All Around & Away We Go
The Phenakistoscope & Persistence of Vision

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Introduction

The object included with this text is a phenakistoscope, an optical toy invented in the early 1830s and the first apparatus to show a sequence of animated images. The phenakistoscope (fig. 1) is simply a cardboard disc loosely mounted on a stick, so that it can whirl around. A number of evenly spaced slots are cut out in the direction of the radius – generally between eight and sixteen. On the front side of the disk figures are drawn between the slots – usually the number of figures is equal to the number of slots. Every figure represents one position in a sequence of movement. The back side of the disk, facing the stick, is wholly black.

Considered on its own the apparatus seems senseless. One can spin the disc and look at the figures, but what is seen is just a blur, much like what is seen when staring out of a train window at the passing grass and stones near the tracks - the only element of distinction being the repetition of blurry form and mingled colour. One has to look through the slots in order to see the separate figures as a distinct animation. And in order to look through the slots as well as see the figures, a mirror is needed. One positions the disc so that there's a slot between the mirror and the eye. Facing the side with the drawings towards the mirror, and staying immobile, one gives the disc a spin. When an opening passes in front of the eye, the figures on the disc can be seen briefly. This short impression occurs every time a slot passes the eye. With the slots functioning as a rudimentary shutter mechanism, the short, looping animation becomes visible.

The phenakistoscope is a precursor of the zoetrope, popularized later in the century. The zoetrope (fig. 11) works on the same principle, but replaces the spinning vertical disc with a spinning horizontal drum. Currently I'm working on a variation of the zoetrope which replaces its fixed illustrations with eighteen small LCD screens. These screens show static digital images whose motion becomes visible through the analogue shutter mechanism. Through two optical sensors the apparatus knows whether it's turning clockwise or counterclockwise. This mechanism determines which animation sequences are shown.

The project came forth out of an interest in pre-cinematic forms of moving images, and while working on it, new questions arose. How was the zoetrope invented? Why in the 19th century? It also made me wonder about the nature of visual perception. How is it that we can see a continuous moving image when in fact we're looking at an array of still images? Why do we see a blur when looking at the figures directly and a moving image when looking at them through the slots?

This thesis investigates these questions. Looking into the history of the zoetrope, one quickly comes across its precursor, the phenakistoscope. It is a small step from phenakistoscope to zoetrope, the devices work on the exact same principle. But as the phenakistoscope was invented first, its history of invention is richer and more telling. Therefore, this thesis takes the phenakistoscope as its centre of interest. The first part (Phenakistoscope) will look at its workings, its context of invention and its subsequent function as popular entertainment. From here, the second part (Persistence of Vision) will attempt to explain how it is that we can see motion in separate still images. Explanations given in the past – sometimes in direct relation to the phenakistoscope – will be considered, the notion of 'persistence of vision' being central. The shortcomings of this idea will come to the fore in exploring more recent explanations of motion picture perception.

Phenakistoscope

The phenakistoscope goes by many names. Phenakistoscope (Münsterberg 12), Phenakisticope (Dulac 228), Phenakistiscope (Crary 106) and Phanakisticope (Bewster 142) are all variations on the combined Greek words for 'deceptive' and 'view'. Another common name, 'stroboscope', comes from 'whirl' and 'view' (Münsterberg 47). Other names are 'Fantascope', 'Phantasmascope', 'Magic Disc', 'Kaleidorama' or 'Magic Panorama' (Cook 125). This diversity of names points to two matters of interest in the history of this apparatus: the first being its parallel invention in different places, the second its place on the intersection between popular culture and contemporary scientific inquiry.

The person most closely associated with the invention of the phenakistoscope is Joseph Antoine Ferdinand Plateau. Plateau, born in 1801, was a Belgian physicist. The phenakistoscope can be seen as an exponent of his interest in visual perception, and predominantly the physiological side of it. His interests were broader, though. He investigated for instance the phenomenon of surface tension - the property of liquid in resisting external forces, seen in action when water striders sprint over a pool.

