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Learning and Cognitive Disorders

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Synopsis

The purpose of this article is to provide a select review of treatments for addressing reading disorder, mathematics disorder, disorder of written expression, auditory processing disorder and poor working memory. This information will be valuable to practitioners in determining the suitability of certain treatments for these various disorders/problems which has direct implications for providing comprehensive, multi-disciplinary treatment for youth.

Keywords

Youth; Children; Adolescents; Learning Disorders; Working Memory; Auditory Processing Disorders; Treatment; Intervention

Introduction

Learning and cognitive disorders affect a substantial number of youth, resulting in considerable concurrent impairment and diminishing the potential for successful long-term academic and social functioning for affected youth. Given these issues, considerable investment has been made to develop and evaluate treatments to address these problems. A comprehensive review of all interventions focused on various learning and cognitive disorders is well beyond the scope of this paper; we focus on a select review of interventions that are commonly used to address reading disorder, mathematics disorder, disorder of written expression, poor working memory, and auditory processing disorder. As the reader will glean from this review, there are numerous treatments, many that are publically-available, for addressing these issues. Although several interventions are well-established for certain disorders, there are several that require considerably more rigorous evaluation.

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See Table 1 for a list and summary of the interventions reviewed herein and Table 2 for the authors' opinions regarding the value of these interventions for the various disorders reviewed herein.

Reading Disorders

Reading disorders are neurobiological conditions with deficient phonologic coding. Subsequently, interventions aimed at this underlying etiology have been the most efficacious. Although many different remediation programs exist, there is not one “magic” program identified in the literature ¹; rather, programs that encompass shared, critical components are recommended ^{1,2}. Essential elements of such interventions include individualization, feedback and guidance, ongoing assessment and regular ongoing practice ³. Programs should be highly structured, intensive and include explicit reading instruction. Content should be organized in a hierarchical manner, starting with phonemic awareness, sound-symbol association, phonics, awareness of rhyme, and word segmentation. Phonemic awareness involves the ability of a listener to be able to hear, identify and manipulate phonemes, the smallest units of sound that can differentiate meaning. Separating the spoken word “cat” into three distinct phonemes, /k/, /æ/, and /t/, requires phonemic awareness. As children develop, instruction should advance to fluency training, vocabulary and comprehension, and then to syllable instruction, morphology, memorization of sight words, spelling, syntax and semantics ⁴. In particular, a multisensory, small group approach which focuses on applying phonemic awareness skills and phonemic manipulation, particularly with letters (vs. sounds) is most commonly recommended ^{2,5}.

Using curricula with many of the components described above, for younger children (k-1st grade), small group instruction (2–3:1) that occurs 4–5 times a week is recommended that includes phonologic awareness, letter knowledge and explicit phonics ². Younger children have the best outcome using this methodology, often with long term gains. For older children, improved outcomes have been achieved with 1:1 instruction, with more intensive work for a longer duration compared to younger youth. In general, reading comprehension appears to be most directly affected with intervention, with less improvement observed in spelling and fluency.

The Orton-Gillingham approach has been used since the 1930s for reading intervention, and many commercial remediation programs based on this approach are available (e.g. the Wilson Reading System, Project Read, Alphabetic Phonics, the Herman method, the Slingerland method, Language!, and the Spalding method). The Orton-Gillingham approach is a multisensory, sequential, phonics-based system that focuses on basic word formation before whole meanings. Few of the commercial programs, however, have been tested in rigorous, randomized controlled trials ⁵. School-based programs that have been more widely studied include Lindamood Phoneme Sequencing (LiPS) ⁶, Fast ForWord (FFW) ⁷ and Peer Assisted Learning Strategies (PALS) ⁸. Although many other programs exist, the literature on their evaluation is scarce ^{9–11}.

LiPS is a multisensory, bottom-up, explicit approach for developing phonemic awareness and phonemic decoding skills with minimal text instruction. FFW is a computer-based

program that consists of a series of adaptive, interactive exercises that use acoustically processed speech and speech sounds. PALS utilizes peer-tutoring, repeated reading and paragraph summary with corrective feedback. These interventions have been evaluated in controlled trials, primarily in school-age children from diverse socioeconomic backgrounds in various settings (e.g., school, summer camps). However, the methods of implementation for these interventions has varied considerably across studies^{8,12–18}.

