“Vision Training” for Concussions

DAVID H. BIBERDORF, OD, FCOVD
The Concussion Crisis

- CDC estimates reveal that up to 3.8 million concussions occur each year.
- Fewer than 10% of sport related concussions involve a loss of consciousness (e.g., blacking out, seeing stars, etc.)
- Estimated 47% of athletes do not report feeling any immediate symptoms after a concussive blow.
- Most studies report that 80–90% of athletes have symptom resolution by 7 days following their injury, although symptom resolution may not always indicate a complete cognitive recovery, as persistent deficits may be present on neuropsychological testing.
- 15% suffer lasting neurophysiological changes.
- Symptoms beyond 3 months is considered Post-Concussion Syndrome.
- Even if neuropsych assessment clears RTP, likelihood of repeat concussion is 2–5.8X greater.
- Repetitively concussed individuals risk long-term possibility of chronic traumatic encephalopathy (CTE) and chronic neurological impairment (CNI).
Typical Symptoms of Concussion

- **Blurred Vision** (accommodation? contrast sensitivity?)
- **Double vision** (binocularity?)
- **Light Sensitivity** (pupillary function? dark adaptation?)
- **Loss of place when reading** (saccadic tracking? binocularity/accommodation? visual information processing?)
- Headaches (binocularity/accommodation?)
- Post-traumatic amnesia (Visual memory?)
- Dizziness (VOR?)
- Confusion (Visual memory? Visual Information Processing?)
- Disorientation (Visual Information Processing?)
- Vomiting and/or Nausea (Visual motion sensitivity?)
- Unsteadiness (VOR? Visual Motor Integration?)
80-90% of all information entering brain is visual.

Over 50% of neural tissue is directly or indirectly related to vision (30 brain regions and 8 cranial nerves).

Because the visual system is sensitive to concussion, a growing number of ocular and visual tests are being investigated as bio-markers of concussion (e.g. King-Devick; VOMS)

Few ocular/visual tests are being used for RTP or RTL decision-making. . .mostly neuro-cognitive testing.

Vision problems frequently persist beyond the natural recovery period of 6–9 months.
The Optometric Evaluation and Treatment of the patient with concussion may include the following:

- Comprehensive eye and vision examination
- Extended sensorimotor evaluation
- Higher cerebral function assessment of visual information processing/visual-motor-integration assessment
- Extended visual field evaluation
- Electrodiagnostic testing (VEP)
- Spectacle prescriptions (including lenses, prisms, and therapeutic tints)
- **Neuro-Optometric Rehabilitation (vision therapy)**
Oculomotor and non-oculomotor-based vision deficits following mTBI

1.) OCULOMOTOR-BASED VISION PROBLEMS (Visual Hardware)
   a.) Versions: Saccades & Pursuits
   b.) Vergences: Eye Alignment; Binocularity; Fusion; Stereopsis
   c.) Accommodation

2.) NON-OCULOMOTOR-BASED VISION PROBLEMS
   a.) Refractive status/Ocular health (Visual Hardware)
   b.) Visual Information Processing/Visual-Motor-Perception (Visual Software)
   c.) Hypersensitivity: Motion Sensitivity; Photosensitivity
   d.) Abnormal Spatial Localization (Midline Shift)
   e.) Visual field defects
   f.) Vestibular (VOR)
Oculomotor Dysfunctions

- **Versions: (Saccades; Pursuits):**
  - Saccadic dysmetria (more saccades than required for sequential target demand).
  - Delayed saccadic latency (reaction time to initiate a saccade in response to a rapid, stepwise change in target position). Usually normalized after 12 days.
  - Pursuit eye velocity does not match target velocity (<30 degrees/sec.)

- **Accommodation (Focusing):**
  - Reduced peak velocity (maximum velocity of an accommodative to a target change in depth to produce in-focus retinal imagery).
  - Receded amplitude of accommodation (maximum amount of accommodation)

- **Vergences (Binocularity; Eye Teaming; Fusion):**
  - Reduced Peak Velocity (maximum velocity of a vergence response).
  - Convergence Insufficiency (reduced nearpoint of convergence where fusion is lost after maximal convergence effort)
Prevalence of oculomotor dysfunctions

