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## PLATEAU'S EXPERIMENTS REVISITED

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### Abstract

*Joseph Plateau's pioneering experiments on the perception of contrast were replicated. The experiments were not done exactly as Plateau did. The main difference in our design was that, we made use of a computer to have the participants to generate grey scales using the bisection method. Our program interacted with each participant in such a way that he/she could generate a grey scale using the grey levels that were generated in the previous step. The experiments were done first with a black background and then with a white background, and with and without linearizing the computer monitor. Subjects with professional training for handling color as well as non trained subjects were invited to participate. The generated grey scales were analyzed with the help of a computer. Our results show that training is an important factor in contrast perception and that linearizing the computer display does not help the observers in the generation of a grey scale.*

Plateau, in his classical experiment (Laming and Laming, 1996; Plateau, 1872a; Plateau, 1872b), apparently done more than ten years before the publication of Fechner's Elements, tried to determine if we humans have the ability of precisely estimating the intensity of visual stimuli. The method that he used is now known as the bisection method (Heller, 2001), or method of equal appearing intervals (Murray, 1993) given that he asked to professional painters to paint a gray whose intensity (i.e. brightness) should be midway between white and a given black. According to Plateau, the participant painters arrived to almost the same tone of gray even though they all used different levels of illumination. That is why he assumed that the perception of contrast differences was not affected by illumination. However, after Plateau reviewed the work of J. Delboeuf (Plateau, 1872b), who was a contemporary Belgian researcher that followed his steps, he arrived to the conclusion that illumination, in fact, played a role in the perception of contrast.

On the other hand, there are evidences that suggest that perceptions of brightness are generated empirically by experience with luminance relationships. According with this, it makes sense Plateau's decision of asking professional painters to participate in his experiments. However, Plateau did not investigate how experience (i.e. training) influenced his results.

In this work are presented some results that were obtained by somehow replicating those pioneering experiments, but with the help of a computer and with subjects with professional experience in handling colour and non-experienced subjects on this matter. Our results show that training influences contrast perception, and that the use of different backgrounds clearly affects brightness perception in both trained and untrained subjects.

In visual perception experiments is a common practice to linearize the devices used to display the visual information (i.e. the computer monitors) so that the non-linear relationship between the applied voltage in the monitor circuitry and the displayed intensity on the monitor screen is corrected. However, an interesting point is that the results obtained in our experiments with a linearized computer monitor were not better that those obtained without linearizing the monitor.

## Materials and Methods

In order to be able to have precise control of the evolution of the experiments and direct accessibility to quantitative results, a computer program was developed specifically for these purposes. The program was developed using the C++ computer language under the Windows XP operating system. The program interacted with each subject in the following way: At the beginning the program it displays, side by side, three 3.5 cm x 3.5 cm squares. The square on the left is black, the one at the center is mid-grey, and the square on the right hand side is white. At the left hand side of the screen are displayed two buttons, one with an arrow pointing upwards (to increment brightness) and the other with an arrow pointing downwards (to decrease brightness). Subjects were instructed to click with the computer mouse on such buttons to modify the brightness of the square in the middle so that its brightness was half way of the brightness of the other two squares. Once completed the task, the subject should click on the OK button that also appeared on the screen. Next, the program displayed a black square, a mid-grey square, in the middle, and a square with the gray just created by the subject in the previous step. The task now was to change the brightness of the square in the middle so that its brightness was half way of the brightness of the other two squares. Each subject interacted with the program the way just described so that he/she created a gray scale of 32 grey shades alternating once towards the side of the black square and once towards the side of the white square. The experiments were done with a linearized flat screen CRT (Cathode Ray Tube) computer monitor (Sony Trinitron CPD-1425), first with a white background, and then

