A novel optical illusion based on visual-acoustical sensory interaction, possible applications

R. Micheletto
Yokohama City University, Graduate School of Nanobioscience, Department of Nanosystem Science, 22-2 Seto Kanazawa-ku, 236-0027 Yokohama, Japan

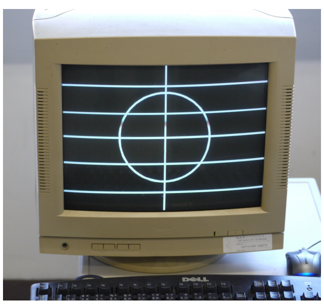
Abstract: We studied the influence of mechanical vibrotactile signals in the acoustic range to the visual perception of flickering images. The "flickering" images are shown on a CRT screen intermittent at about 75 Hz, so in normal conditions are perceived as constant stable images. However, if presented together with the controlled acoustical vibration described in this paper, an illusion is perceived. The images appears to float out of the screen, while the rest of the room is still perceived normally. This illusion can be employed to realize an apparatus and do intensive investigation in order to find new way to study retinal diseases, do visual perception diagnostic tests, and generally study optical perception of the single retinal cells on a live and conscious human subject.

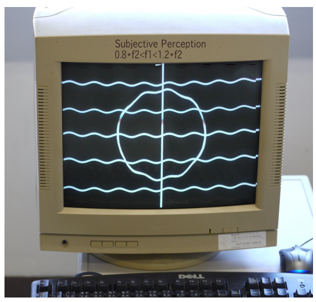
Introduction:

We know that images that reach our visual system (the retina) are elaborated partially in the retina and then in the brain. Finally these signals become a “high-level” sensation that we call “perception” of the object.

However, there is a great difference between what is the actual optical signal on the retina, and the high-level perception we feel. For example, we may look at the traffic while we walk in the street. We perceive cars and people moving around. However, the actual signal in the retina is a very complex dynamical pattern of images, shifted in time and space because of saccadic movements, vibration of the eyeball and other perturbations. How the visual system can put order in this extremely complex pattern of stimuli is unknown (see for example: T. Fumihiko; M. Ken “Spatio-temporal dynamics of the visual system revealed in binocular rivalry” Neuroscience letters (2005), 381(1-2), 63-8).

We established a new laboratory called 知覚情報科学(Sensory Information Science) in Yokohama City University. We conducted first original tests of visual perception via an innovative double-stimuli setup. The method use an optical blinking pattern and an external delicate mechanical vibration of low frequency applied below the jaw of the subject.. With this method it was discovered that images presented on a screen are perceived with unstable oscillations due to the interaction between the double stimuli.





It is difficult to describe a subjective perception, however in the left figure here we show the real pattern presented on the screen (screen is blinking at 70Hz) and we give on the right a representation of the perceived pattern (illusion). We can alter this illusion and making disappear adjusting the two frequency parameters f1(blinking) and f2 (vibration). We consider this particular mechanical-optical stimulation as our discovery in this field and we are going to publish it as soon as we have solid data.

Illusion effect description:

As said above the images that come to the retina are not stable and disturbed by mechanical perturbations and noises. Out brain in real time and without effort is able to filter the signal and create the perception of a clean and stable image. This "cleaning up" elaboration process that the brain does is a heavy and complex task. However, we are not aware of what is happening, nor we are aware of the effort involved. It is a process that is unconscious and transparent to us. Sure, it would be very nice to make it surface to the conscious level and study its characteristics.

We succeeded to devise a simple experiment that does - somehow - that. The experiment outlined here succeeds in interfering with the the visual elaboration process, producing “errors” that can be perceived at the cognitive level. It deals with the interaction between acoustic vibrotactile signals and the perception of flickering images.

To produce flickering images in simple way, we used an old cathodic tube monitor (CRT). This once common device draws images point by point with an electronic brush that scan the screen at a frequency of 75Hz. Still images are shown, while a subject observe them quietly seated on a chair. In normal conditions these images appear stable.

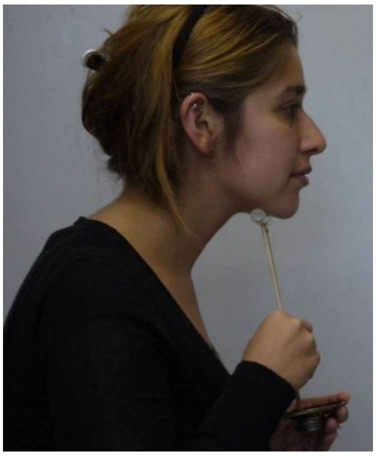


Fig. 1: The very simple way we applied the acoustical perturbation to the subject retina. The vibration is in the 50 – 100 Hz range of very low intensity (almost inaudible)

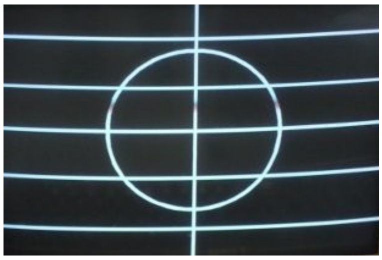


Fig. 2: The image presented to the subjects on a CRT flickering at 75 Hz.

Why it is so if the images are actually flickering at 75Hz ? The standard answer is: because the persistence on the images on the retina is much longer than the scan speed. So the brain has enough time to “integrate” the pattern and create a stable complete image for us. The same thing happens when we go to the cinema. Different images are flickering very fast in front of us, yet we perceive a continuous smooth movement for similar reasons.

