A new technology for artifact-free pattern stimulation

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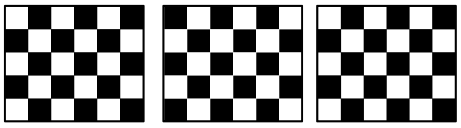
1. Introduction

Pattern stimulations are widely used in visual electrophysiology to obtain a response specific of ganglion cells: the pattern electroretinogram (PERG) and responses from the visual cortex: the pattern visual evoked potentials (PVEP).
Pattern stimulations are usually obtained by reversing the pattern (pattern reversal): black elements are replaced by white element and vice versa) or by replacing the pattern with a uniform gray stimulus (pattern on- off).
One important characteristic of these stimulations if that the average luminance of the stimulation should be constant (ISCEV standards for pattern ERG and for pattern VEP): there should be no change in luminance, even transient when reversing the stimulus of when switching from the on to the off pattern. If constant luminance is not achieved, the PERG stimulus will generate a response not only from the ganglion cells but also from other layers of the retina. In a similar way the PVEP stimulus will activate different types of cortical cells and may results in an error of diagnosis.
This article presents a new technology developed and patented by Metrovision for the generation of pattern stimulations without luminance artifact.



pattern reversal stimulation

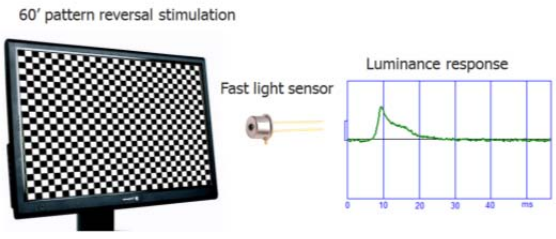
pattern on-off stimulation

2. The luminance artifact of LCD stimulators

Until recently, patterned stimulations were obtained with cathode ray tube monitors (CRTs). Constant luminance was easily obtained for pattern reversal stimuli. However, it required a careful adjustment of the gray level to be obtained with on-off stimuli.
Unfortunately, the production of CRTs has now been stopped for several years and it is only possible to get old or refurbished CRTS. Liquid crystal monitors (LCD) have now taken a dominant, even monopolistic share of the market.


Pattern reversal stimulus generated with a CRT stimulator (Rigaudiere & al, 2009)

The constant luminance of a stimulator can be checked with a fast light sensor placed in the same position as the patient's eye. If luminance is constant, the sensor output does not change when there is a pattern reversal or pattern on-off. If this experiment is done with a standard LCD monitor, we observe a transient light flash at every pattern reversal or pattern on-off. Constant luminance cannot be achieved. This is what is referred to as the luminance artifact.

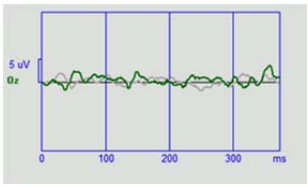


3. How does the luminance artifact affect the pattern responses?

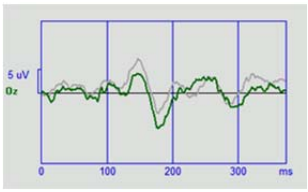
It can easily be demonstrated that the flash artifact has a significant effect on the VEP response with the following simple experiment.

Placing a holographic filter in front of the subject's eye while viewing a pattern reversal stimulus eliminates the perception of the pattern.

With a CRT stimulator, there is no VEP response detected whereas, with a standard LCD monitor, a VEP response is detected, similar to the response to a flash stimulation.



Response to a 30' pattern reversal stimulus obtained with a CRT monitor while wearing an holographic diffuser

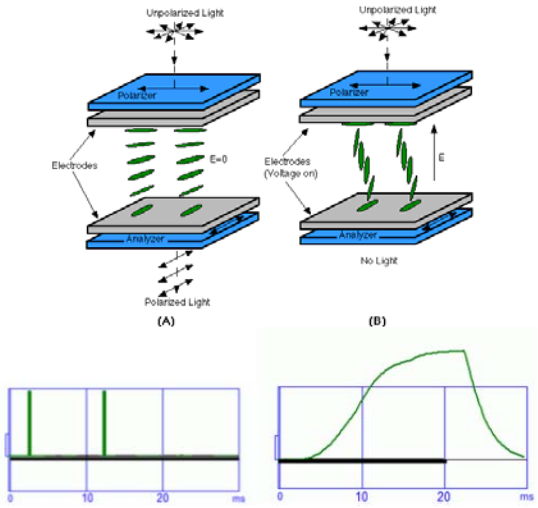


Same response obtained with a standard LCD monitor

4. What is the cause of the luminance artifact?

In order to understand what is causing the luminance artifact of standard LCD monitors, we have to get into the technology of these monitors.
A typical LCD monitor includes a light source called backlight followed by an LCD panel. The LCD panel is made of small cells consisting of a layer of liquid crystal molecules sandwiched between two transparent electrodes and two polarizing filters. The liquid crystal molecules produce a rotation of the light polarization so that the light can go through the second crossed polarizing filter (analyzer).
The application of an electric field between the electrodes changes the orientation of the liquid crystal molecules and consequently the rotation of the light polarization resulting in a blockage of light by the analyzer filter.