Research on LiPS has revealed that children improve in alphabets and reading fluency, with no effects on reading comprehension^{13,14}. Interestingly, these studies reported that alternative interventions that shared critical components to LiPS (e.g., phonemic awareness and decoding, utilizing explicit, systematic instruction, etc.) but differed in delivery were also effective. This suggests that teachers implementing core principles of effective practice rather than LiPS per se can expect benefits on reading outcomes. Of note, 40% of the children across these interventions were no longer in special education classrooms at follow up; however, only about half sustained gains and one-quarter lost gains over a two-year period¹⁴. Effect size (ES) data on primary outcomes of focus in these studies have considerable variability (ES=.12–.54)

Research suggests that, overall, the intensive training and cost necessary for implementing FFW is not warranted (see also section of FFW for Auditory Processing Disorder). For example, although one study found improvements in phonemic awareness after FFW, gains were similar to those of the comparison group, which was a less intensive Orton-Gillingham program¹². A second study found significant gains in nonword reading, word identification, passage comprehension, receptive and expressive language, and rapid naming after FFW; yet only nonword reading outcomes improved enough to be considered clinically meaningful¹⁶. ES data on primary outcomes of focus in these studies range in from no-effect to a small positive effect (ES=.12–.32)

Results from rigorous studies on PALS indicate positive effects on reading fluency and reading comprehension, relative to comparison groups (e.g., typical instruction)^{19,20}. In an evaluation of the PALS literature, What Works Clearinghouse calculated large enough effect sizes for reading fluency and reading comprehension to declare a “substantial, positive effect” in these domains²¹. ES data on primary outcomes of focus in these studies are large (ES> .80)

Most recently, two comprehensive reading interventions have been studied and suggest clear benefits for youth with reading impairments. RAVE-O (<http://ase.tufts.edu/crlr/RAVE-O/>) addresses both overt reading behaviors like word recognition skills and comprehension, and underlying components (e.g., visual scanning, lexical retrieval). RAVE-O simultaneously addresses the need for automaticity in key systems related to reading (e.g., phonological and morphological systems) as well as the importance of teaching explicit connections among these systems. The goal throughout is to teach systematic, theoretical principles that underlie fluency and decoding through explicit instruction in skills underlying fluency and comprehension, imaginative, whimsy-filled opportunities for practice, and a set of strategies that embolden discouraged children to look at written language with whole new eyes. PHAST (<http://www.sickkids.ca/LDRP/Empower-Reading/Program-description/index.html>)

is a comprehensive intervention focused on developing word decoding skills and decoding strategies. Studies have documented effects for both of these interventions across reading and language outcomes and are highly recommended interventions for struggling readers.

It should also be noted that vision-based therapies are advertised as remedying reading disabilities as well (e.g., eye exercises, behavioral vision therapy, or special tinted filters or lenses). The American Academy of Pediatrics, however, noted that vision-therapies are not supported by sound research and are, therefore, not recommended as evidence based treatments²². While vision may interfere with learning to read, it is not considered to be the primary cause of impairment.

Mathematics Disorder

Math related learning disorders (MLD) are present in approximately 5–8% of students²³. These children tend to experience difficulty with procedural operations, working memory, conceptual understanding of numbers, problem solving strategies, and organizing information²⁴. As such, these children frequently fall behind in school. However, given the diverse symptomatology and the lack of a standardized diagnostic tool, there does not currently appear to be one gold standard intervention.

One type of MLD treatment with some empirical support is known broadly as Fact Retrieval Intervention^{25–28}. This kind of program is founded upon the theory that quickly and efficiently accessing learned number combinations is a critical step of rudimentary mathematics. Thus, if children have deficits in this automatized retrieval process, they will be unable to achieve proficient, grade-appropriate math skills. These interventions (e.g., Hasselbring, Goin, and Bransford's "Fast Facts") are computer-based instructional tools centered on imparting fact retrieval strategies. Most programs are comprised of computer-based instruction, math fact flash card practice sessions, and fact review with individualized feedback. Although multiple studies have tested this type of intervention, methodological limitations (i.e., no control group, lack of random assignment, etc.) limit conclusions that can be drawn regarding the efficacy of this approach. ES data on primary outcomes of focus in these studies range in from a small to moderate effect ($ES = .23-.58$)

Concrete-to-Representational-to-Abstract (CRA) is comprised of three primary sequenced components: the use of physical manipulations of concrete objects, followed by the use of graphic representations of these concrete objects, followed by the teaching of abstract thinking specifically geared toward problem solving²⁹. The CRA model is categorized as a multisensory approach because it integrates visual, auditory, kinesthetic, and tactile interactions with content through the direct handling of objects and matching of graphic designs. CRA principles have been utilized to help students with MLD learn various mathematical operations including word problems³⁰, fractions³¹, linear functions³², and algebra²⁹, but it has almost exclusively been used in middle school and high school settings. ES data on primary outcomes of focus in these studies range in from a small to moderate effect ($ES = .21-.52$)

Cognitive strategy instruction (e.g., "*Solve It!*"³³) focuses on the planning and execution of cognitive tasks³⁴. The overriding goals of this type of intervention are to automatize the

cognitive processes critical to problem solving and to encourage self-regulation (namely, self-instruction, self-questioning, and self-monitoring) during mathematical operations. Cognitive strategy instruction has been tested in students with learning disorders³³. Overall, this technique appears to show great promise but will require further rigorous evaluation for improving math skills of children with MLDs.