We want to interfere with this process, so we devised the following method: a controlled acoustical vibration of about same frequency as the display flickering is transferred to the subject. To do that, we used a small wooden stick glued to a round plastic cylinder that is placed horizontally under the chin as shown in figure (1). The stick is mechanically connected to a speaker that the subject simply holds in his hand. Because of its low amplitude and frequency the vibration is barely audible, however it is actually transmitted to the whole head.

The frequency is generated by a sinusoidal function generator while the subject is seated comfortably looking at a geometric image on the screen. We tested several images and all of them produced the desired effect; in the experiments presented here we used the image in fig. (2).

Results:

While varying the frequency and amplitude of the stimulus, we asked the subjects to say when the perception was becoming unstable.

We found that when the audio signal reaches a frequency close to that of the screen flickering, something interesting happens. While the rest of the room appears unchanged to the subject, the images presented on the CRT screen begin to move and appear unstable. The images displayed are distorted with perturbations that change in strength and shape in line with the audio signal intensity and frequency.

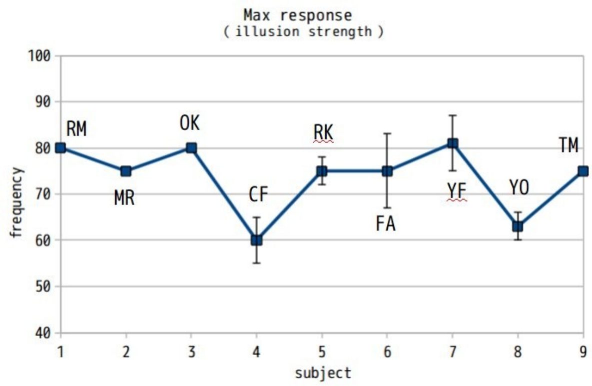


Fig. 3: The frequencies that resulted in the maximum illusion strength for several subject. Some subjects performed the experiments twice or three times, for them the error bar is given.

We asked the subjects to report 4 levels of intensity to quantify this subjective phenomenon: no illusion (image perfectly stable), weak, medium and maximum. In figure (3) are plotted the frequencies of maximum effect for different subjects. The illusion appears and decays with a Gaussian profile.

It is worth repeating that all other objects in the room are perceived as perfectly still, only the images on the display appears to oscillate.

Proposed device:

A single photoreceptor is about 40 micrometer long of about 1 or 2 micron of diameter. A low power intermittent beam of light is originated from a LED. Light will have an angular divergence controllable by a system of lens. The geometry of the eye implies that a 1x1 degree (deg) will cover an area of about 300x300 square micrometer, the know density of cones in the retina is of about 20.000 receptors per square degree. Considering these conditions our specially designed optical stimulus will have to cover an area of 0.01x0.01 degrees, that in this geometry correspond to 1-2 square micron. This localization it is not forbidden by diffraction and realizable by standard passive optical elements.

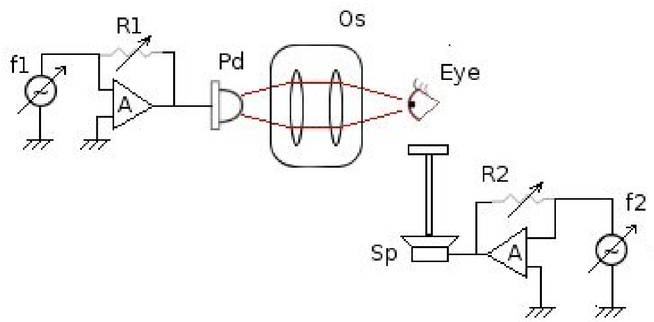


Fig 4: The scheme of a proposed device to test optical cognition characteristics

Our specially designed optical source will be connected to a programmable electronic circuits able to flash the light beam for a desired length of time and with a controllable repetition rate (impulse duration and frequency).

The subject will perceive this optical stimulus on a single cone receptor cell and the doctors can study the ability of the subject to do so in function of the signal duration and frequency in a systematic way. Our specially designed box will include the secondary vibration actuator. This soft rubber device will located on the window of the box on its lower side. In this way the subject will put his jaw on it and will receive a very delicate, low frequency vibration signal on his skull. This vibration is naturally transmitted to the eyeball that contains the retina.

The controllable mechanical perturbation will shift the retina of a few microns. This small measure is enough to shift the optical signal on the retina on adjacent cells at regular interval of times. This perturbation will confuse the retinal elaboration system and the subject will perceive an optical illusion: a sort of fluctuating optical source. The source will appear steady in intensity, but chaotically shifting in its position in space. The adjustment of the two frequency involved (optical source repetition rate) and the vibrational oscillation will control the intensity and dominance of the effect. We verified empirically that the illusion disappears if this condition is realized:

The nature of this optical illusion is the center of our exploratory research. The intrinsic properties of the retinal cell photoreceptor as well as the elaboration properties of retinal ganglion and the whole retina and the brain are responsible of the effect. With the aid of professor N. Mizuki in the Yokohama City University ophthalmology group several systematic calibration test will be performed to optimize the experimental setup

Conclusions:

We found a novel optical illusion related to the interaction of visual and vibrotactile stimulus, we describe here the illusion in details and give experimental quantitative results that describe its characteristics.

Also we propose a device that use this effect as a method to detect the functioning and performance of subject visual system. This device is described and and also it is shown who it can be employed to realize an apparatus and do intensive investigation in order to find new way to study retinal diseases, do visual perception diagnostic tests, and generally study optical perception of the single retinal cells on a live and conscious human subject.