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Active Cognitive Load Reduction (ACLR): A Neuro-Scientific Breakthrough to Optimize Working Memory Processes for Improved Learning & Retention

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December 2019

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Technical Abstract

This short white paper describes a new neuroscientific discovery by Dr. Andy Bevilacqua, a cognitive optical psychophysicist from Huntsville, Alabama and the Advanced cognitive Concepts Team at Bevilacqua Research Corporation. Optically-Stimulated Cognitive Load Reduction (OSCLR) provides users with a method of improving mental focus and reducing physical and mental fatigue during long or strenuous cognitive activities such as training or education. This fully patented new discovery represents a significant disruptive technology for the military training community.

Background: Priorities Within the Human Brain

The human brain is an extremely complex organ therefore It is not known how many individual processes the brain actually supports, where they all reside within the brain (and nervous system and body), how often they require interaction, whether those processes are implemented continuously or on demand or what priority they hold under all of the various different environments and situations in which the body finds itself. **Despite our relative ignorance of the structure and operation of the brain, we do know that operationally, in a broad sense, the brain is a biological computer with classes of discrete, distributed processing functions, continually working in concert to maintain an information sharing environment that maximizes the survival of its host**. Our inferred knowledge of the inner workings of the brain are gained primarily through studying the behavior of the outputs that occur when specific inputs are provided. These studies tell us that brain processes can be generally divided into broad categories based upon their relative priority in the hierarchy of processes that fight to protect the body. For example, some brain processes run continually in the background and cannot be stopped without causing serious damage to the body. These include autonomic processing for respiration, heartbeats, chemical processes, etc. that would result in cessation of life function if they were stopped. The brain also has higher level survival processes that run in the background (outside of attention). However, these intermediate background processes can be stopped without causing immediate harm to the individual. These include processes such as those that provide continual monitoring of sensory inputs from the eyes, ears, etc. These intermediate level background processes continuously monitor the immediate environment for the possible presence of outside threats but you can shut them off (i.e. close your eyes) without causing serious harm to the body. Finally, there is processing that is accomplished on demand to collect the real-time inputs from the immediate environment that constitute things we are directing our attention to at any particular moment in time, (figure 1).

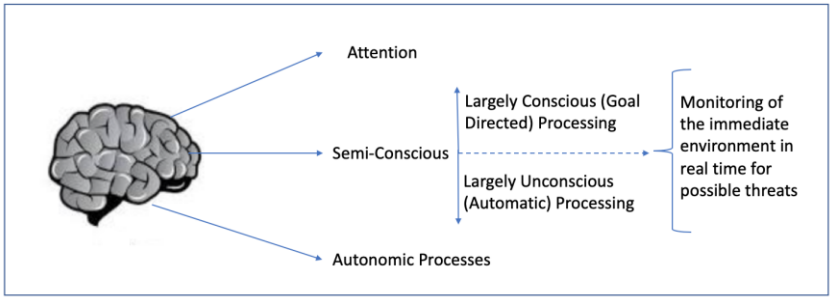

Figure 1: Levels of Processing in the Human Brain

As a biological computer the brain has practical limits in how much information it can process (safely) at any point in time. In fact, the brain has built-in safety features to prevent sensory overload in the intermediate and real-time on-demand processing levels. These safety features prevent high level immediate processes from taking up too much of the brain's resources at the expense of more critical autonomic processing and other survival functions. One of the major safety structures within the brain is short-term or working memory. Working memory filters and prioritizes all incoming information in the intermediate and immediate processing levels to a) make sure enough processing is allocated to critical autonomic processes at all times, b) making sure enough processing capacity is allocated for semi-conscious processing of the immediate environment for threats c) "gisting" of information present within a person's immediate attention (Note: this involves the creating of heuristics or rules to deal with the understanding of new information from the senses and finally d) Storage of new information in long-term memory (learning). In order of priority these processes are listed as follows:

Priority 1: autonomic processes
Priority 2: intermediate survival processing from monitoring the immediate environment
Priority 3: Processing of information within the immediate (on demand) attention of the human
Priority 4: Storage of new information in long-term memory (Learning)

Optically-Stimulated Cognitive Load Reduction (ACLR)

To this point, everything presented in this paper falls within the realm of our common level of scientific understanding of how the brain works and therefore can easily be found within the scientific literature. Top-level neural processes were thought to be largely immutable. In other words, under normal operation the order of the above processing priorities was thought to be fixed. Cognitive Load Theory (Sweller, 1988) is based upon the belief that in order to make more processing available for learning (Priority 4), one had to reduce either the complexity or amount of information being processed within immediate attention (Priority 3) because autonomic processing could not be stopped.

