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insights on Learning Disabilities:

from prevailing theories to validated practices

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INSIGHTS

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FROM PREVAILING THEORIES TO VALIDATED PRACTICES

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Insights on Learning Disabilities: From Prevailing Theories to Validated Practices (ILD) *offers practical, evidence-based solutions to problems facing children with learning disabilities, their teachers, and their parents. As a forum for examining, discussing, and solving problems relevant to learning disabilities, Insights publishes articles and essays that evaluate instructional strategies, evaluate curriculum, analyze educational policies, analyze legal rights and responsibilities, evaluate instructional principles, suggest how to improve evaluations, show how to match teaching strategies to children's needs. As a journal that stresses the application of research and scholarship, Insights publishes articles to immediately solve problems.*

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Learning Disabilities Worldwide publishes the refereed professional journal, *Insights on Learning Disabilities: Prevailing Theories to Validated Practices (ILD)*, twice yearly. The purpose of this publication is to provide the most up-to-date information on the practices of teaching, therapeutically treating, assessing, or otherwise supporting individuals with learning disabilities. *ILD* recognizes as a main part of its mission the requirement to report on the educational services and the social opportunities that may be of benefit to individuals with learning disabilities. In accordance with the aim and scope of *ILD*, all manuscripts should have clear and explicit implications for daily practice of professionally working with children, youth, or adults with learning disabilities. Thus, research papers that do not refer to the application of the particular intervention, strategy, or method will not be considered for publication in the journal. Authors should adhere to the writing guidelines described in the latest edition of the *Publication Manual of the American Psychological Association (APA)*. The types of articles considered appropriate for publication in *ILD* are:

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In addition to original articles, *ILD* also welcomes critical reviews of recently published books, teaching materials, and software programs. They should include a brief summary of the work and offer an opinion about their potential utility. Such reports must contain the complete bibliographic references and should not be longer than 5 typewritten, double-spaced pages. Critical reviews of books, teaching materials, or software programs will not undergo a review process by members of the editorial board of *ILD*. However, the editors reserve the right to reject a submission if publication does not seem appropriate.

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Electronic submissions are to be mailed to nathalis.wamba@qc.cuny.edu and tacitro@aol.com. Authors must send a cover letter with a statement that their manuscript has not been previously published (or submitted for publication elsewhere, while acceptance by *ILD* is under consideration). The first page of the manuscript should include the title of the article and the complete names and institutional affiliations of the authors, as well as a short title to be used as a running head, whereas a second page should indicate only the title. Each article should be prefaced by a brief abstract (120–160 words). Authors should also include a short (40–60 words) biographical statement with the heading.

Manuscripts will be sent for a blind review to at least two members of the editorial board. Authors will be informed on the editorial decision with a formal letter from one of the editors by email. If the manuscript is accepted, the authors will be asked to send it electronically as a Microsoft Word file and to complete a copyright waiver form. The editors reserve the right to make final editorial changes to the manuscript without however altering the content of the original submission. Articles are judged on the following criteria: relevance to practitioners, soundness of conceptualization, adequacy of the research, reliability of conclusions, and comprehensibleness. In reference to the last criterion, authors are encouraged to use an appealing style, avoiding jargon and "academic prose", so that the manuscript provides all readers with as many *Insights on Learning Disabilities* as possible.

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Using Count-Bys to Promote Multiplication Fact Acquisition for a Student with Mild Cognitive Delays: A Case Report

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The purpose of this study was to evaluate the efficacy of a simple technique (Count-Bys) to enhance multiplication facts fluency in struggling learners. A single-case multiple baseline design across three fact sets was applied. The subject was a 12-year old boy with mild cognitive delays, who demonstrated adequate addition skills, but was mostly unable to perform multiplications. At the end of about two weeks of practicing the Count-By strategy with three fact sets, the boy had reached mastery as measured by the number of accurately written digits within five minutes in response to a worksheet containing 30 multiplication problems. Follow-up data taken during a period of two weeks upon termination of the intervention indicated that the student nearly maintained mastery levels across all fact sets. The benefits of using Count-Bys in a peer tutorial setting in order to enlarge teacher's opportunities to attend to the needs of all students in the classroom were discussed.

Keywords: multiplication fact fluency, Count-Bys, single-subject design, mild cognitive delays

Introduction

Mastering basic math facts is essential for every child by the end of his or her elementary school education. Students need to be able to quickly retrieve them from memory and with little effort in order to later successfully tackle higher-level skills (Kilpatrick, Swafford, & Finell, 2001; Poncy, Skinner, & Jaspers, 2007; Woodward, 2006). Children who are not sufficiently fluent in basic addition, subtraction, multiplication, and division facts are likely to struggle not only in math, but in other subjects as well during their continuing school career (Stading, Williams, & McLaughlin, 1996). This is especially true for times tables. Koscinski and Gast (1993) point out that "… although students can develop accuracy and speed for addition and subtraction facts to 18 by continued use of counting strategies, counting methods become less effective for the multiplication facts to 81" (p. 533).

Unfortunately, a considerable number of elementary school children exhibit severe fact retrieval deficits (Geary, Hoard, & Bailey, 2012). The latest

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results from the National Assessment of Education Progress (National Center for Education Statistics, 2014) indicate that only 42% of students achieve an adequate level of automaticity in math fluency by grade 4. Studies with European samples do not give reasons for assuming that the respective students demonstrate more proficient skills in this area than those in the US (e. g. Gaupp, Zoelch, & Schumann-Hengsteler, 2004). There may be multiple reasons for this, ranging from family environments that offer little support for learning, poor teaching in schools, to inherent domain-general deficits in a child's working memory (Swanson & Sachse-Lee, 2001).

There are, however, a number of research-based approaches to build math fact fluency in struggling learners. They include Copy, Cover, and Compare (CCC) (Skinner, McLaughlin, & Logan, 1997), Taped Problems (McCallum, Skinner, & Hutchins, 2004), Racetracks (Beveridge, Weber, Derby, & McLaughlin, 2005), Flash Cards (Skarr, Zielinski, Ruwe, Sharp, Williams, & McLaughlin, 2014), and many other interventions. One technique that has received only little attention in the literature so far, but appears to be very promising in supporting children to increase crucial multiplication fluency, is the Count-By strategy (Beattie, 1987), also known as Skip Counting (Wallace & Gurganus, 2005). It is an extension of counting by 5s or 10s but applied to other times tables (e. g. 3s, 4s, 6s, …) (McIntyre, Test, Cooke, & Beattie, 1991). When using Count-Bys, the teacher presents the concept of multiplication to the students as repeated addition. He or she illustrates a given task by using visual aids like posters or large index cards that depict the particular multiplication set with which the children need to become acquainted. For example, if students need to increase their fluency in solving 3s times tables, he or she presents them with a visual stimulus of the sequence of this series (see Figure 1).

Figure 1. ***A poster to visualize the counting sequence for 3s***

3, 6, 9, 12, 15, 18, 21, 24, 27, 30

Through repeated repetition (and oftentimes with the help of interactive "counting songs"[1]) the children learn to retrieve the sequence from their memory. Subsequently, the teacher models how to solve respective multiplication problems by counting in steps of 3. For example, in order to come up with the correct response for 4 • 3, one needs to take four of those steps (3, 6, 9, 12). The teacher scaffolds the students' attempts as they try to solve problems on

1 The internet platform www.havefunteaching.com provides many different examples of how practicing multiplication facts can be varied and creative.

their own while thinking aloud, providing calibrated feedback, and ensuring task comprehension (Beattie, 1987).

One great advantage that the Count-By strategy has over some other ways of building multiplication fluency in boys and girls is that its aim goes beyond mere rote memorization of basic facts. By illustrating that multiplication is repeated addition, teachers can promote conceptual understanding. Children are thus better able to use their skills across a variety of applications (see Wallace & Gurganus, 2005).

The efficacy of CCC in helping students with math problems has recently been documented in a meta-analysis by Joseph, Konrad, Cates, Vajcner, Eveleigh, and Fishley (2012). Other interventions for increasing math fluency in children have also been extensively evaluated (see Codding, Burns, & Lukito, 2011 for a review). However, as of June 2014, the database PsycINFO lists only one scholarly paper that contains the term „Count-Bys" in its title (McIntyre, Test, Cooke, & Beattie, 1991) and one that mentions "Skip Counting" (Duvall, McLaughlin, & Cooke-Sederstrom, 2003). In both identified studies, a functional relationship between the instruction and increased fluency on the targeted multiplication facts was established.

The purpose of the present experiment was to contribute to the scarce body of existing literature by examining the effects of a Count-Bys intervention through a single-case analysis with a sixth grader, who struggled extensively with times tables. It was hypothesized that this technique would allow the student to reach mastery in those three single-digit multiplication sets that initially caused the greatest problems.

Method

Participant and Setting

The participant was a 12-year old boy in sixth grade by the name of Justin (name altered for anonymity). He attended a special school for slow learners in a rural part of Western Germany. A multi-professional team had diagnosed him with mild cognitive delays when he was 6 years old. These kinds of learning problems are basically defined as "… functioning like younger children in earlier developmental stages" (Klein, Cook, & Richardson-Gibbs, 2001, p. 55). In Germany, in the UK, and in a number of other European countries, mild cognitive delays are seen as one specific form of learning disability (LD). The term LD is used in a broader sense than in the US and comprises moderate deficits in cognitive functions (like mild cognitive delays), different perception-processing disorders, and even problems of school achievement that are mainly caused by sociocultural or socioeconomic deprivation (Al-Yagon, Cavendish, Cornoldi et al., 2013; Opp, 1992).

Justin's teacher suggested him for the study because of his remarkably low multiplication skills and the limited progress that he had made using other instructional approaches (especially different variations of the whole math method, see e. g. Stead & Semple, 1992). According to the Heidelberger Math Test (Haffner, Baro, Parzer, & Resch, 2005), Justin scored below the 5th percentile for the multiplication subtest. He was unable to successfully solve any of the 6s, 8s, and 9s problem sets. However, he was relatively fluent with basic addition facts. Justin was able to score slightly above the 30th percentile for this subtest.

The intervention took place in an unused classroom within his school. A female college student in special education from a large public university served as the research assistant who conducted the intervention. In addition to her teaching experience within the initial teacher education program, she possessed ample experience in working with children with mild cognitive delays in her part time job as a homework assistant. She was trained in the Count-By strategy by the first author. Lessons lasted between 15 and 35 minutes over a two week and one day period, and followed a standard instructional protocol (described below).

Dependent Variables

Remediation focused exclusively on the three basic fact sets with which Justin had little to no competency (6's, 8's, and 9's). Dependent variables were the number of correctly written digits in response to a worksheet containing ten multiplication problems for each fact set. Consequently, each test record consisted of 30 tasks altogether. Each day, Justin received a different worksheet, on which the problems were listed in a random order. A stopwatch was used to time how many items he was able to complete within 5 minutes.

Experimental Design and Data Analysis

A multiple baseline design (AB-extension) (Kazdin, 2011) across fact sets was applied to evaluate the intervention outcomes. In most single-case studies, baseline observations continue until the baseline stabilizes. However, this practice creates a bias in favor of identifying an intervention effect where none exists. Upward random variations followed by downward random variations could easily be misinterpreted as stabilization of the baseline (Todman, 2002). Dugard, File, and Todman (2012) suggest a different approach that Grünke, Wilbert, and Calder Stegemann (2013) describe as follows:

> An alternative … would be to come up with a preset number of total probes and a minimum number of baseline sessions as well as a minimum number of intervention sessions, and then to determine the beginning of the treatment by chance. This procedure cannot avoid random variations, but it turns potentially systematic nuisance variables into random nuisance variables, and thus increases the internal validity of the findings. (p. 55)

In this experiment, a total number of 19 probes were defined. The baseline and the intervention phase had to overall consist of 15 daily measurement points. Four additional probes were designated for collecting follow-up data, which were evenly spread over a period of two weeks. We decided that both the baseline and the intervention phase for each multiplication set should at least consist of three probes. Thus, practicing any of the three sets could have started after the 3rd, the 4th, the 5th, the 6th, the 7th, the 8th, the 9th, the 10th, the 11th, or the 12th measurement point. A random drawing of one option for each set out of these ten alternatives (using paper slips and a small basket) yielded a starting point for teaching the 6s after the 5th probe, for teaching the 8s after the 5th probe, and for teaching the 9s after the 4th probe.

Intervention

Daily practice of each individual fact set took 10 minutes. Thus, the intervention could have lasted between 10 and 30 minutes, depending on the number of sets that were included during the session. Since the aforementioned research assistant started teaching Justin the 9s after the 4th probe, and the 6s as well as the 8s after the 5th probe, the instruction took 10 minutes on day five of the study, and 30 minutes from days six to 15. Justin was able to recite the relevant multiplication sequences almost error-free after the first two sessions that focused on the particular set (6s, 8s, or 9s). Therefore, after the second session focusing on a given basic fact set, the college student helped Justin to determine or recall different multiplication facts.

In order to encourage Justin to try hard to increase his math fact fluency and to fill out his daily probes over the whole length of the intervention, a motivational system was applied. He earned points for filling out the worksheets and for actively participating. At the end of each session, he could trade them for an edible reward (sweets or football stickers). This external reinforcement strategy was consistent with the school‘s motivational system.

Results

As can be seen in Table 1, Justin's baseline data ranged from 3 to 6 correctly answered multiplication problems (*M* = 4.00, 4.00, and 3.00). Before beginning the intervention phase, he was doubtlessly overburdened with the task. He left out the majority of the math problems and mainly focused on those for which he had quickly figured out the answer at the start of the instruction (those basic facts with 1, 2, or 10 multiplicands: 1 • 6, 2 • 6, 10 • 6, 1 • 8, 2 • 8, 10 • 8, 1 • 9, 2 • 9, and 10 • 9). The college student reported that during the baseline phase, Justin became frustrated at times, but never refused to work on his assignments.

***Table 1.* Correctly answered multiplication problems in five minutes**

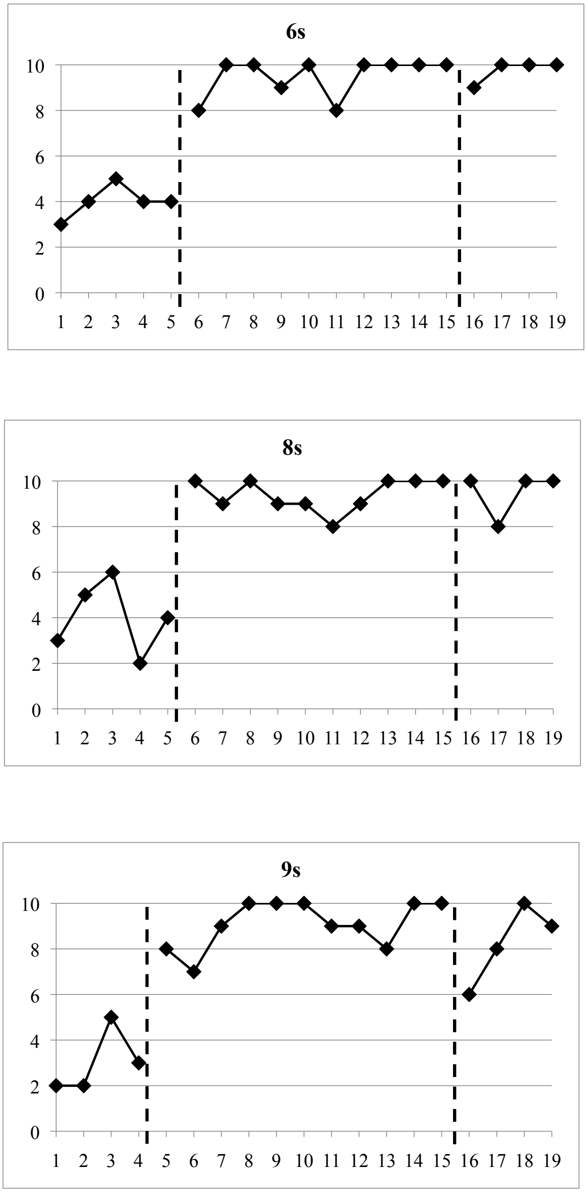
		Baseline	Intervention	Maintenance
6s	N (Probes) Raw Scores *M* Range	5 3; 4; 5; 4; 4; 4.00 3-5	10 8; 10; 10; 9; 10; 8; 10; 10; 10; 10; 9.50 8-10	4 9; 10; 10; 10; 9.75 9-10
8s	N (Probes) Raw Scores *M* Range	5 3; 5; 6; 2; 4; 4.00 2-6	10 10; 9; 10; 9; 9; 8; 9; 10; 10; 10; 9.40 8-10	4 10; 8; 10; 10; 9.50 8-10
9s	N (Probes) Raw Scores *M* Range	4 2; 2; 5; 3; 3.00 2-5	11 8; 7; 9; 10; 10; 10; 9; 9; 8; 10; 10; 9.09 7-10	4 6; 8; 10; 9; 8.25 6-10

The onset of the instruction corresponded with a clear-cut increase in correct answers to the basic facts presented. Figure 2 distinctly illustrates the improvement in Justin's performance. During the intervention phase, the mean number of his correct responses exceeded 9.00. Furthermore, he was able to accurately answer all of the multiplication problems by the end of the intervention. During the maintenance phase, Justin continued to demonstrate a high level of performance, retrieving the answers to most or all of the problems of three fact sets quickly and effortlessly from memory.