Mnemonic strategy instruction targets teaching students to apply mnemonic devices to mathematical operations as a heuristic technique. For example, one model, LAP Fractions³⁵, instructs children to “*Look at the sign and denominator, Ask yourself the question: will the smallest denominator divide into the largest denominator an even number of times, Pick your fraction type*” in order to assist in fraction related problems. Another variation of this type of intervention assigns stories and characters to different mathematical operations to assist in the memorization of difficult rules and procedures³⁶. Again, the results of this category of intervention are promising, but further research should be completed to assess generalizability across ages and math levels.

Schema-based instruction has received empirical support^{37–39}. It includes direct instruction on how to schematically interpret word problems (e.g., identify the operation being asked, and then used schema-based reasoning and logic to organize problem solving efforts). Theoretically, proficient problem solvers create mental representations of the problem schema in order to solve the question accurately. These schemas can then generalize to structurally similar prompts, which should increase efficacy and decrease cognitive load required to complete the computation. Although this technique has garnered some empirical support, many of the studies included a small number of participants, were conducted by the same research group, and only focused on very specific types of mathematical problems. ES data on primary outcomes of focus in these studies range in from a small to moderate effect (ES= .38–.61). Future research should attempt to replicate the results of these initial trials.

Disorder of Written Expression

Disorder of written expression is a learning disorder in which an individual’s writing ability is significantly below the expected range given the person’s chronological age, intelligence, and age-appropriate education. Writings skills must also result in significant impairment in academic achievement or activities of daily living that require the composition of written texts. Numerous interventions to improve writing skills of youth affected with disorder of written expression have been identified and have resulted in significant benefits for affected youth.

Strategy instruction methods have been evaluated to improve various aspects of writing skills in youth with disorder of written expression. Methods that focus on teaching strategies for planning/drafting specific types of text, principally utilizing Self-Regulated Strategy Development⁴⁰, have received considerable empirical support in improving structural elements of composition, writing productivity and writing quality. These improvements are generally maintained over time and generalize beyond trained content. Methods for teaching strategies for editing have also been conducted, with findings generally supporting the effects of this strategy on error detection. To date, strategies for planning/drafting have the

most robust empirical support^{40–42} for youth with disorder for written expression. A recent meta-analyses⁴³ also suggests that this strategy offers considerable promise for youth with primary disabilities other than learning disorders (e.g., attention-deficit/hyperactivity disorder; emotional or behavioral disorders, etc.). ES data on primary outcomes of focus in these studies range in from a moderate to large effects (ES= .57– 1.1).

A secondary set of methods have also been utilized and have demonstrated significant benefit in improving various aspects of writing skills^{40–42}. For example, establishing specific and clear goals (i.e., goal setting) improves the quality of text and writing productivity. Studies have utilized goal setting in various ways including having students' self-monitor goals with public recognition for achieving a goal to teachers' establishing writing goals and providing direct feedback on goal achievement. Studies suggest benefits of goal setting on increasing productivity (number of words written, number or percentage of writing assignments completed). In addition, utilizing word processing appears to have considerable benefits on students' writing. Studies that have focused on using word processing in lieu of handwriting or word processing with prompts to utilize editing features of the word processing programs have demonstrated benefits on increasing writing productivity. Finally, teaching students how best to write different types of sentences and how to combine simpler sentences into more complex sentences have also demonstrated positive impacts on the number of complete sentences produced.

Several interventions, primarily supported through single-subject research designs, also suggest benefits for students with writing difficulties. For example, in a meta-analysis, benefit was reported for reinforcing students for writing productivity, as well as teaching strategies for editing text and strategies for constructing paragraphs⁴¹. Importantly, more rigorous evaluations of these interventions are necessary to further provide support for these interventions.

Working Memory

Working memory, once considered a fixed-attribute, is now considered malleable and, importantly, improvable through direct intervention. This malleability is important as working memory is considered a core executive function that is related to a host of important outcomes for individuals, including academic and professional success. The premise is that if working memory can be improved, there will be benefits across key outcomes (e.g., attention) that are critical for long-term adjustment in youth.

Over the past decade there has been an explosion of commercial and scientific interest in developing and evaluating interventions that improve working memory in both children and adults. For instance, MindSparke, Lumosity, Jungle Memory, Growing with Timocco, and Play Attention are now readily available for commercial use⁴⁴. Unfortunately, commercial development has far outpaced high-quality experimental evaluation of these interventions. For some interventions, practically no rigorous studies published in peer-reviewed outlets have been conducted. As such, it is impossible to state anything more than these remain untested interventions. To date, Cogmed Working Memory Training (CWMT) has stood out as a leader in the working memory training movement given the number of independent

empirical studies of CWMT. As such, a review of CWMT offers an opportunity to objectively critique the field of working memory training interventions.