In 1829, Plateau published his doctoral thesis, the subject being retinal afterimages (Chanan 55). Retinal afterimages are the remnants of visual impressions that persist after their source is gone. When fixedly looking at a red dot for a minute or so and then looking away at a white wall, a 'floating' dot the inverse color, cyan in this case, will be present for a short time. In his thesis, he explained how the duration of retinal afterimages is dependent on the intensity, color, time and direction of the stimulus. He also calculated the average duration of retinal afterimages, this being about a third of a second. (Crary 107) In the same year, Plateau stared uninterruptedly into the sun for twenty-five seconds. This did major damage to his eye, and he was blind by 1842. In fact, when Plateau invented the phenakistoscope he was in a state of half-blindness (Cook 125).

The phenakistoscope was an substantial alteration of a device Plateau invented earlier, in 1829, named the anorthoscope (fig. 2). The anorthoscope consists of two discs with four slots, turning in opposite direction. One disc has a distorted illustration. This illustration 'undistorts' when the discs are turned. In 1832, Plateau took out the second wheel, increased the number of slots and replaced the one distorted figure with an array of figures, each being one frame in an animated sequence. He published the paper 'Des illusions d'optique sur lesquelles se fonde le petit jouet appelé récemment Phenakisticope' in the periodical 'Annales de chimie et de physique' in 1833 - detailing the effects of increasing or decreasing the number of slots in relation to the number of figures (Leskosky 180). The consequence of this being lateral movement of the figure, in the direction of spinning when there are more slots than figures, and in the opposite direction when there are more figures than slots.

In 1832, only weeks after Plateau invented his phenakistoscope and unaware of its existence – Plateau's paper was not yet published – Simon von Stampfer invented the exact same device. Von Stampfer, born in 1782, was a professor of practical physics at the Polytechnischen Institut in Vienna. There, he was also employed as an astronomer and physicist. Being an astronomer, he became interested in the distorting effects of lenses. This interest, in turn, led him to the field of optical illusions (Leskosky 180) Von Stampfer developed two phenakistoscopes, one with a second slotted disc so that the need of a mirror is eliminated (fig. 3), the other being exactly identical to Plateau's. The only difference here was the name the device carried: he called it the stroboscope.

Another inventor of phenakistoscope, though less often credited for it (and for good reason, as will become clear shortly), is Peter Mark Roget. Roget, born in 1779, was a British physician and lexicographer. In 1824 he published a paper named 'Explanation of an Optical Deception in the Appearance of the Spokes of a Wheel seen through Vertical Apertures'. It investigates the optical illusion that occurs when a rolling carriage wheel is seen through a series of vertical slots - the investigation possibly sparked off by idly staring at the traffic outside on the street through a Venetian blind (Chanan 61). Instead of being straight, each spoke seemed to display a different degree of curvature, and, instead of rotating, the wheel seemed to be stationary (fig. 4). 'The distinctness of this appearance is influenced by several circumstances presently to be noticed; but when everything concurs to favour it, the illusion is irresistible, and, from the difficulty of detecting its real cause, is exceedingly striking.' (Roget 131)

To repeat his observation in a more controlled and predictable environment, he constructed an apparatus that involved circular discs and shutter mechanisms. Experimentation with this device lead him to conclude: 'The deception in the appearance of the spokes must arise from the circumstances of separate parts of each spoke seen at the same moment ... several portions of one an the same line, seen through the intervals of the bars, form on the retina the images of so many different radii.' (Roget 135) The design of the device to create this illusion must have been close to the design of the phenakistoscope. And indeed, in 1834 Roget claimed to have constructed one in the spring of 1831, thus more or less parallel to Plateau and Stampfer. Only he didn't publish about his apparatus, only demonstrating it to his circle of friends, then discontinuing investigation because of 'more serious concerns' (Leskosky 180).

Would Roget have published about his phenakistoscope, he probably would have given it yet another name. In any case, what the double name of stroboscope/phenakistoscope bears witness to, is its parallel invention in different places. And though this could be seen as just a curiosity, is telling about the context of invention: the world had changed - as well as the views about perception and the human sensorium.

