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Learning to See Quickly Improves Thinking Abilities: Why PATH neurotraining is essential for improving brain function and ease of learning

Recent scientific research has shown that activating the motion cells in the eye is key for paying attention, understanding problem solving, remembering, and multitasking. These motion cells are activated by various shades of low contrast, gray light. Importantly, these cells are not activated by colors and high contrast patterns, which is why you will see a lot of gray tones, but no color in the program. Motion cells make up the motion pathway. The motion pathway enables us to see images quickly, and is the major input into the attention pathways. Therefore, many developmental disorders, like dyslexia, speech and language problems, attention deficits, and autism (all of which detract from paying attention, understanding, problem solving, and multitasking) are characterized by slow motion processing. Learning to see quickly by improving the function of the motion cells has been found to improve these elements of thinking, see Lawton (2016, 2019).

After a terrible bicycle accident in 1978, Teri Lawton's brain processing was reduced to a child's level of learning, requiring her to learn to speak, walk, and problem solve again. After a few months of visually-based training using PATH to Reading, (patented in the U.S. and worldwide), Teri was able to think more quickly, sustain her attention for longer, and understand more easily. She was able to understand complex ideas about how the cells combine to create different pathways enabling a person to see and understand the world around us. Teri passed her Ph.D. qualifying exams 11 months after this terrible accident, instead of 14 years later as predicted by her neurologist.

Teri has also found PATH neurotraining to be useful for her kids. Both children were found to be dyslexic by Dr. John Griffin, Optometrist and professor at the Southern California College of Optometry. After doing the PATH neurotraining every other day on average, for 3 months, Kelly at the age of 6 was found to be the fastest reader in her first-grade class. This caused Teri to begin clinical trials in the schools to determine whether or not other children aged 5-10 years old would also improve their reading skills from a short amount of PATH training.

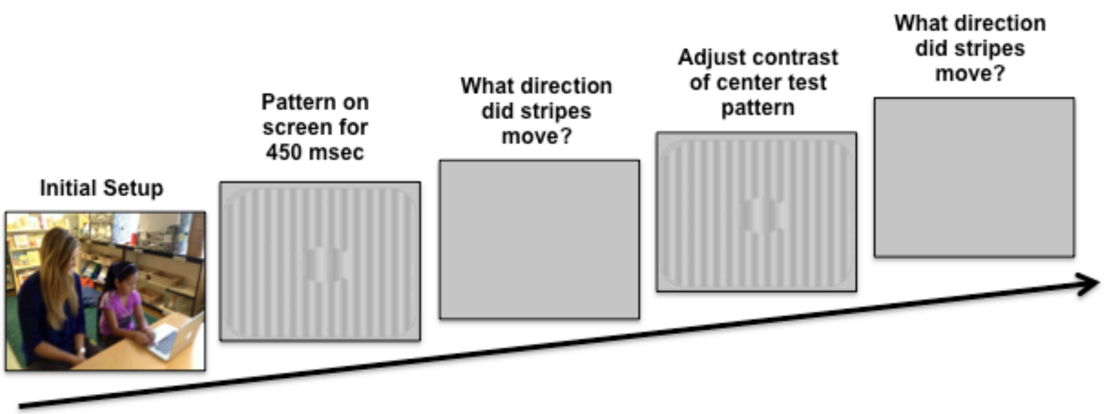
Results from the clinical trials showed that increasing the timing and sensitivity of the motion cells by discriminating movement (left or right) relative to a stationary background significantly improved not only reading skills, but also selective and sustained attention, along with visual and auditory working memory. After patenting this novel method (Lawton, 2000, 2015), these results were published in leading scientific journals (Lawton, 2007; 2008; 2011; 2016; 2019; Lawton & Stephey, 2009; Lawton & Shelley-Tremblay, 2017; Lawton & Huang, 2015, 2019).

Clearly, there is a need to provide this novel treatment not only for individuals who have sustained a concussion or traumatic brain injury, but also for people with learning problems caused by dyslexia, as well as speech and language problems, attention deficits, and autism. As indicated by recent scientific studies, magnocellular deficits are a major factor in these diseases (Brown *et al.*, 2020; Stein, 2019).

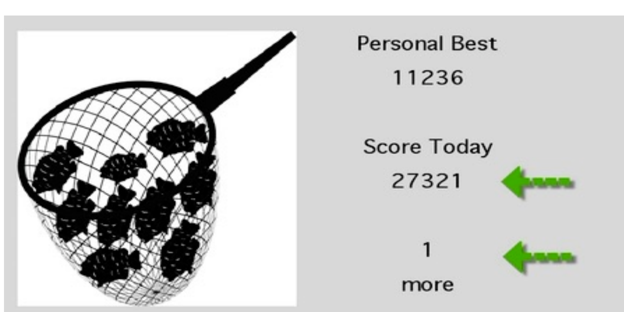
Perception Dynamics Institute provides PATH neurotraining (pathtoreading.com) on a web-based app (app.pathtoreading.com) available for use on all tablet, iPad, and computer platforms so it is easily accessible by individuals, therapists, and schools.

Exactly How Does PATH neurotraining work?

PATH neurotraining uses dim grayscale patterns to **retrain the brain's pathways. These patterns are designed to activate motion pathways** (by using left-right movement) **relative to the pattern pathways** by using a stationary background that entrains motion discrimination (Lawton, 1985). Each pattern is presented for less than half a second, see figure below.