Briefly, CWMT is a computerized training program designed to effectively increase working memory capacity over a five-week training period through targeting both storage and manipulation of verbal and nonverbal working memory components. Training takes place in approximately 30–45 minute increments over five days per week (25 training-days total). CWMT trials are individualized/titrated to the capacity of the individual using an adaptive, staircase design that adjusts the difficulty of the program on a trial-by-trial basis. That is, correct trials are followed by successive trials with heightened working memory demands, whereas incorrect trials result in subsequent trials with diminished working memory load. Support for implementation is provided by a CWMT training aide (usually a parent) and a certified CWMT coach who problem solves implementation issues with the trainee and training aide on a weekly basis.

Studies across children and adults in clinical (e.g., youth with attention-deficit/hyperactivity disorder; learning disorders; stroke patients; individuals with acquired brain injury) and typically-developing populations utilizing several treatment designs (e.g., open clinical trials; randomized clinical trials) with various comparison conditions (e.g., wait-list control, attention-control, etc.) have documented the effects of CWMT. For example, CWMT has been shown to improve working memory ^{45,46}, brain activity ⁴⁷, and attention ^{46,48,49}. ES data on primary outcomes of focus in these studies range in from a moderate to large effect (ES= .52–1.12).

More recently, however, there have been considerable concerns raised regarding the literature on CWMT specifically ^{50–53}, as well as caution in the effusive claims made by cognitive training programs in general ^{44,54}. For instance, there have been inconsistent findings in the literature regarding the results of CWMT between studies ^{46,55} as well as within studies ⁵⁶. Some have suggested that there is poor transfer of training from trained working memory tasks to untrained working memory tasks and further downstream to more complex tasks (e.g., reasoning and attention) ⁵⁰. However, the extant data regarding specific effects of CWMT on specific working memory outcomes suggest some benefit, although further research is needed.

Auditory Processing Disorder

Youth with auditory processing disorder (APD) have significant difficulties in identifying, discriminating, ordering, grouping or localizing sounds. APD appears to be very common in youth with specific reading disorders or specific language impairment, with some studies suggesting that youth with attention-deficit/hyperactivity disorder or autism also suffer from APD. APD, although identified decades ago, has only recently received consideration as a diagnostic entity ⁵⁷. Likewise, the treatment of APD has received more attention over the past decade, with several empirical studies evaluating a variety of treatments.

Treatments for APD have taken various forms and have differed on their conceptual focus of the treatment. For instance, auditory treatments manipulate auditory components of speech and non-speech language (e.g., Fast ForWord) while language treatments manipulate

language form, content and use (e.g., Earobics)⁵⁸. Environmental modification (e.g., preferential seating; hearing aides) and compensatory strategies (e.g., memory and attention strategies) have also been used to support youth with APD. Specifically we discuss herein the treatment literature on auditory integration training (AIT), Tomatis, Earobics, and Fast ForWord (FFW), given the use of these interventions in clinical practice.

AIT focuses on improving hearing distortions and hearing hypo/hypersensitivity which impair an individual's attention, comprehension, and therefore, learning. AIT involves multi-session sound therapy where individuals use headphones to listen to modulated music from an AIT device in order to normalize hearing responses. AIT has been utilized as a treatment for various clinical disorders (e.g., autism, attention-deficit/hyperactivity disorder) as well as for individuals with APD across the life span. Despite the long history of AIT, there have been very few rigorous evaluations of AIT for the treatment of APD. In fact, the only study that has been conducted on school-age youth with APD or language disorders suggests no benefit of AIT⁵⁹. This study reported the effects of AIT relative to a control condition on various behavioral and physiological outcomes and found no differential benefit of AIT on these outcomes. Several other studies have been conducted on AIT but lack the experimental rigor needed to be able to support the utility of AIT for treating youth with APD and/or language disorders. As such, there is no clear empirical justification for AIT in the treatment of APD.

The Tomatis Method, developed in the 1950s, aims to more efficiently transmit and process acoustic sensory messages via the stimulation of muscles in the ear through the use of specialized auditory equipment that is calibrated to the profile of the user. Despite the use of the Tomatis Method for the treatment of auditory processing disorder (as well as other disorders including language disorders, emotion disorder; attention disorders; autism spectrum disorders) over several decades and its use in practice settings internationally, few studies have systematically evaluated the benefits of this method. A meta-analysis⁶⁰ found no effect of this treatment approach on auditory-related outcomes across studies utilizing the Tomatis Method. More recently, Ross-Swain⁶¹ utilizing retrospective reports of individuals between the ages of 4–19 who completed the Tomatis Method found significant benefits of the method on auditory memory, sequencing, discrimination and cohesion. This study is limited in that it utilized a nonrandomized retrospective design of selected patients who completed the 90-hour Tomatis Method. These patients were not assessed for APD but had features commonly associated with APD. Given the state of the literature, further empirical evaluation is needed prior to recommending the Tomatis Method for the treatment of APD.

