The RAVE-O Intervention: Connecting Neuroscience to the Classroom

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ABSTRACT—This article explores the ways in which knowledge from the cognitive neurosciences, linguistics, and education interact to deepen our understanding of reading's complexity and to inform reading intervention. We first describe how research on brain abnormalities and naming speed processes has shaped both our conceptualization of reading disabilities and the design of a multicomponent reading intervention, the RAVE-O program. We then discuss the unique ways this program seeks to address the multiple and varied sources of disruption in struggling readers. Finally, we present efficacy data for the RAVE-O reading intervention across multiple school settings.

Wonderful ideas are not born (Duckworth, 1996), they are connected. Each wonderful idea rests on the human mind's ability to make *novel connections* out of familiar perceptions and concepts. Underlying this ability is one of the brain's unique design features: the capacity of already existent circuits of neurons to forge whole new pathways among themselves. Because of this plasticity, we are genetically poised to make novel neuronal connections, the basis of all cognitive breakthroughs. The brain's acquisition of reading is a penultimate example of this: to read, the brain must build new connections among circuits designed thousands of years ago for older visual, auditory, linguistic, and cognitive operations. Such a new arrangement of circuits makes reading both a remarkable achievement and potentially vulnerable to multiple sources of difficulties.

Appreciating the complexity and vulnerability of the reading process requires a new form of novel connection: the bringing together of knowledge bases from typically unconnected disciplines—in this case, linguistics, education, and the cognitive neurosciences. In this article, we first present a case study of how theoretical insights and questions from these disciplines informed the design of a research intervention program for children with reading difficulties. We then summarize findings demonstrating the efficacy of this intervention for children with dyslexia in different school-related settings.

CASE STUDY OF AN IDEA: HOW THE STUDY OF THE BRAIN AND ITS "DISCONNECTIONS" LED TO EDUCATIONAL INSIGHTS

Four decades ago, two converging but unconnected insights emerged from educational and neurological research about the prediction of reading ability and disability. The first was that children's knowledge of letter names represented one of the best predictors of reading (Chall, 1967, 1983; Johnson & Myklebust, 1964; Roswell & Natchez, 1971). The second highlighted the importance of the *connections* among brain systems for cognitive and linguistic functions such as reading (Geschwind, 1974). Using a case study by French neurologist Dejerine of a patient with alexia (i.e., *acquired* reading loss), Geschwind illustrated how different forms of reading breakdown resulted from disconnections between particular areas of the brain. Dejerine's patient with "classic alexia" could "see" the world using his intact right visual areas, but could not "read" letters, numbers, or musical notes because that information could not be connected to left hemisphere linguistic areas. Intriguingly, the patient could not *name* colors.

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Based on this observation, Geschwind hypothesized that reading and color naming must share similar cognitive, perceptual, and linguistic requirements and similar neurological structures. He went one step further bridging neuroscience and education by hypothesizing that children's color naming might provide a unique measure of reading readiness.

Martha Bridge Denckla, Geschwind's student, pursued his hypothesis among children with dyslexia and found that they could name colors accurately but not *rapidly*. The *time it took* for the brain to perform this visual–verbal function was key, not accuracy. Denckla and Rudel (1974, 1976a, 1976b) found that serial naming speed for basic symbols differentiated children with dyslexia from average readers and from children with different learning disabilities. Continuing this line of work, Wolf and her colleagues demonstrated the predictive capacity of rapid automatized naming (RAN) and rapid alternating stimulus (RAS) measures, for reading development over the school years (Wolf, Bally, & Morris, 1986; Wolf & Denckla, 2004).

