Computer Science and Artificial Intelligence Laboratory

Technical Report

MIT-CSAIL-TR-2005-065
AIM-2005-029
CBCL-256

October 18, 2005

Towards the Prevention of Dyslexia

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Towards the prevention of dyslexia

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This report describes research that was sponsored by a grant from an anonymous foundation.

Abstract
Previous studies have shown that dyslexic individuals who supplement windowed reading practice with intensive small-scale hand-eye coordination tasks exhibit marked improvement in their reading skills. Here we examine whether similar hand-eye coordination activities, in the form of artwork performed by children in kindergarten, first and second grades, could reduce the number of students at-risk for reading problems. Our results suggest that daily hand-eye coordination activities significantly reduce the number of students at-risk. We believe that the effectiveness of these activities derives from their ability to prepare the students perceptually for reading.

Introduction
Developmental dyslexia (dyslexia in short) also named severe reading disability (SRD) is the condition where a person is severely impaired in reading in spite of adequate intelligence, adequate tutoring and absence of obvious pathologies. The prevalence of dyslexia among the student body is estimated to range from 3-5% (Yule et al. 1974) to 20% (Shaywitz 1996) depending on when the study was conducted, the criteria used to define dyslexia and the socio-cultural background (Lindgren et al. 1985). In the USA, dyslexics constitute 80-85% of learning disabled students (Shaywitz 1996, Senate Bill Report 2005).

Most commonly, dyslexia is described as a cognitive language based disorder of phonological processing and phoneme awareness (e.g. Liberman et al. 1974, Lyon 1995). However, several studies in recent years have demonstrated sensory involvement in dyslexia (Livingstone et al. 1991, Stein and Walsh 1997; however e.g. Amitay et al 2002, Sperling et al. 2005; auditory system Tallal, 1980; and attention e.g. Brennan and Williams 1987, Richards et al. 1990, Hari et al. 1999).
Whatever the suggested view, it is generally accepted that severe reading retardation is common to all dyslexics independent of the definition used.

During the past 20 years Geiger, Lettvin and their colleagues have shown that dyslexics have a wider perceptual strategy than ordinary readers do and the difference between the groups is significant (Geiger and Lettvin 1987, 2000, Geiger, Lettvin and Zegarra-Moran 1992, Lorusso et al. 2004 see also Perry et al. 1989, Dautrich 1993). They define perceptual strategy as the pre-cognitive level of perception that comprises sensory processing and its interactions with attention; a highly integrated level in which the perceived is prepared for cognitive interpretation. The visual strategy was characterized by the form-resolving field (FRF). An FRF is the plot of the correct recognition of briefly presented pairs of letters (or other visual icons) as a function of eccentricity. The FRF measure classified persons correctly to be dyslexics or not consistently 87% of the time (Geiger and Lettvin 2000, Lorusso et al 2004). In addition, different sub-types of dyslexia (according to Boder 1973, or Bakker 1979), have similar wide visual strategies suggesting that the wide perceptual strategy is common to most dyslexics independent of the type of dyslexia (Lorusso et al. 2004). The difference in the visual strategies was suggested to be accounted for by the difference in the distribution of lateral masking: little or no masking in the periphery with some masking in and at the center of gaze for dyslexics and strong lateral masking in the

periphery with no masking in the center for ordinary readers (see also Bouma and Legein 1977, Atkinson 1991). That difference was suggested to be due to wider spatial neuronal tuning for dyslexics and narrow tuning in the unmasked region for ordinary readers (Geiger et al. 1992). The lack of masking in the periphery resulted, among other things, in the inability of dyslexics to perceive individual words without interference with the surrounding text.