A recent discovery (Bevilacqua, Paas, & Krigbaum, 2015) has now shown however, that more room can be made for other brain priorities by taking advantage of a "loophole" within Priority 2 (immediate survival processing) (Kazanas, & Altarriba, 2015, Keoneisen, Erdfelder, & Buchner, 2013, Nouchi, 2011, Ohman, Soares, Juth, Lindstrom, & Esteves, 2012), that reduces the amount of processing needed for priority 2 tasks, thus making more processing room available for tasks within the other priority areas of the brain. This technique is called Active Cognitive

Load Reduction, (ACLR). Extensive testing with human subjects since 2015 has shown a definite reduction in overall cognitive load can be achieved when specific visual stimuli are continuously applied through the eyes to the brain (Bevilacqua, Paas, & Krigbaum, 2015, Bevilacqua, 2019). Although it is far beyond the scope of this short paper to explain why active cognitive load reduction works. The prevailing theory is that since detecting biological motion is far more important to survival than the detection of non-biological motion, the brain must expend much more processing resources through the default mode network (BMN) to process biological motion (Hiris, 2007, Grosman, & Blake, 2002, Hamilton, 2012, Dayan, et.al, 2014, Wuerger, et. al, 2014). It is also important for the brain to be able to ignore non-biological motion in favor of biological motion processing to aid survival through improved success in hunting (Geary, Winegard, & Winegard, 2014). Therefore, the brain is thought to have the ability to "ignore" non-biological cues saving its processing instead for more important biological processing tasks.

By applying the specific signals that idle continuous biological processing of visual information using optically-Stimulated Cognitive Load Reduction, (See Patents (Appendix A)), the brain is "fooled" into setting aside extra processing resources that can then be made available for priorities 1, 3, & 4. Although initially there was skepticism regarding the validity of the OSCLR discovery, the Cognitive Load Theory (CLT) community is now embracing the idea that not all information is processed the same way all of the time within the brain (Sweller, 2008). The latest research, an extensive meta-study executed by experts in the Cognitive Load community in 2019, actually expresses agreement with the data presented by Bevilacqua, (2017) in support of the OSCLR phenomena (Castro, et. al, 2019).

OSCLR Testing Results (2015-Present)

In a pilot study that was investigating test methods that could be used to investigate how movement in learning environments affected learner cognitive load levels, the results, as shown in figure 2 below, actually indicated that cognitive load was reduced significantly in males when specific types of non-biological movement was introduced during secondary task execution (Bevilacqua, Paas & Krigbaum, 2016).

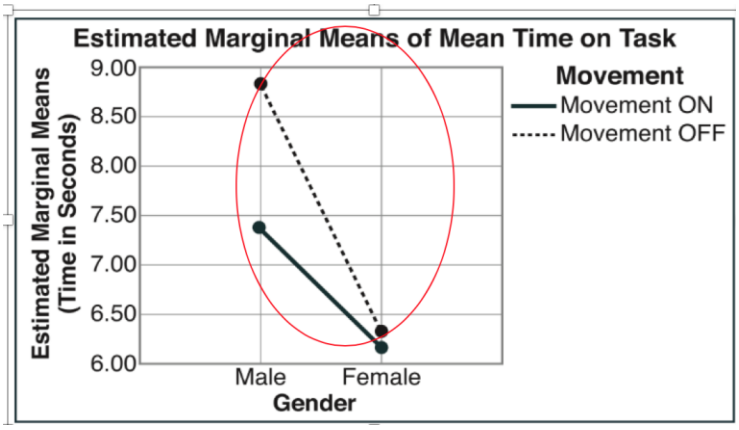

Figure 2: Pilot Study Results Indicated that especially for males, Overall Cognitive Load Levels were reduced when non-biological motion was Introduced

Subsequent tests, performed using human subjects between 2016 and 2017 generally supported the figure 2 results. Testing during this time was used to do preliminary investigations of several excursions of the independent variable (movement) in an attempt to determine how important various factors were to the overall OSCLR process.

There are several theories about where working memory processes actually take place within the human brain (Dayan et al., 2014; Grossman & Blake, 2002; Hamilton, 2012; Hiris, 2007; Wuerger et al., 2012). Working memory is tasked primarily with maintaining vigilance to detect threats from the immediate environment through the senses. It's secondary task is to connect incoming information with long-term memory for learning. The quality of this secondary task is dependent on how much of the brains processing is taken up with sensory stimulation. In a quiet, low threat (low cognitive load) environment learning is faster and deeper and in a confusing high cognitive load environment learning and retention are poor.

The discovery that the OSCLR process can artificially reduce overall CL in working memory, allows learning and retention to be optimized regardless of the learner's emotional state, age or fatigue level.

To validate this effect, in 2018 operational testing was accomplished using standard A/B tests on an operational news website hosted in Huntsville, Alabama. Those tests clearly showed that when non-biological movement was added customers spent less time on the site indicating that they had understood the material presented faster (i.e. cognitive load levels for visitors were significantly reduced when movement was introduced into the advertising display process) (figure 3).