Findings from three decades of rigorous study give overwhelming support to the original insights about the prediction and differentiation capacities of RAN (see reviews in Wolf & Bowers, 1999; Wolf, 2007) in English as well as across a variety of orthographies (see de Jong & van der Leij, 2003; Frith, Wimmer, & Landerl, 1998; Georgiou, Parrila, Kirby, & Stephenson, 2008; Ho, Tsang, & Lee, 2002; Katzir, Breznitz, Shaul, & Wolf, 2004; Lopez-Escribano & Katzir, 2008; van den Bos, 1998) The nagging question remains, *why* is this so? Why are naming speed tasks such "universal" (Tan, Spinks, Eden, Perfetti, & Siok, 2005) predictors of reading failure, particularly given research indicating the primacy of phonological processes in explanations of dyslexia in English? The search for answers spans languages and disciplines and has become the basis for a new conceptualization of dyslexia, fluency, and intervention.

CONCEPTUALIZING NAMING-SPEED PROCESSES

Geschwind began to answer the question of why naming speed could predict reading ability with his observation that naming processes and reading must share similar cognitive demands and underlying neural circuitry. This insight framed our current understanding of rapid naming as a kind of "minicircuit" made up of many of the same processes used in reading—including phonology—but going well beyond. Thus, just as fluent reading draws on the synchronized and efficient translation of visual patterns to their phonological and semantic representations, so too does the act of naming a letter. In this way, RAN and RAS tests provide a unique window into the integrity and speed of the components required for fluent reading before the child ever learns to read. If this premise is correct, then an analysis of the specific cognitive and linguistic processes underlying letter naming would provide a view into some of the original circuits necessary for reading in the brain and a blueprint for what to target in interventions.

This view of naming speed, however, has been repeatedly challenged because prevailing hypotheses have long centered on phonological processes as the basis of dyslexia. To preserve their parsimonious explanation, many researchers suggested that rapid naming processes would be best subsumed under the rubric of phonology (Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Wagner & Torgesen, 1987). If the latter view is held, there would be little reason to expand current understanding of dyslexia intervention, which is largely phonologically based. If, however, phoneme awareness and naming speed are considered the tips of at least two different but overlapping sources of reading breakdown, our diagnosis, understanding, and efforts to treat children with dyslexia would need to be expanded.

These differing conceptualizations of naming-speed deficits—as an aspect of phonological weakness versus an index of additional sources of reading disruption—reflect the tension between unidimensional and multidimensional accounts of reading and reading failure. Thus, efforts to understand differences between naming-speed and phonological processes have implications for far larger issues around the complexity of the reading circuitry and the universality of dyslexia. If both processes are manifestations of the same underlying phonological system, then both processes should be impaired in each child with a reading difficulty, should be equally predictive across all languages, and should show similar brain activation patterns. Described below, converging evidence from subtyping analyses, cross-linguistic studies, and brain-imaging studies gives little support to any of these assertions and consistently documents a dissociation between most processes underlying naming speed and phonology. This work reinforces the need for a more comprehensive view of reading difficulties and intervention.

NEUROLOGICAL AND BEHAVIORAL CHALLENGES TO THE UNIDIMENSIONAL VIEW OF READING

Wolf and Bowers (1999) explored the question of whether naming speed and phonology represent different sources of failure in English using subtyping methods. They found four *subtypes* of reading-impaired children characterized by the presence, absence, or combination of two core deficits in phonology and naming speed. Importantly, the data illumined a relatively unrecognized subtype of poor readers characterized by adequate phonological and decoding skills, early naming-speed deficits, and later reading fluency and comprehension difficulties. This fluency-based subtype would be completely unpredicted by the more parsimonious phonological view of reading failure. Furthermore, the most intractable subtype exhibited both or *double deficits* and represented the most severely impaired subtype across all measures, particularly in reading fluency. This subtyping approach was named the *double-deficit hypothesis*, as a heuristic to underscore the need to include but go beyond phonological deficits in explanations of reading failure in English and in other languages (See also Escribano, 2007; Ho et al., 2002; Manis, Doi, & Bhadha, 2000). As such, the double-deficit hypothesis constitutes a "transitional hypothesis" in preparation for more comprehensive classifications. One of its major contributions was to underscore the need to understand that there are *at least* two major sources of deficits in our reading-disabled children, and that at least 70% of these children have fluency-related issues. It also helped spur cross-linguistic investigations that further illuminated the role of processes underlying naming speed as sources of reading breakdown, independent of phonology.

