Dyslexia

Dyslexia (specific reading disability) is the most well-knownSLD, and characterised by difficulties with accuracy and/or fluent word recognition and by poor spelling and phonological decoding ability (Lyon, Shaywitz, &Shaywitz, 2003). Dyslexia affects at least 10-15% of school age children (Vellutiono et al., 2004) with boys twice as likely to be affected as girls (Rutter et al., 2004). Dyslexia occurs even with normal levels of intelligence, education and socio-economic background (Ramus, 2003).

Reading is not a natural behaviour, but must be learnt and presumably adapts cognitive functions that may have evolved for other purposes. It is without doubt a complex process that takes years to perfect, involving word identification and language comprehension. Word identification requires recognition of an array of alphabetic letters as a familiar word and retrieving the name of the word and its meaning from memory. Language comprehension is an integration of word meanings into a deeper understanding of ideas conveyed by sentences. Written language comprehension is dependent on word identification, but word identification also depends on comprehension as the ongoing expectation of a sentence develops during reading. Nevertheless, in early readers, word identification is the limiting process, regardless of language comprehension, whereas language comprehension becomes the limiting process in advanced readers. There is ample evidence that (developmental) dyslexia is a problem in word identification (Vellutino et al., 2004).

Word identification requires discriminating sequences of small visual symbols and translating them into phonemic sequences of sounds (Stein & Walsh, 1997).Over the years, different schools of thought have emerged. One school proposes that dyslexia is a linguistic deficit in which phonemes are poorly constructed from alphabetic sequences - the “phonological school”. There is alsosome recent evidence that auditory function may also be affected.However, it is difficult to explain the number of other deficits experienced by dyslexics, such as clumsiness, temporal sequencing problems, poor spatial localisation, spatial orientation, and directing auditory and visual attention (Stein & Walsh, 1997). The “visual school”, on the other hand, argues that the deficit lies in the visuomotor system, either as a deficit in visual perception (dorsal stream), visual attention,or in oculomotor control.Both schools claim experimental support, and the pendulum of popularity has swung back and forth between these two approaches for decades. With the advent of fMRI, however, there is now clear evidence that both auditory and visual cortices are modified by literacy training (Dahaene et al. 2010). Some have raised the issue of causality. Do visual deficits lead to linguistic problems, or do phonological deficits lead to visual disturbances? Based on fMRI, OLulade et al (2013) have shown that visual deficits cortical visual area V5 are affected by reading, implying that at least the dorsal stream deficit seen in dyslexics is an epiphenomenon of the dyslexia - not a cause. However, this is controversial, and it has been argued that attentional deficits could arise from poor dorsal stream function, and which could have top-down effects on reading (Gori &Facoetti, 2014). Thus, the debate continues.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Phonological Approach

Poor phonological processing is a core feature of dyslexia and is consistently related to poor reading (Vidyasagar&Pammer, 2009). Some studies show that up to 100% of sampled (dyslexic) participants (n=16) can be affected by phonological deficits (Ramus et al., 2003). Phonological theories argue that dyslexia is a direct result of cognitive deficits in the processing and representation of those speech sounds (for a review, see Beaton, 2004). However, some cases of dyslexia are not characterised by phonological deficits, but instead by failures in processing irregular words (Castles &Coltheart, 1993).

Interventions

The best documented methods for teaching a student with phonological dyslexia are largely based on principles of the Orton-Gillingham approach to reading that was developed in the 1930's by Samuel Torrey Orton and Anna Gillingham.

Their approach includes the following six elements:

1. Personalized: Teaching begins with recognizing the differing needs of learners.
2. Multisensory: Involve regular interaction between the teacher and the student and the simultaneous use of multiple senses including auditory, visual, and kinesthetic (touch). For example, a dyslexic learner is taught to see the letter A, say its name and sound and write it in the air – all at the same time. The use of multisensory input is thought to enhance memory storage and retrieval.
3. Structured, Systematic, Sequential, and Cumulative: Language elements and rules are introduced in a linguistically logical, understandable order. Students go back to the very beginning of their language learning, to lay a proper foundation.
4. Beginning by reading and writing sounds in isolation (phonemes), then blending sounds into syllables and words. Elements of language—consonants, vowels, digraph blends, and diphthongs are introduced in an orderly fashion. Only later, learners proceed to advanced structural elements such as syllable types, roots, prefixes and suffixes.
5. Cognitive: Students study the many generalizations and rules that govern the structure of language.
6. Flexible: Instructors ensure the learner is not simply recognising a pattern and applying it without understanding. When confusion of a previously taught rule is discovered, it is re-taught from the beginning.
7. Personal and Direct: Building a close teacher-student relationship with continuous feedback and positive reinforcement leading to success and self confidence.

Programs that work (from http://www.dyslexia-reading-well.com/dyslexia-treatment.html):

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

- described in Sally Shaywitz's book "Overcoming dyslexia"
- the Orton Gillingham approach (described here: http://www.dyslexia-reading-well.com/orton-gillingham.html)
- theLindamood Bell method (described here: http://www.dyslexia-reading-well.com/lindamood-bell.html); it can be said that it incorporates the OG method, plus something more; they have a focus on the articulation and perception of sounds.