- General Population: 8-18%
- mTBI clinic: 90% of patients were diagnosed with one or more oculomotor dysfunctions following acute mTBI phase and natural recovery period. About 40% had some type of accommodative dysfunction: Insufficiency, Intfacility and Excess (mostly A.I.) About 60% had some type of vergence dysfunction (mostly Convergence Insufficiency). About 30% had version dysfunction (mostly saccadic dysfunction). (Ciuffreda, Kapoor, Runtner Occurrence of oculomotor dysfunction in acquired brain injury: a retrospective analysis. Optometry 2007: 78;155-161)
Oculomotor Dysfunctions

Oculomotor dysfunction is prevalent in patients after concussion:

- About 40% have some type of accommodative dysfunction: Insufficiency, Infacility and Excess (mostly A.I.)
- About 60% have some type of vergence dysfunction (mostly Convergence Insufficiency)
- About 30% have version dysfunction (mostly saccadic dysfunction)

- 42 UND athletes completed battery of nearpoint and visual-perceptual-motor tests, concussion history questionnaire, neuro-cognitive testing (ImPACT)

- ImPACT was not sensitive to lifetime history of concussion, but 2 oculomotor measures and one attention measure were.
Neural Plasticity

- Brain will modify continuously both structure and function per its range of dynamic multi-sensory experiences.
- Formation of new synapses, strengthen or alter existing synapses, alter firing, etc.
- Repeated stimulation induces long-term potentiation by activation of N-methyl-D-aspartate (NMDA) receptors that trigger a cascade of cellular mechanisms resulting in learning and memory.
- Motor learning to acquire new skill or recover a lost skill involves: 1.) trial and error with constant feedback; 2.) repetition of newly learned task; 3.) motor skill becomes automatic without feedback control.
Vision therapy is a sequence of activities individually prescribed and monitored by an optometrist to develop efficient visual skills and processing. It is prescribed after a comprehensive eye examination has been performed and has indicated that vision therapy is an appropriate treatment option. The vision therapy program is based on the results of standardized tests, the needs of the patient, and the patient's signs and symptoms. The use of lenses, prisms, filters, occluders, specialized instruments, and computer programs is an integral part of vision therapy. Most effective vision therapy programs in the U.S. are provided by a Certified Optometric Vision Therapist (COVT) under the direction and supervision of a Fellow of the College of Optometrists in Vision Development (FCOVD).
Versions-Saccadic Testing

Saccades (Reflexive; Voluntary; Anti-saccades): Latency and Accuracy measured

1.) EyeTrain Device (Pro-saccades and Anti-saccades)
2.) King-Devick Test (K-D); Developmeal Eye Movement Test (DEM); (Voluntary eye movements with visual-verbal responses)
3.) Visagraph: Voluntary sequential saccades with and without reading text
FixTrain: Pro-Saccade; Anti-Saccade Testing & Training
Saccade Testing

- King-Devick Saccade Test
Visagraph Oculomotor Testing
Fixation test 1
Look steady on the x for 20 seconds.
Fixation test 2

Look on the x-es back and forth as fast as you can for 20 seconds.
### Numbers Test

Start on the ring, and then look on the numbers from left to right row by row.

<table>
<thead>
<tr>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>5</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Midway through the Civil War, Lincoln decided that the country needed to be tied together by a railroad. At the time, it took four months to sail from one coast to the other and more than a month to go by stagecoach. Many people thought that the railroad companies should pay for the construction of the railroads themselves. Lincoln felt that it would help the country recover from the war if a railroad were built. After Lincoln died, the government continued the project. Free land and payments for each mile of construction were given to the railroad companies. It took 20,000 workers six years and millions of private dollars to lay the 1,086 miles of track. Many died in the effort. In 1869 in Utah, the last spike driven in was a gold one.
Visagraph Oculomotor Testing

- Measures Fixations, Regressions, Fixation Duration, Reading Rate and composite Grade Level Equivalent (GLE); anomalies and cross-correlation are indicators of eye teaming efficiency

- Test using text at grade level and 5 grades lower: >3 grade levels in GLE improvement suggests vision problem is language based; <3 GLE improvement suggests oculomotor based problems
Visagraph
Visagraph Reading Profile

Reading Profile Visagraph

<table>
<thead>
<tr>
<th></th>
<th>Recorded</th>
<th>Grade Aver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixations/100 words</td>
<td>169</td>
<td>96</td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>31</td>
<td>18</td>
</tr>
<tr>
<td>Fixation Duration (sec)</td>
<td>0.29</td>
<td>0.26</td>
</tr>
<tr>
<td>Reading Rate (words/min)</td>
<td>119</td>
<td>237</td>
</tr>
<tr>
<td>Grade Level Equivalent</td>
<td>2.4</td>
<td>11</td>
</tr>
<tr>
<td>Regression/Fixation Ratio</td>
<td>18%</td>
<td>13%</td>
</tr>
<tr>
<td>Anomalies (Fix/Regr/Both)</td>
<td>1/1/3</td>
<td></td>
</tr>
<tr>
<td>Cross Correlation</td>
<td>0.747</td>
<td></td>
</tr>
<tr>
<td>Correct Comp. Answers</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Analysis Reliability</td>
<td>88%</td>
<td></td>
</tr>
</tbody>
</table>