For example, as mentioned earlier, although naming-speed measures reliably predict reading difficulties across orthographies, the effect is particularly robust for languages with more transparent orthographies (Holopainen, Ahonen, & Lyytinen, 2001; Korhonen, 1995; Landerl & Wimmer, 2000; Tressoldi, Stella, & Faggella, 2001; Verhagen, Aarnoutse, & van Leeuwe, 2008). In these languages, phoneme–grapheme correspondence rules are relatively simple, and dyslexia does not always involve a failure to learn to decode words. Rather, it involves a failure to read *fluently* with comprehension (see Wimmer, Mayringer, & Landerl, 2000). The predictive power of naming speed in these cases suggests that rapid naming tasks are indexing some processes that are separate from phonology, but equally important to reading. Thus, the cross-linguistic literature points to the importance of understanding and accounting for the heterogeneity of reading difficulties across orthographies (Tan et al., 2005).

Neurological investigations mirror these findings and provide new evidence for the differentiation of naming speed from phonological processes. In one brain-imaging study, Misra, Katzir, Wolf, and Poldrack (2004) investigated the neural substrates underlying rapid naming for letters and objects and found activation in inferior frontal cortex, temporal–parietal areas, and the ventral visual stream. Notably, these regions were largely nonoverlapping with known sites for phonological tasks indicating that the tasks represent distinct processes with separate contributions to reading. Research by Eden and her colleagues also shows similar nonoverlapping neural sites for these tasks (Turkeltaub, Gareau, Flowers, Zeffiro, & Eden, 2003).

Case Study of an Isolated Fluency Deficit—How Brain Abnormalities can Inform Educational Theory

Further support for the importance of processes involved in fluency for reading takes the form of a case study involving individuals with a congenital brain malformation, periventricular nodular heterotopia (PNH). This condition leads to inefficiently organized white fiber tracts in the brain and affords a rare opportunity to investigate the behavioral consequences of a specific deficit in the integrity of the *connections* between brain regions. Based on our conceptualization of reading's complexity, we would expect individuals with this condition to have a selective deficit in the rapid and efficient integration of information from several brain regions, resulting in dysfluent reading. This is exactly what the evidence suggests. Individuals with PNH exhibit normal intelligence, attention, working memory, and phonological skills but have an isolated deficit in reading fluency and rapid naming (Chang et al., 2007). Particularly revealing is that the most reading-impaired individuals in this population are those with the most widespread disruptions to the white matter tracts. These findings are further bolstered by increasing evidence of a relationship between white matter integrity and reading ability both in normal readers and dyslexics (Deutsch et al., 2004; Klingberg et al., 2000; Niogi & McCandliss, 2006). In this way, the profiles of individuals with PNH provide compelling support for a dissociation between fluency-related naming-speed processes and phonological processes. They also attest to the importance of efficient connections between and among brain regions involved in the reading circuit, which has critical implications for intervention.

BROADENING OUR VIEW OF READING AND ITS INTERVENTION

To summarize thus far, the behavioral and neurological evidence forces us to recognize that reading involves a complex circuit of linguistic and cognitive processes, each of which contribute to decoding and fluent comprehension. This means that successful reading depends on the integrity, speed, and automatic connections among all these subprocesses. Within this context, research on the naming-speed task ultimately implies that the more unidimensional accounts of reading disabilities provided by phonological core-deficit explanations, although indisputably important, are insufficient.