Auditory Aspects

Over the years, developmental dyslexia has been associated with various deficits, including poorer phonological awareness, speech in noise perception, working memory and attention. More recent work shows some specific temporal processing deficits which can be used as a basis for early screening and pre-literacy interventions. Firstly, those with poorer reading skills show greater variability in the auditory brainstem responses (ABRs) than normal readers (see figure 1) (Hornickel & Kraus, 2013). Variability in ABRs specifically in response to speech sounds, longer latency responses, and higher degradation in the presence of noise (Hornickel et al., 2011) are all factors which would make it harder for the developing brain to form stable representations of the sounds of their native language. These temporal deficits at the time scale of 10's of milliseconds, are interestingly not evident in normal hearing tests of peripheral processing or in ABRs to click trains. Secondly, phonological awareness correlates strongly with temporal processing at the time scale of the syllable (~2Hz); a) the ability to entrain to an external temporal signal (beat) is predictive of phonological awareness (figure 2) (Woodruff Carr et al., 2014), rhythmic production (remembering and reproducing short rhythmic patterns, ~8 notes) predicts phonological abilities (Flaugnacco et al., 2014), and deficits in neural encoding of the speech envelope is strongly linked to developmental dyslexia (Goswami et al., 2011). While early musical experience has often been suggested as an intervention, e.g. Patel(Patel, 2011), the lack of randomised trials and idiosyncratic training means that conclusive evidence for its efficacy is still lacking (Cogo-Moreira et al., 2012). Nevertheless, in its promotion of sensorimotor integration, engagement with the emotional and reward systems, and use of regular patterns which encourage development of predictive representations, musical training may have beneficial effects. However, these benefits may only be realised within a social context (e.g. improvements in beat synchronisation abilities of 2-3 year olds were only achieved within a social/imitative context (Kirschner & Tomasello, 2009)).

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

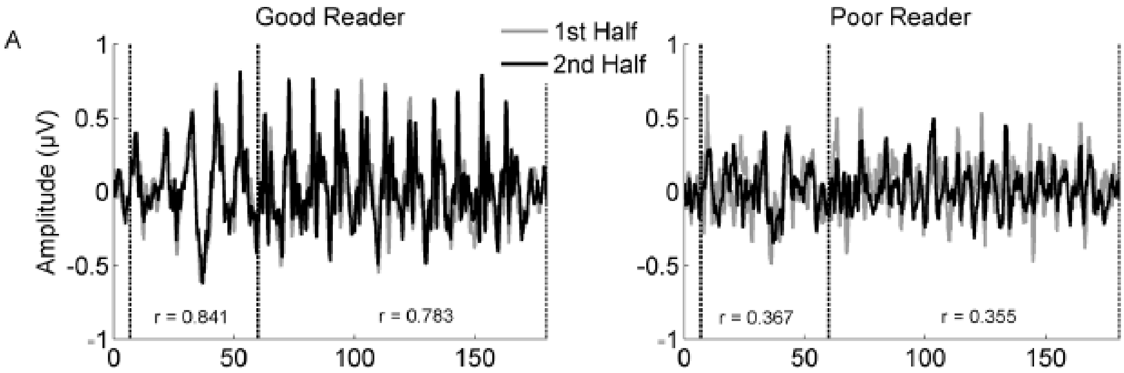

Figure 1. Auditory brainstem responses are more vairable in poor readers than in good readers (from(Hornickel & Kraus, 2013)).