The industrial revolution brought the world trains and railroads, and factories with cogs and wheels spinning. These mechanized, high-speed rotations and fast lateral movements were new forms of motion, not possible to perceive before. As the railroad network expanded and the number of factories increased, the chance of seeing oddities within these new forms of movement increased as well. As Chanan points out:

> [...] Curious observations were very often made by scientists outside the main field of their work. We tend to think that scientific experiments are derived from hypotheses, and that they're intended to measure precise values which is the function of the hypothesis to designate beforehand. [...] Sometimes, however, puzzling observations are made virtually by chance, which command a scientist's attention even without the existence of a proper theoretical framework into which they can be fitted. In that case, experiments may be designed not so much to gather information of a kind which has been designated beforehand, but in order to re-create or simulate the conditions of the chance observation so as to be able to study it in isolation. (61)

One case of casual observation leading to scientific investigation is Roget noticing the rotating wheel and his subsequent building of an apparatus. Another example is given by Michael Faraday. Faraday, born in 1791, was a British chemist, physicist and philosopher who discovered amongst other things electromagnetic induction, electrolysis and benzene. A few years after Roget investigated his spokes, he made a chance observation which turned his mind to the same questions:

> Being at the magnificent lead mills of Messrs. Maltby, two cog-wheels were shown me moving with such velocity that if the eye were retained immovable no distinct appearance of the cogs in either could be observed; but, standing in such a position that one wheel appeared behind the other, there was immediately the distinct though shadowy resemblance of cogs moving slowly in one direction. (Crary 111)

He built a device to replicate the phenomenon that came to be known as the 'Faraday Wheel' (fig. 5). It consists of two interchangeable cogged and spoked wheels mounted on the same axis, allowing them to rotate in the same or opposite directions, at either the same speed or different speeds. This way, various optical phenomena could be displayed - one of them being the appearance of distinct cogs when looking through wheel closest to the eye to the wheel behind it. In contrast: when looking at both wheels from the side, both were perceived as blurry with no distinct cogs (Leskosky 179). He detailed the workings of this device and the phenomena observed in his paper 'On a Peculiar Class of Optical Deceptions' in 1831, and it was in part an aesthetic experience that lead him to do so: 'The beauty of many of the effects obtained by this apparatus has induced me to describe it more particularly than I otherwise should have done' (Faraday 209).

He starts his explanation like so:

> The cause of these appearances, when pointed out, is sufficiently obvious [...] The eye has the power, as is well known, of retaining visual impressions for a sensible period of time; and in this way, recurring actions, made sufficiently near to each other, are perceptibly connected, and made to appear as a continued impression. The luminous circle visible when a lighted coal or taper is whirled round - the beautiful appearances of the kaleidophone - the uniform tint spread by the revolution of one of the spoke or cog wheels already described - are a few of the many effects of this kind which are well known. (210)

Later in the same paper he describes a simplification of his apparatus using a mirror:

> Several of the effects with wheels already described, and some new ones, may be obtained with great simplicity, by means of reflection. [...] A very striking deception may be obtained in this way, by revolving a single cog wheel between the fingers before the glass, when from twelve to fifteen or eighteen feet from it. It is easy to revolve the wheel before the face so that the eye may see the glass through or between the cogs, and then the reflected image appears as if it were the image of a cog-wheel, having the same number of cogs, but perfectly still and every cog distinct; instead of being the image of one in such rapid motion, that by direct vision the cogs cannot be distinguished from each other, or their existence ascertained. The effect is very striking at night if a candle be placed just before the face, and near to it, but shaded by the wheel; in reflection the wheel is then well illuminated, and the reflected face or shadow forms a good back-ground against which to observe the effect. (217)

The device described here is identical to Plateau's phenakistoscope. It's telling of the close ties between scientists of the day that Plateau read this paper, and in fact reproached Faraday for not citing his earlier experiments (Chanan 63). Though it is a muddy matter who influenced whom, Plateau did send a sample of his phenakistoscope to Faraday (Leskosky, 180), either before or after Faraday's publication.

In any case, new forms of movement in the world led to new investigations. Seeing two wheels turning in parallel, making it seem as if one moves slowly backward, makes one wonder about the relation between what one sees and what is objectively happening. As Jonathan Crary points out: 'new experiences of speeds and machine movement disclosed an increasing divergence between appearances and their external causes.' (112)

But these chance observations weren't the only source that sparked of new inquiries into human vision. Crary argues there's another reason, not as clearly present in the external world, but to be found in the world of thought. In the 19th century, views about the nature of perception altered. Before the 19th century, visual perception was seen as instantaneous, an analogy being the workings of the camera obscura (fig. 6). A camera obscura (Latin for 'dark chamber') is an instrument that in its most rudimentary form consists of a box with a tiny hole in it. The light falls through the hole, into the box. If the box is big enough to sit in, one can witness the projection of the outside world (though upside down) on the wall opposite the hole. Seeing was perceived as such – light falls into the eye and an objective, one-on-one image is detected:

> For over two hundred years [the camera obscura] subsisted as a philosophical metaphor, a model in the science of physical optics, *and* was also a technical apparatus used in a large range of cultural activities. [...] The virtual instantaneity of optical transmission (whether intromission or extromission) was an unquestioned foundation of classical optics and theories of perception from Aristotle to Locke. And the simultaneity of the camera obscura image with its exterior object was never questioned. (Crary 29)

Subjective visual phenomena like the afterimage had been noticed and written about since antiquity, but they were seen as 'mere appearance'. In the 19th century this changed, they were no longer perceived as deceptions that obscure a more 'true' objective world. Perception became a more subjective matter. Goethe's investigations in colour were one source of this notion of vision as subjective. According to Goethe, when looking at a green leaf, the eye doesn't take in its greenness in static objectivity. Instead, the greenness one perceives could be seen as a constant process, subjectively taking place over time. In his 'Zur Farbenlehre', published in 1810, he writes:

> The eye cannot for a moment remain in a particular state determined by the object it looks upon. On the contrary, it is forced to a sort of opposition, which, in contrasting extreme with extreme, intermediate degree with intermediate degree, at the same time combines these opposite impressions, and thus ever tends to be whole, whether the impressions are successive or simultaneous and confined to one image. (Crary 99)

Colour perception became a process taking place over time, and with colour perception, so perception in general. This way, more obscure subjective phenomena – afterimages for example – were given a new importance: 'As observation is increasingly tied to the body in the nineteenth century, temporality and vision become inseparable. The shifting processes of one's own subjectivity experienced in time became synonymous with the act of seeing, dissolving the Cartesian ideal of an observer completely focused on an object.' (Crary 98)

This new disjunction between 'eye' and 'object' gave way to particular kinds of investigations, based on self-observation. One person who studied his own perception and closely described various subjective visual phenomena was Jan Evangelista Purkinje.