Support for this more comprehensive view of reading comes from cognitive and linguistic research emphasizing the importance of high-quality orthographic, semantic, morpho-syntactic, and phonological lexical representations, as well as the binding, or connections between and among them for fluent reading and comprehension (Adams, 1990; Berninger, Abbot, Billingsley, & Nagy, 2001; Foorman, 1994; Henry, 2003; Perfetti, 2007; Seidenberg & McClelland, 1989). For example, rich semantic knowledge facilitates word recognition and is strongly related to comprehension (Beck, Perfetti, & McKeown, 1982; Nation & Snowling, 1998). Similarly, well-represented orthographic and morphological knowledge consistently predicts word reading and comprehension (Berninger et al., 2001; Carlisle, 2000; Cunningham, Perry, & Stanovich, 2001; Katzir et al., 2006a; Kieffer & Lesaux, 2007; Reed, 2008).

Recent research in cognitive neuroscience underscores the importance of the *developing* connections between and among these component systems in reading (Lavric, Clapp, & Rastle, 2007; Norton, Kovelman, & Petitto, 2007; Shankweiler et al., 2008), and also the importance of addressing each one in interventions (Sandak et al., 2004a). Imaging studies comparing novice and expert readers document the movement from an effortful set of processes that draws on many brain areas to one that is more efficient and streamlined (see Pugh et al., 2000; Sandak, Mencl, Frost, & Pugh, 2004b; Turkeltaub et al., 2003). This research underscores that the developing reading circuit needs time and practice to build high-quality representations in each component and to connect them automatically. Most importantly, it implies that the quality, efficiency, and connections among all these representations should be explicit goals for reading intervention.

Together, these neurological, behavioral, and educational data refocus our attention on the need to understand *all* the processes involved in reading acquisition and reading breakdown. When we examine children and adults with dyslexia across languages, rare brain abnormalities, and reading subtypes, we are faced first with the extraordinary complexity of the reading circuit and then with the multiple potential sources of breakdown. Such an expanded, more universal view of dyslexia implies that intervention based largely on phonological processes, and decoding accuracy is necessary but insufficient to meet the diverse needs of struggling readers (see Katzir et al., 2006b). Evidence from phonologically based interventions confirms that these interventions work well in the improvement of decoding skills, but not as well in fluency and comprehension (Lyon & Moats, 1997). Thus, we conclude that although phonologically based interventions are a critical platform for early reading skills (see Foorman & Al Oitoba, 2009), explicit attention to those additional processes underlying rate, fluency, and comprehension are of equal importance for the development of the fluent comprehending reader.

CONNECTING THEORY TO THE CLASSROOM

Over the last decade, much of our research has been directed to understanding the development and multicomponent nature of reading fluency (see Wolf & Katzir-Cohen, 2001; Wolf, 2001) and applying this knowledge to intervention. For example, Wolf and Katzir-Cohen (2001) argue the following:

> *In its beginnings, reading fluency is the product of the initial development of accuracy and the subsequent development of automaticity in underlying sublexical processes, lexical processes, and their integration in single-word reading and connected text. These include perceptual, phonological, orthographic, and morphological processes at the letter-, letter-pattern, and word-level; as well as semantic and syntactic processes at the word-level and connected-text level. After it is fully developed, reading fluency refers to a level of accuracy and rate, where decoding is relatively effortless; where oral reading is smooth and accurate with correct prosody; and where attention can be allocated to comprehension (p. 219).*

This view of fluency emphasizes several key elements: first, the development of rapidly functioning, high-quality orthographic, phonological, semantic, syntactic, and morphological representational systems; second, automatic connections between and among these systems; and, third, extensive learning and practice to ensure that automatic decoding becomes a bridge to fluent comprehension. Within such a developmental framework, efforts to address fluency need to begin at the start of the reading acquisition process, not after reading is already acquired (see Kame'enui & Simmons, 2001).