Subject information

Grade Level of Text Read 5
Lines to analyze in text 10
Lines found by analysis 16
Saccades in Return Sweeps 1.6
Vision Therapy is a subset of motor and perceptual learning.

Targeted, specifically programmed paradigms structured to improve related visual functions

Enhance neuronal connections and synaptic strength through repetition

Usually begun around one month post-concussion.
Percon Saccade Training
Hart Chart Saccade Training
Saccade Training: Wayne Saccadic Fixator
Focus Builder App

Focus Builder by Cedrick Noel

Updated: 12 Jan 2013
Requires iOS: 4.0 for devices: iPad3G, iPadWi, iPhone, iPad2G, iPad2Wi, iPhone 3GS, iPodTouch(3Gen), iPodTouch(4Gen)
Category: Medical
Price: $24.99

Eye Movements are a very powerful way to exercise the brain and to create long term change in the brain, known as plasticity. The “Focus Builder” app contains a variety of exercises which challenge users to voluntarily move their eyes in various patterns, speeds and directions, which have been proven to activate specific parts of the brain depending on which eye movement is performed.

This app is specifically designed for doctors that operate in Functional Neurology and their patients. There is currently no app available that can provide these specific exercises. For best results, patients should consult a Functional Neurologist to determine how to use this app according to their needs and goals of the specific tasks.

There are 4 types of eye movements that can have profound health benefits, all of which are available in this app.
Versions-Pursuit Testing

- Direct observation (slow moving target): Watch for corrective saccades prior to 30 degrees/sec.
- Infrared Eye Tracker: Visagraph and Rotator (Alter speed until breakdown of smooth pursuits is observed)
Marsden Ball Pursuit Training
Computerized Pursuit Training: Sanet Vision Integrator
Accommodative Dysfunctions

Accommodative Tests (pre and early presbyopes)

1.) Accommodative Push-up Amplitudes: diminished (receded)

2.) Accommodative Facility (+/-2.00 flippers): Receded cycles/minute compared to age norms

3.) Objective measures: WAM-5500 Open-Field; Optometer (Grand Seiko)
Accommodative Dysfunction

- Accommodative Insufficiency (AI): Reduced amplitudes; 80% of AI have CI
- Accommodative Infacility: Focusing quickness is sluggish
- Ill-sustained Accommodation: Focusing starts good, but gets worse
- Accommodative Excess (spasm)
Accommodative Push-up Amplitude Test (monoc/binoc)
## Accommodative Amplitudes (age adjusted)

<table>
<thead>
<tr>
<th>Age</th>
<th>Minimum distance (Cm)</th>
<th>Minimum AMP (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>8</td>
<td>12.5</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>11.5</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>10.5</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>11</td>
<td>9.5</td>
</tr>
<tr>
<td>20</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>8.5</td>
</tr>
<tr>
<td>24</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>26</td>
<td>13</td>
<td>7.5</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>32</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>34</td>
<td>18</td>
<td>5.5</td>
</tr>
<tr>
<td>36</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>38</td>
<td>22</td>
<td>4.5</td>
</tr>
<tr>
<td>40</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>42</td>
<td>29</td>
<td>3.5</td>
</tr>
<tr>
<td>44</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>46</td>
<td>40</td>
<td>2.5</td>
</tr>
</tbody>
</table>
+/-2.00 Accommodative Flipper Test (8 cpm)
Accommodation Testing: WAM-5500 open-field autorefractor
Abnormal Accommodation in mTBI
Abnormal Accommodation in mTBI

Figure 4.
Dynamic accommodative responses to near stimuli (2D and 4D) as a function of time in (a) a control subject (subject N-3) and in three mTBI subjects manifesting (b) approximately normal (subject TBI-A8) and (c)-(d) significantly abnormal responses (subjects TBI-A9 and -A10, respectively). Monocular viewing with the right eye. mTBI = mild TBI, TBI = traumatic brain injury.
Near-far Accommodative Rock Training (step)
Loose Lens Accommodative Training (Ramp)
Accommodative Flipper Training with red/green suppression checks (dissociation of accommodation and vergence)
Cross-coupling of Accommodation and Vergence Systems
ZoneTrac Negative Accommodation Biofeedback Training
Vergences