Pairwise Data Overlap (PDO, see Wolery, Busick, Reichow, & Barton, 2010) was used to determine the magnitude of the effects. PDO is calculated by identifying the overlap of all possible paired data comparisons between baseline and intervention phases. It usually produces more reliable results than other ways of generating an effect size from data reported in a single-case study (Alresheed, Hott, & Bano, 2013). For all multiplication fact sets, the PDO was 100%.

For the data from the baseline and the treatment phases, we also conducted a randomization (or shuffle) test. This is a useful method that considers all possible arrangements of the data, given the randomization procedure that was used in the experiment. Even though this technique is not yet well known among applied researchers, it has been employed in some single-case studies (e. g. Grünke, Wilbert, & Calder Stegemann, 2013; Mastropieri et al., 2009; Regan, Mastropieri, & Scruggs, 2005) and has been outlined in a large amount of theoretical papers and textbooks (e. g. Dugard, 2013, 2014; Dugard, File, & Todman, 2012; Edgington & Onghena, 2007; Heyvaerta & Onghena, 2014). We therefore did not see the need to elaborate on the randomization test in detail at this point and instead refer the reader to the aforementioned literature.

Figure 2. ***Number of accurately answered multiplication problems for each fact set in the baseline, the intervention, and the maintenance phase.***



In the case of this study, the intervention point was selected by chance for each fact set out of ten possible options. The total of the differences in absolute value across the two phases and across the three outcome measures (6s, 8s, and 9s) equaled (9.50-4.00) + (9.40-4.00) + (9.09-3.00) = 16.99. This sum was compared with total sums calculated from $10^3 = 1,000$ selected arrangements of intervention starting points. The chance that 16.99 is the highest total out of all theoretically possible assignments is 1/1,000, making a p-value of 0.001 possible. If 16.99 was not the highest difference out of all potential options, but "only" one of the highest ten, it would still be part of the top 1% of the 1,000 alternatives. A specific Microsoft® Excel macro for AB multiple baseline designs, downloadable from the webpage that accompanies the textbook by Dugard et al. (2012) (www.routledge.com/books/details/9780415886932/), enables users to calculate an exact p-value for an observed value like 16.99. In this case, the differences between the mean baseline and mean intervention phase data across fact sets was statistically significant with an exact p-value of 0.002. The maintenance phase data was not considered in the calculation, because the aforementioned website provides no macros for an AB-extension design.

Discussion

The results of this study indicate that the Count-By strategy can be very effective in increasing multiplication facts fluency in struggling learners. Using this approach with a male sixth grader, who had previously not been able to develop a sufficient skill level in this respect, proved to be remarkably successful. During baseline, our subject was only able to produce on average 11 correctly written digits out of 30 responses on a given worksheet within a period of five minutes. By the end of this short intervention of ten to eleven 10 minute-sessions per targeted fact set, he had reached mastery. The magnitude of the effects, as quantified by the PDO of the data, has to be considered very large. A randomization test, conducted on baseline-treatment phases across the three targeted fact sets (6s, 8s, and 9s), yielded a statistically significant result of $p < 0.01$. The student was able to keep up a high level of fluency after the instruction ended. During a short maintenance phase consisting of four probes evenly dispersed over a two-week period, our subject managed to succeed with over 90% of the presented multiplication problems. The outcomes thus replicate previous findings (Duvall, McLaughlin, & Cooke-Sederstrom, 2003; McIntyre et al., 1991), and are a good reason to consider the Count-By approach for children who experience significant difficulty learning basic multiplication facts.

However, the phenomenon that the performance of an individual changes in response to knowingly being part of an experiment (see e. g. Cook & King, 1968) could have limited the internal validity of this study. Typically, the boy received the usual classroom instruction from his teachers. In our experiment, however, he was taken out of his familiar environment and was individually trained by a female college student in a separate room of his school. The 1:1 attention could be partially responsible for the remarkable outcomes, as well as the fact that our subject knew that the purpose was to test the efficacy of a certain intervention. His level of cooperation might not have been as high as it was, had he just been one of many in a whole group of students.

Despite the limitations, the Count-By method may prove to be a very useful tool, and should be considered when planning instructions aimed at improving multiplication fact fluency in children. Future studies need to test the impact of this approach with a small group of learners, and then with an entire class as part of the standard instruction.

Teachers have to make sure that all of their students acquire a sufficient level of computation fluency by the end of their elementary school education. This competency seems to be a hallmark for being able to process more complex tasks at higher grade levels (Goldman & Pellegrino, 1987). Count-Bys are practical and easy to implement. No specific materials are needed. If a teacher were to use this strategy in his or her classroom, it would only take a couple of minutes each day. In fact, the application of this intervention seems so simple that even a fellow student should be able to take over the training of a struggling classmate like it is done in the Class-wide Peer Tutoring approach (Greenwood, Terry, Utley, Montagna, & Walker, 1993; Maheady & Gard, 2010; Rohrbeck, Ginsberg-Block, Fantuzzo, & Miller, 2003). Templeton, Neel, and Blood (2008) demonstrated in their review that peer tutoring can be a very effective way to deliver basic-facts mathematics interventions. This insight might open up a window of opportunities for teachers for economically using Count-Bys as a means of making sure that even in groups of very diverse students, no one falls behind in his or her endeavors to develop automaticity in multiplication facts. The strategy seems certainly eligible for applying it in a peer tutorial setting. Such a possibility could effectively relieve teachers of the burden of having to attend to every child in their classroom simultaneously. Additional research is warranted to establish the generalizability of the present findings and to investigate under which conditions Count-Bys can be economically taught in everyday classroom situations.

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Meares-Irlen/Visual Stress Syndrome, Classroom Fluorescent Lighting and Reading Difficulties: A Review of the Literature

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A key stimulus behind the present review has been the growing debate among educational researchers, politicians, and the general public concerning apparent declines in the literacy and numeracy levels of school students. Recent years have also witnessed a plethora of research by educational psychologists investigating the underlying causes of key learning disorders. Most such studies have primarily focused upon reading and writing deficits in children with developmental dyslexia and/or Attention-Deficit/Hyperactivity Disorder (ADHD), with others examining the respective incidences of these well-publicised disorders. At the same time, the very common visual processing disorder Meares-Irlen/Visual Stress Syndrome, *which can also cause reading, writing, and attention problems, has been grossly under-researched. Although there remains some controversy surrounding this condition, there is sufficient evidence indicating that its prevalence exceeds those of dyslexia and ADHD combined. Thus, this review evaluates the latent role that Meares-Irlen/Visual Stress Syndrome may play in overall literacy and numeracy statistics, and whether increasingly brighter fluorescent lighting and visual media in school classrooms may be enhancing that contribution. To explore these issues further, the review also examines the literature relating to both recent and long term trends in the literacy and numeracy levels of school students.*

Keywords: Meares-Irlen Syndrome, Visual Stress Syndrome, literacy, numeracy, fluorescent lightning

Introduction

During the past three decades, there has been increasing awareness of a common visual processing deficit first referred to as *Scotopic Sensitivity Syndrome* (SSS). In recent years, however, the condition has become more widely known as *Meares-Irlen Syndrome* (MIS) or *Visual Stress Syndrome* (VS), with the latter term increasingly utilized due to its simplicity. Individuals with this relatively unknown form of learning disability (hereafter referred to as VS) report various print distortions when reading, such as words appearing to move or vibrate, de-

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spite the individuals having no optometric or ophthalmological abnormalities. Their span of word recognition (the number of words seen in one eye-fixation) is also greatly reduced, as is the ability to maintain extended reading (Loew & Watson, 2012a, 2013; Robinson, 1994). These symptoms inherently hinder reading, writing, spelling, as well as visual attention, and thus can compromise literacy and learning potential. This can be the case regardless of the academic levels a student is achieving, as the condition is equally prevalent in gifted and talented children and knows no socio-economic boundaries. As a result, symptoms of VS in children can often be misinterpreted as signs of laziness or inattention. However, many affected individuals learn to compensate for the above difficulties, as VS is a visual-perception dysfunction which can significantly hinder reading-based learning.

Depending on the definition of dyslexia adhered to by researchers, VS is often referred to as a subtype of dyslexia, while others describe VS as a separate condition that can, however, co-exist with dyslexia. The problem here is the absence of well-defined diagnostic criteria for dyslexia itself, thus it is difficult for researchers to be in accord as to whether the many dyslexic individuals diagnosed with VS are comorbid or simply have a common subtype of dyslexia. Studies investigating the incidence of VS in Britain and Australia have reported prevalence rates ranging between 5% and 20% (Evans, 2004; Jeanes et al., 1997; Robinson, Hopkins & Davies, 1995; Wilkins, Jeanes, Pumfrey, & Laskier, 1996). These findings have been primarily based upon observable improvements in reading speed, and diminished distortions of text, when a trial participant reads through colored lenses and/or translucent colored overlays. With respect to the prevalence of dyslexia in general, estimates of 4-8% in the UK have recently been reported (Rose, 2009), with prevalence estimates in the USA ranging from 5% to as high as 17% (Dehaene, 2009). However, the methodologies and often the definitions of VS and dyslexia utilized in many of the above studies are debatable and are, therefore, examined in greater detail in following sections of this review.

A key problem in defining dyslexia, and thus its prevalence, appears to lie in the determination of precisely what degree of *unexplained reading impairment* constitutes a valid diagnosis of dyslexia. In the case of VS, however, there seems to be a reverse situation, where the degree of *reading improvement* brought about by colored filters is the prime area of contention in defining VS morbidity. Similarly, the question of whether VS is a subtype of dyslexia, or a separate entity which often co-exists with dyslexia, remains controversial. Thus, to avoid ambiguity in these areas, the present review adopts the following definitions of dyslexia and VS with respect to their currently accepted causal mechanisms:

Meares-Irlen/Visual Stress Syndrome (or, Scotopic Sensitivity Syndrome) is a visual perception disorder causing photophobia and distortions of text when reading. Affected individuals have a low threshold to perceptual distortions when viewing striped patterns of lines with high contrast and spatial frequencies not unlike black text on white paper. Studies utilizing fMRI BOLD imaging have identified hyperexcitability of the visual cortex as a major factor (Wilkins, Huang, & Cao, 2004). Others suggest a magnocellular pathway deficiency, leading to disrupted synchronisation of signals conveyed to the visual cortex (Stein, 2003).

Dyslexia (or developmental dyslexia) is a reading deficit believed to primarily have a phonological basis involving inadequate single-word decoding and a deficiency in grapheme-phoneme conversion. These processes, in turn, are carried out in the left temporal lobe of the brain. However, a subset of dyslexic children and youth present with solely a visual deficit (Ramus et al., 2003).

Thus, based upon definitions of VS and dyslexia derived from causal factors, VS would not be considered a subtype of dyslexia. Nonetheless, if one focuses on consequences rather than causes, VS could be considered an independent condition which, in many individuals, can similarly affect reading skills and therefore be prone to misdiagnosis as dyslexia. One distinguishing feature of VS however, is that it can also be present in capable readers.

Individuals with VS frequently report that their symptoms are exacerbated by fluorescent lighting (Whiting, Robinson, & Parrott, 1994; Winterbottom & Wilkins, 2009). However, colored lenses or overlays have been reported to be effective in alleviating VS symptoms (Allen, Evans, & Wilkins, 2012; Robinson & Foreman 1999; Wilkins & Evans, 2009) though this still remains controversial (Ritchie, Della Sala, & McIntosh, 2011). In addition, trials of colored filters fitted directly to overhead lighting have also produced significantly positive results (Loew & Watson, 2012a; Loew, Rodriguez, Marsh, Jones, Núñez, & Watson, 2014).

Similar or identical symptoms of VS that are equally evoked by light sensitivity have been identified in a significant proportion of individuals with independent conditions that also affect learning, and these include: Developmental dyslexia (Rodriguez-Pérez, González-Castro, Álvarez, Álvarez, & Fernández-Cueli, 2012; Wright & Conlon, 2009), attention- deficit/hyperactivity disorder (ADHD) (Loew & Watson, 2013; Taurines, Schmitt, & Renner, 2010), autism spectrum disorders (ASD) (Ludlow, Taylor-Whiffen, & Wilkins, 2012), migraine and photosensitive epilepsy (PE) (Wilkins, Huang, & Cao, 2007), binocular instability (BI) (Evans, Drasdo, & Richards, 1996a; Evans et al. 1996b), and chronic fatigue syndrome (CFS) (Loew, Marsh, & Watson, 2014; Robinson, McGregor, Roberts, Dunstan, & Butt, 2001).

Seemingly unaware of the above-cited research, education authorities in many nations continue to discuss and search for potential causes of the apparent declines in literacy and numeracy skills of school students entering the workforce and university in recent decades. Indeed, recent studies in Australia indicate that concerns of falling literacy achievement are well justified (Leigh & Ryan, 2012; Thomson & De Bortoli, 2008). Similar trends have also been reported in other OECD nations, in spite of exceptionally large increases in education spending over the past three decades (Flynn, 2009; Gundlach, Woessmann, & Gmelin, 2001; Hanushek, 1997). However, the methodologies and resulting data pertaining to these and similar studies are discussed in greater depth in subsequent sections of this review.

Conspicuously absent from most debates concerning literacy data however, has been the significant incidence of visual stress in the population, including school children. Previous studies have reported that VS significantly affects reading in at least 5% of school students, with 12-14% of individuals having at least moderate symptoms of VS (Kriss & Evans, 2005). It is noteworthy that even a 5% incidence of VS symptoms in school students could plausibly influence the mean literacy and numeracy test-results of each and every school.

Research Questions

The purpose of this paper was to provide an overview of the current state of knowledge regarding VS in form of a literature review. We wanted to provide the reader with some up-to-date information on this widespread but still very under-researched phenomenon. In particular, the present review examines:

1. The general etiology of VS considering the prevalent etiological models of dyslexia and other reading difficulties.
2. The special role that underlying biological factors play in the development of VS.
3. The prevalence and symptoms of VS and developmental dyslexia.
4. The effects of fluorescent lighting upon visual comfort and visual-task performance.
5. Current levels of literacy and numeracy in school students, compared to long-term trends (with a specific focus on Australia, the authors' country of residence).

Notably, it appears that research in the aforementioned fields has not previously been assessed in unison in a single review of the literature.

Method

We conducted an extensive search of the electronic databases PsycINFO, Medline, and ERIC for papers that either contained the term "Meares-Irlen Syndrome", "Visual Stress Syndrome", or "Scotopic Sensitivity Syndrome" in their titles, abstracts, or keywords. As of August 2014, this quest yielded 43 journal articles and book chapters. The lead author has reviewed the abstracts and asserts that all publications were relevant for the aim of this review. Our following explanations and illustrations make reference to these publications, complemented by sources cited in them. Of course, we also considered a great number of supplementary references to support our statements whenever appropriate.

Results

The General Etiology of VS Considering the Prevalent Etiological Models of Dyslexia and other Reading Difficulties

Children with reading abilities falling well below other indicators of their intellectual potential, and which cannot otherwise be attributed to social or physiological causes, are typically categorized as having dyslexia. Underlying causes of this broadly described condition can include cognitive delays, though the core deficit is believed to lie in phonological processing. However, even pre-eminent proponents of a phonological basis for dyslexia concede that around one in four students with dyslexia present with pronounced visual perception deficits and no phonological impairments (Ramus et al., 2003; White et al., 2006).With respect to those individuals with the visual form of dyslexia, the majority of cases are not caused by optometric deficiencies but rather by VS. A possible biological mechanism underlying the perceptual distortions of text reported in this condition is believed to be deficient synchronisation of visual signals from the retina to the visual cortex while being conducted through two key neurological corridors: the *magnocellular* and *parvocellular* pathways (Livingstone, Rosen, Drislane, & Galaburda, 1991; Robinson, 1994; Stein, 2003; Solan, Shelley-Tremblay, Hanson, & Larson, 2007).The pioneering research by Livingstone et al. (1991) utilized electrophysiological measurements to reveal that their dyslexic subjects (n = 5) had significantly slower response times in visually evoked potentials for rapid visual stimuli compared to the controls (n = 7), but had normal response times for slow stimuli. These results were consistent with defective functioning of the magnocellular pathway and were subsequently supported by the second phase of that study, which compared the brains (in autopsy) of five dyslexic subjects with five normal readers. The magnocells of the students with dyslexia were found to be significantly smaller ($p < 0.05$) than those of the controls, whilst there were no significant differences in the parvocellular layers of each group.