This approach to fluency provides the theoretical basis for an intervention designed to address as many of these cognitive and linguistic processes as possible. Described in detail elsewhere (Wolf, Gottwald, Galante, Norton, & Miller, 2009; Wolf, Miller, & Donnelly, 2000), the Retrieval, Automaticity, Vocabulary, Engagement with Language, and Orthography (RAVE-O) program represents our evolving knowledge from the cognitive neurosciences, linguistics, and education, and its integration with best classroom practices. The program simultaneously addresses both the need to explicitly teach phonological, orthographic, semantic, syntactic, and morphological information in a systematic, sequenced fashion as well as the importance of teaching *explicit connections* among these linguistic systems (Adams, 1990; Berninger et al., 2001; Foorman, 1994; Henry, 2003; Seidenberg & McClelland, 1989).

At its most basic, the RAVE-O program is about teaching young readers to enrich and connect all their knowledge about a word as fast as possible. Within a more physiological context, the RAVE-O program places heavy emphases on representational processes within each component in the brain's reading circuit. This includes representations of common letter patterns, multiple semantic meanings, phonological representations, and the most used morphemes and syntactic uses of words in the children's lexicon. Very importantly, the design and sequence of the program seek to make the initially "novel" connections among these representations as automatic as possible. In so doing, we hope to simulate what the typical reading brain circuit does during the earliest stages of acquisition and fluency. Over the course of the intervention, we hope to propel the developmental move from the use of a more laborious route (found in most early readers) to the use of a more streamlined route used by fluent readers (see Pugh et al., 2000; Sandak et al., 2004b).

These principles are applied in the RAVE-O classroom in several ways. To begin, all children receive some form of an explicit decoding program in their school, which involves intensive work on phoneme awareness, letter-sound correspondence rules, and so on (see Lovett et al., 1994). Then within the RAVE-O program, they are taught a group of *core words* each week that exemplify critical phonological, orthographic, and semantic principles. Syntactic and morphological principles are gradually added after initial work has begun in the program. Each core word is chosen on the basis of: (a) shared phonemes with the phonological treatment program; (b) sequenced orthographic patterns that represent most of the most common letter patterns in English; and (c) semantic richness (e.g., each core word has at least three different meanings). Thus, the core words enable teachers to foster an awareness of the different linguistic components (semantics, phonology, orthography, morphology, and syntax) involved in reading and to make explicit connections between and among these components. In the following section, we briefly explore some of the ways our intervention achieves these ends by examining how the program develops representations in each linguistic component and the connections among them.

Phonology

Although we assume that each child receives systematic attention to core phonological knowledge within the school's program, we leave nothing to chance. The program incorporates phonological principles and teaches explicit connections between phonology and all other components in every lesson as discussed below.

Orthography

Based on the importance of orthographic knowledge for reading fluency, many activities focus on the automatic recognition of orthographic patterns at the sublexical and lexical levels and their use within the connected-text level. Other activities stress orthographic connections to the other linguistic components. For example, the trained orthographic patterns in RAVE-O correspond to the phonemes in the core words and to the individual phonemes in the classroom phonological program (e.g., "a," "t," and "m" become "at" and "am," along with their word families; see work of Juel & Solso, 1981). Based on Reitsma's (1983) and Levy's (2001) work emphasizing the need by impaired readers for multiple exposures in order to learn letter and word patterns, there is daily emphasis on practice and rapid recognition of the most frequent orthographic letter patterns in English. Evolving computerized games (see Speed Wizards, Wolf & Goodman, 1996) and manipulative materials (e.g., letter dice, sound sliders, cards, etc.) are used daily to allow for maximal practice with the orthographic patterns and to increase the speed of orthographic pattern recognition (i.e., onset and rime) in an engaging fashion.