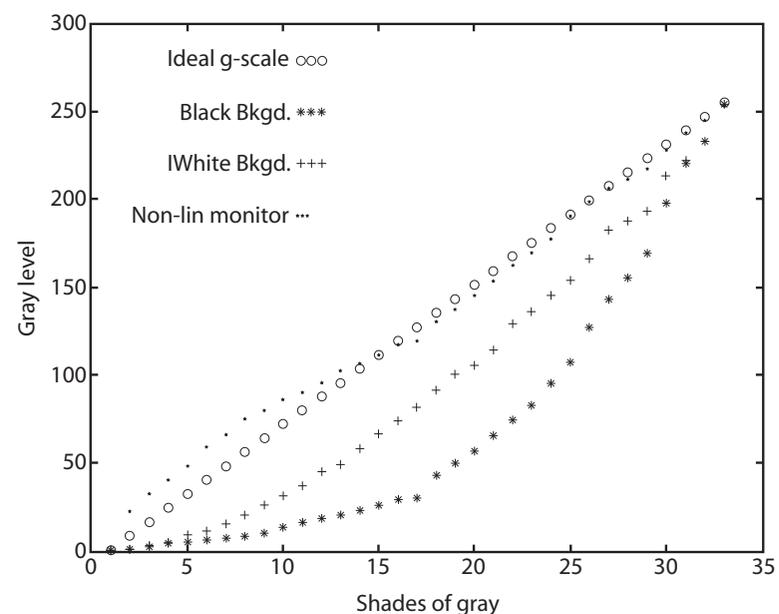


Figure 1. Representation of the gray scales created by an experienced subject with a linearized monitor, using black and white backgrounds, and a non-linearized monitor with white background.

with a black background. Then, the experiment was done without linearizing the monitor using background. Then, the experiment was done without linearizing the monitor using a white background. The monitor was linearized using a ColorCal photometer (Cambridge Research Systems Ltd. Rochester, Kent ME2 4BH, England), especially designed for that purpose. A total of six subjects participated in the experiments. Three of them were trained in using color and painting and the other three were untrained in such matters. The images used to present the squares on the monitor screen were 8-bit gray-scale images (which imply 256 grey levels).

## Results

In Figure 1 are shown the graphical representations of the gray scales created by a subject with professional training on art. The values of the horizontal axis correspond to the grey shades of the gray scales. Number 1 corresponds to black and number 32 corresponds to white. The values of the vertical axis represent the gray levels of the digital images of the squares used to construct the gray scales during the experiments. The ideal gray scale was plotted with circles. As can be seen, when the experiment was done with a black background, the trained subject had perceptions that overestimated the dark grays and underestimated the light grays without exception. That is, his tendencies were consistent all along the experiment. When the white background was used the same tendencies for over and under estimation persisted but at a lesser degree. Finally, when a white background was used but without linearizing the monitor, the trained subject created an almost perfect grey scale. This means that, according to our results, the non-linear relationship between the applied voltage in the monitor circuitry and the displayed intensity on the monitor screen, cancels the non-linear relationship between the lightness of a grey surface and the corresponding perceived brightness.

In Figure 2 are shown the graphical representations of the gray scales created by a subject without any professional training on art. As can be seen, with the black background the untrained subject also had perceptions with a tendency to over estimate the dark grays and to under estimate the light grays, but without the regularity shown by the trained subject.

When the white background was used, the untrained observer has perceptions that overestimated the dark grays, while the light grays were perceived as if they were evenly spaced, like in an ideal gray-scale. When the white background was used without linearizing the monitor, the dark and light grays produced perceptions opposed to the perceptions that the untrained observer had when the monitor was linearized with white background.

## Conclusions

Perception of contrast of achromatic colors is affected by the brightness of the background on which the contrast is perceived.

Considering the results of the subject that received professional training on art, our results suggest that perception of contrast of achromatic colors follows an exponential law, very similar to the gamma function of CRT monitors.

Professional training on the use of color affects the perception of achromatic colors.