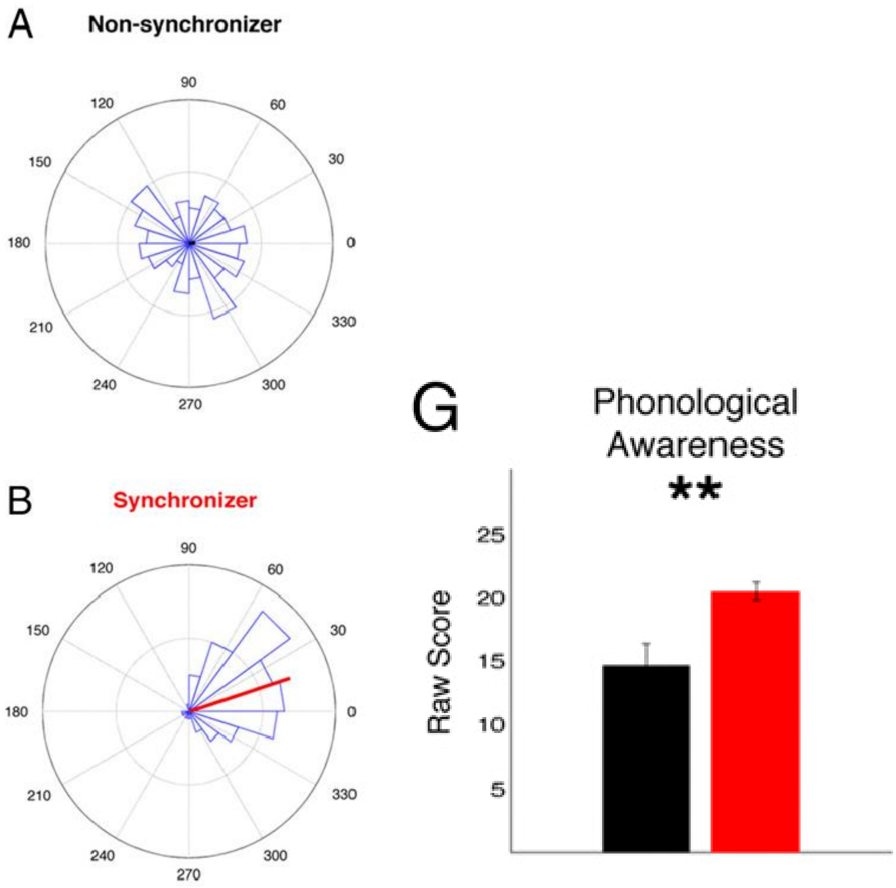

Figure 2. synchronisation to an external beat (tapping) is associated with phonological awareness, from(Woodruff Carr et al., 2014)

It is possible that neither school is incorrect. Interaction among sub-networks is typical of biological development, and causality is elusive (Harris, 2011). From the ALS perspective it would not be prudent to back the wrong 'horse', and we propose that both phonological and

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

visual attention interventions should be adopted. However, we recognise that visual manipulations are probably more easily implemented than phonological ones.

Visuo-Spatial Function

Learning to read is a perceptually taxing task requiring fine auditory, visual and motor skill. Vidyasagar and Pammer (2009) argue that one of the most relevant neurocognitive functions employed during reading are the same top-down visual-spatial attentional mechanisms used for visual search. The visual system consists of two parallel processing streams specialised to perform particular tasks. The dorsal stream is associated with spatial localisation and visually guided action, and the ventral stream is associated with object and form recognition (for a review, see Grill-Spector &Malach, 2004). To read, the dorsal stream employs an attention spotlight which guides visual attention to extract the spatial sequences of letters in words. A gating function in the dorsal stream parses whole and parts of words which are input to ventral visual pathway for detailed processing. A deficit in the dorsal stream may result in poorer allocation of spatial attention and thus reading deficits, both of which are characteristic of dyslexia (Vidyasagar&Pammer, 2009; Schneps, Thomson, Chen, Sonnert, &Pomplun, 2013a; Schneps et al., 2013b).

Evidence for visual spatial attention deficits - visual search

Vidyasagar andPammer (2009) argue that dorsal stream deficits in dyslexia should be made apparent using visual search paradigms. They argue that serial visual search requires the dorsal stream to select information in visual scenes for detailed ventral processing, as with reading. In visual search tasks, participants are required to detect a target item amongst a number of distractor items. When time to detect a target is not dependent on the number of distracters, the task is a parallel search task. If time to detect a target is dependent on distracter items then the task is a serial search task. In conjunction search tasks, targets differ from distractor items across two or more dimensions (e.g., orientation and colour) and are serial as time taken to find targets increases linearly with number of distractors. Serial search tasks are thought to tap parietal lobe functioning due to the requirement for shifting attention across space (Jones, Branigan, & Kelly, 2007).

Vidyasagar and Pammer (1999) explored serial visual search using conjunction search tasks in reading impaired and age matched normal reading children. The authors report that dyslexic children show impaired performance compared with normal readers when number of distracter items was large. Similar findings are reported by Sireteanu et al. (2008) who found that dyslexic children were impaired on conjunction search tasks, where dyslexic children were faster but less accurate in detecting letter-like stimuli amongst distractors, but slower and less accurate when detecting non-letter-like distractors. However, the search deficits in dyslexic children reported were less apparent in groups of older children (between ages 8-13 years old).Associations between poor visual search in a letter cancellation task and poor reading performance have also been reported by Casco, Tressoldi, and Dellantonio (1998). Another study reports that high performing adult dyslexic

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

readers show poorer performance on a visual search task than normal readers, but also that visual search performance was negatively correlated with phonological decoding tasks of non-word reading (r = -.416, p< .01) as well as rapid automized naming (r = -.275, p< .05). Further, regression analysis showed that visual search performance predicts non-word reading (Jones et al., 2007).

These studies provide more direct evidence that visual-spatial attention is related to reading ability, and that deficit in this ability are associated with poorer reading skills observed in dyslexia.We now explore how paradigms have been used to understand differences in the distribution of visual spatial attention between dyslexic and normal readers

Evidence for diffused and asymmetric visual-spatial attention in dyslexia

Evidence suggests that people with dyslexia have a broader visual attention gradient, showing poorer inhibition of information from the periphery (Facoetti, Paganoni, &Lorusso, 2000; Facoetti et al., 2006; Geiger et al., 2008; Geiger &Lettvin, 1987; Geiger, Lettvin, &Fahle, 1994; Geiger, Lettvin, &Zegarra-Moran, 1992; Lorusso et al., 2004; Lorusso, Facoetti, Toraldo, &Molteni, 2005;Schneps, Rose, & Fischer, 2007). The peripheral bias in dyslexia was demonstrated by Geiger and colleagues in studies of lateral masking, the inhibition of background and flanking stimuli which enhances foveal information. It is argued that reading problems in dyslexia may result from a mislearned use of lateral masking (Geiger &Lettvin, 2000). To study this hypothesis, Geiger and Lettvin (1987) developed a visual perception task called the Form-Resolving Field (FRF), which measures accuracy of letter recognition across a horizontal axis.