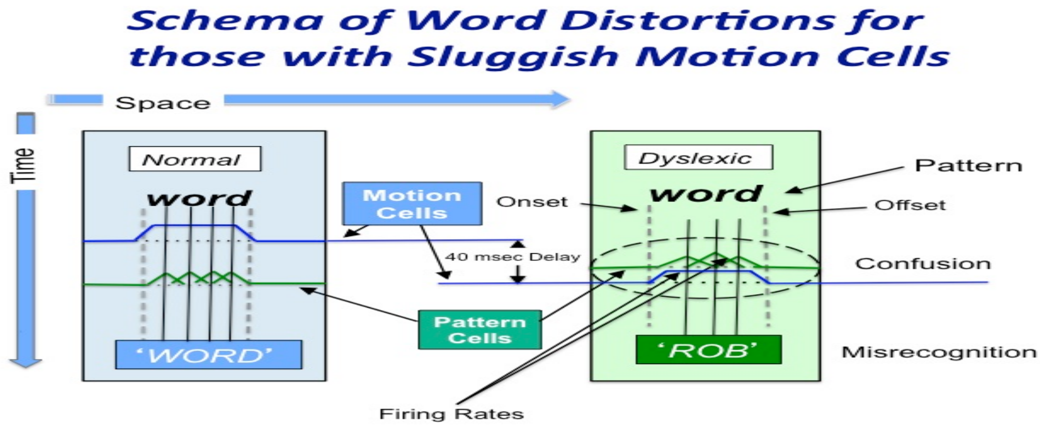
Only the contrast of the center stripes in the fish shaped object that moves left or right relative to a stationary striped background are dimmed until the direction cannot be seen. There are 24 levels of complexity, each increasing in difficulty slowly, for both one (**Motion** Program) and two (**MotionMemory** Program) directions of left-right movement. Thus, a total of 48 levels of complexity are used to train the user quickly and effectively, improving the functionality of their dorsal, attention, and executive function networks. The feedback to the user makes this a fun game that **motivates the user to continue to improve.** Positive feedback is provided in the form of catching more fish in the net -resulting from meeting specific thresholds-, and through a score that increases as performance improves. There is also immediate feedback in the form of a beep if the user identifies the direction of movement incorrectly, in addition to other verbal feedback when needed. A **ReadingRate** program where the user reads 6 words at a time from an interesting story provides an ongoing measure of reading speed during training.



Simply interacting with a game-like training program on a computer for 30-45 minutes for 12-16 weeks, followed by problem solving, remembering, or reading is all that is involved.

Directions for playing PATH are shown in a short movie: https://youtu.be/HgCZn9uVdS0.

From a neuroscience perspective, the motion (magno) cells are responding up to 1/10th of a second slower than they should. Therefore, the motion pathway and the pattern pathway are not in sync and working together optimally, so the brain pathways are slowed down. This slowdown causes problems with attention, multitasking, and remembering easily, as shown in this short movie: https://youtu.be/LDdhuhPeXNI.



Sluggish motion cells make it difficult to locate the beginning and end of a word, causing confusion and misrecognition, causing slow reading, as shown in the figure above. Slow neural pathways cause the brain to confuse what the eye sees, reduce the ability to remember, and create attention deficits.

Just practicing left-right movement discrimination using patterns that activate the motion pathways, improves our ability to think more quickly. This improvement comes from neural plasticity, which is a basic concept known for decades in neuroscience: "neurons that fire together wire together". In fact, brain imaging at UCSD in Dr. Ming-Xiong Huang's lab has shown that after using PATH for 15-20 minutes twice a week for 8-12 weeks, the attention, problem solving, and working memory (executive control) networks improve in function significantly (Lawton & Huang, 2019: https://doi 10.3233/RNN-180856).

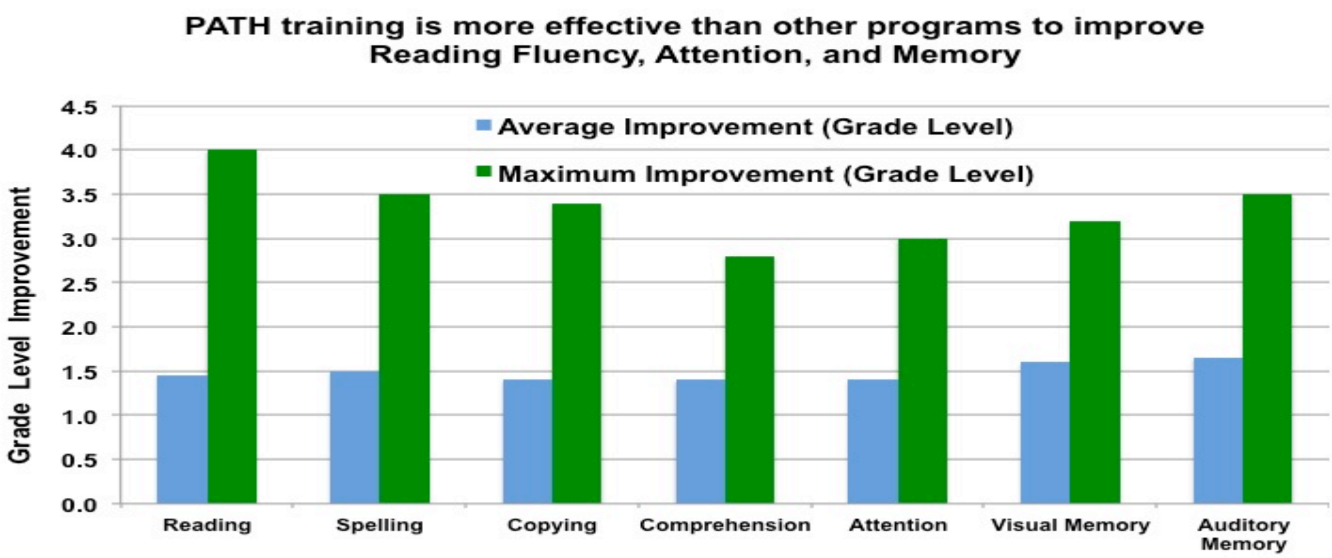
Performing the PATH game helps the brain to select the correct -most efficient- pathways to be used, enabling cortical function to be more focused. This results in improved multitasking, problem solving, and ease of learning. Using the most efficient pathways makes a big difference. It's a bit like driving. If you want to drive from New York to San Francisco, your best bet is to take the straightest, most efficient route possible subject to traffic, construction, speed limit and other factors. You would want to avoid driving down to Texas, up to Chicago, and so on, before you got to see the Golden Gate bridge. That would be an inefficient pathway and as a result, would be slower and more difficult, and might make you more tired and frustrated. There are many real-world examples where the brain can benefit from using the most efficient pathways. For example, when we have errands to run, do we remember to do everything in the simplest order? What about the activities that make up a given day? While it seems simple, when we break down everything that is done in a day from brushing our teeth, to showering, to getting dressed, and so on, we recognize that each day is composed of a great number of events. The more efficiency in performing these events, the easier it is.

