, Eds. Paul H. Brookes Publishing Co., Baltimore, MD, 1996, 203-210.

6. Denckla, M. B. A clinician-researcher's perspective on LD/ADHD: The "Thirty Years War" to focus on language. Presentation at the 3rd Annual Scientific Conference of the Lab School of Washington, National Institutes of Health, Bethesda, MD, 1998.

7. Dickman, G. E. The link between learning disabilities and behavior. In *Learning Disabilities,* S. Cramer & W. Ellis, Eds. Paul H. Brookes Publishing Co., Baltimore, MD, 1996, 215–228.

8. Fletcher, J. & Shaywitz, B. Attention-Deficit/Hyperactivity Disorder. In *Learning*

Disabilities: Lifelong Issues, S. Cramer & W. Ellis, Eds. Paul H. Brookes Publishing Co., Baltimore, MD, 1996, 265–276.

9. Gao, J. H., Parsons, L. M., Bower, J. M., Xiong, J., Li, J., & Fox, P. T. "Cerebellum implicated in sensory acquisition and discrimination rather than motor control" in *Science* vol. 272, no. 5261 (1996), pp. 482–483.

10. Gopnik, A., Meltzoff, A. N., & Kuhl, P. K. *The Scientist in the Crib: Minds, Brains, and How Children Learn.* William Morrow & Co., New York, 1999.

11. Gregg, S. "Preventing antisocial behavior in disabled and at-risk students." *Policy Briefs*. AEL, Charleston, WV, 1996.

12. Gregg, S. "ADHD–Building academic success." *Policy Briefs*. AEL, Charleston, WV, 1995.

13. Gregg, S. "Understanding and identifying children with ADHD: First steps to effective intervention." *Policy Briefs*. AEL, Charleston, WV, 1995.

14. Kotulak, R. *Inside the Brain.* Andrews and McMeel, Kansas City, MO, 1996.

15. Kujala, T., Karma, K., Ceponiene, R., Belitz, S., Turkkila, P., Tervaniemi, M., & Näätänen, R. "Plastic neural changes and reading improvement caused by audiovisual training in reading-impaired children" in *Proceedings of the National Academy of Sciences* vol. 98, no. 18 (2001), pp. 10509–10514.

16. Lyon, G. R. The state of research. In *Learning Disabilities: Lifelong Issues,* S. Cramer & W. Ellis, Eds. Paul H. Brookes Publishing Co., Baltimore, MD. 1996, 3–61.

17. Merzenich, M. *Fast ForWord: Training children to improve their fundamental acoustic speech reception abilities.* Available from http://www.icdl.com/merzenic.html; accessed 2 January 2002.

18. Merzenich, M., Jenkins, W., Johnston, P., Schreiner, C., Miller, S., & Tallal, P. "Temporal processing deficits of language-learning impaired children ameliorated by training" in *Science* vol. 271, no. 5245 (1996), pp. 77–81.

19. Merzenich, M. Brain plasticity: Contributing to variations in human performance ability. In symposium celebrating 50 years of brain research of the National Institutes of Health, Bethesda, MD, October 10, 2001.

20. Paradiso, S., Andreasen, N. C., O'Leary, D. S., Arndt, S., & Robinson, R. G. "Cerebellar size and cognition: Correlations with IQ, verbal memory, and motor dexterity" in *Neuropsychiatry,*

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

Neuropsychology, and Behavioral Neurology vol. 10, no. 1 (1997), pp. 1–8.

21. Pennington, B. *Diagnosing Learning Disorders.* The Guilford Press, New York, 1991.

22. Pinker, S. *How the Mind Works.* W. W. Norton & Co., Inc., New York, 1997.

23. Rapoport, M., van Reekum, R., & Mayberg, H. "The role of the cerebellum in cognition and behavior: A selective review" in *The Journal of Neuropsychiatry and Clinical Neurosciences,* vol. 12 (2000), pp. 193–198.

24. Ratey, J. *A User's Guide to the Brain.* Pantheon Books, New York, 2001.

25. San Miguel, S., Forness, S., & Kavale, K. *Social Skills Deficits in Learning Disabilities: The Psychiatric Comorbidity Hypothesis.* Available from http://www.ldonline.org/ld_indepth/social_skills/psychiatric_comorbidity.html (1996); accessed 25 March 2002.

26. Schmahmann, J. D., & Sherman, J. C. "The cerebellar cognitive affective syndrome" in *Brain* vol. 121, (1998), pp. 561–579.

27. Schumaker, J. B., & Deshler, D. D. *Social Skills and Learning Disabilities.* Available from http://www.ldonline.org/ld_indepth/social_skills/socialskills_and_ld.html (1995, March-April); accessed 11 September 2002.

28. Shaffer, R. J., Jacokes, L. E., Cassily, J. F., Greenspan, S. I., Tuchman, R. F., & Stemmer, P. J., Jr. "Effect of Interactive Metranome training on children with ADHD" in *American Journal of Occupational Therapy* vol. 55 (2001), pp. 155–162.

29. Shaywitz, S. "Dyslexia" in *Scientific American* vol. 275, no. 5 (1996), pp. 98–104.

30. Sony sales data for holiday season. *GameInsider*. Available from http://gameinsider.net/news/ps2/article/SonySalesDataForHolidaySea.php (2004, January 15); accessed 7 February 2004.

31. Tallal, P., Miller, S., Bedi, G., Byma, G., Wang, X., Nagarajan, S., Schreiner, C., Jenkins, W., & Merzenich, M. "Language comprehension in language-learning impaired children improved with acoustically modified speech" in *Science* vol. 271, no. 5245 (1996), pp. 81–84.

32. Willcutt, E. G., & Pennington, B. F. "Comorbidity of reading disability and attention-deficit/hyperactivity disorder: Differences by gender and subtype" in *Journal of Learning Disabilities* vol. 33, no. 2 (2000), pp. 179–191.

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.

33. Wolff, P. H. “A candidate for phenotype for familial dyslexia” in *European Child & Adolescent Psychiatry* vol. 8, Supplement 3 (1999), pp. 21–27.

AUTHOR NOTE

This document is based on work sponsored wholly or in part by the Institute of Education Sciences (IES), U.S. Department of Education, under contract number ED-01-CO-0016 held by Appalachia Educational Laboratory (AEL). Its contents do not necessarily reflect the views of AEL, IES, the Department, or any other agency of the U.S. government.

Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play.