Vergence Testing
1.) Cover Test
2.) Nearpoint of Convergence (NPC)
3.) Nearpoint of Nearpoint of Fixation Disparity (NPFD)
4.) Phorometry (phoria measurement; prism vergence ranges)
Nearpoint of Convergence Test (NPC)

- 94% of Optometrists use NPC as the main test for diagnosing CI (Rouse, et al., 1997)
- Normal: 0-6 cm from tip of the nose
- Abnormal: receded >6 cm from the tip of the nose
- Not age dependent
Convergence Insufficiency (CI)

- CI is a common binocular (two-eyed) vision disorder where the eyes have a strong tendency to drift outward when reading and doing near work (exophoria at near). This difficulty in maintaining single vision at near can cause discomfort, headaches, blurred vision, double vision and concentration difficulties when engaging in near work. Prevalence is about 8% of the population, but thought to be underdiagnosed. Most common test used for diagnosis is the Nearpoint of Convergence Test (NPC).
Nearpoint of Fixation Test (NPC)

- Subject fixates a 20/30 target that is slowly (1-2 cm/s) moved toward bridge of nose until it becomes double (break point), then the direction is reversed until the target becomes single (recovery point).
Similar to the NPC test, but target is comprised of nonius lines around a fused circle and letter E. The right eye sees the top arrow and the left eye sees the bottom arrow when wearing cross-polarized lenses.

The subject is asked to report when the arrows no longer appear to be aligned vertically as the target slowly (1-2 cm/s) approaches the bridge of the nose. The distance at which misalignment is seen is NPFD break point.

The NPFD tends to be more sensitive than NPC to errors of binocularity in persons with Convergence Insufficiency (CI). This is because a vergence response that lags behind a vergence demand will be seen as misaligned vertical lines prior to the target going double.
Nearpoint of Fixation Disparity Test
1.) 60 pediatric patients with binocular and/or accommodative problems: 35 asymptomatic; 25 symptomatic

2.) Receded NPC at near in many cases was not sufficiently sensitive to the symptoms of CI.

3.) NPC was 19% sensitive to CI (81% of the pediatric CI-patients classified as having no CI) while NPFD was 95% sensitive and 100% specific to CI.

4.) CI likely underdiagnosed when using NPC alone.

5.) Should clinicians substitute NPFD for NPC in concussion assessments (e.g. VOMS)?
Pencil Pushups Convergence Training (gross convergence)
Brock String Vergence Training
Aperture Rule Vergence Training
(Separating Accommodation and Vergence)
Vectogram Ramp Vergence Training
Computerized Ramp/Step Vergence Training
Computerized RDS Ramp/Step Vergence Training
Virtual Reality Activities (VIVID Vision)
Split Prism Vergence Facility Training
EyeTronix Alternating Flicker Anti-suppression/StereoTraining (7 Hz)

Suppression (competitive disadvantage of one eye, active mechanism)
- Foveal (central)
- Intermittent, alternating
- Constant (longer duration of dysfunction)

Purpose: Reduce demand for precise binocular alignment (fixation disparity)
Stereopsis Training
VIP/VMI Problems

- Figure Ground Disturbances
- Visual Memory Disturbances
- Intermodal sensory integration problems, as well as errors in visual direction and delays in visual processing.
- Tested with TVSP-R; Nike Sensory Station; Sanet Vision Stimulator, etc.
VIP/VMP Testing/Training
<table>
<thead>
<tr>
<th></th>
<th>1) Visual Clarity #</th>
<th>2) Contrast Sensitivity #</th>
<th>3) Depth Perception #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="circle.png" alt="Visual Clarity" /></td>
<td><img src="darker_circles.png" alt="Contrast Sensitivity" /></td>
<td><img src="nested_circles.png" alt="Depth Perception" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>4) Near-Far Quickness</th>
<th>5) Target Capture #</th>
<th>6) Perception Span</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="smartphone_with_circles.png" alt="Near-Far Quickness" /></td>
<td><img src="target_capture.png" alt="Target Capture" /></td>
<td><img src="nested_circles.png" alt="Perception Span" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>7) Eye-Hand Coordination</th>
<th>8) Go/No Go</th>
<th>9) Hand Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="green_circles.png" alt="Eye-Hand Coordination" /></td>
<td><img src="red_circles.png" alt="Go/No Go" /></td>
<td><img src="green_and_white_circles.png" alt="Hand Response Time" /></td>
</tr>
</tbody>
</table>
Nike Performance Profile