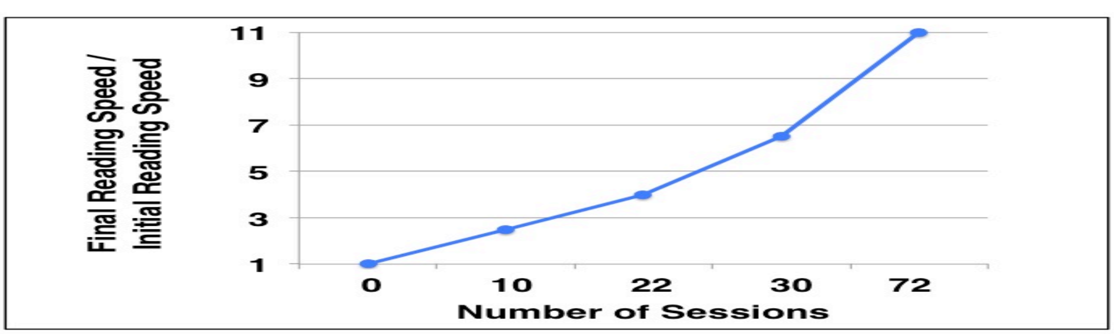
Why do you want to play PATH on a regular basis each week? The reason to play PATH consistently is that the regular practice trains the brain to utilize and ingrain those efficient pathways. Said differently, it enables the string of different activities that are completed throughout the day to become an efficient process.

Playing PATH every day is like oiling the joints, allowing the door to open without squeaking. PATH creates effortless competence when stringing together every action of the day, and then learning as you go to make the process easier the next time and the time after that. We look at our calendars and see one thing after the other, this action in itself can be overwhelming, which is one of the important aspects that PATH improves, because PATH improves the ordering of events and seeing in chronological order of what to do next (sequential processing). It helps one multitask and organize your day more efficiently. Think of playing PATH not as the oil for the joints of a squeaky door, but as the oil to loosen up our brain so it can break free from our routines and learn more effortlessly. PATH training enables learning new pathways that can be combined with positive thinking to change our goals so they are more in alignment with the direction we wish to pursue in life. PATH training is a brain warm-up that enables anything practiced immediately afterwards to be noticeably easier than before doing the PATH neurotraining, since it is improving our attention networks and executive function, enabling higher order tasks to be completed more easily (with less effort). Therefore, to obtain the greatest benefit from PATH neurotraining, it should be completed in the morning before reading the paper, for example.

Benefits of PATH training

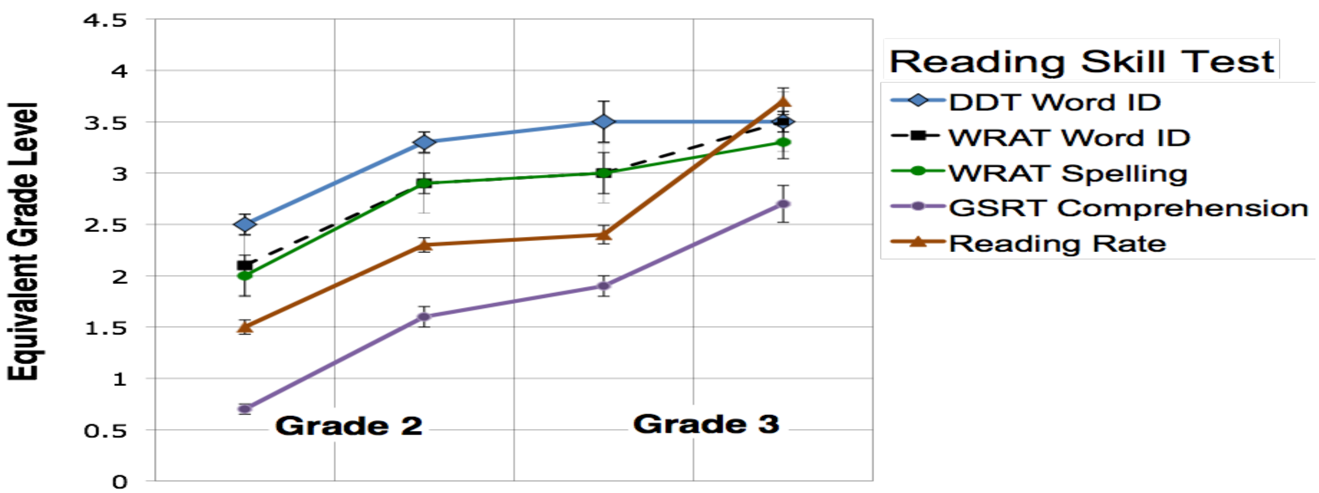
We have published data from hundreds of students in grades 2-4, both challenged (dyslexia, autism, ADHD, speech&language) and typically developing readers doing PATH training twice a week for 12 weeks substantially improved academic skills from 1.5 to 4 grade levels as shown below, and found on our website: pathtoreading.com. PATH training significantly improves a person's ability to learn by retraining their brain's pathways, so the results are long-term.