Based on their research Geiger and Lettvin designed a regimen of practice for teaching dyslexics a new perceptual strategy for reading. The regimen comprises small-scale hand-eye coordination tasks (like art work and the similar) and reading with a window mask (allowing to read individual words without interference from the surroundings text) (Geiger and Lettvin, 1987). The regimen was practiced for 1 to 2 hours daily depending on age. Those dyslexics (both children and adults) who practiced the regimen have improved reading dramatically (Geiger, Lettvin and Fahle 1994, Fahle and Luberichs 1995, Geiger and Lettvin 2000). At the same time, the FRF of the dyslexics who practiced the regimen narrowed to resemble that of ordinary readers, suggesting sharper neural tuning and more focused attention.

In this work, driven by the idea that dyslexics learn a new perceptual strategy for reading by practicing hand-eye coordination tasks and reading with a window mask we ask whether it is possible to prepare children perceptually for reading. Will intensive hand-eye coordination activities in the early stages of learning to read reduce the incidence of dyslexia?
For young subjects, it is not known who might be dyslexic. Therefore, the practice has to be given to all the children. Since artwork is liked by children and is not harmful, it could be given without reservation (it is given by schools as part of the curriculum but with a low frequency). The expectation is that the practice of small-scale hand-eye coordination tasks will reduce the number of students at-risk for reading problems.
In order to answer these questions we conducted a three-year study in an inner-city public school in Boston. Its general design was to divide each grade level (kindergarten, first and second grades) into two groups: the revised/experimental group that performed artwork every school day for 40 minutes and the control group that at the same time did preparation for school as given in the usual curriculum. At the end of each year the numbers of students at-risk for reading problems in each group were compared.

Method
Students in the regular classes of kindergarten (K-2), first and second grades from an inner city Boston Public School participated in the study that extended to three consecutive school years (2002 to 2005). In its first year only first grade students participated, in the second year students from the second grades were added and the kindergarten students were added in the third year.
Each grade level was divided into a revised (experimental) group and a control group. The revised groups started every school day with 40 minutes of arts and crafts activities (listed in appendix A) and at the same time the control groups did preparation for school activities, as indicated in the curriculum (also described in appendix A). The two groups had a similar curriculum except for the first 40 minutes of the day. In most cases students of a particular

class were assigned to the same group in order to avoid moving students between classes. The assignment of a class to a group was randomly chosen. The groups in each grade level were closely matched by age, gender and initial reading level (average ages were: kindergarten 5.71 (SD 0.36), first 6.74 (0.49) and second 7.76 (0.48) grade).
All the students that participated (n=175) received signed permission from their parents/guardians to take part in the study. The students who did not have signed permission joined the control groups for the first 40 minutes of the school day. Their data were not included in the results. Only students who completed the school year were considered in the analysis of the data. Those who moved away during the year (9) were not considered.
In the second and third years of the study, the students from kindergarten, first grade and 21 from the second grade were all new to the school. We endeavored to keep the 43 second grade students who participated in the study in the year before we tried to keep in the same group activity they were in the previous year. However, for reasons of the school's priorities that was not always possible.
Reading assessments were made with the Developmental Reading Assessment (DRA) (Beaver et al. 1996) three times a year (September, January and June), as part of the school's requirements. The class teachers administered the assessments to the students individually.
The class teachers alternated yearly between the classes that were assigned to the revised and the control groups. However, the supervision of the art activities by the revised groups alternated between the teachers in each grade every few days. These procedures were taken to avoid systematic "teacher bias" effects.
The activities of the revised groups were performed individually, in pairs and in teams to encourage active participation of all the students (the students who need the activity most tend to avoid it). According to the teachers' reports all the students in the revised groups participated in the activities.
At the end of each year the groups were compared for the number of students "at risk" who did not make the benchmark in reading (as measured with the DRA).
Six teachers, an organizer and the school's principal (also one of the PIs) took an active part in the study.

Results

Overall results

The aggregate results collected over three years from kindergarten (n=43), first (102) and second (21) grade students are shown in Table 1. It depicts the total of 166 students who each participated in the study for one full year; 85 students in the revised groups and 81 in the control groups. At the end there were 10 students (11.76%) in the revised groups who finished the year at risk for reading problems compared with 20 students (24.69%) from the control groups. This difference is significant as confirmed by the Fisher Exact test ($p=0.024$) and by a chi square test ($p<0.05$).
Some students participated in the study attending the first and the second grades, only their first year participation was considered in Table 1.