Geiger and Lettvin (1987) used a tachistoscope to briefly present adult dyslexic and normal readers with pairs of letters simultaneously to a central fixation point and to eccentricities of 2.5°, 5°, 7.5°, 10° and 12.5° of the right visual field. Successful performance in this task requires accurate identification of both letters and the FRF is found by plotting correct recognition rates at various eccentricities. The study found that ordinary readers show the greatest accuracy in letter recognition when letter pairs were presented within a more central visual angle < 5° with a sharp drop in accuracy as eccentricity increases. However, the surprising finding was the FRF of dyslexic groups differed from normal readers, as they displayed stable recognition rates up to peripheral eccentricities of 10° before dropping at 12.5°. So, the FRF in normal readers is narrow, and in dyslexia the FRF is wider as demonstrated by greaterperipheral accuracy. Similar findings were reported elsewhere (Geiger et al., 2008; Lorusso et al., 2004; Lorusso et al., 2005; Perry, Dember, Warm, & Sacks, 1989) but not all report performance differences between dyslexic and non-dyslexic readers (Bjaalid, Hoien, & Lundberg, 1993; Goolkasian& King, 1990; Klein, Berry, Briand, D'Entremont, & Farmer, 1990).

The work by Geiger and colleagues argues that lateral masking (or lack of) is a learned perceptual strategy in reading. The concept of crowding is relevant here as it refers to how we process information in peripheral vision. Crowding is the difficulty recognising letters surrounded by other letters in the periphery characterised by excessive feature integration and inappropriate inclusion of surrounding features during target (e.g., word)

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

recognition. When we read, we have an uncrowded central window through which we can read, and a crowded peripheral window through which we cannot read. Reading is thus limited to the visual span of the central window, which is simply the number of characters that are not crowded (Pelli et al., 2007). Crowding effects are increased in dyslexia, and increased crowing is associated with slower letter processing in children (Spinelli, De Luca, Judica, &Zoccolotti, 2002) and poorer reading and spelling scores in adults with dyslexia (Moores, Cassim, & Talcott, 2011). Enhanced crowding effects may be the result of visual-spatial attention deficits in dyslexia.

Facoetti et al. (2000) present evidence using visual attention measures that visual attentional resources are more diffused over the visual fields in dyslexia. There is also evidence that attention is not distributed equally across visual fields in dyslexia. Spatial cueing paradigms (Posner, 1980) demonstrate dyslexic asymmetry in covert spatial orientation across visual fields. Using a spatial cueing paradigm Facoetti, Turatto, Lorusso and Mascetti (2001) showed that dyslexic children show lack of inhibition of information in the right visual field when they are attending to the left visual field and tend to neglect information in the left visual field when attending to the right visual field. Similar findings are reported using flanker tasks (Facoetti&Turatto, 2000). Facoetti et al. (2006) show that asymmetry in the spatial cueing paradigm predicts impaired non-word reading in dyslexic children, which specifically links deficits in visual-spatial attention to dyslexia. In addition, the FRF is asymmetric in dyslexia (Geiger &Lettvin, 2000; Geiger et al., 1992; Lorusso et al., 2004; Lorusso et al., 2005) where recognition accuracy is higher in the peripheral field which corresponds to reading direction (cf. Geiger et al., 2008). Furthermore, Lorusso et al. (2004) also show that the wider more diffused gradient of visual attention does not differ according to dyslexia subtypes and therefore may be general to the dyslexic population. Attention shifting also appears sluggish in people with dyslexia. For example, dyslexic groups are shown to be slower than normal readers when processing stimuli presented to the left vs. right hemifield (Facoetti&Molteni, 2001). Others report attentional capture is sluggish over both visual fields in dyslexia (Facoetti, Lorusso, Cattaneo, Galli, &Molteni, 2005; Hari et al., 2001). The attention bias and sluggish attention may be intensified during reading. If attention is slow to disengage from previously fixated words the effects of crowding are thus exaggerating (Schneps et al., 2013b).

Visual-spatial interventions to improve reading in dyslexia

Interventions reviewed here come in two forms. Some aim to train visual spatial attention mechanisms in dyslexic people to operate as those in normal readers. Others aim to modify text displays to provide an optimal fit the visual attention span of those with dyslexia. Some apply both methods as we shall see in the first example.