Earobics is a comprehensive computer-based program for training phonological awareness and auditory-language processing skills. Few studies have been conducted on Earobics for the treatment of APD^{62–64}. These studies have had mixed findings. For instance, several studies^{62–64} reported positive training effects of Earobics on phonological awareness skills and neurophysiological factors related to auditory processing but did not find effects on reading and spelling outcomes. One study, utilizing a series of case studies, found mixed benefits of Earobics on reading and spelling across study participants⁶⁵. Another report evaluated the effects of Earobics compared to other alternative treatment conditions and found no significant benefit of Earobics on language outcomes¹⁵. Collectively, the handful

of studies on Earobics have mixed findings, which suggest caution and further exploration of Earobics as a potential intervention for youth with APD and/or language disorders.

FFW is an adaptive intervention that utilizes modified sounds (speech and nonspeech) to train temporal processing, speech perception and language comprehension skills. To date, it is the intervention which has undergone the most extensive empirical investigation with over 20 studies evaluating FFW as an intervention for APD and/or language disorders.

Collectively, findings across these studies have been mixed. For instance, some exploratory studies have documented significant improvements in auditory measures^{65–67}, and language outcomes^{68,69}. However, more methodologically rigorous studies have found no specific effect of FFW on auditory outcomes or language outcomes^{15,58,70,71}, with ES in the no to small effect range (ES= .08–.23).

Conclusions

Clinical Implications

When predicting treatment response in youth with reading disorders, baseline phonological awareness and rapid naming ability have consistently emerged as important factors for successful outcomes⁷². However, there is also evidence to suggest that reading outcomes have multiple determinants and that other more broad neurocognitive factors should be included in this discussion as well. Indeed, baseline visual, verbal, and memory processes have also been shown to be important predictors, in addition to phonological awareness and rapid naming⁷³. This evidence suggests that those with poor baseline functioning in other cognitive domains, not traditionally associated with reading outcome, may have little- no treatment response, and therefore traditional treatments may not be an appropriate recommendation. As such, it would be important to have a more comprehensive evaluation of the child's neurocognitive functioning when treatment planning, in order to predict treatment response to traditional interventions and more appropriately individualize treatment. Lastly, when considering treatment recommendations, it would also be important to correctly identify the etiology underlying reading difficulty. For instance, while dyslexia is most widely studied, there are other reading disorders which have distinct neurobiological underpinnings⁷⁴, and therefore, may have different treatment considerations. For instance, youth may also have a specific comprehension deficit, with intact word-level abilities. Evidence suggests that these youth may have difficulty accessing lexical-semantic representations during word recognition⁷⁴. As such, it is important to keep in mind that other etiologies exist and that the correct identification of reading difficulty is important in order to appropriately individualize treatment.

In light of the extant literature, some general implications for the treatment of reading disorders include utilizing intensive, explicit training with critical elements including individualization, feedback and guidance, ongoing assessment and regular ongoing practice, and explicit reading instruction organized in a hierarchical manner starting with phonemic awareness, sound-symbol association are efficacious, with considerable latitude regarding delivery. However, specific commercially-available programs are often costly and difficult to implement, requiring trained specialists. This is often unfeasible for many school or home based programs. In contrast, there is empirical support that PALS has substantial effects on

multiple reading domains, while being relatively easy to implement. In terms of potential costs for clinicians and parents interested in utilizing interventions for RD, it is cost-effective to focus on individual or small-group learning that is focused on explicit and intensive treatments. Commercially available programs will clearly be more costly but there is little conclusive data suggesting that these improve outcomes. The cost of PALS is also minimal and is a one-time cost; once the material is purchased it can be subsequently used in the classroom without additional costs. Both RAVE-O and PHAST incorporates multiple, evidence-based methods to improve reading and language and have demonstrated significant benefits for struggling readers. Given the strong data supporting PALS, RAVE-O, and PHAST and the relatively minimal costs, these are interventions that are highly recommended for school-based use.

There is a growing recognition that youth who present with mathematics disorders suffer from various and multiple deficits (e.g., poor math facts; poor calculation fluency^{24; 75}) and often also have underlying broad deficits in working memory, which compounds difficulties in math as children are required to utilize increasing levels of working memory when completing more advanced mathematics calculations⁷⁵. As such it is important to go beyond standardized assessments of math achievement tests to include more specific evaluation of specific math deficits (facts, skills, etc) in order to provide personalized approaches to targeting the specific math deficits that a child may suffer from. Currently, although there are numerous interventions and approaches for treating mathematics disorder, it seems that interventions comprised of repeated practice trials and concrete, easily relatable examples, instructions, or strategies have garnered the most empirical support. It also appears that interventions should target the most basic elements of a given skill to ensure that children are learning and understanding the principles underlying the mathematical operations. This extra support should be provided to children as early as possible to prevent them from falling farther behind.