The above study was obviously limited by the small number of subjects involved, however many subsequent studies of dyslexia have also pointed towards a magnocellular deficit (Borsting et al., 1996; Chase et al., 2003, 2007; Omtzigt, Hendriks, & Kolks, 2002; Sperling, Lu, Manis, & Seidenberg, 2003). Moreover, in the study carried out by Omtzigt et al. (2002), it was found that the magnocellular system is far more crucial in the dissemination of flanked letters (e.g. "xax") than single letters (e.g. "a"). The study's methodology involved the requesting of 24 normally reading subjects to identify flanked and single letters in lighting designed to have a color contrast disadvantageous to efficient magnocellular processing.According to Robinson (1994), the magnocellular pathway is believed to filter the inherent overlap of images caused by rapidly changing points of visual fixation when high speed visual-scanning is essential, such as in reading. Without such filtering, following each micro-fixation of the eyes one would experience an after-imaging effect, similar to that occurring after looking at a bright or high contrast object and then closing one's eyes. Stein (2003) reported that during reading, eye fixations continually move around by up to one degree of visual angle (equal to 4-5 letters), and thus proposes that in normal readers the visual magnocellular system detects such unintended motion and plays a crucial role in stabilizing visual fixation points. Anomalies in the magnocellular pathway have also been suggested as an explanation for the many students with dyslexia exhibiting poor visual motion sensitivity, as such deficits have been found to correlate well with reading and spelling abilities (Eden, Vanmeter, Ramsey et al., 1996; Stein, 2003; Talcott et al., 2000).

Interestingly, it is orthographical as opposed to phonological abilities that the above studies mostly associate with motion perception skills. There is also evidence, produced through functional magnetic resonance imaging (fMRI), of altered neurobiological brain processes (Chouinard, Zhou, & Hrybousky, 2012) in VS subjects, and Sperling et al. (2003) found visual pathways to be comparatively less active in students with dyslexia during motion perception tasks. This agrees with Stoeger, Zeigler, and Martoz (2008), who showed that deficits in fine motor skills (also motion-perception reliant) were able to distinguish a group of gifted underachievers (n = 31) from a group of gifted achievers (n = 97). Yet, it must be emphasized that magnocellular dysfunction is by no means the only hypothesized explanation for the symptoms manifested in visual stress. Earlier studies have suggested that retinal anomalies can equally account for the various VS symptoms reported (Barbolini, Caffo, Robinson, & Wright, 1998; Lewine, 1999), while later fMRI studies implicate hyperexcitability of the visual cortex as a likely neurological cause (Wilkins et al., 2004, 2007; Huang et al. 2011).

The study by Barbolini et al. (1998) compared morpho-chromatic analysis of the central foveal area of the retina in subjects with VS to a control group and found significant differences in the digitalised foveal images of the VS group. The studies by Wilkins et al. (2004, 2007) used fMRI technology to show that the visual cortex is indeed hyper-activated in subjects with VS. Moreover, in a review of research associating dyslexia and the integrity of the magnocellular system, Skoyles and Skottun (2004) reported: "…that on the basis of previously published data it can be estimated that a large number of non-dyslexic individuals also have magnocellular deficits" (p. 79). However, one should not dismiss the magnocellular hypothesis with haste, as novel evidence of a variant of motion and spatial perception abnormalities affecting reading ability was only recently reported by Aleci, Piana, Piccili, and Bertolini (2012). The results of that study, involving 39 young "disabled readers" and 23 "normal readers", showed a very strong correlation ($r = 0.87$, $p < 0.01$) between reading efficiency and abnormal spatial relationship anisotropy (SRA) in the dyslexic group, but no significant correlation in the control group.Still, in the absence of any definitive and broadly accepted diagnostic criteria for dyslexia, VS, or even magnocellular dysfunction itself, excessive doubt continues to be cast upon virtually all hypothesized underlying causes of VS or dyslexia. This shortcoming in the literature is not only inopportune, but clearly poses a quandary for those wishing to evaluate research estimates of VS and/or dyslexia prevalence. What can be acknowledged nonetheless, is that a significant number of students with dyslexia are found to have visual rather than phonological deficits, or often both, and that many such individuals are subsequently diagnosed with VS. However, symptoms of VS are also frequently identified in disorders such as migraine and epilepsy (Allen et al., 2012) and binocular instability (Evans, 2007). While VS has recurrently been associated with anomalies in the magnocellular pathway, more recent research indicates that causal factors stem from the visual cortex itself (Huang et al. 2011).

Underlying Biological Factors

Genetic predisposition. Genetic predisposition has often been implicated in both VS and dyslexia (Pary, Lewis, Matuschka, & Lippman, 2002; Richardson & Ross 2000; Robinson et al., 2003; Loew & Watson, 2012b). An early study by Robinson et al. (1995), involving 751 children with VS, found that there was an 84% chance of one or both parents of VS individuals showing similar symptoms. However, the study did not clearly define the exact degree of '*similarity in symptoms*' which was determined to be indicative of familial morbidity. Others might also argue that, as the parents may have been poor readers, a plausible explanation for the above finding could be that the parents did not encourage reading, or even discouraged it.The high heritability index of VS reported by Robinson et al. (1995) is similar to reports of the risk of inheriting dyslexia (Schumacher, Hoffmann, Schmäl, Schulte-Körne, & Nöthen, 2007; Schulte-Körne, Warnke, & Remschmidt, 2006). The latter study scrutinised multi-national statistics across three linguistic zones and concluded that a child with one dyslexic parent has a 50-60% risk of inheriting reading difficulties and a 50-70% risk of also having poor spelling ability, although the impact is much lower in phonetically-based languages. Such statistics infer that any alleles predisposing offspring to symptoms of dyslexia are likely to be genetically dominant, however, the large degree of variation in the severity of dyslexic and/or VS symptoms in affected individuals is more suggestive of co-dominant expression.Additional studies have reported that a significant genetic component is likely to account for both the similarities in symptom expression, and the high incidence of comorbidity among dyslexia and other disorders which similarly affect reading, learning, and concentration abilities (Chen, Hsu, Hsu, Hwang, & Yang, 2004; Haag, 2003; Richardson, 2004). However, perhaps the most conclusive evidence of the role of genetics in dyslexia, and related disorders affecting reading ability, has been produced by relatively recent research involving genetic linkage studies. Genes believed to predispose susceptibility to dyslexia have been identified at specific loci on chromosomes 1, 2, 3, 6, 15 and 18, with linkage studies showing that some loci can be strongly associated with a broad range of dyslexic traits which encompass all subtypes of the condition (Schumacher et al., 2007). Research involving twins has also produced valuable genetic information, with some studies estimating that reading proficiency itself has a heritability index of 50-70% (Byrne, Delaland, Fielding-Barnsley et al., 2002; DeFries and Gillis, 1993; Schulte-Körner et al., 2006).The study by Byrne et al. (2002) is particularly noteworthy, as it not only measured the heritability of early reading skills as a whole, but also of various sub-sets of skills which are needed to acquire effective and functional literacy. As evident in the data shown in Table 1, the study found strong genetic influences in phonological analysis/synthesis, phoneme identity, and also learning-memory. Conversely, grammar and morphology, vocabulary, and print knowledge were found to be predominantly influenced by environmental factors, although genetic influences still played a substantial if not significant role.

Table 1. Twin Correlations and Mx Model Fitting Estimates for Composite Measures

Measure	**MZ r**	**DZ r**	***h2***	***c2***	***e2***
Phonological Analysis & Synthesis	.69	.40	.52**	.16	.31
Phoneme Identity Training	.69	.48	.50***	.22	.28
Learning/Memory	.49	.18	.47*	.00	.53
Grammar/Morphology	.67	.51	.22	.43*	.35
Vocabulary	.69	.55	.18	.49**	.33
Print Knowledge	.83	.68	.28*	.55**	.17

Note. Sample sizes ranged between 80-109 MZ pairs and 83-103 DZ pairs. *= p < .05; ** = p < .01; *** = p < .001 for significance of the estimates for heritability (h2) and shared environment (c2) < 0. [MZ = monozygotic; DZ = dizygotic; c2 = shared environment; e2 = unique environment]. Excerpted from: Byrne et al., 2002, 'Longitudinal Twin Study of Early Reading Development in Three Countries: Preliminary Results', Annals of Dyslexia, Vol. 52, pp. 49-73

The data obtained by Byrne et al. (2002) appears to be quite robust for the following reasons: 1) The study involved several hundred monozygotic and dizygotic twins, recruited from a diversity of nations (Australia, USA, and Norway); 2) A total of 26 separate aspects of literacy and learning were measured, with each of these correlated against measurements of nonverbal IQ; 3) All twin pairs (aged 47–68 months) were in the final pre-school year of their respective countries, thus environmental influences due to large variations in education quality were largely avoided; 4) The testing was not only broad-ranging, but was also carried out over five days, spread over a two week period, thereby minimizing the effects of day to day fluctuations that might occur in a child's attentiveness and willingness to participate.

Biochemical anomalies. Biochemical anomalies such as irregularities in lipid status, have also been detected in experimental groups with reading or attention disorders. Robinson et al. (2001) identified significant indications of deficient fatty acid metabolism in subjects with chronic fatigue syndrome (CFS) who were comorbid for VS. The study noted that the degree of these disturbances correlated well to the severity of several key symptoms of VS. Sparks et al. (2003) found significantly decreased plasma levels of cholesterol in subjects with VS, as well as unusually high levels of the 17-carbon fatty acid heptaneoic acid. Interestingly, synthesis of this odd-chain fatty acid is more commonly associated with bacteria, rather than humans. More recently, Laasonen, Hokkanen, Leppamaki, Tani, and Erkkila (2009) detected highly similar irregularities in fatty acid and cholesterol metabolism in dyslexic, ADHD and CFS subjects, and Loew and Watson (2012b) found that certain alleles of a gene (APOB) known to play a role in cholesterol regulation were more common in individuals diagnosed with VS.

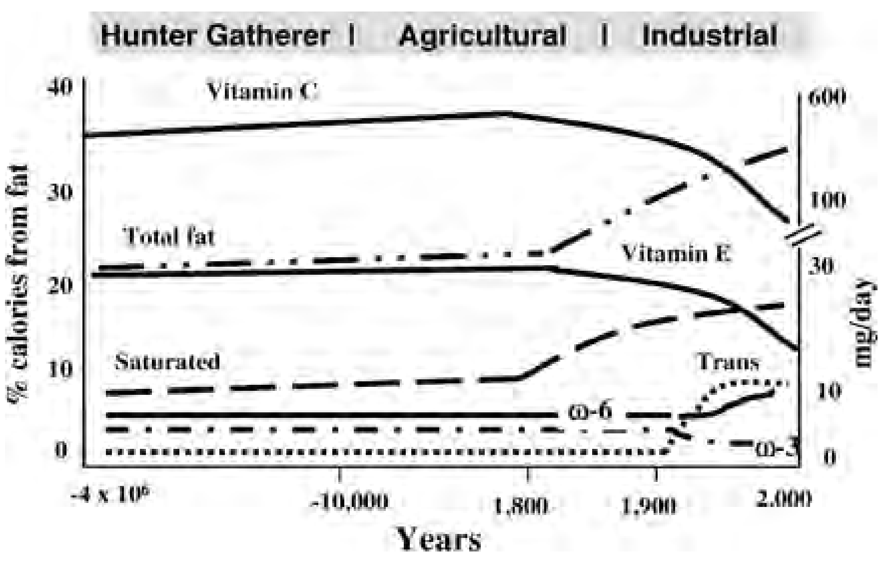
Additional studies have reported that fatty acid metabolism may be a component in the aetiology of not only VS and CFS, but also of dyslexia, ADHD, and mild ASD (Chen et al., 2004; Haag, 2003; Richardson & Ross, 2000; Robinson et al., 2003, Robinson, Sparkes, Roberts, & Dunstan, 2004). A noteworthy study involving dyslexic subjects, by MacDonnell, Skinner, Ward et al. (2000), found abnormally high levels of an enzyme known as cytosolic phospholipase-A2 (PLA2), which aids in the removal of fatty acids from cell membranes. Researchers have also found deficiencies in essential fatty acids (EFAs) in blood samples from children with ADHD (Anatilis et al., 2006; Burgess, Stevens, Zhang, & Peck, 2000; Colter, Cutler, & Meckling, 2008). However, it is perhaps worth bearing in mind that samples obtained from red blood cell membranes can only be indicative of recent EFA status, as these cells have a relatively short cellular lifespan of no more than three months.Other investigations have focused purely upon potential associations between reading difficulties and EFA status (Cyhlarova et al., 2007; Kidd, 2007). The study by Cyhlarova et al.

(2007) analyzed fatty acid levels in 32 adults with dyslexia and 20 control subjects, and found that word-reading skills (based upon standardized tests) in both groups were positively associated with higher omega-3 fatty acid concentrations in red blood cell membranes.In one of the few randomized, double blind, placebo controlled (RDBPC) treatment trials involving omega-3 supplementation in dyslexic children, Richardson and Puri (2002) divided a group of 29 dyslexic children (who also had attention deficits) into active and placebo groups. Although the data revealed no improvements in dyslexic symptoms after 12 weeks of omega-3 EFA supplementation (docosahexaenoic acid DHA: 480 mg/day; eicosapentaenoic acid EPA: 186 mg/day), the study found a significant reduction in ADHD symptoms. From a wider perspective, a number of non-RDBPC studies have reported significant improvements in dyslexic subjects following EFA supplementation trials. In one such study, Lindmark and Clough (2007) provided omega-3 rich daily doses of EFAs (DHA 480 mg; EPA 108 mg; gamma-linolenic acid GLA 96 mg; arachidonic acid AA 35 mg) to 19 dyslexic individuals and found highly positive results after five months. The study measured a 60% increase ($p < 0.01$) in the reading speed of 13 of the 17 participants (aged 9-17 years) who completed the study and a 23% improvement ($p < 0.05$) in motoric-perceptual velocity. Both measures were obtained using a standardized word-chain test. Treatment evaluation forms completed by the participants and their parents also produced positive data, albeit of a subjective nature.

A number of other treatment studies have also reported positive outcomes for dyslexic individuals undergoing EFA supplementation, nonetheless, a comparable number of similar studies have found little or no benefit for their dyslexic subjects. In a placebo controlled study involving 61 dyslexic children, Kairaluoma, Naerhi, Ahonen, Westerholm, and Aro (2009) found no significant differences in reading improvements between the experimental and control groups after 90 days receiving supplementation containing ethyl-EPA (500 mg/day) and carnosine (400 mg/day), but not containing DHA. There have also been studies of EFA supplementation in ADHD subjects which have reported no observable benefits. In an RDBPC trial involving 54 ADHD children, Voight, Llorente, and Jensen (2001) found that supplementation with DHA (345mg/day) did not produce measurable treatment effects, despite a 260% increase in plasma levels of DHA in the active group. Since that study, however, there has been increasing evidence suggesting that supplementation of DHA alone is ineffective in treating ADHD and different cognitive disorders (Marangell, Martinez, & Zboyan 2003; Peet & Horrobin, 2002; Vaisman et al., 2008). The latter study found significant improvements in visual attention in ADHD children (n = 60) following a 3 month RDBPC supplementation trial providing a combination of DHA and EPA (250mg/day), with 16-27mg of omega-6 EFAs added to the treatment. Indeed, the large disparity in the supplementations provided in such trials is probably the greatest single hindrance to any meta-analysis of EFA supplementation in VS, dyslexia, and ADHD.

