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INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY

International Journal of Psychophysiology 36 (2000) 69–72

www.elsevier.com/locate/ijpsycho

An early antecedent to modern random dot stereograms — 'The Secret Stereoscopic Writing' of Ramón y Cajal

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Received 5 October 1999; received in revised form 28 October 1999; accepted 19 November 1999

Abstract

The use of computerized random dot stimuli in modern neuroscience was introduced by Julesz in the 1960s. This method made it possible to study exclusively cortical processing of binocular information by disparity-sensitive neurons, and it has attained widespread use among neuroscientists and psychologists. It is now largely forgotten that in the last century, the famous neuroanatomist Ramón y Cajal had worked on random dot stereograms as a means of encoding written information. A brief note was finally published in a Spanish journal on photography in 1901. We present a translation of this text and summarize the early ideas on random dot stereograms, and we also supply a brief historical account on stereoscopic perception. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Human vision; Stereoscopic perception; Random dot stereogram; History; Ramón y Cajal

Binocular vision and stereoscopic perception have been examined over many centuries, starting with the anatomical description of the visual system where the selective chiasmal crossing of axons originating in the two retinae was related to visual perception. Early anatomists found that the retinal projections from both eyes to the brain pass through the optic chiasm, and this fact formed the basis for explaining a central convergence of information originating in homonymous

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PII: S0167-8760(99)00111-7

visual hemifields. This neuroanatomical knowledge prompted early theories of vision as proposed by Descartes (1686) and Newton (1704).

The concept of a 'cyclopean eye' was finally introduced by studies on physiological optics by a number of researchers in the last century (Helmholtz, 1867; Hering, 1879). Based on psychophysical investigations by Vieth (1818) on the horopter, Wheatstone (1838) had invented the stereoscope. It was only in modern times that neurophysiological correlates of the processing of binocular disparity were observed by Barlow et al. (1967), who recorded activity of cortical neurons which are exclusively sensitive to horizontal stimulus disparities within Panum's area (Panum, 1858). In a similar line, data on human brain activity elicited selectively by such disparity sensitive neurons has been reported in this journal (Skrandies and Vomberg, 1985).

Stereoscopic images contained in so-called autostereograms (e.g. as used in 'Magic Eye' books) became very popular outside of vision research only a few years ago. Such stimuli contain meaningful, three-dimensional information only when they are binocularly fused. The basic concepts for generating such stereograms, however, had been worked out many years earlier for research and practical or military applications. The historical development of stereograms is related to anaglyphs and techniques of stereographic photography in the 19th century. It is of particular interest that as early as 1866 Ernst Mach reported on how he constructed stereoscopic stimuli that contained no visible contours, and thus constituted exclusive binocular stimuli (Mach, 1866).

A Russian artist, Boris Kompaneysky, prepared a picture of a face that could be extracted from an array of specks only after successful binocular fusion (Kompaneysky, 1939). Also, later simple stereograms were used for encryption purposes and were discussed in connection with the detection of hidden objects in camouflaged scenes. Aschenbrenner (1954) published a photogrammetry study on the analysis of aerial photographs. In this paper it is described how words and letters can be encoded in stereograms and how monocularly the random elements cannot be deciphered while with adequate binocular fusion information can be seen in vivid depth (see Fig. 5 of Aschenbrenner, 1954, also reprinted by Shipley, 1971).

Arrays of random elements had also been used to eliminate monocular cues to three-dimensional structure: Ames (1946) performed experiments on perception in a 'leaf room' where all walls of the room were covered with leaves in order to obscure the monocular perspective. Under monocular viewing, there occurred no stereoscopic percept, only binocular fusion led to the detection of disparity information and vivid three-dimensional vision. The central aim of such experiments was to illustrate a characteristic distortion of the perceived shape of the room when different types of magnifying lenses were put in front of one eye introducing anisokonia because this procedure alters the disparity relationships on the two retinae (Ames, 1946, see also summary by Ogle, 1964).

For experimental application in modern neuroscience, computerized random dot stimuli were introduced by Julesz in the 1960s (Julesz, 1960). With such stimuli, each eye is presented a field of random dots. In certain defined areas the pattern of one eye is displaced horizontally and this binocular disparity is extracted by the visual system resulting in a stereoscopic percept. Since the input of the two eyes remains separated up to the level of the visual cortex, and each eye sees only meaningless random information, this method makes it possible to study cortical processing of binocular information independent of monocular cues, and it has attained wide-spread attention among neuroscientists and psychologists. The introduction of such random dot stereograms made it possible to examine stereovision objectively and quantitatively in isolation, and the computerized production of such stimuli stirred many quantitative experimental investigations on visual processing.