There is substantial evidence from numerous studies that methods focused on teaching strategies for planning/drafting specific types of text have considerable empirical support for addressing written expression difficulties. In particular, Self-Regulated Strategy Development appears to be a first-line intervention for treating writing skills. Likewise there appears to be considerable support for other interventions (e.g., goal-setting; use of word processing). These interventions, although less effective, are beneficial. Given the relative simplicity of goal-setting and the increasing use of word processing in schools, these interventions should be consistently utilized, preferably along with strategies for planning/drafting texts. The costs with the reviewed treatments for MLD are minimal and these methods are likely good practice for supporting math learning in youth, although some more cognitively complex interventions may be more challenging for younger youth.

Although there has been considerable interest and investment in the development of treatments for improving working memory, there is considerable debate regarding the efficacy of such approaches. Importantly, although there are numerous commercially available interventions for improving working memory, there have been limited, if any, rigorous, independently conducted evaluations to test the claims of these interventions. Given the numerous conceptual issues and methodological limitations of CWMT, a firm

conclusion regarding the benefits of CWMT cannot be made. However, there appears to be some stronger support for CWMT on core working memory components that are “trained” during treatment with more concern about the transfer of these abilities to non-trained tasks. More rigorous evaluation is clearly needed. The cost of CWMT may be substantial as these are provided directly by a CWMT-certified practitioner (usually a physician or psychologist). This may be an intervention that is cost-prohibitive for families with fewer financial resources.

Collectively, there is great variability in the number and methodological rigor of studies that have evaluated AIT, Tomatis Method, Earobics, and FFW for the treatment of APD. In general, there is limited evidence supporting Earobics and FFW with no compelling evidence supporting AIT or the Tomatis Method as an intervention for APD or related problems of language and academic performance. Clinically, the conclusions presented herein suggest that clinicians should conduct a careful assessment for APD with accompanying assessments focused on language, reading and academic achievement problems. Evidence based treatments (some of which has been reviewed herein) should target these accompanying problems as first-line treatments. There should be close monitoring of progress with these interventions to determine ongoing response to treatment. If there appears to be little improvement despite high-quality implementation of these interventions, an intervention focused on treating identified auditory processing issues may be warranted. This will also require ongoing monitoring of the impact of an APD treatment not only on auditory outcomes but also on language, reading and academic performance. Similar to CWMT, many of these interventions are commercially-packaged and only available through a certified provider. However, given the stats of the evidence for these interventions for treating APD, there is little rationale for utilizing these interventions.

Research Implications

There are multiple research implications derived from this review. First, there is a great need to understand how characteristics of youth and their contexts (e.g., family, classroom) moderate treatment response. Knowing for whom and under what contexts a well-supported intervention is more or less effective has clear implications for practice. These types of studies are clearly necessary for treatments that have robust empirical support. Similarly, many interventions (e.g., FFW) reviewed herein are multi-faceted. As such, it is unclear as to which components of these interventions are having a direct impact on outcomes. Research directed at understanding the underlying mechanisms of how a particular treatment impacts key outcomes is clearly needed to develop more parsimonious treatments. Resulting refined and simplified treatments/approaches are likely to be more closely adhered to and will allow for the delivery of a more potent dose of the active ingredients, which should directly result in improved outcomes.

There are multiple interventions reviewed herein that offer promise but have been inadequately studied (e.g., reinforcing students for writing productivity; schema-based instruction for math). More rigorous studies must be conducted with these interventions as there is a need to identify alternative approaches to treating learning and cognitive disorders given patient and provider preferences, heterogeneity in response to treatment, and

moderators of treatment response. Having a robust armamentarium of evidence-based treatments will allow for greater tailoring of treatment.

Of the areas reviewed herein, treatment for poor working memory (and interventions to enhance neurocognitive functioning in general) is likely the most promising line of future empirical investigation. Given the importance of working memory, there needs to be continued investment into further refining CWMT (as well as other working memory interventions). Such efforts are beginning to be an increasing focus of second-generation studies⁷⁶. More generally, with the advances gained through the ever-growing literature on neuroscience, we are discovering how the brain is affected in youth with learning and cognitive disorders and are increasingly better able to develop interventions that more precisely target these underlying deficits/mechanisms. There is no simple translation of findings from basic science into psychosocial treatment but there is great potential to provide tailored and perhaps more effective treatment through this line of empirical inquiry.