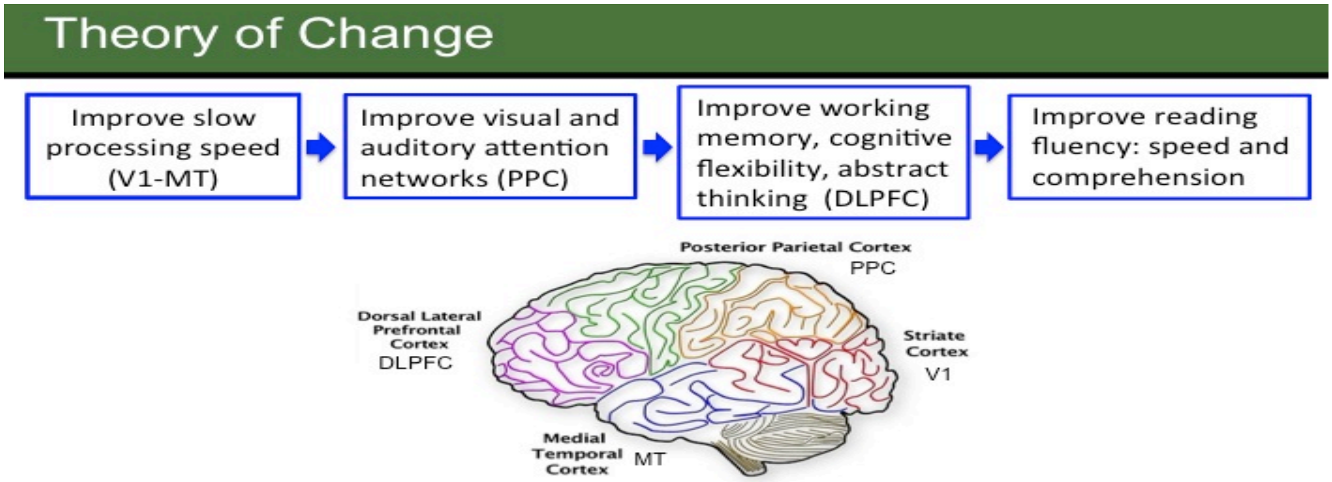
The more PATH was trained **the larger were the improvements,** speeds improved up to 11 times faster (Lawton, 2011), and the longer it lasts. Each session increases in what it teaches you AND builds upon the previous session, teaching you at a deeper level, improving brain function at higher levels of processing**,** as validated in magnetoencephalography (MEG) source imaging of the brain by Professor Ming-Xiong Huang at UCSD (Lawton & Huang, 2015, 2019).

There is evidence for significant improvements in reading scores (speed and comprehension), selective attention, both visual and auditory working memory, and phonological processing in dyslexics from discrimination training in visual motion perception, relative to a stationary background pattern (frame of reference), thereby being an effective training stimulus to improve magno-parvo integration deficits at both early and higher levels of motion processing (Lawton, 2016; Lawton & Shelley-Tremblay, 2017). The background frame of reference entrains motion discrimination, since it repeats at the same periodicity (harmonically-related) as the test pattern moving left or right (Lawton, 1985). Increasing the ease of magno-parvo integration by oscillatory entrainment of motion discrimination facilitates figure/ground discrimination within a wider window of focused attention, improving reading skills by strengthening coupled theta/gamma and alpha/gamma activity (Lawton, 2016; Lawton & Shelley-Tremblay, 2017; Lawton, 2019; Lawton & Huang, 2019). No other single program has been found to improve these cognitive skills when skills practiced afterwards, and is why there are no proven solutions before PATH was developed.

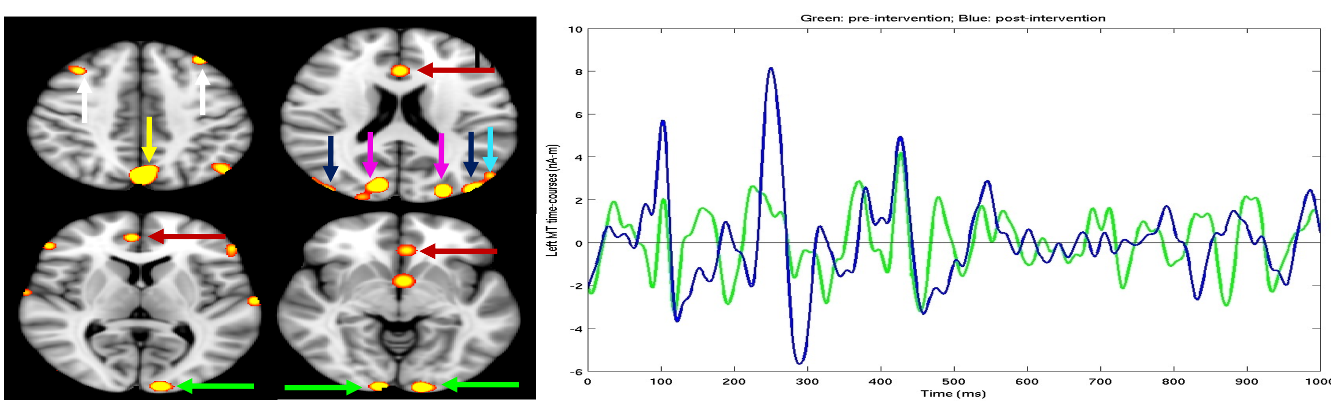


Moreover, these results are sustained over time, as shown above with the same children in grade 2 and 3 who improved more in reading speed, comprehension, spelling and word ID the more PATH was trained (Lawton, 2011). **When a student finds it easier to read, they feel less frustrated in their learning experience and this leads to better attention span, more excitement about learning, and better memory capabilities both inside and outside the classroom.** The increase seen by the **grade level improvements** in reading skills, attention, and working memory is the **proof that PATH neurotraining improves reading and learning**. This has been proven by thousands of children and adults and published in leading scientific journals (Lawton, 2007, 2008, 2011, 2016, 2019; Lawton & Shelley-Tremblay, 2017, Lawton and Stephey, 2009, Lawton & Huang, 2015, 2019).

Neuroscience Underlying Improvements in Cognitive Skills After PATH Neurotraining



Our theory of change shows how improving movement discrimination (V1-MT) improves high-level cognitive function (PPC, DLPFC). PATH to Reading training targets the temporal dynamics of the visual-attention and reading pathways. By using repeated exposure to stimuli optimal for improving the brain's visual timing (via motion discrimination), PATH training increased comprehension, attention, and memory from 1-4 grade levels and reading speeds from 2-11 fold, as shown above. Neural connections are strengthened to repair dysfunctional connections, enabling the most efficient pathways to be used, thereby improving you and your child's ability to learn. PATH employs the brain's plasticity to improve the function of brain pathways so they work together and significantly improve reading, attention, and memory.