Table 1. The total number of at risk students after one year of practice

Grade	year	# of stdents total	# of stdents in a group		# of stdents at risk		% of stdents at risk	
			revised	control	revised	control	revised	control
K-2, 1st &2nd	02-05	166	85	81	10	20	11.76	24.69

We next present the results broken down according to grade.

First grade

As seen in Table 2, a total of 102 first grade students participated in the study for one full year in three consecutive years, 51 students in each group. At the end of the three years an average of 15.69% of the revised groups were at risk for reading difficulties compared with 27.4% of the control groups. This difference is significant (Fisher Exact test p=0.045) and consistent through the years. In each year there were at least a third fewer students at risk in the revised groups compared with the controls.

Table 2. The number of first grade students at risk after one year of practice

Grade	year	# of stdents total	# of stdents in a group		# of stdents at risk		% of stdents at risk	
			revised	control	revised	control	revised	control
first	02-03	34	17	17	3	5	17.65	29.41
	03-04	35	17	18	3	5	17.65	27.78
	04-05	33	17	16	2	4	11.76	25
total first grade	**02-05**	**102**	**51**	**51**	**8**	**14**	**15.69**	**27.40**

Kindergarten:

Table 3 depicts the result of one year's participation by kindergarten students. There were 5 students at risk for reading problems at the end of the year, 4 in the control group and 1 in the revised.

Table 3. The number of kindergarten students at risk after one year of practice

Grade	year	# of stdents total	# of stdents in a group		# of stdents at risk		% of stdents at risk	
			revised	control	revised	control	revised	control
K-2	04-05	43	23	20	1	4	4.3	20

Second grade:
Sixty-four second grade students participated in the last two years of the study; 34 students in the second year and 31 in the third. From the second grade students 43 participated in the study for the second year and 21 students were new to the school hence participated for only one year. Table 4 depicts the number of students at risk from all the 64 participants (noted as "second all") and the numbers of at risk among the 21 new students. As is evident, all the students at risk for reading problems came from the group of new students; there was 1 in the revised groups and 2 in the controls. (Only the new students were considered in Table 1.)
At the end of the year all second graders were measured for their visual strategy with the FRF. Those who were at risk for reading problems had wide strategies, similar to that of dyslexics.

Table 4. The number of students at risk in the second grade

Grade	year	# of stdents total	# of stdents in a group		# of stdents at risk		% of stdents at risk	
			revised	control	revised	control	revised	control
second, all	03-05	64	40	24	1	2	2.50	8.33
second, only new	03-05	21	11	10	1	2	9.09	20

Repeaters
Some of the students ended one year's participation at risk without passing the benchmark were recommended by the school to repeat the grade they were in. Their second and third year of participation were not considered in the tables.
There were 9 first grade repeaters of whom 5 students originally participated in the revised groups and 4 in the controls. In the repeating classes 7 students were in the revised groups and 2 in the controls. At the end of the repeated year, 7 students passed the benchmark and 2 remained at risk, one from each group.
Four of the repeaters were confirmed to be dyslexics with additional testing and were given special advice.

Discussion
The main results strongly suggest that daily small-scale hand-eye coordination activities in the form of arts and crafts reduce by half the number of students at-risk for reading problems. An important caveat to keep in mind is that the use of the DRA made it possible only to affirm the status of 'at-risk for reading problems' but not confirm the diagnosis of dyslexia.
At the end of the second grade all the students were measured with the FRF. The students who were at-risk by the DRA also had a wide FRF. They were later confirmed to be dyslexics by the appropriate tools for the diagnosis. The majority of the students who

