Silvanus Phillips Thompson on Perception

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Silvanus Phillips Thompson (1851-1916, Figure 1) is celebrated for the wide-ranging researches he conducted, particularly in engineering. He commanded enormous scientific respect for his work on magnetism, electricity, light and x-rays. In 1896 he delivered the Christmas Lectures at the Royal Institution on *Light visible and invisible* (Thompson, 1897) and again in 1910 on *Sound musical and non-musical* (although he made no printed account of these). His forays into visual and auditory perception were penetrating but they have not received the recognition they deserve. He investigated a range of visual motion illusions and carried out some of the first experiments on binaural hearing.

Figure 1. Upper left, detail of a portrait of Silvanus Thompson, derived from the frontispiece illustration in Thompson and Thompson (1920). Upper centre, stimuli for investigating MAEs (from Thompson, 1880). Upper right, Thompson's (1879b) illustration of the pseudophone. Lower left and centre, concentric and strobic circles as illustrated by Thompson (1880) and modified in an advertisement for Pears' soap on the right (from the Christmas edition of *The Illustrated London News*, 1887).

Thompson was born in York, and received his early education at Bootham School, a Quaker institution at which he later became a teacher. He studied at the School of Mines in London, and moved to Bristol University in 1876, becoming Professor of Physics in 1878. From 1885 until he died he was Principal and Professor of Applied Physics at Finsbury College, London. His biography, written by his wife and daughter, commenced "Measured in years, the life of Silvanus Phillips Thompson was not a long one; but each day and each year

was full, and in that sense long" (Thompson and Thompson, 1920, p. v). Throughout his life, Thompson remained fascinated by light and its effects although it was largely in the late 1870s, during his tenure at Bristol University, that he engaged in perception research and published papers on vision and hearing.

Thompson was a lucid lecturer and his initial account of the motion aftereffect (MAE) was delivered to a meeting of the 1877 British Association for the Advancement of Science BAAS), held at Plymouth. Thompson extended observations of MAEs seen from a moving train to depth as well as direction:

> "Thus, if from a rapid railway train objects from which the train is receding be watched, they seem to shrink as they are left behind, their images contracting and moving from the edges of the retina towards its centre. If after watching this motion for some time the gaze be transferred to an object at a constant distance from the eye, it seems to be actually expanding and approaching." (Thompson, 1877a, p. 32)

The brief report at the BAAS Plymouth meeting was expanded into two articles which addressed the history as well as his experiments on the MAE (Thompson, 1879a, 1880). He mentioned Addams's (1834) observation of rising rocks following fixation on descending waters and he was probably the first to refer to the phenomenon as the 'waterfall illusion'. Addams adopted an eye movement interpretation of the waterfall illusion, as did others after him: the eyes unconsciously pursue the descending waters and move in the opposite direction when viewing stationary rocks. Thompson argued otherwise and provided logical and experimental evidence against it. On logical grounds any eye movement aftereffect would result in apparent motion of the whole visual field rather than a part of it. Thompson used the occurrence of the MAE in depth (reported in his first paper) as evidence against eye movement interpretations, and his view was supported by observations from rotary and spiral MAEs (see Figure 1 for the stimuli he used). More convincingly, he demonstrated that fixation between two discs rotating in opposite directions produced clockwise and anticlockwise MAEs simultaneously. Thompson's preferred interpretation was physiological and psychological; it was considered to account for motion illusions in general as well as colour contrasts. He presented:

> "an empirical law based on the physical fact of retinal fatigue, and on the psychological fact of association of contrasts. It is as follows:- *The retina ceases to perceive as a motion a steady succession of images that pass over a particular region for a sufficient time to induce fatigue; and on a portion of the retina so affected, the image of a body not in motion appears by contrast to be moving in a complementary direction*." (Thompson, 1880, p. 296, original italics)

In all the papers on motion illusions, Thompson described one he thought was novel: a pattern of concentric circles (Figure 1), drawn for the purpose of testing for astigmatism, appeared to induce illusory motion when it was moved in a circular path. Thompson was unaware that the effect had been described earlier by Purkinje (1825), who also observed it in a pattern of concentric circles. Thompson (1880) modified and illustrated the stimulus and the 'strobic circles' (as he called them) were printed for sale as well as being used in advertisements for Pears' soap (Figure 1).

There was a flurry of experimental activity on MAEs at and after the time Thompson was publishing his findings (see Wohlgemuth, 1911 for a summary). His 'law' of motion illusions generated both opposition and support. For example, Bowditch and Hall (1881) were critical of the link between colour and motion contrasts whereas Cobbald (1882) considered that it was the only viable theory available. These researchers devoted much space to examining Thompson's strobic circles as well as the MAE. Thompson demonstrated his strobic circles in his 1896 Christmas lectures at the Royal Institution and retained his conviction that the effect was due to the persistence of vision.

It was at the same Plymouth meeting of the BAAS that Thompson (1877b) described his experiments on binaural beats: "Two tuning-forks tuned nearly in unison when sounded together give rise to interference 'beats'. These 'beats' are heard also if the forks be held one to each ear, or if their sounds be conveyed separately to the ears with pipes" (pp. 37-38). More detailed accounts were presented in three subsequent articles (Thompson, 1877c, 1878, 1881). He was among the first to use the term 'binaural audition'. Thompson (1882) examined auditory localization in the context of visual localization. Both were analyzed in terms of direction and distance and he noted the differences between ears and eyes in terms of focusing, receptor layout, and motor control. The features involved in auditory localization were listed:

> "There are four physical characteristics of waves of sound by which one sound is discriminated from another, viz:- (i) *Intensity*, or loudness, depending upon extent or energy of the vibratory motions. (ii) *Pitch*, or frequency, depending upon the rapidity of the vibratory motions. (iii) *Phase* of the vibratory motions, as to whether moving backward or forward or at any other state. (iv) *Quality*, or timbre, depending upon the degree of complexity of the vibratory motion. The third of these physical characteristics is one for which the single ear possesses no direct means of perception." (Thompson, 1882, p. 408, original italics)

Thus, Thompson argued that phase differences alone were in the province of binaural hearing and so served the function of localizing the direction of sounds in space. Distance presented a more complex problem, and he considered that: "In the case of known sounds we doubtless judge chiefly of their distance by their relative loudness, the intensity decreasing inversely as the square of the distance" (1882, p. 415). Nonetheless, Thompson did entertain the possibility of 'acoustic parallax' playing a role in its determination for sounds at short distances. He suggested that differences in pitch and phase were also involved. Between these papers on binaural localization Thompson (1879b) described his pseudophone (Figure 1) for changing the direction of sounds normally received by each ear. It was considered to be the auditory equivalent to the pseudoscope; whereas the pseudoscope essentially reversed the optical projections to the two eyes the pseudophone changed the directions of sound to each ear.

Towards the end of his life Thompson was able to forge a link between electricity and vision by studying the effects of magnetic induction on the brain: "Some six years ago, when experimenting with an alternating electro-magnet…I observed a faint visual effect when my forehead was placed close to the magnet" (Thompson, 1910, p. 396). This laid the foundations for transcortical magnetic stimulation or TMS. The circle of Thompson's perceptual research has now been completed as one of the phenomena investigated with TMS is the MAE (Murd, Einberg & Bachmann, 2012).

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