Significant MEG signal increases (color scale for t-test: 3 – 3.5) in post- versus pre-intervention exams for an adult male dyslexic aged 29 years. Green arrows: V1; Blue arrows: MT; Magenta arrows: V3; Cyan arrow: MST; Red arrows: ACC; Yellow arrow: precuneus/PCC; White arrows: DLPFC; Right Panel: MEG source time-courses from left MT area during post-intervention (Blue line) and pre-intervention (Green line) exams in the figure above.

Notice that the improvements above happen in the first 300 msec, showing we are speeding up the brain's pathways. PATH neurotraining improves the function of many related brain pathways, improving the visual, attention, and memory networks, as shown by MEG brain imaging conducted by Dr. Ming-Xiong Huang at UCSD after only 8 weeks of PATH training 2 times/week. Substantial MEG signal increases in **Motion Networks** (V1, V3, MT, MST) and **Attention Networks** (ACC, DLPFC, VLPFC and precuneous/PCC areas) were observed following training on direction-discrimination 2 times/week for 8 weeks for a 29 year adult dyslexic (Lawton & Huang, 2015). These benefits have been proven clinically both by **brain imaging** studies above**, and behaviorally,** see the Table below.

Standardized Tests	Pre-Test	Post-Test
Reading Speed	154 wpm	437 wpm
Focusing Attention	1%	54%
Sustained Attention	10%	82%
Impulsivity	18%	62%
Visual Working Memory	6%	99%
Delayed Recall	1%	25%

After 8 weeks of PATH training significant improvements in memory (34-86%, 55-97%) were also found in a 71 year-old adult who was adept at paying attention, yet still improving more after training (81-87%). She also improved substantially in processing speed: 42-77%, over doubling her reading speed (229-541 wpm), as shown in the Table below.

Standardized Tests	Pre-Test	Post-Test
Reading Speed	229 wpm	541 wpm
Processing Speed	42%	77%
Attention	81%	87%
Cognitive Flexibility	81%	87%
Visual WM	34%	86%
Auditory WM	55%	97%

Substantial MEG signal increases in **Motion Networks** (V1, V3, MT, MST) and **Attention / Memory Networks** (ACC, precuneous/PCC, and DLPFC areas) were also observed following PATH training 2 times/week for 8-16 weeks after a mild Traumatic Brain Injury (mTBI) for those aged 15-68 years old, as well as significant behavioral improvements in movement discrimination, processing speed, reading speed, attention using several different tests, and both auditory and visual working memory (Lawton & Huang, 2019).

Scientific Evidence that PATH neurotraining Improves Cognitive Function After a mTBI

What is the underlying problem in a mTBI ?

Research has found that the effects of a mTBI reflect disuptions of the neural networks for attention and working memory (Knight, 2007; Huang et al. 2018). After suffering a mTBI, patients have longer reaction times, are more distractible, and have trouble in sustaining attention (Huisman *et al*., 2004). Cognitive deficits in those with a mTBI are hypothesized to result from neural timing deficits (Ghajar & Ivry, 2008). Compensation for timing issues by increased prefrontal cortical recruitment would be manifest as increased distractibility, working memory deficits, and problems with balance and coordination. This expended effort may underlie fatigue, headache, irritability, anxiety, and when prolonged, depression (Ghajar & Ivry, 2008). Visual timing deficits, resulting from magnocellular (motion) deficits are persistent in individuals with a mTBI (Poltavski, Lederer & Cox, 2017), manifesting as timing deficits in the dorsal pathways, and attention and executive control networks (Lawton & Huang, 2019; Ghajar & Ivry, 2008). Thus, daily living is dramatically impaired after a mTBI.

Improving visual timing in mTBI patients improves cognitive skills significantly

The scientific premise of PATH neurotraining is that remediation of a fundamental visual timing deficit affecting motion discrimination at a low level of cognitive processing generalizes to high level cognitive abilities reliant upon motion processing as a foundation. Literature on many species including humans has identified the specific cortical region vital for motion discrimination, widely known as middle temporal cortex (MT) (Felleman & Van Essen, 1991). Human MT (as determined by fMRI) is located posterior to the Temporal-Parietal-Occipital junction in cerebral cortex (Tootell *et al*., 1995; Kolster *et al*., 2010). Long white matter tracts connecting this region to pre-frontal cortex are especially vulnerable to damage from a mTBI (Knight, 2007). The visual dorsal stream is composed of predominantly magnocellular (motion) neurons (Livingstone & Hubel, 1988; Maunsell *et al*., 1990; Merigan & Maunsell, 1993). The dorsal stream provides information about 'where' an object is located, whereas the ventral stream provides information about 'what' high contrast, high resolution shape and color object attributes are present. The dorsal visual stream provides the input to the dorsal attention network (Vidyasagar, 2013), and executive control networks (Menon & Uddin, 2010).

Pre/post comparisons using standardized tests of cognitive skills and MEG physiological brain recordings found that **15-20 minutes of training** on movement discrimination, *PATH* to Insight/Reading (*PATH*) neurotraining, U.S. Patent 8,979,263, twice a week for 8-12 weeks significantly improved each mTBI subject's (15-68 years) cognitive skills, including visual and auditory working memory, attention, processing speed, and reading speed (Lawton & Huang, 2019), see Figs. 1-2 & Table 1. MEG recordings provide a biomarker to validate brain improvements in mTBI (Huang *et al*., 2014, 2016, 2018). This indicates that *PATH* neurotraining helps develop the attention and executive control networks, as is shown in MEG recordings, see Fig. 1, by the improved functionality of the dorsal, attention, and executive control networks (Lawton & Huang, 2019). This improvement in neural timing was evidenced by increased signal power in the target regions following training. The magnocellular deficits persistent in those having a mTBI (Poltavski *et al.,* 2017) were remediated quickly (Lawton & Huang, 2019) by completing a short amount of movement-discrimination (*PATH*) training designed to optimally activate magno-cellular (left-right movement) relative to parvocellular (stationary background) neurons in the dorsal stream. This *PATH* neurotraining intervention used for cognitive remediation trains the dorsal stream by using low contrast grayscale patterns, see figure above, optimized for low- and high-level dorsal stream processing (Lawton, 2016). The mechanism that causes neural timing improvements is the repeated viewing of *PATH* stimuli that are moving left or right at a speed of between 6.7 to 13.3 cycles per second, with sensitivity to the fastest moving patterns improving the most (Lawton & Huang, 2019).