In assessing the likelihood that lipid metabolism might be a potential factor in reading and attention disorders, it is perhaps worth bearing in mind that significant changes to fatty acid intake in the human diet have occurred since industrialization. The ratio of omega-6 to omega-3 fatty acids upon which our Palaeolithic ancestors evolved, estimated to have been between 1:1 and 2:1 (Simopoulos, 2008), has become substantially distorted during only the last 100 years (Figure 1). Though estimations concerning human dietary intake 10,000 years ago may be debatable, the substantial increase in omega-6 intake during the 20th century is well documented and today the n-6/n-3 ratio in most European-based diets ranges between 15:1 and 25:1. The dramatic increase in total fat intake since industrialization, particularly highly saturated fat, is also beyond contention (Figure 1). However, during the last century, the accompanying growth in access to healthcare (thus medical diagnosis) in most developed nations might equally account for an increased awareness of learning and reading disorders.

Figure 1. ***Intake of Fat, Fatty acids, Vitamins E and C. Excerpted from: Simopoulos (2008), Experimental Biology and Medicine** 233, **674-88.***



In a review of the biological significance of fatty acid levels, Horrobin (1999) emphasized that frequent reports of abnormal fatty acid metabolism in individuals with dyslexia may well make sense, as visual processing is particularly dependent upon cellular membrane fatty acid status. The review also noted the importance of certain long-chain EFAs to normal functioning of the eye and brain, and that these can only be obtained in adequate quantities through dietary consumption. Horrobin (1999) also asserted that if crucial EFAs, such as DHA, are not biologically available to cells (especially neuronal cells) in sufficient quantities to cells (especially neuronal cells) they are likely to be replaced by less desirable fatty acids. Thus, prior reports of reduced cholesterol levels in VS subjects are of particular relevance to the present review, as cholesterol is known to be essential to maintaining functional levels of DHA in retinal-neuron membranes and it is accepted that DHA almost exclusively crosses the blood-retinal barrier as a constituent of LDL cholesterol esters (Bretillon et al., 2008). Moreover, cholesterol is also known to modulate the activity of the photo-pigment, rhodopsin, thereby acting as a regulator of the visual signal transduction cascade in rod-photoreceptors (Albert & Boesze-Battaglia, 2005). Interestingly, retinal pigment has been shown to significantly reduce visual discomfort thresholds for short wavelengths of light within the scotopic band (Snodderly, & Stringham, 2010).

Prevalence and Symptoms of VS and Developmental Dyslexia

A comprehensive study commissioned by the UK parliament recently reported that dyslexia is prevalent in 4-8% of English-speaking populations (Rose, 2009). The British Dyslexia Association has produced similar figures. Similarly, the European Union's NEURODYS project (the largest genetic study of dyslexia ever undertaken) stated on its inaugural website (http://www2.cnrs.fr/en/668.htm) that dyslexia affects the outcomes of at least 5% of European school children. Commenced in 2009, the NEURODYS project has involved 1,644 dyslexic children and 1,281 healthy controls from 9 European nations in a coordinated effort to analyze how reading problems relate to genes. Recently completed, the endeavor has achieved the building of an unprecedented genetic database relating to dyslexia and reading disorders in general.

With regard to incidence rates of VS, Kriss and Evans (2005) reported that 31% of dyslexic children (n = 32) and 12.5% of non-dyslexic children (n = 32) were able to read > 10% faster using colored overlays. Other studies have indicated that the prevalence of VS in the general population may be as high as 20-24% (Jeanes et al., 1997; Robinson & Conway, 1994; Wilkins et al., 1996). Jeanes et al. (1997) found that 24% of unselected school children (n = 152) continued to voluntarily use their colored overlays 10 months after receiving them, while Robinson et al. (1995) reported that in a screening of high school students (n = 353) at least 20% of individuals had noticeable symptoms of VS.

However, in the absence of universally acknowledged diagnostic criteria for the above disorders, assessing even the most conservative estimates of prevalence is difficult. This apparent shortfall in recognized diagnostic criteria for reading disorders is even evident in the benchmark guide to psycho-neurological diagnosis, the American Psychiatric Association's *Diagnostic & Statistical Manual-IV* (DSM-IV), which contains no references to VS, and only a brief general description of diagnostic criteria pertaining to reading disorders (Table 2).

Table 2. **DSM-IV: Diagnostic Criteria for 315.00, Reading Disorder**

A.	Reading achievement, as measured by individually administered standardized tests of reading accuracy or comprehension, is substantially below that expected given the person's chronological age, measured intelligence, and age-appropriate education.
B.	The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living that require reading skills.
C.	If a sensory deficit is present, the reading difficulties are in excess of those usually associated with it.

As VS has been controversially suggested by some to be a subtype or visual form of dyslexia, one might logically question as to how it can be more prevalent than dyslexia itself. A simple explanation lays in the fact that many VS individuals are not necessarily affected to such a degree that they are clearly unable to read or write efficiently (dyslexia by definition). Rather, it is often the case that only a lack of *fluency and speed* in an individual's reading and writing abilities are noticeable, though these skills tend to rapidly deteriorate after continual reading of more than a few minutes (Tyrrell, 1995). It stands to reason, therefore, that such seemingly mild impediments in the oral reading of a few sentences may not necessarily arouse a great deal of attention in a child's educators. Moreover, any reading tests of short duration are unlikely to detect a VS individual's weaknesses. Potentially complicating the identification of VS still further is the fact that many affected individuals develop coping strategies at an early age. These often include avoiding prolonged oral reading in front of teachers and peers, and completing the reading and writing components of tasks at home.

Although organizations such as the British Dyslexia Association in the UK and the Irlen Institute in the USA suggest that a general estimate of VS prevalence of around 12% is a reasonable figure, others have questioned the differing methods of obtaining the very data needed for such calculations. Indeed, the above-cited study by Kriss and Evans (2005) noted that the indicated prevalence of VS in any given trial greatly depends upon the stringency of the criteria used. That study employed the use of colored plastic overlays that were placed upon the printed text presented to the participants, and then utilized the *Wilkins Rate of Reading Test* (WRRT) (Wilkins et al., 1996) to assess any changes in reading ability. The researchers found an immediate increase in reading speed of more than 5% (a questionable benchmark, in any case) in a significant number of their control participants which, in turn, suggested a general population prevalence of 25%. However, when the same study employed the stricter criterion of reading > 25% faster, the indicated prevalence of VS fell to 5%.

The above study by Kriss and Evans (2005) compared 32 dyslexic children with 32 control children, matched for age (7-12 years), gender and socio-economic background. Perhaps the most interesting finding of their work lies in the fact that *both groups* increased their reading speeds with the use of the overlays (however, the degree to which the Hawthorn Effect may have influenced these results remains an unknown quantity). Nevertheless, the overall improvement in reading speed when using the colored overlays was significant ($p = 0.009$). Kriss and Evans (2005) subsequently concluded that VS is quite prevalent in the community, and even more so in the dyslexic population.

The propensity for researchers to employ varying methods to determine rates of VS prevalence is perhaps demonstrated in the results of a large study by the University of Newcastle (Australia), in which 353 Year 7 and Year 11 students at two separate high-schools were screened for VS (Robinson et al., 1995). Authors used colored overlays to conduct group screenings of 20-35 students at a time, and found that the incidence of noticeable symptoms of VS was 20% in one school, and 24% in the other. However, the vagueness of the study's definition of VS-diagnosis (*'noticeable symptoms of VS'*) could be considered questionable, as individuals with other learning disorders, such as ADHD, might easily fall within the confines of such a broad description.

In addition, the efficacy of screening 20 to 35 students at one time may also be debatable, not least because of potential confounding factors such as distractions from peers and variations in seating (thus lighting). Moreover, the proportions of students having a prior history of reading difficulties were not made clear, nor were the socio-economic backgrounds of the schools involved. The significance of trial participant backgrounds in studies of reading disorders is quite apparent in the literature, and suggests that the degree of VS incidence estimated in any given trial is partly dependent upon the previously established reading abilities of the trial participants. Several studies have found incidences in the order of 70% when screening students with *'lower-ability'* reading-competence (Geaney et al., 1991; Irlen, 1991; O'Connor, Sofo, Kendall, & Olsen, 1990). Conversely, research by Williams, LeCluyse and Rock-Faucheux (1992) indicated the prevalence of VS in capable students [those achieving adequate literacy levels or above] to be approximately 15%.

Diagnostic criteria for VS have been published by several research institutions and, whilst they may vary in detail, virtually all such lists are remarkably consistent. A particularly concise outline of VS diagnostic symptoms utilized by special education researchers at the University of Newcastle (Australia) is presented below (Table 3), as it appears to fit well with symptoms listed by other institutions involved in the treatment or research of VS, (e.g. British National Health Scheme [NHS], Irlen Institute, and British Dyslexia Association).

Table 3. **Diagnostic Symptoms of VS**

1)	Inefficient reading.
2)	Strain and fatigue when reading.
3)	Photophobia, discomfort and distortions due to glare, (especially fluorescent light).
4)	Print resolution, (blurring and movement of print).
5)	Difficulties reading black text on bleached-white paper, (particularly under bright and/or fluorescent lighting).
6)	Narrowing of scope/span of text recognition.
7)	Difficulties maintaining sustained attention.
8)	Inability to maintain extended reading.

Note. Source: Special Education Centre, University of Newcastle, Australia

With respect to the above diagnostic criteria for VS morbidity, it has not gone unnoticed by the present authors that half of these criteria (symptoms: 1, 2, 7, and 8) could just as easily be applied to a description of the distinctly separate learning disorder ADHD. Moreover, these four symptoms are by far the most easily observed by a healthcare professional or special education assessor, regardless of their speciality or training. Symptoms 3, 4, 5, and 6 can only be observed by the individuals who actually experience them. To complicate things further, a person being assessed for reading difficulties is likely to be totally unaware that experiencing perceptual distortions when reading is unusual, as this is how they have always seen and read text. Accordingly, in the absence of deliberate and carefully designed prompting by the attending professional (with respect to distortions of text), only the secondary symptoms of VS could possibly become apparent to the observer. As these tend to overlap with widely-accepted signs of ADHD, the inherent potential for misdiagnosis may well be significant. Thus, the conjecture surrounding both the definition and prevalence of VS may be further confounded by potential misinterpretation of the condition as being symptomatic of ADHD, the incidence of which has risen exponentially during the past two decades.

Effects of Fluorescent Lighting on Visual Comfort and Performance

The general role that different forms of lightning play for different cognitive and health-related conditions. A number of studies have investigated the possible effects of fluorescent lighting upon visual comfort and visual acuity tasks, with some also measuring effects upon cognition and fatigue

(Wilkins & Wilkinson, 1991; Boyce, 1994; Navvab, 2001; Winterbottom & Wilkins, 2009). Additional studies have examined associations between lighting and chronic disorders such as migraine and epilepsy (Harding, 1994; Wilkins et al., 2007). However, the vast majority of this lighting research has focused almost exclusively upon comparisons between different fluorescent lamp types (Küller & Laike, 1998; Veitch & McColl, 1995, 2001), and not between this form of lighting and incandescent lighting or natural sunlight. At the same time, prior investigations of visual comfort have seemingly overlooked the significant prevalence of light-sensitive individuals with VS in the general population. Conversely, the literature contains extensive research relating to three aspects of interior lighting relevant to the present review, which are discussed at length in the following pages: (1) Brightness levels of workplace and classroom lighting and optimal levels of illumination, (2) visual discomfort and headaches caused by the flicker frequency of fluorescent lighting, and (3) spectral distributions of various lamp types and their effects on visual comfort and acuity.Brightness and glare levels of office and classroom lighting**.** Studies examining artificial illumination are by no means a new area of research, yet it is only in the last two decades that researchers began to question the appropriateness of the typically high levels of illumination in workplaces and schools. The possible relationship of brightness and glare to reading and learning difficulties became an area of interest even more recently (Winterbottom & Wilkins, 2009), and other studies have reported that excessive lighting (particularly fluorescent lighting) can provoke migraine headaches and visual stress in susceptible populations (Wilkins et al., 2007).The study by Winterbottom and Wilkins (2009) measured lighting flicker frequencies, desk illuminance and reflected glare in a sample of 90 classrooms across 17 schools. The data showed that the lighting in 88% of British classrooms exceeds illuminance recommendations, with 84% having highly excessive illumination. The study concluded that any detrimental effects upon learning due to excessive lighting were also likely to be further compounded by reflected glare from whiteboards and other bright visual media.Why, then, might building designers have a propensity to over-illuminate office and classroom settings in the first place? According to Berman et al. (1996), this is in large part due to significant shortcomings in general lighting practice guidelines. The above researchers reviewed a wealth of ophthalmological and vision science research, and then compared this literature to contemporary publications emanating from lighting industry associations, such as the Illuminating Engineering Society of North America (IESNA). They found the key problem to be that virtually all lighting guidelines, and for that matter the calibrations of all illuminance-measuring devices, are based upon the light sensitivity of only one of the two key types of photoreceptors in the retina. How and why this may have become standard lighting practice is further discussed in the following paragraphs.

The fact that our eyes have two types of photoreceptors (the *rods* and the *cones*) has been known since early last century, although a third photoreceptor has been discovered just a little over ten years ago (He, Dong, Deng, Wing, & Sun, 2003). This third retinal cell type is believed to be linked to circadian rhythm. Conversely, the roles of the rod and cone retinal cells have long been established, with the rods acknowledged as being night vision (scotopic) receptors and the cones being day vision (photonic) receptors. However, according to Berman et al. (1996), this traditional view is not only over-simplistic, but is also based upon outdated optical measurements which appear to have been designed "more for observational convenience, rather than scientific accuracy".The basis upon which rod receptors were first assigned with the single role of being night vision receptors has been hitherto determined through measurements of rod cell responses (scotopic sensitivity) under clearly inadequate conditions (Berman et al., 1996). These measurements (to which all lighting industry guidelines still adhere) have traditionally been carried out under extremely low light levels designed to be well below the threshold of cone sensitivity, thereby excluding any visual input from cone receptors. It appears that because rod receptors can be shown to function efficiently in very faint light, which is well below the sensitivity threshold of cone receptors, this finding has then been extrapolated to indicate that the rods are solely night vision receptors. However, the fact that very dim lighting conditions are utilized to isolate rod receptor responses does not automatically rule out the functioning of rod sensitivity at higher light levels, particularly those of typical interior lighting.In a similar fashion, the methodology used to measure visual input from cone receptors (photonic sensitivity) has traditionally been carried out under highly unrealistic conditions, which are even more restrictive than those utilized to ascertain rod receptor responses. Indeed, photonic sensitivity is still routinely measured by constricting the test subject's field of view to a maximum of two degrees (less than 0.1% of the normal field of view of the human eye) in order to exploit the absence of rod receptors in the central portion of the retina, thus isolating the cone responses (Berman et al., 1996). As a result of these longstanding methods, virtually all lighting industry guidelines for measuring indoor illuminance and estimating optimal room brightness have been based solely upon the sensitivity of only one of the two key photoreceptor cell types: the cones (responsible only for photopic sensitivity). The now widely accepted contribution of the rod cells (scotopic sensitivity) to vision at typical interior lighting levels has been completely excluded from such guidelines, despite the significance of the scotopic contribution under artificial lighting being reported upon some 16 years ago in the *Journal of the Illuminating Engineering Society* (Berman, Jewett, Benson, & Law, 1997).Previous studies by Berman, Jewett, Fein, Saika and Ashford (1990; 1992) have demonstrated just how easily the perception of brightness can be affected by changes in the spectral distribution of interior lighting. In the former study (Berman et al., 1990), trial subjects were asked to assess which of two room lighting conditions appeared brighter. The chromaticity specifications of the two types of lighting provided equal color appearance of the room and its contents. One form of lighting emitted a spectral distribution favouring rod excitation (thus, enhancing the scotopic response). However, conventional illumination measurements showed this to be 30% dimmer than that produced by the second form of lighting. Interestingly, the participants repeatedly chose the weaker illumination as appearing brighter. When the two forms of lighting were viewed again, this time through a narrow black tube restricting the field of view (and decreasing rod cell excitation), the same subjects consistently found that both illumination types gave equal room brightness. Similar results were also obtained when a group of lighting technicians (n = 100) were subsequently invited to repeat the above experiment. These findings appear to be in agreement with Navvab (2001; 2002) who, following studies involving several hundred adolescents completing difficult visual tasks, found the proportion of shorter wavelength light in the spectral distribution (the 'scotopic content') emitted by indoor lighting to be the actual dominating factor affecting visual comfort and performance, not the overall degree of room illumination.

Illuminance modulation frequency of fluorescent lighting.