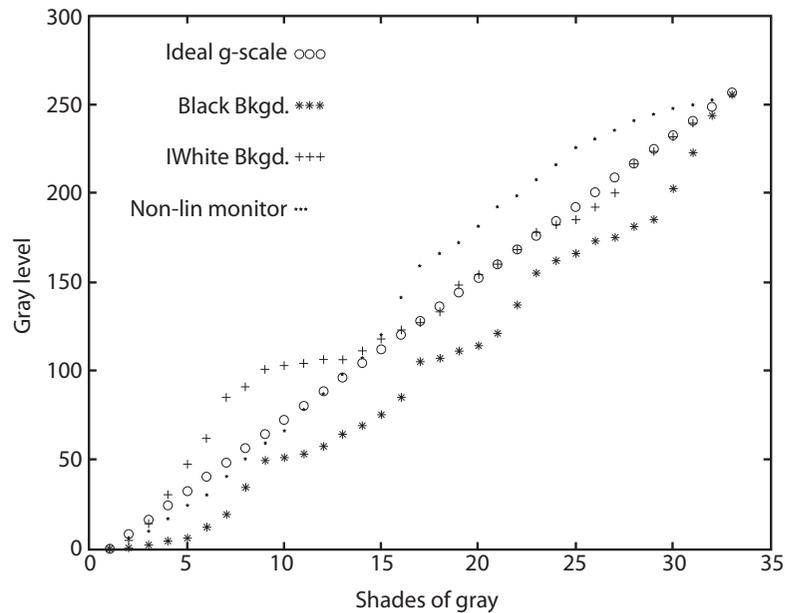


Figure 2. Representation of the gray scales created by a non-experienced subject under the same conditions as in Figure 1.

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## A FORGOTTEN CONTRIBUTION OF HERBART (1837/1851) TO THE LITERATURE ON THE MEASUREMENT OF SENSATIONS

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### Abstract

It was in 1824 that J. F. Herbart (1776-1841) presented the most complete version of his Newtonian model of events involving consciously experienced mental representations (*Vorstellungen*). In 1837, Herbart wrote a fragment (published posthumously, in 1851) concerning the measurability of *Vorstellungen*. According to Herbart, mental sensation-*Vorstellungen* differ quantitatively from the physical objects they represent in not possessing spatial dimensions, and in having magnitudes on a psychological dimension as opposed to a physical dimension (with the boundaries of the former differing qualitatively from those of the latter). Because, in Herbart's model, interactions between *Vorstellungen* always demand the simultaneous presence of at least two *Vorstellungen*, Herbart contended that the laboratory measurement of the strength of a single sensation is not necessarily relevant to the establishment of either the validity or the reliability of his model. This opinion anticipated present-day viewpoints such as that of Laming (1997) concerning sensation measurability.

By 1824, a full-fledged system of psychology, incorporating mathematics, had been worked out by Johann Friedrich Herbart (1776 - 1841) in Part 1 of a book entitled *Psychologie als Wissenschaft* [Psychology as science] (Herbart, 1824/1890b). The system had fallen out of favour for most of the 20th century, as explained by Boudewijnse, Murray, and Bandomir (1999, 2001). The fragment here summarized was written in 1837.

Herbart wanted to emulate the success with which Sir Isaac Newton (1642-1727) and his successors had described the world of matter; so Herbart devised a system of psychology that applied Newtonian mathematics to the world of mind. As the mental equivalents of physical 'objects', Herbart used the word *Vorstellungen* (plural); a *Vorstellung* (singular) refers to a mental experience (experienced only by the person having it and not by anybody else at the same time). More than one *Vorstellung* can be experienced by an individual at a given moment. Among 'mental experiences' are included sensations, perceptions, bodily feelings, emotional feelings, mental images, and thinking in words.

G. T. Fechner (1801-1887) may possibly not have known about this fragment. It was first published by Gustav Hartenstein (1808 - 1890), a colleague and friend of Herbart, who undertook the enormous task of editing and publishing Herbart's collected works after Herbart's death in Göttingen in 1841. Hartenstein's edition, which appeared between 1850 and 1852, contains twelve volumes. The first time the present author saw the Hartenstein edition was in the historical building of the Research Library of the 18<sup>th</sup> Century at the University of Göttingen in September 2004, and he thanks Hermann Kalkofen and Jürgen Jahnke for their assistance in accessing the library and in arranging for a photocopy of the article here summarized.

Hartenstein found this hand-written unfinished fragment (Herbart, 1837/1851) among Herbart's papers. Hartenstein reproduced it in volume 7 of his edition along with other miscellanea concerned with psychology. Its apparent date, 1837, puts it firmly after the main exposition of Herbart's mathematical psychology in 1824, and firmly prior to the publication of Fechner's *Elemente der Psychophysik* [Elements of psychophysics] in 1860. The fragment was not included in the 19-volume edition of Herbart's collected works edited by Kehrbach