It is likely that the *PATH* movement-discrimination training paradigm improves not only magnocellular function, attention, and memory, but also feedback, that can be measured by the strength of coupled theta/gamma and alpha/gamma frequency oscillations (Vidyasagar, 2013; Lawton, 2016; Lawton & Shelley-Tremblay, 2017). Moreover, our pilot study (Lawton & Huang, 2019) provides evidence that abnormal visual motion processing is a fundamental cause of reading, attention, and memory problems in those with a mTBI. Furthermore, there is evidence that improvements in cognitive skills after this movement-discrimination training are sustained over time (Lawton, 2011). Our pilot study found that *PATH* neurotraining improved attention pathways so less effort was spent decoding incoming information, and more effort was spent on interpreting the information, improving cognitive skills by using the most efficient working memory (WM) network (Menon & Uddin, 2010), skills that improve a person's quality of life after a mTBI.

MEG functional brain imaging that measured responses evoked from an N-back WM test on mTBI patients confirmed this improvement over their baseline in brain function after *PATH* training (Lawton & Huang, 2019), as shown in Fig. 1 below. This pilot study illustrates the brain plasticity found in mTBI patients, that is, they show neurophysiological reorganization as evidenced by the MEG findings. The work of Hillary and colleagues (2017) over the past decade has demonstrated that neural networks do change in their connectivity as a result of a mTBI. Our next study is uniquely positioned to determine whether *PATH* can address the phenomenon of "hyperconnectivity" so often seen in mTBI patients. In response to neurological insult, the brain attempts to reorganize to increase information processing efficiency while bypassing damaged network connections. In the case where the damage occurs in a processing "hub" (e.g. perisylvian cortex damage yields Broca's aphasia), this hyperconnectivity allows for as much compensatory information processing as possible but at the cost of local hypermetabolism. In diffuse mTBI the effect of prolonged hypermetabolism may actually be increased oxidative stress and long-term neural degeneration. By using MEG measures of functional connectivity, our team has found that the hyperconnectivity demonstrated in mTBI patients becomes ameliorated post treatment.

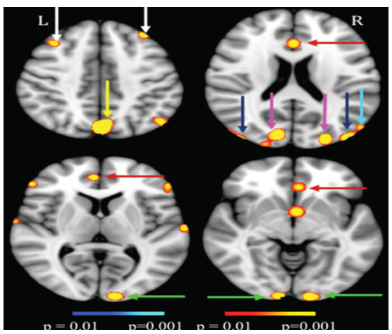


Figure 1. Significant MEG signal increases (color scale is based on paired-sample t- tests having values between 3 – 3.5 that correspond to significance levels between p=0.01 to p=0.001 were found for mTBI patients in post- versus pre-*PATH* intervention exams. Cluster analysis was used to control family-wise errors. Green arrows: V1; Blue arrows: MT; Magenta arrows: V3; Cyan arrow: Medial Superior Temporal (MST); Red arrows: Anterior Cingulate Cortex (ACC); Yellow arrow: precuneus/PCC (Posterior Cingulate Cortex); White arrows: dorsal lateral Prefrontal Cortex

After a short amount of visual movement-discrimination (PATH) training not only visual skills, but also attention, processing speed, reading speed and working memory improved significantly, as shown in Fig. 2 and Table 1 below.

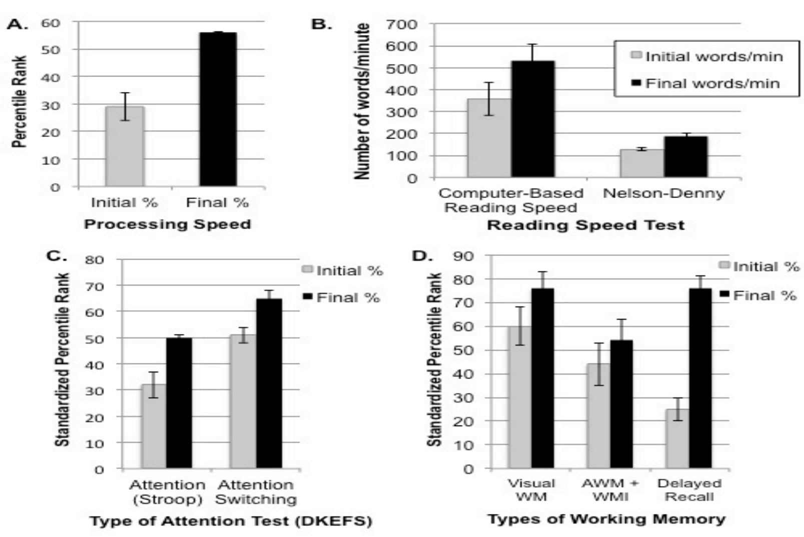


Fig. 2. Mean and Standard Error of Improvements in Cognitive Skills before and after *PATH* neurotraining, all improvements being significant (Lawton & Huang, 2019). **A**. Standardized percentile rank of Processing Speed Index measured using *WAIS-4* coding and symbol search subtests; **B.** Reading Speed measured using the Computer-Based Reading Speed test, and the Nelson-Denny Reading Rate Test; **C.** Attention measured using the *DKEFS* color word interference test; **D.** Working Memory (WM) measured using the *Test of Information Processing Skills* for Visual (VWM), Auditory (AWM), and Delayed Recall, and the *WAIS-4* Working Memory Index (WMI).