passed the benchmark according to the DRA had narrow FRF and some had wider ones (mostly border cases on the DRA). In order to sort the dyslexics among the students that finished the second grade all the students will have to go through the appropriate psychometric testing.
The results of this study suggest that small-scale hand-eye coordination activities reduce the number of students at-risk for reading by half. The effect is presumably the result of preparing the students perceptually for reading as was shown with dyslexic children (Fahle and Luberichs 1995, Geiger et al 1994). Our hypothesis is that the small-scale hand-eye coordination activities result in sharpening the neural tuning by practice (Ito et al. 1998) and the focusing of attention as a result of the bi-modal practice (Roach and Hogben, 2004).

Recent major efforts in prevention of dyslexia are in the cognitive domain of the phonological theory of dyslexia (e.g. Alexander and Slinger-Constant 2004) that treats mainly children sorted to be at-risk (Velutino et al 3003 but Fletcher et al. 2004). Our approach, as demonstrated here, was to prepare perceptually all the children (and not only few) in the early stages of learning to read before the establishment of the at-risk cases. The daily practice of artwork has additional educational values like motivation work in class and teamwork. These notions are reflected in the written teachers' comments.

Although these results are very promising it will be necessary to expand the study to a larger sample of students before we will be able to disseminate this method to schools' curricula. The introduction of arts and crafts to classes and the method of introduction are both preliminary and need to be refined. For this purpose the practical details of the practice itself and its administration to the students have to be worked out. We also need to determine what are the critical ages for optimal results of the practice.

Acknowledgments
For their dedicated work pecial thanks to the teachers Michele Davis, Karen Elias, Kelly Fessler, Linda Mullen, Patricia Powers, Patricia DeSanctis, Patricia Simpson, Shirley So and Shalisha Smith. Thanks also to Tomaso Poggio and Pawan Sinha for fruitful discussion. Thanks also to Sanmay Das and Sayan Mukherjee for help in the statistical analysis and Karen Smith-Drew for administrative issues.

7. References

Alexander, A.W. and Slinger-Constant, A-M. (2004). Current status of treatment for dyslexia: Critical review. *J. Child Nerol., 19(10), 711-757.*

Amitay, S., Ben-Yehudah, G., Banai, K. and Ahissar, M. (2002). Disabled readers suffer from visual and auditory impairments but not from specific magnocellular deficit. *Brain, 125, 2272-85.*

Atkinson, J. (1991). Review of human visual development: Crowding and dyslexia. In J. Stein (Ed.) *Vision and visual dyslexia (pp. 44-57).* Boca Raton: CRC Press.

Bakker, D.J. (1979). Hemispheric differences and reading strategies: Two dyslexias?. *Bulletin of the Orton Society, 29, 84-100*.

Beaver, J and colleagues (1996). The developmental reading assessment (DRA). Celebration press.

Boder, E. (1973). Developmental dyslexia: A diagnostic approach based on three atypical reading patterns. *Dev. Med. Child Neurol., 15, 663-687*.

Bouma, H. and Legein, Ch.P. (1977). Foveal and parafoveal recognition of letters and words by dyslexics and average readers. *Neuropsychologia, 15, 68-80.*

Brennan, M. and Williams. (1987). Allocation of visual attention in good and poor readers. *Percept. Psychophys. 41, 23-8.*

Dautrich, B. (1993). Visual perceptual differences in the dyslexic reader: Evidence of greater visual peripheral sensitivity to color and letter stimuli. *Perceptual and Motor Skills, 76, 755-764.*

Fahle, M. and Luberichs, J. (1995). Extension of recent therapy for dyslexia. *German Journal of Ophthalmology, 4, 350-354.*

Fletcher, J.M., Coulter, A.W., Reschly, D.J. and Vaughn, S. (2004). Alternative approaches to the definition and identification of learning disabilities: Some questions and answers. *Annals of Dyslexia, Dec. 2004.*

Geiger, G., and Lettvin J.Y. (1987). Peripheral vision in persons with dyslexia. *N Engl J Med 316:1238-1243.*