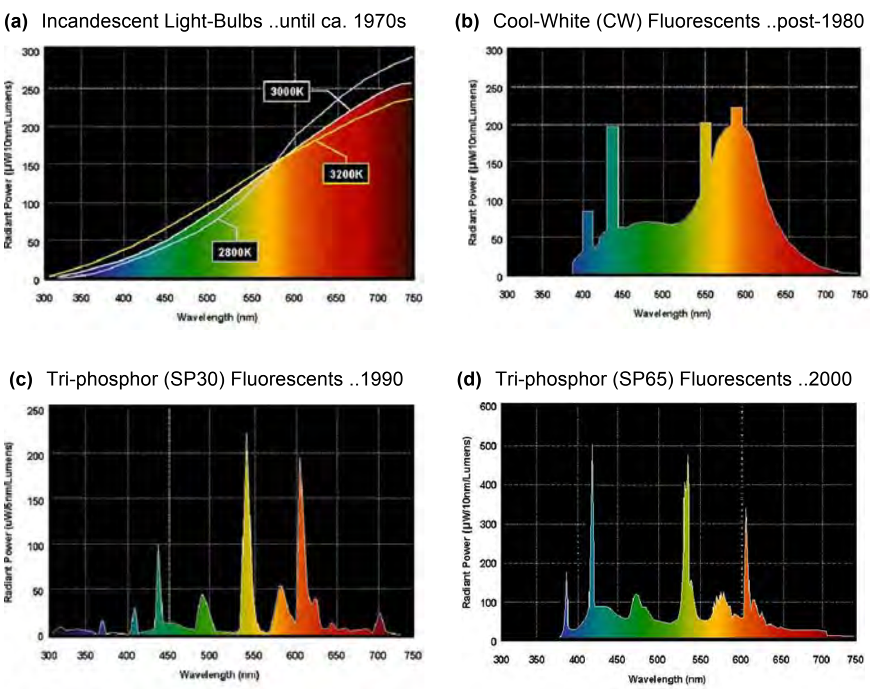
The underlying cause of the discomfort experienced by some individuals when in fluorescent lighting has often been postulated to be the illuminance modulation (or 'fluorescent flicker') inherent to such lighting (Wilkins et al., 2007). Proponents of the "flicker-based" school of thought rightly point out that the rapid 100 Hz modulation of fluorescent lighting can be subliminally detected by certain individuals, and propose that flickering underlies the sensitivity to this form of lighting in a section of the population.Although humans cannot consciously detect the rapid flicker of fluorescent lighting, it has been well established that other forms of flickering light can indeed influence brainwave patterns (as measured by EEG), and are even capable of inducing seizures in epileptic subjects (Childers & Perry, 1971; Harding, 1994; Hess, Harding, & Drasdo, 1974; Küller, 1981). However, such studies have mostly tested flickering frequencies well within the range that can be *consciously* perceived by humans and, accordingly, are a questionable comparison to the effects of standard 100 Hz fluorescent lamps. It is also noteworthy that the upper limit of flicker frequency (which can be visually detected by any individual) is accepted to be well below 90 Hz, with the vast majority of people being unable detect frequencies above 50 Hz (Küller & Laike, 1998; Van De Grind, Grüsser, & Lunkenheimer, 1973). Thus, it might be argued that as the 100 Hz flicker of standard fluorescent lamps cannot be consciously perceived by humans, it is unlikely to be a major cause of sensitivity to such lighting.Alternatively, the above-cited study by Küller and Laike (1998) showed that *subliminally* detected 'flicker' can also affect brainwave patterns. In that study, a significant attenuation of EEG α-waves was detected in one of two sub-groups of participants when sitting under standard 100 Hz '*cool-white*' fluorescent lighting in comparison to high-frequency (20-30 kHz) fluorescent lighting. None of the group (n = 16) were able to consciously detect flicker greater than 44 Hz in tests prior to the experiment (although all had detection-thresholds above 39 Hz). The individuals in the second group (n = 21), with flicker-detection thresholds of 39 Hz or less, showed no changes in α-wave patterns. The researchers undertook a further experiment to measure the respective proof-reading efficiencies of the two groups under the standard 100 Hz fluorescent lighting. The subjects in the sub-group with higher flicker-detection thresholds (> 39.0 Hz) were able to proof read significantly more words in a given time, but also displayed a far higher error-rate ($p = 0.007$). The researchers concluded that the results of the study could have implications for lighting design in schools.

Other researchers propose that rather than illuminance modulation, it is the slight variations in the modulation of different colors emitted by fluorescent lighting (chromatic modulation) that presents a more plausible cause of light sensitivity in certain individuals (Wilkins & Wilkinson, 1991). Proponents of this hypothesis also suggest that tinted lenses designed to reduce '*chromatic flicker*' can be highly effective and, moreover, that "…this form of tinting produces clearly observable visual and perceptual benefits for people with a history of perceptual distortion and reading difficulties" (Wilkins & Neary, 1991). However, one might question how the researchers were able to clearly determine that the symptom alleviations reported by their subjects ('with a history of perceptual distortions') were in fact brought about by reduced chromatic modulation, and not simply by the altered spectral distribution of the filtered lighting. It might also be argued that the effects of tinted lenses designed to filter certain colors, as a means of reducing chromatic modulation, may also be beneficial to individuals who are merely sensitive to specific wavelengths of visible light and not the modulation thereof.A further aspect of most studies of fluorescent flicker that is difficult to reconcile is their sole reliance upon comparisons of visual performance under 'low-frequency' (100-120 Hz) versus 'high-frequency' (20-30 kHz) fluorescent lighting. Although the spectral distributions of these different fluorescent lamp-types are known to vary dramatically (Veitch & McColl, 2001), there is little mention of this in the majority of these types of investigations. Thus, the significant spectral differences among various fluorescent lamp-types (and the vast variations in spectrum between these and incandescent lamps) tend to become increasingly conspicuous due to their absence in the details of most studies of the effects of fluorescent flicker.

The fact that differing spectral distributions can affect visual performance and brightness perception was first demonstrated in early research by Bouma (1962) and was subsequently corroborated by Berman, Fein, Jewett, and Ashford (1993, 1994) and Navvab (2001, 2002). These studies clearly showed that visual acuity is largely determined by pupil size which, in turn, is a determinant of the proportion of the illumination emitted in the shorter wavelength-bands. The above studies demonstrated that the violet, blue, and green regions of the visible spectrum induce the greatest retinal cell response in rod receptors (the scotopic response), and that the human perception of illumination brightness is a positive correlation of this response.The findings by Berman et al. (1996) concerning spectrally induced changes in pupil size appear to be quite robust, as the results were obtained by using infra-red imaging technology to measure any changes in pupil size in their subjects. Data relating to pupil size acquired through this type of methodology can only be viewed as entirely objective, primarily because trial participants cannot voluntarily alter the size of their pupils. Although there appears to be strong evidence of a spectral relationship to brightness perception, a detailed experiment by Veitch and McColl (1995) did not find an association between visual performance and the spectral distribution of fluorescent lighting. The study also found little evidence supporting the role of the scotopic response in visual acuity tasks and no evidence at all of sensitivity to chromatic modulation in the trial's subjects. However, as Berman, Benson, Veitch, and McColl (1997) pointed out in responding correspondence, there may have been flaws in both the design and conclusions of the Veitch and McColl (1995) study. Indeed, the methodologies employed in that experiment (thus certain conclusions) appear to be debatable and are hence further discussed in the next pages.The Veitch and McColl (1995) study was designed to compare participant accuracies in visual performance tasks carried out in standard (100 Hz) 'cool-white' fluorescent lighting (CWFL) to those observed under the same lighting with a spectral-filter covering, and again under high-frequency (20 kHz) 'full-spectrum' fluorescent lighting (FSFL) without a filter. Intriguingly, the researchers utilized a between-group (rather than within-subjects) design to obtain these comparisons. This aspect of the study's reported methodology elicited negative correspondence from Berman et al. (1997), who stated that the observed variations in visual performance (7.1%) under the three forms of fluorescent lighting were not enough to counter natural variations in (mean) visual acuity which might occur among three different and small groups of subjects (n = 16, per group). This would be especially true if each of the groups was assigned to visual tasks under a different set of lighting conditions, as was the case in this instance.Another potential limitation of the above study is that the view of each visual task was restricted to approximately 5% of the full field of normal vision, thereby, largely eliminating any perceptual contributions from the rod cells. Based on the small variations in the proportion of scotopic to photopic wavelengths (*S/P* ratios) emitted by the three forms of lighting, Berman et al. (1997) also calculated that any changes in pupil size would only be in the order of 7%. This fact alone must call in to question the significance of observed variations in visual performance of 7.1%. Veitch and McColl (1995) also reported that poorer visual performance was observed in both the 'full-spectrum' lighting (the most scotopic content), as well as the filtered 'cool-white' lighting (the least scotopic content). These results suggest two trends (in opposite directions), yet only one of these trends was mentioned in the conclusions of the study.The strong emphasis by Veitch and McColl (1995) concerning the variations in 'scotopic content' among the lamp-types is also puzzling, and for the following reason: All types of fluorescent lamps similarly emit a vastly higher ratio of shorter wavelength (scotopic) light to longer wavelength (photopic) light than do more traditional forms of illumination, such as incandescent light or natural sunlight. Thus, the merit of comparing various fluorescent lamps for differences in their emissions of still excessive ratios of scotopic light is questionable.The assertion by Veitch and McColl (1995) that the filter utilized in the study reduced the chromatic modulation of the standard fluorescent lighting while not affecting its spectral properties is also debatable. A description of the filter was not included in the report, other than the manufacturer's claim that the filter gives fluorescent lighting a more 'naturally balanced' spectrum. However, given that any form of spectral filtering can only subtract from the total illuminance transmitted, then substantially reducing chromatic modulation without also significantly reducing the overall illumination and spectral distribution is likely to be problematic, if at all achievable. This dilemma might be circumvented to some degree by specifically filtering the spikes in energy emitted at specific wavelengths in the spectrum of fluorescent lamps (Figures 2b; 2c; 2d) while minimizing the filtering of emissions in the broad intervening wavelength bands between. However, as the narrow wavelength bands of light emitted at high intensity represent a very small portion of the spectrum emanating from fluorescent lamps, any reduction of the chromatic modulation transmitted would be minimal.An alternative explanation for the reported benefits of spectral-filtering to visual comfort and performance was recently proposed by Northway, Manahilov, and Simpson (2010), who stated that a key factor underlying reading and visual discomfort problems can be attributed to contrast sensitivity, rather than fluorescent and/or chromatic modulation. According to the researchers, key determinants of visual acuity include not only the scotopic content of the illumination, but also the background upon which the visual task is situated. That report concluded that colored lenses enhance visual performance in subjects with reading problems by decreasing background contrast interference, which the study termed: "visual noise".

Spectrums of various lamps and effects on visual comfort and cognition. It has sometimes been suggested that because the sun has been the primary lighting source throughout human evolution, it only stands to reason that the human visual system has probably evolved to function most efficiently in light emitting similar spectral properties to sunlight (Hughes, 1980; Thorington, Parascandola, & Cunningham, 1971; Wurtman, 1975a; 1975b). Indeed trials using colored filters with a yellow-bias to reduce reading discomfort have yielded positive results (Maas, Jayson, & Kleiber, 1974; Loew & Watson, 2012a). In this context, it is perhaps also pertinent that until the advent of fluorescent lighting, virtually all visible light entering human eyes had emanated from thermal sources, such as the sun, fire, candles, oil or kerosene lamps, and eventually incandescent light-bulbs, all of which emit a continuous spectrum (Figure 2a).

Figure 2. **Typical Changes to Classroom Lighting in Primary Schools since mid-1970s. SPD* of: (a) incandescent lights (b) cool-white fluorescents (c) tri-phosphor fluorescents (d) 'brighter' tri-phosphor fluorescents. Source: www.gelighting.com/na/business.**



Upon comparison of the spectral distribution emitted by a thermal light source, such as incandescent lighting (Figure 2a), to the spectrums emitted by three common fluorescent lamp-types (Figures 2b; 2c; 2d), the disparity in the ratios of color intensities are apparent. A further dissimilarity between these forms of lighting is that spectral graphs of incandescent lighting always produce a continuous curve (as is the case for sunlight), whereas graphs of spectral emissions from all fluorescent lamps do not remotely resemble a continuous curve. The spectrums presented above also suggest that the recent trend of replacing earlier ‘cool-white’ fluorescent lamps with their brighter/bluer ‘tri-phosphor’ counterparts constitutes a further move away from the traditional use of lighting sources which emit a continuous spectrum, and a drift towards the blue end of the spectrum to increase perceived brightness.

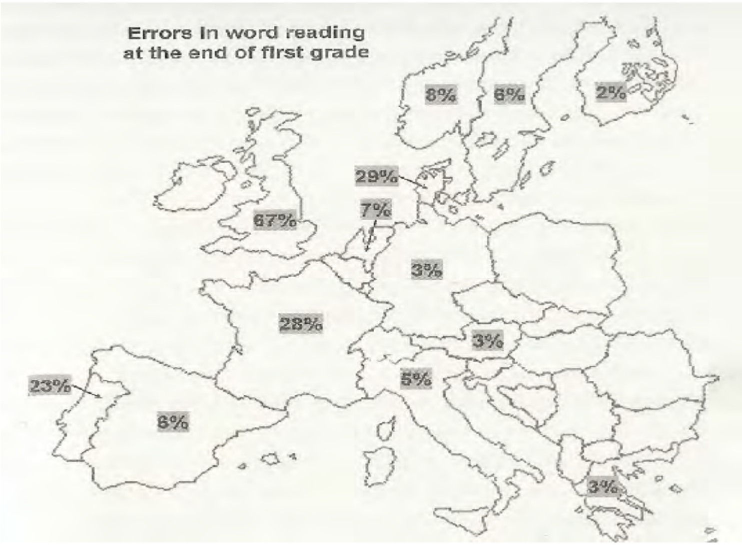
In one of the few studies investigating the possibility that human vision might function most efficiently in light with a continuous spectrum and a slight yellow bias (such as sunlight), Maas et al. (1974) tested various spectra produced by different types of indoor lighting for their effects on fatigue in students after a four hour period of study in a lecture hall. The researchers observed significantly less visual fatigue and improved visual acuity under lighting which emitted a spectral distribution more similar to sunlight, as compared to *cool-white* fluorescent lighting. Maas et al. (1974) deliberately excluded subjective input from their participants in the analysis of the data. However, only one of their three objective measures of fatigue revealed significant variations, and this was based upon a lowering of their subjects’ *critical flicker fusion* (CFF) thresholds, (the frequency at which a flickering light appears to become uninterrupted). As hyperactive children have also been reported to have lower CFF thresholds (O’Leary, Rosenbaum, & Hughes, 1978; Ott, 1976), yet are not well known for exhibiting signs of fatigue, the use of CFF scores as a key measure of fatigue may perhaps have been a less than optimal choice.The results of a study by Ray et al., (2005) also suggested that optimal artificial lighting for reading may require an adequate proportion of yellow light in its spectral emissions. Their placebo-controlled study tested the effects of yellow lenses upon visual and reading problems in a total of 77 children (aged 7-14 years) diagnosed with reading disabilities. These children were subsequently split into the following three subgroups: those with severely reduced convergence and accommodation (n = 15), those with normal visual acuity and vergence, but deficits in motion sensitivity (n = 24), and those with severe reading disabilities, yet normal visual acuity and vergence (n = 38). The study found that wearing yellow lenses not only boosted activity in the magnocellular visual pathway (possibly by eliminating “inhibitory blue input” into that pathway), but also produced significant long-term improvements in the reading abilities of the active subjects.The findings of Ray et al. (2005) appear to have been based on particularly objective observations, as the improvements in reading were sustained after three months and this was not the case for the control students wearing neutral-density lenses (which lower the amount of visible light without bias). Motion-sensitivity and convergence also showed significant and sustained improvement in the group using yellow filters, but not in the control group. The study concluded that yellow filters are clearly capable of reducing reading and visual acuity deficits by improving magnocellular function, and that the improvements seem to be lasting.

Curiously however, it appears that the majority of research relating to possible effects on vision, reading, and attention caused by indoor lighting has confined itself to the recruitment of subjects *without* any visual, reading, or attention difficulties. Most such studies have also primarily focused upon comparisons (by normal readers) of visual comfort and visual-task performance under different fluorescent lamp-types (Navvab, 2001; Veitch & McColl, 2001). In the field of lighting research, it seems there have been no trials comparing levels of visual comfort under different types of fluorescent lamps which have involved subjects with sensitivities fluorescent lighting. This seems to be an oversight on the part of the lighting industry, as individuals diagnosed with VS would be potentially ideal trial-participants in respect to assessing variations in visual acuity and comfort under different lamp types. It is also possible that many studies of rod cell responses to shorter wavelengths of visible light, or the *'scotopic sensitivity'* of the retina, have perhaps overlooked the possibility that certain individuals may be more *sensitive* to the scotopic content of light than are others.