Morphology

Similar to the approach to teaching orthographic patterns, the RAVE-O program explicitly emphasizes morphological knowledge and its connection to the orthographic, phonological, semantic, and syntactic aspects of words through a series of metacognitive terms and strategies. For example, the term "Ender Benders," which itself illustrates the ways in which morphemes can transform words, serves as a mnemonic illustrating the ways in which morphemes such as "ed," "er," and "s" can change a noun to a verb (e.g., "ram" to "rammed"), an action to a person who performs that action (e.g., "move" to "mover"), and a singular word to a plural (e.g., "bug" to "bugs"). The use of these terms helps readers understand how common morphemes work to expand words and to alter their meanings. This knowledge is rarely taught in an explicit manner, but is known to critically facilitate faster word identification, vocabulary, and comprehension (Berninger et al., 2001; Carlisle, 2000; Henry, 2003; Kieffer & Lesaux, 2007; Reed, 2008).

Syntax

Knowledge of how words are used within different grammatical or syntactic contexts is essential for the child's fluency and comprehension, along with the need to become familiar with a variety of increasingly sophisticated sentence constructions and literary conventions. RAVE-O directly addresses how morphemes can change the grammatical role of words and how different sentence contexts influence which particular word meaning to use when. Although a relatively small amount of time was previously devoted to the development of syntactic knowledge, new iterations of RAVE-O give increased attention to understanding basic syntactic principles at the word, sentence, and story levels.

Semantic Knowledge

The RAVE-O program places a heavy emphasis on fostering deep, rich, and flexible semantic knowledge. Toward these ends, the multiple meanings of core words are introduced and thoroughly discussed to illumine their different connotations and connections with other words. Furthermore, imagistic cards that depict the word in varied semantic contexts (e.g., for the word "track," image cards depict railroad tracks, animal tracks, and a detective "tracking") are used to engage students in an exploration of a word's related images and different syntactic roles. *Image cards* for the word "ram," for example, provide pictures of the animal, the act of ramming, a battering ram, and computer ram. In so doing, these images serve as a visual mnemonic that aids word retrieval (a common challenge in dyslexia) and reinforces the word's semantic richness.

Vocabulary growth is conceptualized as essential to both rapid retrieval (in oral *and* written language) and also to improved comprehension, the ultimate goal in the program. Word-retrieval skills are taught through a variety of ways, including a set of metacognitive strategies, influenced by early research with aphasia patients with dysnomia (see Goodglass & Kaplan, 1972).

Fluency and Comprehension: Integrating Across Subcomponents

A series of comprehension stories (e.g., *minute stories, minute mysteries,* and *minute heroes*) accompany each week of RAVE-O and directly address fluency and comprehension in several ways. The controlled vocabulary in the timed and untimed stories both incorporates the week's particular orthographic and morphological patterns, and also emphasizes the multiple meanings of the week's core words, and often their different syntactic uses. The stories provide a superb vehicle for repeated reading practice, which, in turn, helps fluency in connected text.

Thus, the minute stories are multipurpose vehicles for facilitating fluency in phonological, orthographic, syntactic, and semantic systems at the same time that they build up knowledge about more sophisticated sentence structures and a range of comprehension skills. Such a multicomponential, multilayered approach is a pedagogical analogue to the insights by Sandak and Pugh and their colleagues (see Sandak et al., 2004b) into the multiple neurological substrates subserving word identification and comprehension.

Within this multicomponential approach, fluency is conceptualized as the bridge to fluent comprehension. Fluent comprehension, in turn, is conceptualized as the bridge to the reader's own best thoughts. RAVE-O teaches a set of three comprehension strategies, the "Think Thrice" strategies, each of which embodies well-known skills from prediction to comprehension monitoring. The final strategy, Think for Yourself, explicitly elicits the reader's insights into the text. In so doing, we hope to teach new readers a set toward critical thinking and an expectation and belief in their own intellectual contributions. We consciously aim to nurture from the start the well-known capacity of individuals with dyslexia to "think outside the box."