[Image: Radar chart showing performance metrics such as static visual acuity, hand reaction time, contrast sensitivity, depth perception, eye-hand coordination, near-far quickness, perception span, and dynamic visual acuity. The chart compares Session 1 and Session 2 with markers indicating the performance levels.]
1.) Low performers on Perception Span, Target Capture, Go/No Go, and Depth Perception sustained twice as many severe head impacts than high performers.

2.) Athlete visual performance may be related to their ability to anticipate and react to impending head impacts on the field.

3.) Sports vision enhancement training may decrease the risk of sustaining injurious head impacts.
Central-Peripheral Split-Attention Training
Visual-Motor Loading
NeuroTracker Multiple Object Tracking
QuickBoard Reaction-Response Training
QuickBoard: Count, React, Sequence Drills
Fit-Light: Eye-Body Reaction
Visual-Motor Loading
General Vision Rehabilitation Guidelines

- Accommodation ➔ Vergences ➔ Versions?
- Monocular ➔ Binocular
- Slow ➔ Fast
- Large Targets ➔ Small Targets
- Voluntary (conscious) ➔ Involuntary (unconscious/automated)
- Kinesthetic/Proprioceptive support ➔ no support
- Near ➔ Intermediate ➔ Far
- Integrate with other visual function and sensory modalities (loading)
General Vision Rehabilitation Guidelines

- Include a Time/Space Component
- Include a Movement Component
- Include a Cognitive Component
- Work in different fields of gaze
- Work in different levels of ambient illumination/contrasts
- Work with different types of balance or posture demands
General Vision Rehabilitation Guidelines

- Help patient to develop smallest JND on all tasks (accuracy before speed)
- Help patient improve speed/accuracy trade-off
- Help patient to learn to monitor themselves and self-direct
- Help patient to learn to integrate visual skills with balance, movement, posture and cognitive demands on a much higher level
Ways to raise the task demand (loading)

- Verbal: counting, spelling, addition, problem solving, room description
- Vestibular: head movement
- Motor: balance boards, bongo boards, walking rails, trampolines, Bosu ball
- Visual: dissociating prisms, yoked prisms, +/- lenses, partial occluders (binasals), alter target size, alter stimulus contrast, reduce exposure time, add suppression controls
- Auditory: metronome, background noise, talking to patient
- Tactual/Kinesthetic: gradually eliminate these feedback mechanisms as therapy progresses
Principles of experience-dependent plasticity

1. Use It or Lose It: Failure to drive specific brain functions can lead to functional degradation.
2. Use It and Improve It: Training that drives a specific brain function can lead to an enhancement of that function.
3. Specificity: The nature of the training experience dictates the nature of the plasticity.
5. Intensity Matters: Induction of plasticity requires sufficient training intensity.
6. Time Matters: Different forms of plasticity occur at different times during training.
7. Salience Matters: The training experience must be sufficiently salient to induce plasticity.
8. Age Matters: Training-induced plasticity occurs more readily in younger brains.
9. Transference: Plasticity in response to one training experience can enhance the acquisition of similar behaviors.
10. Interference: Plasticity in response to one experience can interfere with the acquisition of other behaviors.
Effectiveness of Neuro-Optometric Rehabilitation

Ciuffreda et al. (2008): Oculomotor Vision Therapy yielded 90% improvement in 160 post-concussion patients, as well as improved reading and QOL.

Yadav et al. (2014): Improved VEP amplitude; EEG alpha band power and VSAT in 7 mTBI adults after just 9 hours of OVT.

Orsillo & Derr (2013): Improved VEP latency in 48% of Florida State Football Players after 8 weeks of visual-perceptual-motor training.
Vision Training for Concussion Mitigation?

- An Exploratory Study of the Potential Effects of Vision Training on Concussion Incidence in Football (Clark et al. 2013)
  
  From 2007 to 2009 there were 8.75 +1.7 concussions per year with U of Cincinnati football team. Instituted oculomotor and visual-perceptual-motor training annually beginning in 2010. Since then the concussions have been 1.25 + 1.3 per year.


  120 hockey players (m/f age 13-18) will train 2 hours/week over 10 weeks. Visual hardware vs. visual software cross-over design.