The change in orientation of the liquid crystal molecules produced by the electric field is quite slow, in the order of several milliseconds. This is much larger than the typical time response of the light produced by CRT monitors which is in the order of a few microseconds.
The slowness of standard LCDs results in a delay in the appearance of the stimulus. This delay can easily be compensated, provided it is constant. Another problem is that the velocity in one direction change is not exactly the same as for the change in the opposite direction.
During a pattern reversal, this difference in transition time between white to black and black to white results in a light pulse. This light artifact is present whichever LCD technology is used or whichever adjustment in contrast or luminance is made. It some cases, it may be reduced but it is always present. Even with an optimal adjustment, it may increase with changes of temperature or with aging.



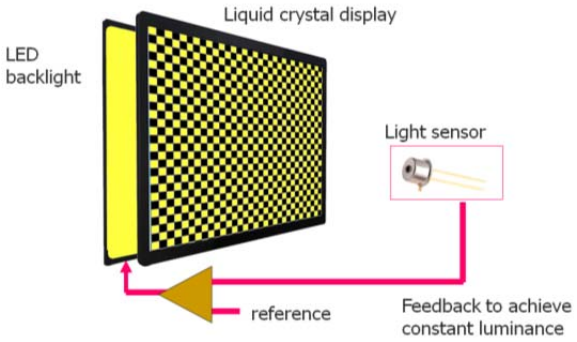
Luminance response of CRT (left) and LCD (right) monitors

Contrast	Waveform	Artifact
100%		-50%
95%		-8% +4%
90%		-8% +4%
85%		+5%
80%		+5%

Example of uminance artifact at different contrast levels

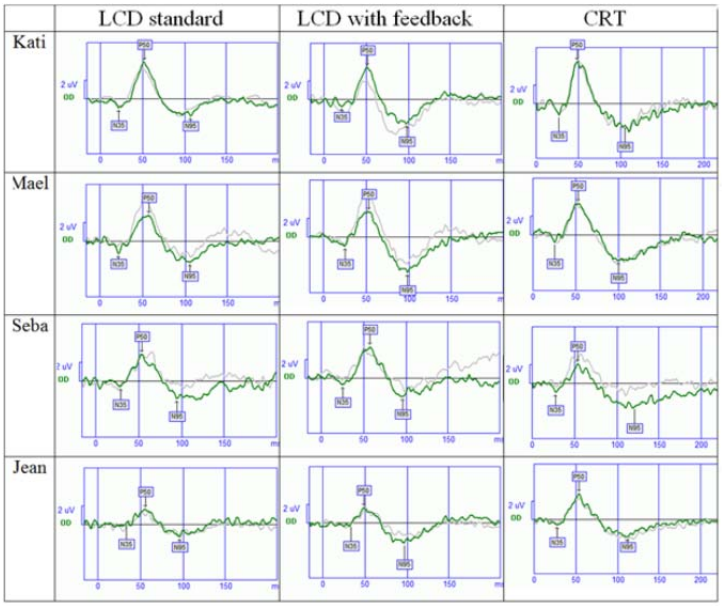
5. Metrovision's technology for artifact-free pattern stimulation

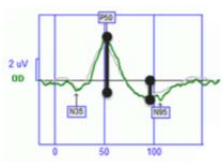
In order to eliminate the luminance artifact of standard LCD monitors, Metrovision has developed and patented a new technology.
This technology involves a light sensor that constantly monitors the average luminance output of the monitor. The signal of this light sensor is compared to a reference value and the difference is used to increase or reduce the luminance of the backlight, resulting in a constant average luminance of the stimulation.
In order to be effective, this feed-back system must be extremely fast, much faster than the time response of the eye. For this reason, Metrovision's stimulator includes a backlight made of light emitting diodes (LEDs have a very short response time compared to the usual electroluminescent backlights) and a very fast light sensor.
The current feedback time is 250 microseconds.
This new technology guaranties a constant luminance for pattern reversal as well as for pattern on-off stimulations.



6. Results for Pattern ERG

The following table shows pattern ERGs recorded from 4 normal subjects, following the ISCEV standard with HK loop electrodes.
3 stimulators models were used: a standard LCD monitor, a CRT (Metrovision's MonPack3 system) and a LCD with feedback (Metrovision 's MonPackONE system). Stimulation parameters were the same for the 3 stimulators (average luminance = 50 cd/m2 and contrast = 95%).