PATH neurotraining improved existing brain pathways, as shown by MEG brain recordings in Fig. 1 and middle of page 6, pathways essential for recovering from a mTBI or from dyslexia, and other learning problems. Working memory deficits in a mTBI have been shown to be reduced following training using a dynamic visual attention therapy (Lawton & Huang, 2019). PATH neurotraining is a validated program based on research in neurobiology that only takes 5-10 minutes each day for 12-16 weeks. PATH neurotraining is faster and more effective than other cognitive interventions. By improving visual timing, reading fluency, comprehension, ability to pay attention, remember, problem solve, and multitask improve significantly. PATH trains the brain pathways to operate together ➔ So improvements are sustained over time.

Table 1. Improvement in Cognitive Skills Following *PATH* neurotraining (Lawton & Huang, 2019)

Test	Initial Mean ± SE	Final Mean ± SE	Improvement
Processing Speed			
Processing Speed Index (WAIS-4)	29% ± 5	56% ±0.4	27%
Reading Speed			
Computer-Based Reading Speed	359wpm ± 76wpm	534 ± 75	175 wpm
Nelson-Denny Reading Test	128wpm ± 8wpm	186 ± 16	58 wpm
Both Reading Tests	243wpm ± 59wpm	360 ± 68	117 wpm
Attention (DKEFS Color-Word)			
Inhibition (Stroop)	32% ±5%	50% ± 1%	18%
Inhibition Switching	51% ± 3%	65% ± 3%	14%
Working Memory			
Visual Working Memory (TIPS)	60% ± 8%	76% ± 7%	16%
Auditory Working Memory (TIPS)	48% ±10%	55% ±11%	7%
Working Memory Index (WAIS)	41% ± 9%	53% ± 9%	12%
AWM + WMI	44%± 9%	54% ± 9%	10%
Delayed Recall	25% ± 5%	76% ± 5%	51%

Testimonials:

"We are so deeply grateful for your special, smart, ground-breaking program. We had tried EVERYTHING up until now and nothing seemed to work. You truly have made a difference in Addie's life. Thank you from the bottom of our hearts." - Kim Macri, Ramsey, New Jersey (Parent of a **Path to Reading** student)

"I notice I can read 10 times faster. I really understand stories more easily. I can remember things from a long, long time ago. Before, I could not remember several things at the same time. That is no longer a problem." - Nicholas Franklin, Del Mar, CA (Elementary Age **Path to Reading** Student)

"My daughter Sophie, who at age 5 could not read when she started PATH neurotraining has improved remarkably in her ability to read. Her speech therapist found a huge improvement in her phonetic awareness abilities and general reading and writing skills! I have noticed that her spoken sentences are getting longer with better structure." - Dr. Annemieke Karyotis, Glasgow, Scotland

"Darcy's teacher has noticed that she has no problem with memorizing and understanding, whereas last year [4th grade] this was a big problem, especially memorizing fractions." - Sheila McCarthy, Ojai, CA (Parent of a **Path to Reading** student)

"I have been intrigued by the remarkable results found after PATH training with a minimum of intervention, ever since my son was helped to overcome his reading difficulties." - Carmen R. Duran, Founder of LA Therapy for Children, Montrose, CA (Therapist and Parent of *PATHtoReading* Student)

"I have improved over 10 fold in cognitive processing skills, including multi-tasking, focusing attention, memory, and sequential processing after a severe TBI." - Tim Tanney, Fresno, CA

"I have noticed more mental flexibility. I have more of an ability to stop what I am working on without a fear that I will lose my momentum or forget what I was working on when I return. I can synthesize and process information better, engage in complex conversations, and follow them, gain insights, and pick up the salient points. I spend less time after meetings to recount the main points and consider the next steps. I've noticed improvements with working memory, which has helped with holding conversations - being able to make my point more clearly. It has also helped me to feel more calm in general, because I am less anxious about trying to remember things, and less upset that I am not remembering; it's helped with info processing; and with music as well. With music, I notice being better able to sing and play guitar at the same time. That has been very hard for me and this made it easier. I also notice I am better at playing guitar, because I can plan ahead for the notes I will be playing. Additionally, I am finding it easier to learn the different scales. Since using PATH, I have really been able to spring forward with this." - Mark Kent, Philadelphia, PA.

"After the first session of PATH training, I noticed large improvements in my vision. Now I see much more clearly, especially when driving. My field of view is constantly widening." - Ruby Mitchell, Covina, CA

"After PATH neurotraining my memory, reading speed, ease of understanding, processing speed, ability to multitask, concentrate, and pay attention have improved remarkably in just a few months. Difficulties driving during dawn or dusk are no longer a problem. These improvements made life much easier and more enjoyable." - Dr. Barash, Scripps Ranch, CA

"After 4 weeks of training on PATH, the biggest change is no longer having memory problems!" - Izola Kerney, Fullerton, CA

Many more testimonials can be found on the website: https://pathtoreading.com/testimonials/

References

Brown, A.C., Peters, J.L., Parsons, C., Crewther, D.P. and Crewther, S.G. (2020) Efficiency in magnocellular processing: A common deficit in neurodevelopmental disorders, *Frontiers in Human Neuroscience*, 14:49. doi: 10.3389/fnhum.2020.00049.

Felleman, D.J., & Van Essen, D.C. (1991). Distributed hierarchical processing in the primate cerebral cortex, *Cerebral Cortex, 1,* 1-47.

Ghajar, J., & Ivry, R.B. (2008) The predictive brain state: Timing deficiency in traumatic brain injury? *Neurorehabilitation and Neural Repair.* 22, 217-227.