The Spaniard Santiago Ramón y Cajal is known to all neuroscientists for his important work on neuroanatomy that was finally rewarded with the Nobel Price in 1906. Unknown to many, Ramón y Cajal was interested in a variety of fields, including photographic techniques. A fascinating and highly readable source are the recollections of his life published in 1923 (an English translation is found in Ramón y Cajal, 1937). He used the method of stereophotography not only to display anatomical structures in three-dimensions but around 1870 he also performed qualitative experiments on stereo perception, and developed a method with basic conceptual similarities to the one elaborated by Julesz (1960). Since Cajal's ideas are very close to modern concepts on stereoscopic vision, we would like to present a brief historical note based on an early paper of Ramón y Cajal published in 1901 in a journal of photography. Due to the fact that this publication appeared only in Spanish, and the journal was not internationally spread, it has escaped the attention of a wider scientific public. The following text is the translation of the crucial part of Ramón y Cajal (1901), and it is obvious that the logic of random dot stereograms is present in this early work:

> 'The stereoscope is suitable for many interesting recreations. Some of them, especially those related to the stereoscopic printed sheet (lines of letters which stand out against others that remain on the paper surface), have been known for a very long time and have delighted the first admirers of the three-dimensional photography.
>
> During my stereoscopic honeymoon, that is to say, long ago between the years 70 and 72, I was absorbed in imagining new fancies and recreations of this genre. My aim was to achieve a mysterious writing, which could only be deciphered with the stereoscope and usable for those people who don't want to divulge their own matters. My little invention is, in fact, a puerile game unworthy of publishing, but it really amused me at that time and it could be possible that others enjoy this pastime as well. That is the reason why we are publishing it.
>
> The game consists of making a proof only with dots, lines and scribbles, or also letters, crossed and entangled in a thousand ways. A proof in which, with the naked eye, you cannot read anything at all. And, nevertheless, as soon as you see the double image of this background in the stereoscope, a perfect legible sentence or text suddenly appears, standing out on the foreground and clearly detaching itself from the chaos of lines or dots.
>
> Two things are necessary to perform this fantasy: the background with dots, lines, letters or entangled scribbles; and a big clean glass, where you write what you want to stand out with the stereoscope. For the illusion to be perfect, it is necessary that the thickness of the lines or the dots of what you write, be the same when you look through the scraped glass as the one of the lines, letters or dots drawn on the background. You get the feeling of three-dimension when you place the glass between 10 and 15 cm away from the background. In picture number 3 we show the disposition of the instrument in the act of the double shooting (*this illustration is reprinted here as Fig. 1*).

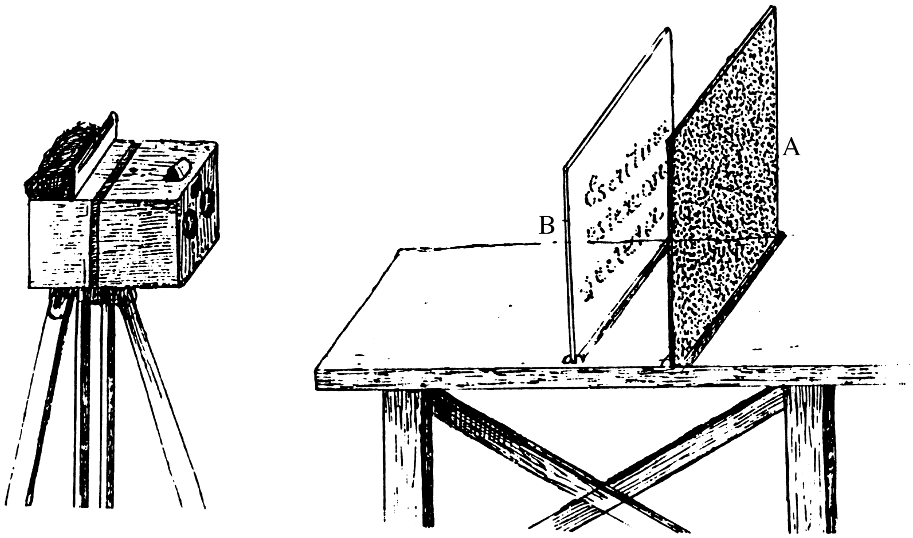

Fig. 1. A procedure to photographically produce a random dot stereogram. (A) An opaque or transparent background, which shows a compact grain, (B) a glass plate with the letters made with dots a bit thinner than those on the background. After photographing with a stereo-camera, the text can be read only with adequate binocular fusion. This is Fig. 3 in Ramón y Cajal (1901).