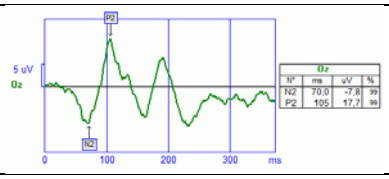
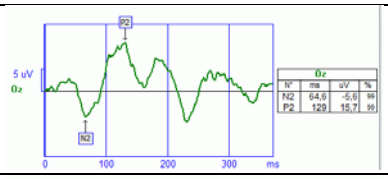
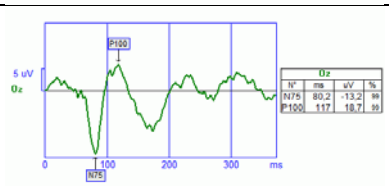
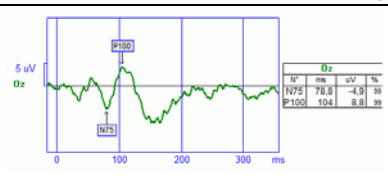
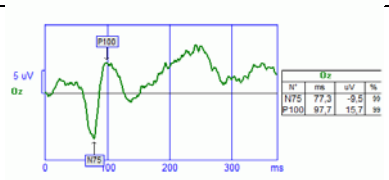
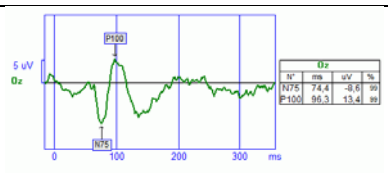
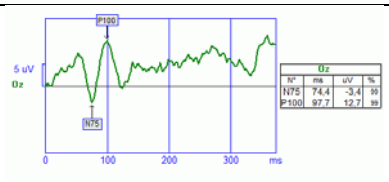
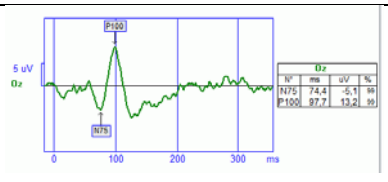
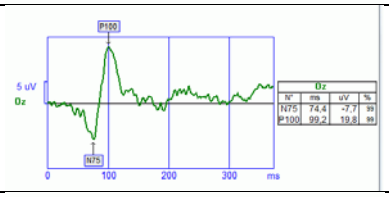
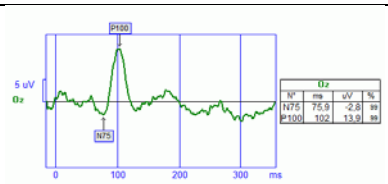
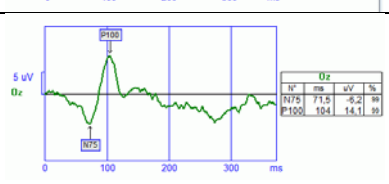
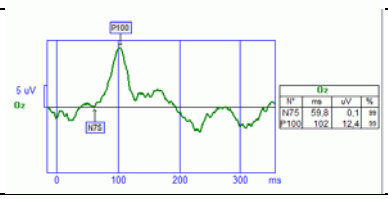
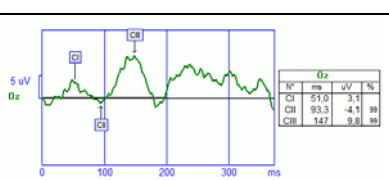
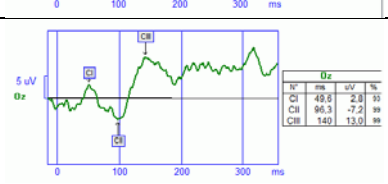
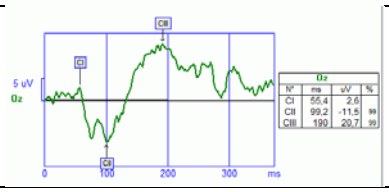
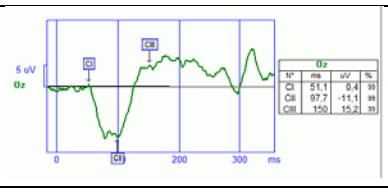


	LCD standard	LCD with feedback	CRT
P50 amplitude	3.75	3.42	3.40
N95/P50	0.25	0.46	0.47

The average values obtained from this group of subjects are very similar for the LCD with feedback and with the CRT. The responses from the standard LCD monitor show larger amplitude for P50 and a reduced ratio for N95/P50 that may correspond to a larger contribution of the non-ganglion cell components.

7. Results for Pattern VEP

Pattern VEP responses obtained with the same subject on with a CRT monitor (Metrovision's Monpack3) and a LCD with feedback (Metrovision's MonPackONE)

Stim.	CRT	LCD with feedback
flash		
Pattern reversal 7'		
Pattern reversal 15'		
Pattern reversal 30'		
Pattern reversal 60'		
Pattern reversal 120'		
Pattern on-off 60'		
Pattern on-off 15'		

8. Conclusion

Constant luminance is important for pattern reversal and pattern on-off stimulations used in visual electrophysiology exams.

Standard LCD monitors present a light artifact that does not allow constant luminance.

We have developed a new technology consisting in a light sensor combined with a LCD monitor and a LED backlight. The light sensor measures in real-time the luminance output of the stimulator and maintains its average luminance constant by driving the LED backlight.

This new technology has been patented and is now available in the MonPackONE stimulator manufactured by Metrovision.