Literacy and Numeracy Levels in School Students

Literacy and numeracy skills: Have they declined in recent decades? The above question has spurred a great deal of educational research in many OECD nations. However very few investigations have sought to resolve this question by reviewing literacy and numeracy test-score data over several decades. In countries such as Australia, education authorities and politicians have traditionally preferred to base their assessments of national literacy and numeracy achievement levels almost exclusively upon international comparisons, and are thus quick to point out that recent student test-scores have not slipped in the OECD rankings of literacy and numeracy performance. However, a perception of stable literacy and numeracy achievement based only upon comparisons with other OECD nations might well be illusionary if, for instance, it were to be the case that many such countries had themselves experienced declines in these key measures. In addition, the ease of literacy acquisition in any given country greatly depends upon the specific language in which a student must become literate (Dehaene, 2009). Indeed, the data shown in Figure 3 suggests that in phonetically "transparent" languages, such as Spanish and German, attaining proficient levels of literacy is far less of a learning task than in relatively "opaque" languages such as English.

Figure 3. **Variations in Early-childhood Literacy Achievement in Europe. Excerpted from: 'Reading in the Brain', Dehaene (2009).**



Thus, any assessment of a nation's progress in literacy and numeracy should also look inward and gauge its contemporary appraisal of these skills against that country's own long term records of school-based testing in these areas. In this respect, there have recently been two comprehensive studies of medium to long-term trends of literacy and numeracy test-scores in Australian students: Thomson and De Bortoli (2008), and Leigh and Ryan (2012). As Australia is an English-speaking country (a language in which reading disorders are more readily apparent), with an education system similar to many European nations and life-style factors comparable to those in the USA, the following paragraphs examine the findings of the above-mentioned studies in detail.The study by Thomson and De Bortoli (2008) reviewed the performance of Australian students in successive international literacy and numeracy tests, which were initiated by the OECD in 2000 and carried out under the Programme for International Student Assessment (PISA). The first of these tests ('PISA 2000') assessed the performance of 15 year-old students in 32 countries. The second PISA test, in 2003, involved 15 year-old students from 41 countries. In PISA 2006, there were almost 400,000 student participants (aged 15) from all 30 OECD nations as well as 27 partner nations. This included 14,170 Australian students, drawn from 356 schools across the nation. Thomson and De Bortoli (2008) compared the test-scores of Australians in these three successive literacy and numeracy examinations, and found that overall progress in mathematics in Australian students had stagnated between 2000 and 2006, with the performance of female students between 2003 and 2006 declining significantly. In addition, the PISA data also revealed a significant decline in literacy skills for both male and female students between 2000 and 2006.Later data from PISA 2009 showed that the significant decline in literacy in Australian students from 2000 to 2006 had continued into 2009. The mathematics test-scores of both girls and boys also declined significantly (from 2003) in PISA 2009 (Thomson, De Bortoli, Nicholas, Hillman, & Buckley, 2010), and there were also significant declines in the number of students attaining higher test-scores (level 5 or 6). In literacy, the percentage of students reaching these higher levels fell from 18% in PISA 2000 to 13% in PISA 2009, and those reaching equivalent levels in mathematics fell from 20% in PISA 2003 to 16% in PISA 2009.Subsequent results from PISA 2012 have very recently become available from the Australian Council for Educational Research (ACER). The new sets of data show that both literacy and mathematics test-scores have continued to decline significantly from 2009, with 36% of Australian students taking part in PISA 2012, having failed to reach the national baseline proficiency level in reading literacy and 42% of students failing to reach the baseline proficiency level in mathematics literacy (Thomson, De Bortoli, & Buckley, 2013).

Declining trends in these vital areas of education were also observed in a longer-ranging study at the Australian National University (Canberra) by Leigh and Ryan (2012). The study tracked the performance of 13-14 year-old Australian students in national literacy tests from 1975 to 1998, and in numeracy tests from 1964 to 2003. The time-frames were selected purely on the basis that only during these periods were the researchers able to trace and isolate an adequate number of identical questions which had been presented to successive groups of Australian school students. The study found a significant decline in numeracy between 1964 and 2003, with Year 9 students in 2003 being a quarter of a grade behind their 1964 counterparts. Moreover, this decline had occurred in spite of an increase in per-child educational funding of 258% (in real terms) and a 43% fall in class sizes during the same period. There were also significant declines in both literacy and numeracy in the testing results of both male and female students between 1975 and 1998.The above trends in literacy and numeracy are not peculiar to Australia and have indeed been observed in other developed nations. In the USA, literacy and numeracy test-scores have reportedly remained flat from 1970 to 1998, even though per-child education expenditure rose by 2.5–3% per year (in real terms) over the same period (Hanushek, 1997). From a wider international perspective, a review of literacy and numeracy test results in 11 developed nations in a study by Gundlach et al. (2001) found that progress in these key areas of education had essentially remained flat in OECD nations from 1970 to 1994. The study further noted that this had occurred in spite of dramatic increases in per-child spending in most developed countries over the same period.Increased investment in education by the British government appears to have shown equally poor returns, with a study by Flynn (2009) revealing declines in the literacy and numeracy test-scores of 14-15 year-old students between 1980 and 2008. Still, the creditable test-scores achieved in many poorer nations suggest that higher test-scores are not necessarily a direct correlate of higher education spending. Thus, declining trends in literacy across such a wide range of developed nations may suggest that, at some point in time during the past few decades, changes have occurred to certain aspects of teaching or the classroom environment which are common to all of these countries. If so, the above-cited studies would appear to implicate the 1970s to early 1980s as the time-frame in which such changes first took place.Perhaps coincidently, fluorescent lighting was not installed into the classrooms of Australian primary schools until the mid-1970s, hence the first children to have commenced kindergarten under this form of lighting were entering university circa 1990, or around the same time as declining student literacy first became a highly topical issue amongst tertiary educators in Australia. Still, other factors might equally account for declines in student literacy and numeracy, such as increased time watching TV and playing digital games, the advent of social media, or even changes in attitudes to learning. However, it appears that Leigh and Ryan (2012) have rigorously allowed for these possible influences, though altered classroom conditions, changes to teaching methods, or disparities in teacher quality would seem difficult to control for in any long-term comparisons of student test-scores.Student to teacher ratios are also a factor which could potentially influence education outcomes, and Australian teaching federations have long argued that present day class sizes are far too large. In a recent media release by the Australian Education Union (AEU), it was asserted that primary school students in Australian states such as New South Wales (NSW) are being disadvantaged by excessively large class sizes. This conclusion was based upon the 'State of Our Schools Survey 2010', in which the AEU found that 4% of classrooms in NSW have 30 or more students, as opposed to only 1% in some states and 3% of classrooms nationwide. The general sizes of classes across Australia were also deemed to be far too large. However, as Leigh and Ryan (2012) demonstrated, average class sizes in Australia fell by 20% between 1975 and 1998, and by 43% from 1964 to 2003. Moreover, if one examines the statistics collected in the survey (Table 4), it is clear that the same data could just as easily be interpreted as showing that 97% of Australian primary school classes contain no more than 30 students, with 73% of classrooms having 25 or less students. To students of the 1960s and 1970s, class sizes of this order would most likely seem remarkably small.

Table 4. ***Percentage of Different Class Sizes in all Primary Schools Surveyed***

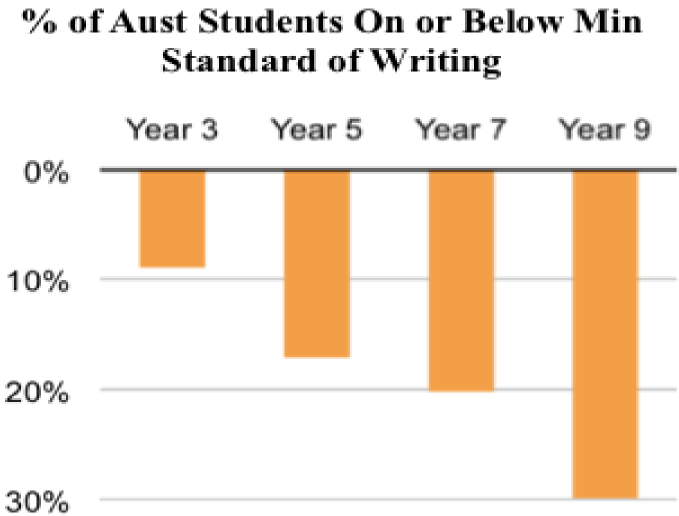
Students:	**20 or Less**	**21-25**	**26-30**	**Over 30**
ACT	38%	52%	10%	1%
NSW	27%	36%	32%	4%
QLD	26%	48%	26%	1%
SA	35%	34%	28%	4%
NT	30%	54%	14%	3%
VIC	36%	49%	15%	1%
TAS	31%	51%	17%	1%
WA	26%	42%	27%	5%
National:	**30%**	**43%**	**24%**	**3%**

Note. Excerpted from: 'State of Our Schools Survey', Australian Education Union, 2010

Changing demographics can also represent a significant variable in any long-term comparisons of student literacy, particularly in Australia. For instance, an increase in the proportion of students from non-English speaking backgrounds could plausibly affect average test-scores in literacy (though recent PISA, 2009 data suggests an opposite effect). Other demographic shifts in Australia during recent decades are more likely to have enhanced, rather than hindered, student literacy and numeracy test results. An example of this has been the steady rise in the proportion of students with parents who have a tertiary education, a factor known to raise mean student test-scores in these key areas (Cardak & Ryan, 2006).

Irrespective of potential confounding factors, the directional trends of Australian literacy and numeracy levels reported by Thomson and De Bortoli (2008) as well as Leigh and Ryan (2012) appear to be supported by subsequent data (Figure 4) from the Gratten Institute, Australia. The data shows that a reliance on comparisons of OECD rankings to gauge a nation's literacy levels is farcical, as it was possible for Australia to be ranked sixth in OECD international reading tests (PISA, 2009) whilst clearly experiencing a literacy dilemma in its schools.

Figure 4. **Trend of Progression in Writing Literacy through High School. Excerpted from: 'Measuring what matters: Student progress', School Education, 27 Jan, 2010.**



Current directions of research in literacy and numeracy in Australia. Perusal of many educational research journals may give the interested reader the impression that a large proportion of funding for literacy research is consumed by studies that are often protracted in nature, complex in detail, yet short on solutions. Although much educational research in Australia has indeed focused upon highly important issues, it also seems that studies investigating the efficacy of *current* teaching strategies far outnumber those aimed at developing *novel* or *improved* approaches, especially in relation to reading difficulties. Indeed, several years ago, the then CEO of the Australian Council of Educational Research (ACER), Geoff Masters, asserted that there has for too long been an oversupply of research simply investigating the *status quo* (Masters, 1999). However, the long lists of recent publications ardently presented on the websites of Australian educational research organisations (such as ACER) suggest that this is still the case.In Australia, educational research studies specifically targeting recognized reading and learning disorders appear to be dwarfed by the number of studies investigating current teaching methodologies. Perhaps as a result, neither the VS condition itself, nor the simple classroom adaptations shown to be highly beneficial to individuals with VS, seem to be remotely on the agenda of those responsible for the implementation of government-funded 'reading-recovery' programs. This apparent under-recognition of VS in Australia is perhaps best exemplified by a research report commissioned by the Literacy and Numeracy Strategies Branch of the Federal Department of Education. Although the report (Forster, 2009) is titled "*Literacy and Numeracy Diagnostic Tools: An Evaluation*", it contains no mention of VS (or any other reading disorders) within the entirety of its 96 pages. As the report was presumably aimed at assisting teachers of literacy and numeracy, it would seem that the priorities of educational researchers and the needs of education practitioners have become dissociated. It is thus little wonder that the term *Visual Stress* is still unknown to most Australian educators as well as to most educators around the world.

Discussion

A broad-scoped review of the literature indicates that visual stress is likely to affect at least 12-14% of the general population, with the condition equally prevalent in children and adults. The literature also contains several lines of converging evidence indicating that different forms of illumination have differing effects upon visual comfort, visual acuity and visual performance, all of which may affect reading proficiency. It is also clear that individuals with VS are at a particular disadvantage when reading under fluorescent lighting. Moreover, the results of some of the studies examined indicate that fluorescent lighting can also cause visual and reading discomfort in capable readers, as well as in individuals with VS and/or dyslexia. Accordingly, the primary conclusions drawn from the areas of research examined here were: 1) The incidence of moderate to severe levels of VS in the population is significant, and thus would likely impact upon statistics relating to a nation's literacy and numeracy levels and 2) the substantial increases to brightness levels of fluorescent lighting in classrooms (particularly in primary schools) during the past three decades may have amplified this impact.

There is also sufficient evidence indicating that differing forms of indoor lighting can (to varying degrees) not only affect visual-task performance, but also concentration and fatigue in most individuals. Taken in the context that underlying causes are continually being sought for persistently high incidences of reading and attention disorders, it is thus surprising that many educational researchers appear to have not tapped into the wealth of available research offered by inter-related fields. As the debate continues concerning literacy and numeracy levels, in many countries this common visual-perception disorder affecting reading ability has not received an inkling of the attention afforded it in some nations. For instance, the benefits of screening *all* school students for symptoms of VS have been supported by Scottish politicians since 2001, and in the UK the costs of diagnosing and treating VS have been in large part covered by the British National Health Scheme (NHS) for several years now. In many countries, however, under-recognition of VS, and similarities in its secondary effects to symptoms of ADHD raise the possibility that misdiagnosis of VS may well be a common occurrence. In view of the recent phenomenal rise in childhood ADHD diagnoses in many developed nations, particularly in the USA, it is also noteworthy that the majority of DSM-IV criteria required for a diagnosis of ADHD (which are largely unchanged in DSM-5) could equally describe deficits in those specific aspects of classroom behaviour which are ideally expected by teachers.Although teachers do not, *per se*, diagnose conditions such as ADHD, dyslexia, VS, and ASD, they often recommend the type of specialist that a student experiencing difficulties should be assessed by. This method of referral is far from ideal (Graham, 2008). However, when considered together with the linkage of governmental funding for literacy programs to only a few very specific disorders, the potential for misdiagnosis seems a realistic possibility. Furthermore, previous research has shown that teachers are usually the first to suggest a diagnosis of ADHD, or that a child at least be assessed for ADHD (Sax & Kautz, 2003). Add to this the potential influence of teacher subjectivity, and perhaps even gifted children (for whom inattentiveness and daydreaming are recognized traits) might eventually find themselves accompanying their parents to visit an ADHD diagnostician.

Finally, the studies of VS prevalence presented in this review suggest that in typical primary school classrooms there are likely to be three or four students who are significantly disadvantaged by the relatively recent use of highly reflective whiteboards and ultra-white paper in combination with increasing levels of bright fluorescent lighting. Moreover, the lack of awareness of this very common visual condition on the part of educators is regrettable, as the effects of VS are possibly the most easily catered for of all known learning difficulties.A prime intention of this review was to investigate the possibility that visual stress may not necessarily prevent all affected individuals from acquiring sufficient levels of reading ability. The results derived from *'normal readers'* under standard lighting in specific studies indicate that this may indeed be the case (Kriss & Evans, 2005; Loew & Watson, 2012a). The findings of such studies demonstrate that VS can affect all sectors of the population and are consistent with prior reports that the severity of VS morbidity is a continuum (Evans & Joseph, 2002). Accordingly, the question begs as to why the limited number of randomized controlled trials (RCTs) investigating the efficacy of spectral filters as a treatment for VS have (to date) produced such diverse and often conflicting results. The answer may well lie in evidence disseminated throughout this review, which suggests that the control measures utilized in many such studies are questionable. For example, certain RCTs have utilized control filters which were pale-yellow in color (Bouldoukian, Wilkins, & Evans, 2002). However, filters with a yellow-bias have been found to reduce visual fatigue (Maas et al., 1974), enhance magnocellular functioning (Ray et al., 2005), and moreover, pale-yellow filters were later shown to alleviate reading discomfort in VS subjects and controls (Loew &

Watson, 2012a), and also in a group of expert readers (Loew et al., 2014).There have also been RCTs in which the control comparator has been a 'placebo' filter (Robinson & Foreman, 1999; Wilkins et al., 1994), whereby the placebo lenses or overlays are so similar in color to that previously selected by a subject as giving the best reduction in symptoms that the subject cannot notice the difference. However, scientific intuition would suggest that a highly similar color is likely to provide at least a somewhat similar effect.Other controlled studies have typically utilized so-called 'neutral' filters as a comparator, yet spectral graphs freely available from the manufacturer (Hoya™) show that although these filters reduce most wavelengths of visible light without bias, they actually block substantial amounts of violet and blue light, both of which are emitted in large excess from fluorescent lighting. It is thus possible that the very control filter conditions used in some investigations of the treatment efficacy of colored filters may themselves act as an effectual treatment for visual discomfort, particularly in individuals sensitive to illumination emitting large amounts of violet and blue light. Consequently, the choice of filters utilized as control comparators in several studies may partially explain the wide disparity of results reported concerning the effects of colored filters upon reading in VS and/or dyslexic individuals.