Attention training and crowding interventions

Gieger and Lettvin (2000)argue that the differences in FRF are learned task dependent perceptual strategies that can be modified through training. Geiger et al. (1992) shows that

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

the FRF of severe adult dyslexics show little variation over time. However when adult dyslexics practice a new regime which emphasizes use of focussed attention, reading ability improves and the FRF narrows to that of normal readers (for a review, see Geiger &Lettvin, 2000; Geiger et al., 1994; Lorusso et al., 2005). The training regime by Geiger et al. (1992) aimed to teach dyslexic people to 1) mask text surrounding a word and to direct attention to the word to be read, 2) practice reading word by word, and 3) practice the recognition of word forms. The regime consisted of two complementary tasks. Participants were asked to complete small scale, hand-eye coordination tasks like drawing or painting for 1-2 hours a day. Following this, participants were asked to practice reading using a reading aid, a specially designed mask laid on text with a small window isolating single words to be read,for 1 hour a day. Participants could shift the window along lines of text, masking surrounding text and thusreducing crowding and allowing greater focus on single word reading. Daily practice for 4-6 months narrowed the FRF and improved reading ability dramatically in severe adult dyslexics (Geiger et al., 1992). In a controlled examination of the new reading strategy in dyslexic children aged approximately 11 years old, Geiger et al. (1994) found that dyslexic children also demonstrate narrowing of the FRF and improved reading ability and that the new regime was more effective than general remedial interventions.

The studies by Geiger and colleagues appear to offer an effective albeit time consuming remediation to reading difficulties experienced by people with dyslexia. However, the studies are now quite dated in regards to technology available today. More recent research has identified the value of e-readers in reading interventions, offering new ways of displaying texts better suited for the atypical neural functioning of those with dyslexia. Indeed, people with dyslexia are known to report how reading is easier on e-reading devices (Schneps et al., 2013a).

Optimising text displays using e-readers

Schneps, O'Keeffe, Heffner-Wong, andSonnert (2010) argued that reformatting text into narrow columns in e-readers and presenting only a few words per line is better matched to the larger peripheral span of those with dyslexia. A study by Schneps et al. (2013b) looked at the role of e-readers in addressing problems associated with dyslexia, such as poor oculomotor control and deficits in visual-spatial attention span. They used eye tracking to monitor eye movements during reading in high school students with dyslexia whilst they used traditional texts or e-readers. More specifically, the authors were interested in the effects of attention on holding the device in the hand (HAND vs NO HAND), the effects of line width using devices of different size (IPOD vs IPAD), and effects of letter spacing in words (SPACED vs NORMAL). Overall, findings show that using a smaller device (IPOD) improved reading speed by 27%, reduced number of fixations by 11% and reduced regressive saccades by more than a factor of 2. All these improvements came at no cost to comprehension. However, the authors argue that the benefit of device size is entirely down to the device linewidth, since the IPOD displayed 2.19 words per line (12.7 characters) and the IPAD displayed 11.6 words per line (67.2 characters). Increased letter spacing improved comprehension in dyslexic readers, however dyslexic students with poor visual attention span (measured using a six letter global report task - number of letters correctly identified) incurred an oculomotor cost making more fixations which slowed their reading.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Another study by Schneps et al. (2013a) compared the speed and comprehensionof reading in high school students with dyslexia (n=103) who used either paper or an IPOD e-reader with modified short line text. They found that reading speed and comprehension was significantly improved in subset of dyslexic readers who read from IPOD with shorter lines. More specifically, those with phonological decoding or sight word reading deficits read faster on the IPOD, and those with visual attention span deficits as measured with using the global report task gained in comprehension.

Overall, the findings by Schneps and colleagues show that effective interventions are available with modern e-reader technology. Dyslexia is associated with poor oculomotor control, but e-readers with shorter lines of text and larger fonts reduce demands of fixation accuracy. Furthermore, because text scrolling is operated manually, the oculomotor demands for tracking gaze are reduced. Shorter lines also reduce crowding of surrounding text and helps inhibit text previously read. Thisfacilitates reading in with dyslexic people sluggish attention shifting and crowding problems by guiding attention to the uncrowded attention span using a narrower window of text (Schneps et al., 2013a; Schneps et al., 2013b).

Fun computer game interventions improve visual-spatial attention

Playing action video games has a positive effect on visual-spatial attention. Green and Bavelier (2003) have found that people who play video games (VGP) outperform non video game players (NVGP), showing enhanced attentional resources and greater spatial distributions of attention. Other researchers have also demonstrated that VGP of all ages show enhanced visual spatial attention compared with NVGP (e.g., Dye, Green, & Bavelier, 2009). As video games may have positive effect on attention, Franceschini et al. (2013) explored the effects of video games on children with dyslexia, proposing that action game training should produce improvements in attention which manifest in improved reading abilities. Franceschini et al. (2013) measured pre-post attention and reading ability in Italian dyslexic children assigned to either action video game treatment condition (VGP; n=10) or non-action video game control condition (NVGP; n=10). Gaming took place for 12-hours over 9 days using mini-games in a commercial video game called "Rayman Raving Rabbids". The authors report that children assigned to the AVG treatment group had greatest improvements post-treatment showing faster general reading, pseudo-word reading and word test reading, without decrements in accuracy. In addition, scores in measures of focussed and distributed attention also increased in AVG groups post-treatment. Regression analysis revealed that the attentional enhancements accounted for ~50% of unique variance in reading improvements ($R^2 = .48$, $p < .01$). Franceschini et al. (2013) conclude that AVG training could thus be part of an effective low-resource-demanding early prevention program that could reduce the incidence of reading disorders. However, whilst speed of reading in the children improved following AVG treatment, comprehension was not assessed and so the there is no evidence that AVG actually helps dyslexic children comprehend and understand text (Bavelier, Green, & Seidenberg, 2013).