Engagement

The end goal of RAVE-O is not about how rapidly children read, but about how well they understand and enjoy what they read. Critical to this ultimate goal, every daily lesson in RAVE-O incorporates an additional system too little discussed by many researchers—the affective-motivational one. The secret weapons of the RAVE-O program are the game-like *whimsy* in every dimension of the theoretically motivated activities and the daily, systematic efforts to help each child find and feel success. We want our children to read and to appreciate the richness of oral and written language. We want them to remember and easily retrieve what they know. By engaging them and ensuring that they find success often, we seek to empower what are often linguistically disenfranchised children and give them a sense of the fluidity of their growing knowledge (Dweck, 2000). Such a method of instruction demands a special involvement from teachers. Throughout the program, therefore, we strive in as many ways as we can to engage not only the learner's interests but also the teacher and the teacher's own love of language. Our goal is a group of mutually engaged teachers and learners with a mutual appreciation for words.

EFFICACY OF RAVE-O

We have now studied the RAVE-O program in a variety of contexts: school-based intervention, summer school, and after-school settings. Along with our colleagues, Robin Morris in Atlanta and Maureen Lovett in Toronto, we have studied the efficacy of RAVE-O alongside another highly effective multidimensional program, the metacognitive strategy program by Lovett called PHAST (Lovett et al., 1994; Lovett, Steinbach, & Frijters, 2000). This program, which combines a phonological analysis and blending program (PHAB) with a word identification strategy program (WIST), emphasizes phonological, orthographic, morphological, and affective components. We compared the two multidimensional programs with two control conditions: the more traditional phonological analysis program (PHAB), taught alongside a study skills program, and a classroom control condition that included a math and a study skills program (classroom control).

In our first 5-year randomized treatment-control study, 279 impaired readers in the second and third grades received 70 hr of treatment in one of the control conditions, or in one of the multidimensional programs, each combined with half an hour of the phonology program. The effects of these conditions were compared across an extensive battery of tests covering multiple aspects of reading from single-word decoding to connected text reading and comprehension as well as language measures. As summarized in Table 1 and described in detail in a recent quantitative paper, the results from this study strongly support

Table 1
Summary of findings at the single word, connected text, comprehension, fluent comprehension, and vocabulary levels from the longitudinal investigation of reading interventions in second and third graders with RD*

Skills Measured	*Results after 70 hours of intervention*
Word level skills	
WRMT Word Attack	RAVE-O = PHAST > PHAB > Classroom Control
WRMT Word Identification	RAVE-O = PHAST > PHAB > Classroom Control
WRE	RAVE-O = PHAST = PHAB > Classroom Control
WRAT Reading	RAVE-O = PHAST > PHAB > Classroom Control
Connected text level skills	
GORT Accuracy	RAVE-O = PHAST > PHAB > Classroom Control
GORT Rate	RAVE-O = PHAST > PHAB > Classroom Control
Comprehension	
GORT Comprehension	RAVE-O >** PHAST > PHAB > Classroom Control
WRMT Passage Comprehension	RAVE-O = PHAST > PHAB > Classroom Control
Fluent Comprehension	
GORT Oral Reading Quotient	RAVE-O > PHAST > PHAB > Classroom Control
Vocabulary Knowledge	
No. of multiple meanings on Word-R	RAVE-O > PHAST, PHAB, Classroom Control
Experimental multiple meanings measure	RAVE-O > PHAST, PHAB, Classroom Control

RAVEO = RAVE-O intervention, including half an hour of PHAB. PHAST = PHAST intervention, including half an hour of PHAB
PHAB = Study Skills program/PHAB Intervention. Classroom Control = Study Skills program/Math program.
WRE = Test of Word Reading Efficiency, early version of the Test of Word Reading Efficiency (Torgesen, Wagner, & Rashotte, 1999)
WRMT = Woodcock Reading Mastery Test-Revised (Woodcock, 1987); WRAT = Wide Range Achievement Test-3 (Wilkinson, 1993); GORT = Gray Oral Reading Test (Wiederholt & Bryant,1992); Word-R = Multiple Meanings subtest of the Elementary Word-R test (Huisingh, Zachman, Blagden, & Orman, 1990)
*all values $p < .05$ or less
** $.05 < p < .06$

the efficacy of both multidimensional programs in general, and in RAVE-O's approach in particular, for advancing children's reading performance at the letter-pattern, word, and text levels (see Morris et al. 2009).