In addition, researchers have often used control measures involving reading tests which have been developed with, and targeted towards, young children (i.e. WRRT). This may have led to a 'ceiling effect' in trials involving adolescents and adults, whereby there was little room for gains in reading speed or accuracy for the group as a whole. It is thus pertinent that reading tests designed to detect changes in reading speed and accuracy in VS individuals who despite VS *can read effectively* appear to be lacking, particularly for adults with VS.In this context, the participants enlisted in some of the above studies were university students, and thus were in effect (by virtue of the reading skills needed for tertiary studies) 'ideal control subjects'. Therefore, the results showing reduced reading discomfort in these groups due to spectral filtering (Loew et al., 2014; Loew & Watson, 2012a; Maas et al., 1974) have implications for all studies of VS involving a control group, as the findings suggest that a significant number of control subjects are likely to also experience VS symptoms when reading under fluorescent lighting, which (one assumes) would likely be the standard form of room-illumination in most such studies.The above research may also have implications for individuals working in situations where rapid and accurate reading is crucial. In this respect, medical professionals working in high-stress (and highly illuminated) hospital settings directly come to mind. In such situations the misreading of a patient's medical chart (e.g. not noticing a decimal point in the amount of medication prescribed) can be a matter of life or death for the patient. Indeed, the alarmingly high number of avoidable medical errors occurring in hospitals is a serious issue which is recurrently discussed in the media. If one considers that all hospital areas have illumination levels similar to their operating theatres and that medical staff work long hours involving shift-work in a high-pressure environment, and then further considers that symptoms of VS have been shown to be prevalent in capable readers, one might conclude that VS could be a latent dynamic in hospital settings and thus a potential factor in a number of medical errors.There is one further aspect of the research reviewed here which requires attention, as it is a contributor to any controversy surrounding VS and/or colored filters: *There appears to have been little or no replication of prior studies!* In fact, a reader of this review could easily gain the impression that researchers of VS and/or dyslexia go to a great deal of effort to carry out their studies as 'differently' as possible, even though a fundamental driver of progress in scientific research is that studies can be replicated, hence allowing their findings to be tested. Thus, any governmental reviews of VS tend to conclude that the evidence is still 'equivocal'.In relation to the key issues examined in this review, a number of gaps in the scientific literature appear to be evident. However, research in the following directions is particularly warranted: First, the research evidence detailed in this review highlights an urgent need for educational researchers to determine if (and to what degree) different forms of classroom lighting and visual media may be affecting reading, learning, and for that matter, any aspects of education. Second, if it is shown that the learning skills of particular individuals can indeed be affected by the above, estimations of prevalence and, moreover, screening of all school students for this potentiality should be undertaken with urgency. Third, and perhaps most importantly, if problems with lighting and visual media were to be definitively identified, and quantified, investigations of how to most efficiently and promptly mitigate such effects should be forthcoming and given high priority by all levels of government.Lastly, any future trial-based research investigating the effects of fluorescent lighting upon visual or reading discomfort might do well to consider the potential merits of enlisting participants with histories of reading difficulties (and/or light-sensitivities), as opposed to the traditional recruitment of "normal" readers.

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Children's Thoughts on Spelling: Considering Children's Strategies and Errors to Guide Instructional Remediation

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Current research on general and special education spelling achievement concentrates on either the various academic abilities among groups, or the success of different kinds of instruction. Little attention has been paid to how children think about spelling. Children's thoughts about spelling are critical features in understanding and designing effective spelling instruction for good and poor spellers. This paper provides an overview over relevant findings regarding the significance of children's attitudes and beliefs about spelling as the try to correctly arrange letters to form written words. Based on these elaborations, five instructional recommendations for teachers in inclusion classrooms are introduced. They are presented in a way that teaching instruction can be tailored to facilitate various learning abilities.

Keywords: spelling, mild disabilities, informal interviews, remediation, instruction, inclusion

A Rationale for Assessing Children's Spelling Strategies Importance of Spelling

Spelling has been a frequent topic in educational research throughout the last decade. It is a highly complex process and is often characterized as an area of difficulty for students with learning disabilities (LD) (Carpenter & Miller, 1982; Kirk & Elkins, 1975). A large body of empirical data related to spelling instruction in regular education exists; however, more attention needs to be paid to investigating the effectiveness of these programs when being used in the classrooms of students with learning and behavior problems (Vaughn, Schumm, & Gordon, 1992). In addition, research shows that students have difficulty transferring newly acquired spelling skills to other content areas (Butyniec-Thomas & Woloshyn, 1997; Darch, Kim, Johnson, & James, 2000; Wirtz, Gardner, Weber, & Bullara, 1996). It is important that students with LD build spelling skills and generalize them to other content areas. Graham (1999) states it best: "Students with learning disabilities typically have difficulties with handwriting and spelling, and such difficulties can interfere with the execution of other composing processes, constrain writing development, and mark a child as a poor writer" (p. 78). This article reviews students' approaches to spelling, how to assess strategies students use to spell, and discusses how teachers can remediate spelling difficulties and promote generalization.

Formative Assessment and Spelling Instruction

Building a better understanding of the processes students use to spell will help researchers and educators improve methods for spelling instruction and increase children's spelling skills. Formative assessment that examines children's error patterns along with their thought processes can lead to more effective spelling instruction because teachers will be able to guide children in the implementation of choosing a more appropriate strategy for spelling unfamiliar words. Instruction can then be provided to specifically remediate spelling errors as well as the selection of a strategy. For instance, a child who spells "take" as "taek" may know the final e rule, but not know how to apply the skill correctly. The teacher would then need to provide more opportunities for practice with a wide range of examples in using the skill. Thus, assessing how the student approached spelling the word "take" shed insight into why he or she spelled the word as *taek* and the remediation would involve the application of the rule as well as the approach to spelling itself. How students approach spelling involves perceptions of spelling efficacy and the strategies employed to spell unfamiliar words. Both are discussed in the following sections.

Perceptions of Efficacy and Spelling Performance

Downing, DeStefano, Rich, and Bell (1984) studied children's perceptions of their ability to spell based on their grade level. Participants included a group of 122 children in grades one through six. Findings suggested a drop in spelling self-efficacy as children progress through grades. They found that three out of four first graders thought they were good spellers. But at grade three and beyond, this feeling dropped to less than half of the students perceiving themselves as effective in spelling. Students at all grade levels responded to whether or not they were good spellers solely based on their weekly test grades.

Building on the research regarding self-efficacy in spelling, Licht, Kistner, Ozkaragoz, Shapiro, and Clausen (1985) wanted to determine whether children with LD were more likely to attribute their spelling difficulties to ability level, effort, or to external factors (i.e., factors beyond their control). Since most students with mild to moderate LD have experienced repeated academic failure, these incidences may lead the student to believe that they do not have the ability to succeed, therefore attributing spelling difficulties to ability level or external factors. Such beliefs lead to students with LD choosing to give up more easily on an assignment compared to students who do not have a disability. Thirty-eight children with LD and 38 elementary students without disabilities were selected for the study. It was found that children with LD were significantly less likely to attribute their failures to insufficient effort. Moreover, the girls with LD were more likely than girls without LD to attribute their failures to insufficient ability; boys in general were more likely to blame external factors for their failure. These findings support the assumption that beliefs about oneself as a speller may affect spelling performance.

Rankin, Bruning, and Timme (1994) examined the relationship between spelling performance and students' beliefs about spelling, including self-efficacy and outcome expectancy for students in grades four through seven. Their findings support previous research about low self-efficacy and its relationship to poor spelling performance. The outcomes that students expect rely heavily on their judgment of how well they will be able to perform a given task. Since individuals usually see outcomes as depending on their performance, and because they care about their outcomes, they will rely on self-efficacy to determine what to do and how much effort to expand to an academic task. The students in the fourth-grade group reported spelling performance attributed to both their effort and ability, while the seventh-grade group stressed their effort as more of a predictor of their performance. The authors suggested that spelling programs should focus on strategically building student' confidence since there seems to be a reciprocal relationship between their thoughts about spelling and spelling performance. In order for a student to believe that effort will improve their spelling, teachers need to provide students with tasks that they know they will master in order for them to believe that they can be successful. In addition, teachers need to provide instruction in effective ways of approaching unfamiliar words and a repertoire of strategies that can be implemented.

Spelling Strategies and Spelling Performance

Weiner (1994) compared the spelling descriptors of poor versus good spellers through unstructured interviews of four first graders (two good and two poor spellers). Interviews revealed that poor spellers were less likely to take risks in spelling, demonstrated less automaticity, and were less able to transfer knowledge than good spellers. One student was described as saying, "I ask the teacher what they are and how to spell them" (p. 325). This cautionary attitude may limit some students in transferring knowledge into other spelling words. Another student described how she "just knows" a word: "…you learn it from school or at home or something, and then you get time to get the word stuck in your mind. It's just like bubblegum; it just sticks on your face when you blow bubbles" (ebd.). On the other hand, poor spellers relied heavily on sound/symbol knowledge while good spellers were more likely to use symbol knowledge and within-word patterns strategies such as the i before e rule.

Steffler, Varnhagen, Friesen, and Treiman (1998) explored the errors children make in their spelling. Their study included 93 children in second through fifth grade. Children spelled CCVC (consonant, consonant, vowel, consonant), CVCC (consonant, vowel, consonant, consonant), and CVCe (consonant, vowel, consonant/silent e) words dictated to them and reported on strategies they used to spell them. Strategies were coded into five categories: (a) retrieval, (b) phonetic, (c) explicit rule, (d) analogy, and (e) other. When children said they "knew" how to spell a word, they were coded as retrieval. When they reported "sounding it out", it was coded as a phonetic strategy. When they stated an orthographic rule or strategy, it was coded as a rule strategy. When the children compared the word to another known word, it was coded as an analogy strategy. Retrieval response processes yielded a higher percentage of correctly spelled words than the phonetic strategy and children at all grade levels were successful in applying specific rule to spell words. Results also indicated that the explicit rule strategy was more effective than a phonetic strategy in the second-grade group. Steffler et al. (1998) explained that the strategy children use for spelling gives valuable insight into their cognitive processes.

Spelling and Informal Interviews

Darch et al. (2000) investigated the strategic spelling skills of students with LD through structured interviews. They revealed four major categories of spelling descriptions: (1) rule-based, (2) multiple, (3) resource-based, and (4) brute force. Rule-based approaches were adopted by children who applied the correct rule when spelling. The multiple strategy was when students used more than one strategy during spelling. A resource-based strategy indicated the consideration of a prior learning experience. A brute force response was when children used a less sophisticated strategy to spell. Results from the interviews revealed that students almost exclusively used a brute force strategy. An example comment would be: "I keep on trying. I keep thinking about the word. Sometimes I guess if I don't know. I just spelled it and did the best I could" (p. 20). Students who used the brute force strategy usually showed high levels of frustration when trying to spell. When children were asked to describe how their teacher taught them spelling, they had poor descriptions of instruction and failed to recall any details. This suggests that students need to be taught specific spelling strategies with intensive instruction and to learn when and how to apply them.

Simmons (2007) conducted a study that examined how children at-risk and with disabilities report on the strategies they utilize when spelling. A total of six randomly selected students were asked to participate in informal interviews. Their purpose was to see if any themes or patterns in the way students describe their spelling skills were similar to other reports and use that information to make recommendations for remediation in the general education classroom. Informal interview questions were compiled from previous research (Darch et al., 2000). The five interview questions were:

1. What makes somebody a good speller?
2. When you don't know how to spell a word, what do you do to try and spell it?
3. Do you like how we did spelling? Why or why not?
4. Have you used your new spelling skills in another subject?
5. How do you feel when you can't spell a word?

Results of Simmons (2007) were similar to findings from previous spelling research (Darch, et al., 2000). For example, when asked, "What makes somebody a good speller?", most students did not respond with any type of spelling strategy. Replies often consisted of ineffective approaches like writing words neat, paying attention, and trying hard. Unfortunately, most students have developed compensation techniques that are time-consuming and frequently unsuccessful. Their only effective approach involved seeking assistance from others. Also, students contend that they are able to correct their own mistakes; however, during spelling tests, they would put an X next to a word they knew was wrong. They seemed to recognize that a word was misspelled, but could not utilize effective spelling strategies.

Spelling Instruction and Spelling Strategies

Regardless of error type, students need to be taught specific spelling strategies with intensive instruction and to learn when and how to apply those strategies. Based on research, there are six types of strategies students use to spell. They are a) retrieval, b) phonetic, c) analogy or resource based, d) rule-based, e) brute force, and f) other, which means the students ask for the correct word spelling. Definitions, student examples, and teacher instructional techniques deemed as "best practices" are described below for each strategy.

I. Retrieval

Retrieval is a skill students use to spell when they just know it or have memorized the spelling of the word. It is the process of maintaining information over time (Matlin, 2005). Behaviors that help students memorize words include writing the words and paying attention to details of the word spellings. Examples of how students report the use of retrieval are, "Pay attention to your words," "Write them well and write them neat," and "You have to try real hard. Especially when you have to write down hard words."

Appropriate think time after asking students to spell a word will aid them using the retrieval skill. This gives them sufficient time to process and develop a reply to a question before the teachers asks a specific student to respond. Staff Development for Educators (2013) and Gambrell (1980) provide tips for implementation:

1. Give students 3-5 seconds of wait time
2. Some students need more than 5 seconds when the word is difficult

3. Some boys may need up to 60 seconds to recall information
4. Many students from low socio-economic status (SES) or English language learners (ELL) need additional wait time
5. Prepare students by letting them know they have some “think time.” Curbing the desire to answer first with answering accurately
6. Keep an adequate pace.

The teachers’ consistency in keeping students on-task and, just as importantly, keep them accurate in their responses, are important. Wait time allows student not to feel rushed in spelling a word. Carefully controlling the duration of think time is a very important factor in maintaining student attentiveness and providing students with a successful learning experience.

II. Phonetic

When learning to read, students are first taught the sound associated with each letter, then sounds for combinations of letters (ie, sh-, th-, -ion), and how to blend those sounds into words. The same skill for “sounding out a word” to read can also be used to help spell a word. Students can apply the phonetic strategy when spelling words and use self-talk like, “I sound the word out or skip it,” “I ask somebody to sound it out for me,” “I listen to the way people pronounce frequently-used words.”

To teach the phonetic skill, teachers can prepare for lessons ahead of time by identifying the irregular words before the lesson by marking them in some discreet way. Teachers need to make sure to look at the sounds and think about how each letter is supposed to sound. Consistently using this strategy makes for accurate readers who learn how to read “the fast way” and more quickly become fluent spellers. Teachers can use the following format for sounding out:

Step 1. Say the word (Student says: “Mat”).
Step 2: Stretch out it (student says: “Mmmmmaaaaat”).
Step 3: Write the first sound (student writes:” M”).
Step 4: Stretch out it (student says: “Mmmmmaaaaat”).
Step 5: Write the middle sound (student writes: “a”).
Step 6: Stretch out it (student says: “Mmmmmaaaaat”).
Step 7: Write the ending sound (student writes: “t”).
Step 8: Teacher praise: “Yes, good job spelling Mat!”

Teachers will need to model, lead, test, and retest the skill until students learn to use it covertly. The steps can also be listed on a poster for students to refer to when beginning to use the skill independently.

III. Analogy or Resource-Based

Analogy or resource based involves using prior knowledge and word comparisons to spell. When students learn more complex words, analogy or resource based strategies are applied. Using prior knowledge and word comparisons involves students activating what they have previously learned to spell a word. This can range from using a tool to spell the word correctly, to using a previously learned skill. Examples of students reporting on analogy or resource based strategies are: “I find a dictionary. My teacher doesn't tell us how to spell a word.”, “Maybe in language, I tried to use some of my words in language”, or “Yes, because you used the words in a sentence”.