Visual Spatial Intervention Summary

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Interventions reviewed take form of attention training, modification of reading materials, or both. The work of Geiger and colleagues shows that a new reading strategy emphasising focused attention and modification of text to reduce crowding can improve reading ability in adults and children, albeit at a heavy investment of time and resources. The promising research by Schneps et al. (2013a) and Schneps et al. (2013b) show that manipulating texts on e-readers has value for improving reading speed and comprehension in people with dyslexia. Action gaming also may also provide valuable intervention for training attention systems. Whilst the action mini-games used in the Franceschini et al. (2013) emphasized visuo-motor control, precision aiming and precise motor action, divided attention and planning, a greater understanding how AVG treatment can improve reading will be useful for designing games for fun intervention for children and adults with dyslexia (Bavelier et al., 2013).

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

References

Beaton, A. (2004). Dyslexia, reading and the brain: A sourcebook of psychological and biological research. Easy Sussex, UK: Psychology press.

Bjaalid, I. K., Hoien, T., & Lundberg, I. (1993). Letter identification and lateral masking in dyslexics and normal readers. Scandanavian Journal of Educational Research, 37, 151-161.

Casco, C., Tressoldi, P. E., &Dellantonio, A. (1998). Visual selective attention and reading efficiency are related in children. Cortex, 34, 531-546.

Castles, A., &Coltheart, M. (1993). Varieties of developmental dyslexia. Cognition, 47, 149-180.

Cogo-Moreira, H., Andriolo, R. B., Yazigi, L., Ploubidis, G. B., Brandao de Avila, C. R., & Mari, J. J. (2012). Music education for improving reading skills in children and adolescents with dyslexia. Cochrane Database Syst Rev, 8, CD009133. doi: 10.1002/14651858.CD009133.pub2

Dehaene, Stanislas, Felipe Pegado, Lucia W. Braga, Paulo Ventura, Gilberto NunesFilho, Antoinette Jobert, GhislaineDehaene-Lambertz, Régine Kolinsky, José Morais, and Laurent Cohen. 2010. “How Learning to Read Changes the Cortical Networks for Vision and Language.” Science 330 (6009): 1359–64. doi:10.1126/science.1194140.

Dynarski, M., R. Agodini, S. Heaviside, T. Novak, N. Carey, L. Campuzano, B. Means, et al. 2007Dynarski, M.; Agodini, R.; Heaviside, S.; Novak, T.; Carey, N.; Campuzano, L.; Means, B.; Murphy, R.; Penuel, W.; Javitz, H.; Emery, D.; Sussex, W. “Effectiveness of Reading and Mathematics Software Products: Findings from the First Student Cohort.” U.S. Department of Education, Institute of Education Sciences.

Dye, M. W., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. Neuropsychologia, 47, 1780-1789.

Facoetti, A., Lorusso, M. L., Cattaneo, C., Galli, R., & Molteni, M. (2005). Visual and auditory attentional capture are both sluggish in children with developmental dyslexia. ActaNeurobiologiaeExperimentalis, 65, 61-72.

Facoetti, A., &Molteni, M. (2001). The gradient of visual attention in developmental dyslexia. Neuropsychologia, 39, 352-357.

Facoetti, A., Paganoni, P., &Lorusso, M. L. (2000). The spatial distribution of visual attention in developmental dyslexia. Experimental Brain Research, 132, 531-538.

Facoetti, A., &Turatto, M. (2000). Asymmetrical visual fields distribution of attention in dyslexic children: a neuropsychological study. Neuroscience Letters, 290, 216-218.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Facoetti, A., Turatto, M., Lorusso, M. L., & Mascetti, G. G. (2001). Orienting of visual attention in dyslexia: evidence for asymmetric hemispheric control of attention. Experimental Brain Research, 138, 46-53.

Facoetti, A., Zorzi, M., Cestnick, L., Lorusso, M. L., Molteni, M., Paganoni, P., ... &Mascetti, G. G. (2006). The relationship between visuo-spatial attention and nonword reading in developmental dyslexia. Cognitive Neuropsychology, 23, 841-855.

Flaugnacco, E., Lopez, L., Terribili, C., Zoia, S., Buda, S., Tilli, S., Monasta, L., Montico, M., Sila, A., Ronfani, L., & Schon, D. (2014). Rhythm perception and production predict reading abilities in developmental dyslexia. Front Hum Neurosci, 8, 392. doi: 10.3389/fnhum.2014.00392

Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M., & Facoetti, A. (2013). Action video games make dyslexic children read better. Current Biology, 23, 462-466.