Geiger, G. and Lettvin J.Y. (2000). Developmental dyslexia: A different perceptual strategy and how to learn a new strategy for reading. *Saggi, 26, 73-89.*

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

Geiger, G., Lettvin, J.Y. and Zegarra-Moran, O. (1992). Task-determined strategies of visual process. *Cog. Brain Res., 1, 39-52.*

Hari, R., Valta, M. and Uutela, K. (1999). Prolonged attentional dwell time in dyslexic adults. *Neuroscience Letters, 271, 101-124.*

Ito, M., Westheimer, G. and Gilbert, C.D. (1998). Attention and perceptual learning modulate contextual influences on visual perception. *Neuron, 20, 1191-1197.*

Liberman, I.Y., Shankweiler, D., Fischer, F.w. and Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology, 18, 201-212.*

Lindgren, S.D., De Renzi, E. and Richman, L.C, (1985), Cross-national comparisons of developmental dyslexia in Italy and the United States. *Child Development, 56, 1404-1417.*

Livingstone, M.S., Rosen, G.D., Drislane, F.W. and Galaburda, A.M. (1991). Physiological and anatomical evidence for a magnocellular defect in developmental dyslexia. *Proc. of the National Academy of Science, USA, 88, 7943-7947.*

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

Lyon, G.R. (1995). Towards a definition of dyslexia. *Annals of Dyslexia, 45, 3-27.*

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

Richards, G.P., Samuels, S.J., Turnure, J.E. and Ysseldyke, J.E. (1990). Sustained and selective attention in children with learning disabilities. *J. Learn. Disabil., 23, 129-136.*

Roach, N.W. and Hogben, J.H. (2004). Attentional modulation of visual processing in adult dyslexia. *Psychological Science, 15(10), 650-4.*

Senate Bill Report SB 5664, February 16, 2005.

Shaywitz, S.E. (1996). Dyslexia. *Scientific American, Nov. 275(5), 98-105.*

Sperling, A.J., Lu, Z-L., Manis, F.R and Seidenberg, M.S. (2005). Deficits in perceptual noise exclusion in developmental dyslexia. *Nature Neuroscience, 8(7), 862-3.*

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

Tallal, P. (1980). Auditory temporal perception, phonics and reading disabilities in children. *Brain Lang. 9,182-98.*

Vellutino, F., Scanlon, D. and Jaccard, J. (2003). Toward distinguishing between cognitive and experiential deficits as primary sources of difficulty in learning to read: A two year follow-up of difficult to remediate and readily remediate poor readers. In Foorman, B.R. (Ed): Preventing and remediating reading difficulties: Bringing science to scale. Timonium, *M.D., York Press, 2003, 73-120.*

Yule, W., Rutter, M., Berger, M. and Thompson, J. (1974). Over- and under-achievement in reading: Distribution in the general population. *Br.J Ed. Psychol. 44, 1-11.*

Appendix A:

A list of the main activities performed by the revised groups

drawing
tracing
painting
coloring
water colors
markers
paint by numbers
crayon and torn paper
decorative tiles using paint
stenciling
beading
bracelets
necklaces
beading jewelry
mosaics with beads and beans
paper maché
building and gluing with craft sticks
decorating with ribbon
cross-stitch
tiles
glitter
macramé
creating with clay
murals using paint
friendship pins
friendship – braiding – bracelets
puppets
cut paper
dolls cut outs
yarn stitching
potholder
gimp - plastic cord
connect dots
quilting
decor page
popsicle sticks
weaving
gingerbread house.

The activities performed by the control groups while the revised groups did artwork:

The daily curriculum included reading, vocabulary/word study, daily oral language, phonic worksheet, independent reading, writers' workshop, homework, math worksheet, social studies, attendance and other routine preparations for the day.
They also participated in arts and crafts related to the seasons for about 1 hour each week. These activities included painting, drawing, cutting and gluing.