There were significant differences in every reading and language measure at every level between children who received the RAVE-O program and both the classroom control and the phonological control condition. Specifically, the children in the RAVE-O group outperformed the latter groups on measures of decoding, word reading, connected text reading, and comprehension. We expected and found no significant differences in decoding and word recognition between the multidimensional programs (RAVE-O and PHAST), which produced similarly significant gains on every standardized measure of word identification and reading.

Of keen importance to our goals, however, is that there were additional significant differences achieved by children in RAVE-O in measures of vocabulary (Barzillai, Wolf, Morris, & Lovett, 2009) and connected text-level fluent comprehension measured on the Gray Oral Reading Quotient (ORQ). In other words, children in the RAVE-O group made equal or greater improvements on the word-attack and word-identification measures, and outperformed children in the other treatment groups on measures of vocabulary and fluent comprehension on the ORQ. The latter have been extremely difficult to change in previous large intervention studies.

Additional investigations revealed that the positive outcomes for RAVE-O and PHAST were true across all readers, regardless of IQ levels, ethnic backgrounds, and socioeconomic circumstances (Morris et al., 2009). Taken together, these results support a multidimensional view of reading and its intervention with heterogeneous struggling readers. The fact that children in the RAVE-O intervention (a) spent far less time on specific decoding skills and more time enhancing connections across orthographic, semantic, morphological, and sytanctic processes; (b) made gains in word reading measures comparable or superior to programs that spent more time solely on these skills; and (c) made superior gains on measures of vocabulary and fluent comprehension on the ORQ provides compelling evidence in support of such a multidimensional view of reading and intervention.

Based on these strong efficacy results, we began a series of interventions in other settings with other populations. Donnelly Adams (2009) investigated the use of RAVE-O in a summer school setting and found significant improvement in both listening and reading comprehension, sight-word reading, and reading fluency for an intensive, half-day, 4-week RAVE-O intervention. In addition, we are working to understand the potential of RAVE-O to address the multiple issues of children with comorbid reading and social-emotional challenges. Toward these ends, we (Pierce, Katzir, Noam, & Wolf, 2007) are studying RAVE-O along with a resiliency program (Noam, Winner, Rhein, & Molad, 1996) in an after-school setting with this population. Furthermore, future analyses will focus on differential treatment outcomes for subtypes of impaired readers. In this way, we hope to better understand which children with what defining characteristics are most helped by a particular intervention (see Francis et al., 2005); for, there is no "one size fits all" intervention.

The RAVE-O program itself continues to evolve with feedback from teachers who use it in their classrooms. One of our most valuable resources concerning the long-term efficacy of the intervention are these teachers whose observations and suggestions shape each version of the program. For example, in another ongoing study, Miller, Wolf, Anton-Oldenburg, & Ellison (2009) are working with classroom teachers to expand the present RAVE-O to a first-grade implementation. The past success of the RAVE-O intervention and its future iterations are testament to the power of the reciprocal, dynamic interactions between neuroscience and classroom practice.

In summary, we have chronicled here the case history of an idea that emerged from the observations of a 20th-century neurologist about the brain of a 19th-century patient with stroke. The research program that emerged became the basis of a comprehensive, highly successful intervention program for many children with dyslexia. The theoretical basis of the RAVE-O program is the reading brain and what it does every time a single word is read. From Chall's prescience about letter naming prediction to functional magnetic resonance imaging (fMRI) studies of this same process, every aspect of this intervention research program has been influenced by the increasing connections between education and the neurosciences.

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