Geiger, G. (2000). Developmental Dyslexia: a Different Perceptual Strategy and How to Learn a New Strategy for Reading. Child Development and Disabilities, 26, 73-89.

Geiger, G., Cattaneo, C., Galli, R., Pozzoli, U., Lorusso, M. L., Facoetti, A., &Molteni, M. (2008). Wide and diffuse perceptual modes characterize dyslexics in vision and audition. Perception, 37, 1745-1764.

Geiger, G., &Lettvin, J. Y. (1987). Peripheral vision in persons with dyslexia. New England Journal of Medicine, 316, 1238-1243.

Geiger, G., Lettvin, J. Y., &Fahle, M. (1994). Dyslexic children learn a new visual strategy for reading: a controlled experiment. Vision Research, 34, 1223-1233.

Geiger, G., Lettvin, J. Y., &Zegarra-Moran, O. (1992). Task-determined strategies of visual process. Cognitive Brain Research, 1, 39-52.

Goolkasian, P., & King, J. (1990). Letter identification and lateral masking in dyslexic and average readers. American Journal of Psychology, 103, 519-538.

Goswami, U., Wang, H. L., Cruz, A., Fosker, T., Mead, N., & Huss, M. (2011). Language-universal sensory deficits in developmental dyslexia: English, Spanish, and Chinese. J Cogn Neurosci, 23(2), 325-337. doi: 10.1162/jocn.2010.21453

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. Nature, 423, 534-537.

Grill-Spector, K., &Malach, R. (2004). The human visual cortex. Annual Review of Neuroscience, 27, 649-677.

Hari, R., Renvall, H., &Tanskanen, T. (2001). Left minineglect in dyslexic adults. Brain, 124, 1373-1380.

Harris CM (2011) Oculomotor developmental pathology: an evo-devo perspective. In Oxford Handbook of Eye Movements eds. S Liversidege, I Gilchrist, S Everling Oxford University Press, Oxford. pp. 663-686.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Helland, Turid, Tomas Tjus, MaritHovden, Sonja Ofte, and Mikael Heimann. (2011). Effects of Bottom-up and Top-down Intervention Principles in Emergent Literacy in Children at Risk of Developmental Dyslexia: A Longitudinal Study. J Learn Disabil. 44 (2): 105–22.

Hornickel, J., & Kraus, N. (2013). Unstable representation of sound: a biological marker of dyslexia. J Neurosci, 33(8), 3500-3504. doi: 10.1523/JNEUROSCI.4205-12.2013

Hornickel, J., Chandrasekaran, B., Zecker, S., & Kraus, N. (2011). Auditory brainstem measures predict reading and speech-in-noise perception in school-aged children. Behav Brain Res, 216(2), 597-605. doi: 10.1016/j.bbr.2010.08.051

Kirschner, S., & Tomasello, M. (2009). Joint drumming: social context facilitates synchronization in preschool children. J Exp Child Psychol, 102(3), 299-314. doi: 10.1016/j.jecp.2008.07.005

Jones, M. W., Branigan, H. P., & Kelly, M. L. (2008). Visual deficits in developmental dyslexia: relationships between non-linguistic visual tasks and their contribution to components of reading. Dyslexia, 14, 95-115.

Klein, R., Berry, G., Briand, K., D'Entremont, B., & Farmer, M. (1990). Letter identification declines with increasing retinal eccentricity at the same rate for normal and dyslexic readers. Perception and Psychophysics, 47, 601-606.

Lorusso, M. L., Facoetti, A., Pesenti, S., Cattaneo, C., Molteni, M., & Geiger, G. (2004). Wider recognition in peripheral vision common to different subtypes of dyslexia. Vision Research, 44, 2413-2424.

Lorusso, M. L., Facoetti, A., Toraldo, A., & Molteni, M. (2005). Tachistoscopic treatment of dyslexia changes the distribution of visual–spatial attention. Brain and Cognition, 57, 135-142.

Lundberg, I., Frost J., and O.-P. Peterson. (1988). Effects of an Extensive Program for Stimulating Phonological Awareness in Preschool Children. Reading Research Quarterly 7 (2). Kluwer Academic Publishers: 171–88. doi:10.1007/BF01027184.

Lyon, G. R., Shaywitz, S. E., &Shaywitz, B. A. (2003). A definition of dyslexia. Annals of Dyslexia, 53, 1-14.

Mathes, PG., Carolyn A. Denton, Jack M. Fletcher, Jason L. Anthony, David J. Francis, and Christopher Schatschneider. (2005). The Effects of Theoretically Different Instruction and Student Characteristics on the Skills of Struggling Readers. Reading Research Quarterly 40 (2). Blackwell Publishing Ltd: 148–82. doi:10.1598/RRQ.40.2.2.

Moores, E., Cassim, R., & Talcott, J. B. (2011). Adults with dyslexia exhibit large effects of crowding, increased dependence on cues, and detrimental effects of distractors in visual search tasks. Neuropsychologia, 49, 3881-3890.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Nicolson, Roderick I, Angela J Fawcett, and Paul Dean (2001). “Developmental Dyslexia: The Cerebellar Deficit Hypothesis.” Trends in Neurosciences 24 (9): 508–11. doi:http://dx.doi.org/10.1016/S0166-2236(00)01896-8.