Before closing, it is beneficial to briefly discuss the emerging data on the neurobiological underpinning of learning disorders (i.e., reading and mathematics disorders) where data may begin to better inform the potential targets for treatment and provide more personalized treatment regimes. For reading disorders⁷⁷, there has been increasing recognition that there is an underactivation of left hemisphere temporoparietal regions that may affect phonological processing and underactivation of the left hemisphere occipitotemporal region which is believed to be important for word recognition. There is also evidence that implicates white matter disruption in the left hemisphere perisylvian regions. In mathematics learning disorders⁷⁸, there is an inter-relationship between occipitotemporal (fusiform gyrus), parietal lobe (intraparietal sulcus and angular gyrus) and the frontal lobe (prefrontal cortex) that is responsible for potential difficulties in mathematics difficulties. For instance, the occipitotemporal and parietal lobes are required for mapping digits and number word to numerosity representations. The prefrontal cortex is responsible for learning new facts and procedures. The parietal lobe is involved in simple and complex calculations. Multiple studies have demonstrated reduced activation of the parietal lobe in youth with MLDs relative to their peers when participating in numerosity tasks, reduced grey matter in the parietal lobe (i.e., intraparietal sulcus) in individuals with MLDs, and differences in connectivity within the parietal regions and between the parietal and occipitotemporal regions. Given this pattern of deficits in key areas related to learning math and between brain regions associated with learning math, there has been a growing recognition that differential deficits in and between these brain regions may partly explain the heterogeneity in the presentation of MLD in youth.

Collectively, there is growing recognition that these neurobiological differences between youth with and without RD and/or MLD may offer insights into more effectively treating these disorders. For instance, some interventions that have focused on MLDs have attempted to directly target the numerosity system in the intraparietal sulcus⁷⁹. Interventions for RD have found benefits in improving patterns of neural functioning associated with reading⁸⁰, thereby allowing for more refined understanding of how these interventions improve outcomes which will, ultimately, allow for more personalized decision-making regarding which treatments for which individuals based on baseline neuromarkers of treatment

response. The future appears ripe for further investigation in these areas as advances in technology allow for more precise measurement and development of personalized approaches for treatment. At this time however, despite the enthusiasm for what potential there may be for such approaches, these intervention and methods are not read for “prime-time”; clinicians must consider how best targeting various neurobiological deficits with existing treatments and approaches.

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Key Points

1. Numerous interventions with varying evidence-base exist for the treatment of learning and cognitive disorders.
2. There are clear evidence-based interventions for reading disorders (e.g., Peer Assisted Learning Strategies), and disorder of written expression (e.g., Self-Regulated Strategy Development).
3. There is emerging evidence suggesting that certain intervention approaches (e.g., fact retrieval intervention; schema-based instruction; mnemonic strategy instruction; cognitive strategy instruction) may be beneficial for mathematics disorder but will require more rigorous evaluation.
4. A concrete-to-representational-to-abstract strategy for the treatment of mathematics disorder has good evidence for middle- and high-school students.
5. Although several, commercially available interventions exist for the treatment of auditory processing disorder and poor working memory, review of the existing literature suggests caution in utilizing these treatments.

Table 1

Overview of select treatments/approaches for learning and cognitive disorders.

Area	Intervention/Approach	Summary	Basis in Youth	Modified USPSTF System (Quality of Evidence/Strength of Recommendation)
Reading Disorder	Orton-Gillingham approach	Multisensory, sequential, phonics-based system that focuses on basic word formation	Adequate RCTs	Good/Recommended
	Lindamood Phoneme Sequencing	Multisensory, bottom-up, explicit approach for developing phonemic awareness and phonemic decoding skills with minimal text instruction.	Adequate RCTs	Fair/No Recommendation for or against
	Fast ForWord	Computer-based program that consists of a series of adaptive, interactive exercises that use acoustically processed speech and speech sounds.	Adequate RCTs	Good/No Recommendation for or against
	Peer Assisted Learning Strategies	Peer-tutoring, repeated reading and paragraph summary with corrective feedback.	Adequate RCTs	Good/Strongly recommended
	RAVE-O	Multicomponent program to address both overt reading behaviors like word recognition skills and comprehension, and underlying components	Adequate RCTs	Good/Strongly Recommended
	PHAST	comprehensive intervention focused on developing word decoding skills and decoding strategies	Adequate RCTs	Good/Strongly Recommended
Mathematics Disorder	Fact Retrieval Intervention	Programs are comprised of computer-based instruction, math fact flash card practice sessions, and fact review with individualized feedback.	Uncontrolled designs	Fair/Recommended
	Concrete-to-Representational-to-Abstract	comprised of three primary sequenced components: the use of physical manipulations of concrete objects, followed by the use of graphic representations of these concrete objects, followed by the teaching of abstract thinking specifically geared toward problem solving	Adequate RCTs	Good/Strong recommendation for older youth
	Cognitive strategy instruction	Goals of this type of intervention are to automatize the cognitive processes critical to problem solving and to encourage self-regulation	Uncontrolled studies	Fair/Recommended
	Mnemonic strategy	Teaching students to apply mnemonic devices to mathematical operations as a heuristic technique	Uncontrolled studies and RCT	Fair/Recommended
	Schema-based instruction	Direct instruction on how to schematically interpret word problems	Uncontrolled studies	Fair/Recommended
Disorder of Written Expression	Strategies for planning/drafting	Supporting students to utilize discrete planning and drafting procedures	Adequate RCTs	Good/Strongly Recommended
	Strategies for editing	Supporting students to utilize discrete planning and drafting procedures	Uncontrolled studies	Fair/Recommended