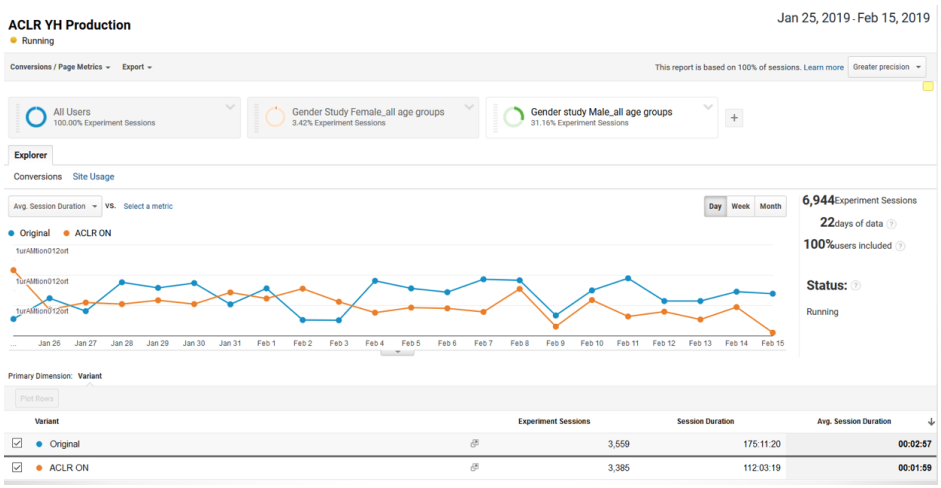

Figure 3: Operational Testing Proved that customers stayed on the site a shorter period of time when non-biological movement was displayed with advertisements

Although most tests support the efficacy of the OSCLR effect, these results only indicate that the effect is possible (initial pilot study results in 2015) and probable (continued tests between 2017

and 2019). To provide a measure of certainty that the effect exists, an independent 3rd party test sequence must be executed. Bevilacqua Research Corporation has retained a University to design and execute independent testing. Test results are expected to be available before July of 2020 (depends on COVID-19).

Applying Optical Stimulation of Cognitive Load Reduction to Training & Education

The OSCLR process can be accomplished in one of two ways. First by adding the OSCLR visual signal directly to a display, document, website or other instructional or informational display within the field of view of the observer (Figure 4).

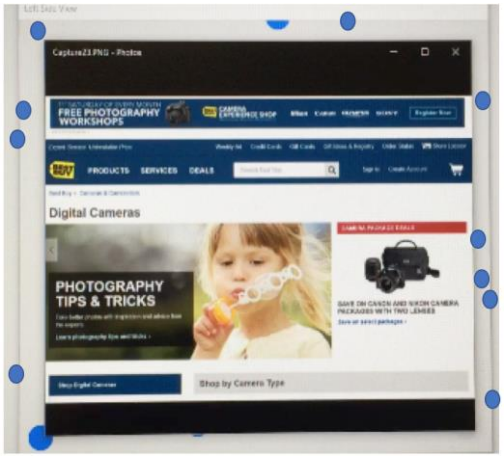

Figure 4: An example of OSCLR stimuli added directly to a webpage, educational material, or Advertisement

Or, when one is unable to add the movement to the display, smart glasses (COGS) can be worn by the observer that continually present the necessary stimuli to the eyes (Figure 5).

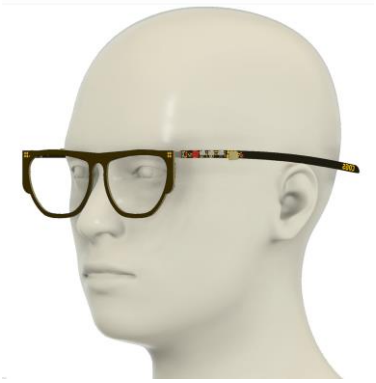

Figure 5: Alpha Version of the COGS TM Glasses for Active Reduction of Cognitive Load

This ability to focus more of the brain's processing resources on the material being viewed will not only shorten the time needed for students to understand information being presented, it will reduce learner physical fatigue and increase retention as well.

Summary

The discovery of a method for the Optical Stimulation of Reduction of Cognitive Load (OSCLR) by Dr. Andy Bevilacqua in 2015 was followed by 5 years of research and data analysis in which first the Probability (initial research), and then the Possibility (Operational testing) of the ACLR methodology were proven. Current tests by an independent third-party University team is currently underway. This testing is expected to prove the certainty of the efficacy of the discovery, opening the door to the commercial application of the methodology across several critical market segments.

The BRC Advanced Cognitive Concepts team continues to optimize the characteristics of the visual stimuli used in the COGS$_{TM}$ smart glasses which will continue to improve their effectiveness for the military training & Education community.

For information on OSCLR$_{TM}$ or the COGS$_{TM}$ smart Glasses contact Dr. Andy Bevilacqua, (256) 603-1657, andyb@brc2.com.

APPENDIX A
TECHNICAL REFERENCES

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APPENDIX B
CURRENT PATENTS

AWARDED: Cognitive Function Improvement System and Method, 15/095,824
AWARDED: Cognitive Function Improvement System and Method, 15/409,518
AWARDED: Cognitive Function Improvement System and Method, 10,482,779
Submitted: Cognitive Function Improvement System and Method: COGS Gamer's Glasses