Olson, Richard K, Barbara Wise, Jerry Ring, and Mina Johnson. (1997). Computer-Based Remedial Training in Phoneme Awareness and Phonological Decoding: Effects on the Posttraining Development of Word Recognition. Scientific Studies of Reading 1 (3). Taylor & Francis: 235–53.

Olulade, Olumide A., Eileen M. Napoliello, and Guinevere F. Eden. (2013.) Abnormal Visual Motion Processing Is Not a Cause of Dyslexia.” Neuron 79 (1): 180–90. doi:http://dx.doi.org/10.1016/j.neuron.2013.05.002.

Patel, A. D. (2011). Why would Musical Training Benefit the Neural Encoding of Speech? The OPERA Hypothesis. Front Psychol, 2, 142. doi: 10.3389/fpsyg.2011.00142

Pelli, D. G., Tillman, K. A., Freeman, J., Su, M., Berger, T. D., &Majaj, N. J. (2007). Crowding and eccentricity determine reading rate. Journal of Vision, 7, 20.

Perry, A. R., Dember, W. N., Warm, J. S., & Sacks, J. G. (1989). Letter identification in normal and dyslexic readers: a verification. Bulletin of the Psychonomic Society, 27, 445-448.

Posner, M. I. (1980). Orienting of attention. Quarterly Journal of Experimental Psychology, 32, 3-25.

Ramus, F. (2003). Developmental dyslexia: specific phonological deficit or general sensorimotor dysfunction? Current Opinion in Neurobiology, 13, 212-218.

Ramus, Franck. 2003. “Developmental Dyslexia: Specific Phonological Deficit or General Sensorimotor Dysfunction?” Current Opinion in Neurobiology 13 (2): 212–18. doi:http://dx.doi.org/10.1016/S0959-4388(03)00035-7.

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. Brain, 126, 841-865.

Schneps, M. H., O'Keeffe, J. K., Heffner-Wong, A., & Sonnert, G. (2010). Using technology to support STEM reading. Journal of Special Education Technology, 25, 21.

Schneps, M. H., Rose, L. T., & Fischer, K. W. (2007). Visual learning and the brain: Implications for dyslexia. Mind, Brain, and Education, 1, 128-139.

Schneps, M. H., Thomson, J. M., Chen, C., Sonnert, G., &Pomplun, M. (2013a). E-readers are more effective than paper for some with dyslexia. PloS One, 8, e75634.

Schneps, M. H., Thomson, J. M., Sonnert, G., Pomplun, M., Chen, C., & Heffner-Wong, A. (2013b). Shorter lines facilitate reading in those who struggle. PloS One, 8(8), e71161.

Sireteanu, R., Goebel, C., Goertz, R., Werner, I., Nalewajko, M., &Thiel, A. (2008). Impaired serial visual search in children with developmental dyslexia. Annals of the New York Academy of Sciences, 1145, 199-211.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Snow, C.E., Burns M.S., and P. Griffin. (1998). Preventing Reading Difficulties in Young Children. Edited by Burns Snow C.E. and P. Griffin. Washington, DC: National Academy Press.

Spinelli, D., De Luca, M., Judica, A., & Zoccolotti, P. (2002). Crowding effects on word identification in developmental dyslexia. Cortex, 38, 179-200.

Stein, J., & Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia. Trends in Neurosciences, 20, 147-152.

Torgesen, JosephK.,RichardK. Wagner, CarolA. Rashotte, Jeannine Herron, and Patricia Lindamood. (2010). “Computer-Assisted Instruction to Prevent Early Reading Difficulties in Students at Risk for Dyslexia: Outcomes from Two Instructional Approaches.” Annals of Dyslexia 60 (1). Springer US: 40–56. doi:10.1007/s11881-009-0032-y.

Ukrainetz, Teresa A, Margaret H Cooney, Sarah K Dyer, Aimee J Kysar, and Trina J Harris. (2000). An Investigation into Teaching Phonemic Awareness Through Shared Reading and Writing. Early Childhood Research Quarterly 15 (3): 331–55. doi:http://dx.doi.org/10.1016/S0885-2006(00)00070-3.

Vidyasagar, T. R., &Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. Trends in Cognitive Sciences, 14, 57-63.

Woodruff Carr, K., White-Schwoch, T., Tierney, A. T., Strait, D. L., & Kraus, N. (2014). Beat synchronization predicts neural speech encoding and reading readiness in preschoolers. Proc Natl Acad Sci U S A, 111(40), 14559-14564. doi: 10.1073/pnas.1406219111

Yeh, Stuart S. (2003). “An Evaluation of Two Approaches for Teaching Phonemic Awareness to Children in Head Start.” Early Childhood Research Quarterly 18 (4): 513–29. doi:http://dx.doi.org/10.1016/j.ecresq.2003.09.009.

This project was financed with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.