Explicit instruction is an effective approach to teach analogy or resource based. It includes an advanced organizer, modeling, guided practice, independent practice, and feedback in order to promote students' ability to use prior knowledge, and word comparisons for spelling (Miller, 2009). When using an advanced organizer, an instructor activates prior knowledge, tells students what they will learn, and builds relevance. For example, the teacher would review hearing the syllables in multi-syllable words as well as specific spelling rules that would apply to the words that are to be taught. After the advanced organizer, the teacher models his or her thoughts and actions, showing students how to use word comparisons or previous knowledge in spelling. For example, a teacher could say to students: “I need to spell the word 'organic'”. The child could think: “I remember learning that multi-syllable words can end on the letter 'c' and I think 'o' is the first syllable in organic. I am going to write the letters 'o' and 'r' and say the next syllable, then write the sounds I hear.” After modeling the teacher implements guided practice. In guided practice, both the teacher and the students spell words and the teacher prompts the students to explain, why they spelled the word as they did. The teacher constantly checks for the children's understanding and monitors them in the spelling process. After guided practice, students write the words independently. The teacher checks their work and provides feedback.

IV. Rule-Based

The rule-based strategy is where students utilize a certain rule to spell a word. For example, a student applying the rule-based strategy could say to him- or herself: “In my DOL, we had words that we had to add –s or –es to.” When teaching a rule-based strategy, teachers should always begin with introducing the rule. For example the “final e” rule. Here, the teacher writes on the board: “mate, bite, cake, fire.” The procedure is then applied as follows:

Step 1: Teacher says, “Remember our rule: if there is an –e on the end of a word you say the vowel name.” Teacher points to the first word (mate).

Step 2: Teacher says, “Is there an –e on the end of this word?” Students respond: “Yes.”

Step 3: Teacher says, “So what does this vowel say?” (Teacher points to the letter a.) Students respond: /aaaaa/

Step 4: Teacher says, "Yes, put /aaaa/ in the word." Pause. "Get ready." Pause. "What word?"

Students respond: "Mate."

Step 5: Teacher says: "Yes, mate."

(Teacher then goes back to step 2 for the rest of the words. For error correction start back at step 1).

V. Brute Force

Brute force is a description for students who guess when spelling a word. Students need to be taught the skills necessary to be successful spellers and leave nothing to chance. Guessing at how to spell a word is not a viable skill. Examples of students describing brute force could be: "No kind of way. I just try and leave it," "When you try real hard."

To help children to distinguish brute force, teachers should follow these steps: First, when teachers are asked about spelling a word, they should be cognizant not to just tell a student how to spell the particular word, but to refer them to the appropriate skill to spell that word. For instance, a teacher can refer to the aforementioned final –e rule, sounding it out, drop the –e rule, or use familiar rhyming words. If necessary, teachers can model, lead, and test the skill. Next, teachers should move around the classroom looking closely at what the students are doing. It is not sufficient to scan a room from a fixed point; teachers need to get close enough to read what students have written. Active monitoring cannot be done effectively in classrooms where aisles are not wide enough for the teacher to stand on at least two sides of every student. Classroom arrangements that prevent the teacher from easily standing next to any student will have students practicing incorrectly or being off task completely. If space is at a premium, it may be necessary to push two rows of student desks together, so that they sit next to each other in pairs, leaving more room for aisles.

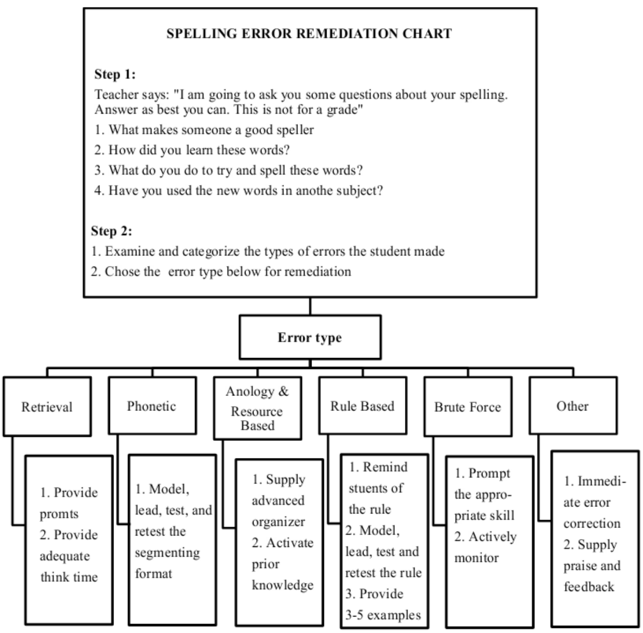
VI. Other

Other is where students rely on others to help them or tell them how to spell a word. Examples of children using other would be, "Ask for help… my teacher will tell me," or "I just ask." One important advantage of involving others is the fact that they can provide error corrections. These procedures offer immediate feedback that students can use to improve their performance (Brophy & Good, 1986; Kinder & Carnine, 1991). Error correction procedures can include a variety of different strategies. Examples include circling incorrect responses on a worksheet or delivering a verbal cue such as, "Double-check your answer." Many curricula ignore the importance of teacher corrections for student mistakes, giving preference instead to allowing (even encouraging) students to discover and learn from their mistakes. Although this discovery learning approach may have some intuitive appeal, research has consistently demonstrated that students receiving teacher-directed programs (that incorporate systematic error correction strategies) consistently outperform students in self-directed learning programs (Becker & Gersten, 1982). In addition to highlighting students' mistakes, error correction can serve an instructive function as well (i.e., by providing information about correct responses).

Conclusion

Many struggling students feel mad, sad, and nervous when they have difficulty spelling a word. Some of them apply maladaptive behavioral strategies, such as hiding their work, or behaving inappropriately so as to avoid work. Students should not have anxieties when learning to spell. The aforementioned remediation skills are only effective when teachers are consistent in implementation. The following figure is a quick and easy guide for teachers to use to determine error type with suggestions for remediation.

Figure 1. ***Error types and strategies for remediation***



In today's classrooms, there are large numbers of students all with varying abilities. Therefore, it is important for teachers to effectively monitor them making them more accurate spellers. Teachers should be constantly moving about the classroom providing feedback when necessary. Being involved in students success' allows for positive learning and positive teaching to exist concurrently.

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Effects of a Simple Relaxation Technique on the Well-Being, the Learning Behavior and the Social Skills of Students with Learning Disabilities

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Creating a productive learning environment in the classroom for academically challenged students is an important goal of special education. Relaxation techniques hold the potential of contributing to reaching this aim. This paper presents an exploratory study conducted with five 8th graders from a special school for learning disabled and mild mentally delayed students in Germany. The participants received Progressive Muscle Relaxation (PMR) in the form of a brief intervention at school. We examined changes in well-being, learning behavior and social skills. Semi-structured interviews with the students and the class teacher were conducted. In addition, the students were observed during training sessions and tested with a standardized attention instrument in a pre-post comparison. Results indicate that the intervention is quite feasible in the school context. All students were able to correctly perform the exercises and the sessions were viewed as helpful by both students and the teacher. However, according to the standardized attention test, concentration did not seem to have improved significantly during the course of the intervention. The results are discussed and implications for applying relaxation training in special schools for children with special educational needs are considered.

Key words: Learning disabilities, relaxation techniques, classroom climate, power of concentration

Introduction

Relaxation techniques are primarily regarded and used as methods for stress management. However, they also seem to bear the potential to positively affect the learning behavior (attention span, memory capacity, motivation, reduction of agitation), the well-being, and the social skills of students with special needs. If applied in a classroom setting, they can contribute to a pleasant and constructive working atmosphere (Petermann, 2007; 2010). Up to now, only a few publications have covered this topic or aspects of it and the research has yielded divergent results. The majority of the studies have been performed on adults in the 1980s. Moreover, many of them have not been conducted in

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the natural environment of the examined persons and have included only small sample sizes (Krampen, 2010; Petermann & Vaitl, 2009). Generally, there is hardly any empirical evidence regarding the acceptance and effectiveness of relaxation methods in children and adolescents. Most of the literature in this regards consists of anecdotal reports (Winkler, 1998). This is particularly true for the application of relaxation methods in school environments (Krampen, 2010; Petermann & Natzke, 2009) and especially regarding the application in the context of special education (Winkler, 1998).

For children and adolescents with academic challenges, creating a productive learning environment and a pleasant class atmosphere is of vital importance. These students need every support they can get in order to enable them to reach their potential. The application of relaxation techniques could contribute to creating the best learning environment possible for them (Wood, 2013). One approach that is relatively easy to learn and to administer is progressive muscle relaxation (PMR), originally developed by Jacobson (1929). Its primary goals are to reduce tension, anxiety, and stress, as well as to enhance self-regulation (Jacobson, 1942). PMR teaches people to consciously concentrate on tensing and relaxing a whole array of muscles in one's body. Participants are supposed to become aware of the difference. This is achieved by tensing specific muscle groups for about five seconds, and then by letting go. The latter state has to be maintained for approximately ten seconds. PMR is termed "progressive", because it systematically proceeds through all major muscle groups (Lopata, Nida, & Marable, 2006).

The technique has been successfully used in preventing aggression in elementary students (Lopata, 2003) and in supporting children with various special needs (e. g. Denkowski & Denkowski, 1984; Moroz, 2000; Muira, Sakano, & Agari, 2000). The purpose of this pilot study is to elicit the feasibility, acceptance and effectiveness of a brief intervention involving PMR with struggling learners. It was expected that the training would be approved by the participants and that it would improve their ability to concentrate.

Method

Participants

The sample consisted of two male and three female eighth graders. They were part of a class of ten students, attending a special school for learning disabled and mild mentally delayed students in the south-western part of Germany. The institution served children and youth with intellectual challenges, who failed to meet the demands in the mainstream curriculum. All of our participants were diagnosed as "learning disabled" by a multi-professional team. The ages of our subjects ranged from 14 to 16 years. One girl had a migration background. Three of the five students already had experience with relaxation exercises (massage, music). The subjects were won through enquiries of the special school teachers.

Instruments

Observation form. During the exercises, a female trained college student of special education filled out an observation form that served as a means to document (1) whether the students seemed to be able to relax during a respective session, (2) whether they closed their eyes, (3) whether their breathing was calm, (4) whether they were able to perform the exercises correctly, and (4) whether any of the participants disturbed the session.

Oral inquiry. At the beginning and at the end of each session, participants were asked about their well-being ("How do you feel today?" and "How do you feel now after the exercises are over?"). After each session they were asked "How do you feel closing your eyes", "Can you sense the difference between tension and relaxation?" The trained college student recorded the answers in writing on a specific form.

Concluding Interviews. Upon completion of the last session, the trained college student inquired of the participants (1) whether they liked the exercises, (2) whether they considered the exercises to be effective, (3) whether they were now better able to relax, (4) whether they noticed a lesser frequency of bodily tensions, 5) whether they were now better able to concentrate, and (6) whether they were motivated to continue with the intervention at home. The trained college student recorded the answers in writing on a specific form. In addition, she also interviewed the teacher about her impressions about the students' acceptance of the exercises, their social behavior, their motivation and any changes in their ability to concentrate.

Attention-to-Detail Test (d2). Prior to the first session and after the last session, the student's ability to concentrate was assessed, using the "Attention-to-Detail Test" (d2) by Brickenkamp (2002). The d2 is a standardized instrument to measure concentration by requiring subjects to coordinate visual and manual activities under time pressure. According to the manual, the test has a split-half reliability of .95.

Intervention

The intervention followed a structured procedure as outlined by Petermann (2010). It consisted of five sessions of 30 minutes in length, which took place on a weekly basis. The training focused on the arms, the eye region, the shoulders, the torso, and legs. Practice took place while seated. The first session served as an introduction. During this initial lesson, students were asked about their knowledge on the effects of stress and about any personal experiences with relaxation methods. They were informed about relaxation methods in general as well as about PMR in particular. Furthermore, rules of behavior were established and agreed upon (e.g., no talking, interrupting others, …). In the remaining four sessions, different exercises were performed. Lessons were always structured in the same way. The introduction was followed by the PMR exercises. At the end, a discussion took place, covering experiences during the relaxation phase and the current state of well-being.

Research Design, Procedure, and Trainer

A single group pre-post study design with interim inquiries and observations was applied. As indicated above, the d2 was administered before and after the intervention. In addition, the participants were observed during and questioned after each session. Finally, concluding interviews were conducted (see above). The sessions were held in a separate, quiet room of the school during regular classroom instruction. An external trainer served as a therapist conducting the relaxation exercises. She was trained in applying PMR to children and studied to become a special school teacher. The students knew her, because she had previously participated in joint cooking activities with them. Thus, a relationship of trust was already established even before the intervention started.

Results

According to the observation of the trained college student, the participants were always able to perform the exercises correctly at the end of each lesson. They appeared to unanimously relax during the sessions, kept their eyes closed when asked to do so, breathed evenly and calmly, and did not disturb the intervention. In 54% of the cases, the students reported that they felt better after the intervention than before – in 46 % of the cases, the well-being at the beginning and at the end was reported to be equally positive. None of the participants reported that their emotional condition decreased in the course of a session. Closing their eyes did not make them feel uncomfortable. They indicated that they were consistently able to sense the difference between tension and relaxation.

During the concluding interview upon completion of the intervention, all participants stated that they liked the exercises and considered them to be effective. They reported an increased ability to relax, due to joining in the training. One student stated: "It feels like being on cloud nine". Three students reported a lesser frequency of bodily tensions, one did not. The remaining participant felt unable to comment on this. Three students reported an improvement in their capacity to concentrate, one student did not notice any difference, and one student did not know. Two students emphasized their willingness to perform the exercises at home, one student considered this as an option, and two students were not sure. According to the class teacher, the participants seemed to enjoy the sessions very much. She reported that the students were always looking forward to the lessons and that they talked about them positively after getting back to their classroom. The class teacher noticed an improvement in the students' social behavior as well as in their general achievement motivation since the beginning of the training. She described the class climate as calmer and more balanced. Supposedly, there were less disturbances. All in all, tlessons

However, a comparison between the degree of attention in the students before and after the intervention, measured with the d2, yielded no significant difference (Wilcoxon signed rank test; $p<.05$).

Discussion

In the present pilot study, we sought to determine whether a simple and easy-to-learn relaxation technique (PMR) is helpful and feasible with learning disabled youth in a regular classroom setting. Inquiries with and observations of students in a special school indicated that the examined approach was well accepted and can be implemented without mentionable difficulties. All participants viewed the exercises to be generally effective and noticed an improved ability to relax. An improvement in well-being (comparisons before and after each session) was reported in 54 % of the comparisons. There were no changes for the worse. More than half of the students indicated that their ability to concentrate had improved. The teacher of our sample also expressed a very favorable opinion regarding PMR. She reported an increase in motivation in all students, improved social behavior and a better class climate. The acceptance of the practice sessions by the students as well as by the teacher was high. In summary, it can be stated that the relaxation sessions can be performed in the school context without any problems occurring and that students are apparently able to correctly perform the exercises as outlined in a manual by Petermann (2010). However, there were no significant pre-post changes in the d2, a standardized test of concentration capacity.

The following arguments give rise to the hope that PMR is an expedient approach to improve the learning environment of students with learning difficulties in the classroom:

- the problem-free feasibility of the exercises in the school context,
- the fact that learning how to perform the exercises was easy for the students,
- the high acceptance of the practice sessions by both the students and the teacher, and
- the positive evaluations of the students and the class teacher, respectively regarding the general effectiveness of the practice sessions, the improved ability to relax and concentrate, the improvement of the well-being, motivation, social behavior and class climate.

However, our study was primarily explorative in nature. Our conclusions are not built on hard data. A great share of our results is predicated on informal inquiries, observations and interviews. The findings could easily feature a bias towards socially desired answers. They reflect subjective value judgements instead of objective measurements. Furthermore, it must be noted that, among other things, our small sample, the low number of practice sessions, as well as our single group pre-post study design limits the validity of our study to a high degree. Changes could easily be attributed to special attention effects.

As mentioned before, the study at hand is primarily to be regarded as explorative in nature. Additional research focusing on the acceptance and effectiveness of relaxation methods in regular classrooms is warrented. For example, the differentiated occupation with potential differential effects of relaxation methods (as the results of our study suggest) and relevant influence variables to the acceptance and effectiveness of the intervention (on the part of the students, the class as well as the type of performance, the spatial conditions, etc.) would be important.

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