Hillary, F. G., & Grafman, J. H. (2017). Injured Brains and Adaptive Networks: The Benefits and Costs of Hyperconnectivity. *Trends in Cognitive Sciences*, 21(5), 385–401. https://doi.org/10.1016/j.tics.2017.03.003)

Huang, M-X, Huang, C.W., Robb, A., Angeles, A., Nichols, S.L., Baker, D.G., Song, T., Harrington, D.L., Theilmann, R.J., Srinivasan, R., Heister, D., Diwakar, M., Canive, J.M., Edgar, J.C., Chen, Y-H, Ji, Z., Shen, M., El-Gabalawy, F., Levy, M., McLay, R., Webb-Murphy, J., Liu, T.T., Drake, A., & Lee, R.R. (2014). MEG source imaging method using fast L1 minimum-norm and its applications to signals with brain noise and human resting-state source amplitude images. *NeuroImage*. *84*, 585–604.

Huang, C.W., Huang, M-X, Ji, Z., Swan, A.R., Angeles, A.M., Song, T., Huang, J.W., & Lee, R.R. (2016). High-resolution MEG source imaging approach to accurately localize Broca's area in patients with brain tumor or epilepsy. *Clin Neurophysiol Off J Int Fed Clin Neurophysiol. 127*, 2308–2316.

Huang, M.X., Nichols, S., Robb-Swan A, Angeles-Quinto, A., Harrington, D.L., et al. (2018) MEG working memory n-back task reveals functional deficits in combat-related mild traumatic brain injury. *Cerebral Cortex*. 1-16, doi: 10.1093/cercor/bhy075/4969847

Huisman, T.A., Schwamm, L.H., Schaefer, P.W., *et al.* (2004). Diffusion tensor imaging as potential biomarker of white matter injury in diffuse axonal injury. *AJNR Am J Neuroradial. 25*, 370-376.

Knight, R.T. (2007). Neuroscience. Neural networks debunk phrenology. *Science.* 316: 1578-1579.

Kolster, H., Peeters, R., & Orban, G. A. (2010). The retinotopic organization of the human middle temporal area MT/V5 and its cortical neighbors. *The Journal of Neuroscience, 30(29),* 9801–9820.

Lawton, T.B. (l985) Spatial frequency spectrum of patterns changes the visibility of spatial-phase differences. *Journal of the Optical Society of America A.*, **2,** 1140-1152.

Lawton, T. (2000). *Methods and Apparatus For Diagnosing and Remediating Reading Disorders*. United States Patent No 6,045,515, Washington, DC: U.S. Patent and Trademark Office.

Lawton, T. (2007). Training direction-discrimination sensitivity remediates a wide spectrum of reading skills. *Optometry & Vision Development, 38,* 37-51.

Lawton, T. (2008). Filtered text and direction discrimination training improved reading fluency for both dyslexic and normal readers. *Optometry & Vision Development, 39,* 114-126.

Lawton, T. (2011). Improving magnocellular function in the dorsal stream remediates reading deficits. *Optometry & Vision Development. 42*, 142-154.

Lawton, T. (2015). *Diagnosing and Remediating Cognitive Deficits Involving Attention, Sequential Processing, Reading, Speed of Processing, and Navigation*. United States Patent No. 8,979,263 B2, Washington, DC: U.S. Patent and Trademark Office.

Lawton T. (2016). Improving dorsal stream function in dyslexics by training figure/ground motion discrimination improves attention, reading fluency, and working memory. *Frontiers in Human Neuroscience,* 397. doi:10.3389/fnhum.2016.00397.

Lawton, T. (2019) Increasing visual timing by movement discrimination exercises improves reading fluency, attention span, and memory retention in dyslexics, *Neurology and Neurosurgery*, 2: 1-8, Doi:10.15761/NNS.1000118.

Lawton, T. & Huang, M.X. (2015). Improving visual timing enhances cognitive functioning by altering dorsal stream and attention networks. *Society for Brain Mapping and Therapeutics*, LA, CA March 7.

Lawton, T. & Huang, M.X. (2019). Dynamic cognitive remediation for a traumatic brain injury (TBI) significantly improves attention, working memory, processing speed, and reading fluency. *Restorative Neurology and Neuroscience,* 37, 71-86, doi:10.3233/RNN-180856.

Lawton, T. & Shelley-Tremblay, J. (2017). Training on movement figure-ground discrimination remediates low-level visual timing deficits in the dorsal stream, improving high-level cognitive functioning, including attention, reading fluency, and memory. *Frontiers in Human Neuroscience*, https://www.frontiersin.org/articles/10.3389/fnhum.2017.00236/full.

Lawton, T. & Stephey, D. (2009). Training direction discrimination improves usable field of view, short term memory, and navigation in older adults. *Optometry and Vision Development, 40,* 82-93.

Livingstone, M.S., & Hubel, D.H. (1988) Segregation of color, form, movement and depth: Anatomy, physiology, and perception. *Science*, *240*, 740-749.

Maunsell, JH, Nealey TA, & De Priest DD. (1990). Magnocellular and parvocellular contributions to responses in the middle temporal visual area (MT) of the macaque monkey. *Journal of Neuroscience, 10,* 3323-3334.

Merigan WH, & Maunsell JHR. (1993). How parallel are the primate visual pathways? *Annual Review of Neurosciences, 16*, 369-402.

Menon, V., & Uddin, L.Q. (2010) “Saliency, switching, attention and control: a network model of insula function, *Brain Structure and Function*, *214*, 655–667.

Poltavski, D., Lederer, P., & Cox, L.K. (2017) Visually evoked potential markers of concussion history in patients with convergence insufficiency. *Optometry and Vision Science*, 94; 742-750.

Stein, J. (2019) The current status of the magnocellular theory of developmental dyslexia. *Neuropsychologia*, 130, 66-77.

Tootell, R. B., Reppas, J.B., Kwong, K.K. et al., (1995). Functional analysis of human MT and related visual cortical areas using magnetic resonance imaging. *Journal of Neuroscience*, 15(4), 3215-30.

Vidyasagar, T.R. (2013) Reading into neuronal oscillations in the visual system: implications for developmental dyslexia. *Frontiers in Human Neuroscience, 7,* 1-10.