> There is no doubt that this experience can be varied in a thousand ways. We have reproduced it as well using as a background a common text (an inoffensive letter, for example), from which we have deliberately deleted, writing them on the glass, those letters which, put together and stereoscopically emphasized, form the secret sentence to be sent.
>
> This singular cryptographic correspondence is a bit annoying, however, on the other hand, it is one of the safest known. It does not matter if one of the proofs falls accidentally into the hands of someone curious, as for the deciphering, we need both proofs and their adequate matching. For better security it is convenient to send both proofs in a consecutive way, that is to say, the second one will be sent not without prior notice of the receipt of the first one'.

Although there are striking similarities to modern random dot stereograms we wish also to point out some differences. Of course, Ramón y Cajal did not have access to computer technology, and thus could not easily obtain different disparities resulting in different planes of depth. This was an inherent limitation of the use of glass plates onto which random elements were drawn. Therefore, also reflections, fingerprints, or dust, could contaminate the pictures altering the stereo-effect. Other authors before Julesz had also attempted to create a pattern with only stereoscopic disparity information, but without much success. Ramón y Cajal worked on the problem for a while but he did not pursue this topic. For him, the stereoscopic experience was (as he describes it) merely for 'recreation', an interesting perceptual phenomenon.

This old, almost forgotten text was only rediscovered recently and it probably did not play an important role in earlier times as it was not translated into English. From the above, the brilliance of the ideas of Ramón y Cajal (1901), Aschenbrenner (1954) and Julesz (1960) is obvious. Although the methods were drastically different — hand-made stereograms and stereophotography employed by Cajal and Aschenbrenner, respectively, and the use of the emergent computer technology of the late 1950s chosen by Julesz — the basic line of thinking was identical. As the flow of publications reporting on experiments employing computerized random dot stereograms illustrates, up until today this unique method makes it possible to study and understand the mechanisms of stereoscopic vision, and it is still useful today.

References

Ames, A., 1946. Binocular vision as affected by relations between uniocular stimulus-patterns in commonplace environments. Am. J. Psychol. 59, 333–357.

Aschenbrenner, C.M., 1954. Problems in getting information into and out of air photographs. Photogramm. Eng. 20, 398–401.

Barlow, H.B., Blakemore, C., Pettigrew, J.D., 1967. The neural mechanism of binocular depth discrimination. J. Physiol. (London) 193, 327–342.

Descartes, R., 1686. Tractus de homine. Typographia Blaviana, Amsterdam.

Helmholtz, H., 1867. Handbuch der Physiologischen Optik. Voss, Leipzig.

Hering, E., 1879. Der Raumsinn und die Bewegungen des Auges. In: Hermann, L. (Ed.), Handbuch der Physiologie, vol. III, Handbuch der Physiologie der Sinnesorgane, Erster Theil, Gesichtssinn, F.C.W. Vogel, Leipzig, pp. 343–601.

Julesz, B., 1960. Binocular depth perception of computer-generated patterns. Bell Syst. Tech. J. 39, 1125–1162.

Kompaneysky, B.N., 1939. Depth sensations: analysis of the theory of stimulation by non-exactly corresponding points. Bull. Ophthalmol. (USSR), 14:90–105 (in Russian).

Mach, E., 1866. Über die physiologische Wirkung räumlich vertheilter Lichtreize (Dritte Abhandlung). Sitzungsber. Österr. Akad. Wiss. 54, 393–408.

Newton, 1704. Optick: Or, a treatise of the Reflexions, Refractions, Inflexions and Colours of Light. Smith and Walford, London.

Ogle, K.N., 1964. Researches in Binocular Vision; chapter 13 The distortion in the stereoscopic perception of space. Hafner Publishing Co, New York, pp. 142–158.

Panum, P.L., 1858. Physiologische Untersuchungen über das Sehen mit zwei Augen. Scher'sche Buchhandlung, Kiel.

Ramón y Cajal, S., 1901. Recreaciones estereocópicas y binoculares. La Fotografía (Madrid) 27, 41–48.

Ramón y Cajal, S., 1937. Recollections of my life. Translated by E. Horne Craigie, Mem. Am. Philos. Soc. 8 (Parts I and II):1–638.

Shipley, T., 1971. The first random dot stereogram. Vis. Res. 11, 1491–1492.

Skrandies, W., Vomberg, H.E., 1985. Stereoscopic stimuli activate different cortical neurones in man: electrophysiological evidence. Int. J. Psychophysiol. 2, 293–296.

Vieth, G.A.U., 1818. Über die Richtung der Augen. Ann. Phys., Neue Folge 58, 233–253.

Wheatstone, C., 1838. Contribution to the physiology of vision. Part 1: On some remarkable, and hitherto unobserved phenomena of binocular vision. Philos. Trans. R. Soc. London (Biol) 128, 371–394.