Area	Intervention/Approach	Summary	Basis in Youth	Modified USPSTF System (Quality of Evidence/Strength of Recommendation)
	Goal setting	Identifying goals for writing quantity/quality with rewards for goal-attainment	Uncontrolled studies	Fair/Recommended
	Word processing	Utilizing word processing features to support editing of text	Uncontrolled studies	Fair/Recommended
Low Working Memory	Cogmed Working memory Training	Computerized adaptive training of storage and manipulation of verbal and nonverbal working memory components	Multiple RCTs	Good/No recommendation for or against
Auditory Processing Disorder	Auditory Integration Training	Focuses on improving hearing distortions and hearing hypo/hypersensitivity	1 RCT; Uncontrolled studies	Poor/Recommend against
	Tomatis Method	Focuses on improving auditory functioning through stimulation	Uncontrolled study	Poor/Insufficient evidence to recommend for or against
	Earobics	Comprehensive computer-based program for training phonological awareness and auditory-language processing skills	Adequate RCTs	Good/No recommendation for or against
	Fact ForWord	Adaptive intervention that utilizes modified sounds (speech and nonspeech) to train temporal processing, speech perception and language comprehension skills	Adequate RCTs	Good/No recommendation for or against

Quality of evidence as good (strong quality), fair (mixed quality), no data (no empirical data available to make recommendation), poor (sufficiently weak data to support intervention). Strength of the evidence is graded as strongly recommends, recommends, no recommendation for or against, recommends against, or insufficient evidence to recommend for or against.

Table 2

Treatment Evaluation: Authors' Personal Opinion

Intervention/Approach	Outcomes	Modified USPSTF System (Quality of Evidence/Strength of Recommendation)	Opinion
Orton-Gillingham approach	Reading	Good/Recommended	General approach focused on phonological-processing/awareness, word analysis, reading fluency, and reading comprehension is useful
Lindamood Phoneme Sequencing	Reading	Fair/No Recommendation for or against	Less intensive interventions found to be as useful
Fast ForWord	Reading	Good/No Recommendation for or against	Less intensive interventions found to be as useful. Likely not beneficial.
Peer Assisted Learning Strategies	Reading	Good/Strongly recommended	Good to use; requires minimal training; small adaptations to classroom must be made to implement but this
RAVE-O	Reading	Good/Strongly recommended	Good to use, particularly for children with significant reading difficulties.
PHAST	Reading	Good/Strongly Recommended	Good to use and can be integrated into classroom.
Fact Retrieval Intervention	Math	Fair/Recommended	Easy to implement but used as a second-line intervention
Concrete-to-Representational-to- Abstract	Math	Good/Strong recommendation for older youth	Strong support for use but may be more challenging for younger youth
Cognitive strategy instruction	Math	Fair/ Recommended	More investment from teacher to implement effectively; may be more challenging for younger youth
Mnemonic strategy	Math	Fair/ Recommended	Easy to implement and can be used for all ages
Schema-based instruction	Math	Fair/ Recommended	More investment from teacher to implement effectively; may be more challenging for younger youth
Strategies for planning/drafting	Written Expression	Good/Strongly Recommended	More investment from teacher to implement effectively; strongly recommended
Strategies for editing	Written Expression	Fair/Recommended	More investment from teacher to implement effectively;
Goal setting	Written Expression	Fair/Recommended	Simple strategy and should have benefits if applied broadly (for entire classroom)
Word processing	Written Expression	Fair/Recommended	Increased use of computers in classrooms will allow for more use of this method. Can and should be utilized.
Cogmed Working memory Training	Poor Working memory	Good/No recommendation for or against	Considerable effort and compliance needed to attain benefits. Some questions as to whether intervention has impact on broader assessment of working memory.
Auditory Integration Training	Auditory Processing	Poor/Recommend against	Costs and supportive data likely prohibit the use of intervention
Tomatis Method	Auditory Processing	Poor/ Insufficient evidence to recommend for or against	Costs and supportive data likely prohibit the use of intervention
Earobics	Auditory Processing	Good/No recommendation for or against	Unclear clinical implications
Fact ForWord	Auditory Processing	Good/No recommendation for or against	Unclear clinical implications