Figures

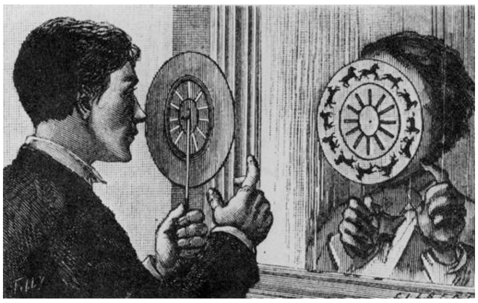

Fig. 1

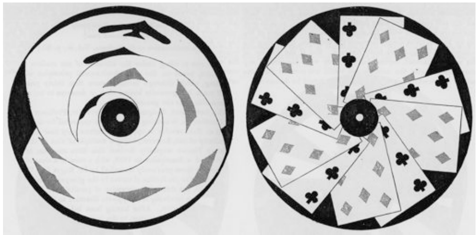

Fig. 2

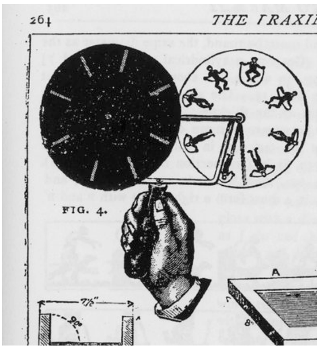

Fig. 3

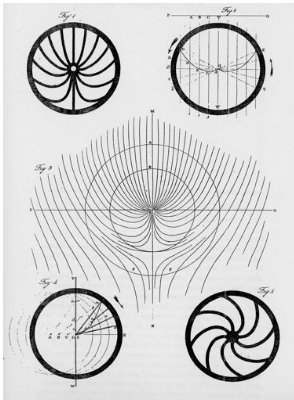

Fig. 4

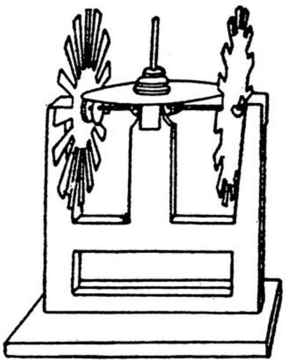

Fig. 5

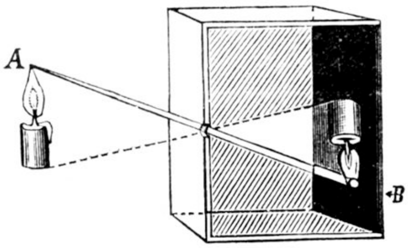

Fig. 6

Figures

Fig. 7

Fig. 8

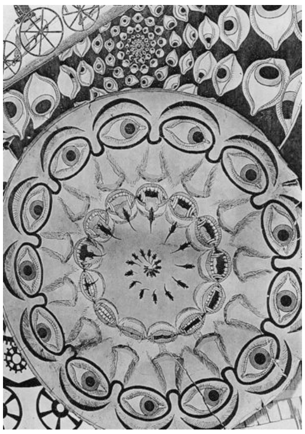

Fig. 9

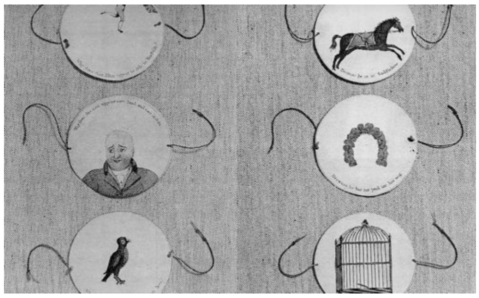

Fig. 10

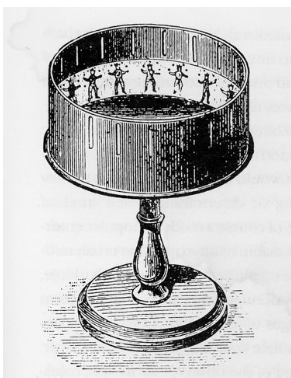

Fig. 11

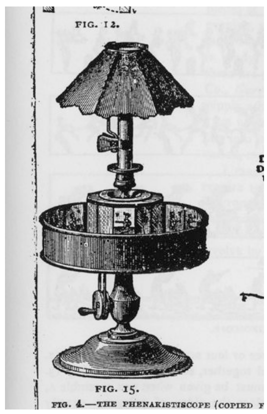

Fig. 12

Born in 1787, he is known primarily for his early neurological research, discovering the Purkinje cell - a neuron among the largest in the human brain. In 1823 he also published a study about fingerprints, categorizing them in nine principal groups. Of interest here, though, is his 1819 publication named ‘Contributions to the Knowledge of Vision in Its Subjective Aspect’. The titles of its chapters are telling: ‘A Light Phenomenon in the Dark Field of My Right Eye During Increased Activity of the Left Eye’, ‘Zigzag Scintillations Following Observation of Parallel Lines’, ‘Visibility of Blood Circulation within the Eye’ and ‘Staring Vaguely into the Distance’, The first phenomenon described, ‘Light and Shade Figures’, gives an account of the checkerboards, spirals and ray patterns perceived when, with closed eyes pointed towards the sun, one waves ones separated fingers in front of ones eyes:

> The lively mind of the child revels in the manifold stimuli of the external world. It gives form to the vague, it rejoices in the repetition of what was done. Every moment brings a new discovery, brings newer and ever richer worlds of experience. Above all they have pleasure in following the path of joyful light and immersion in the stimulating colors of the present. [...] Who does not remember, if only dimly, such games from that beautiful time? One of them, which could keep us busy at a more serious age, is as follows: I stand in bright sunlight with closed eyes and face the sun. Then I move my outstretched, somewhat separated, fingers up and down in front of the eyes, so that they are alternately illuminated and shaded. In addition to the uniform yellow-red that one expects with closed eyes, there appear beautiful regular figures that are initially difficult to define but slowly become clearer. When we continue to move the fingers, the figure becomes more complex and fills the whole visual field. (Purkinje 65)

He goes on to describe some of these figures:

> I see a field of larger hexagons, with gray sides and white centers. To the lower left of the central spot I see overlapping half circles, the direction of which continuously changes. They resemble tree rings or roses with many petals. [...] When we continue to move the fingers and do so rapidly, a ‘rectangular spiral’ appears independently. It consists of several straight lines that grow in size. [...] Sometimes the eight-ray star appears in the field of vision before the spiraling rectangle [...] It consists of a few rods that cross in the center and thus create a star pattern. (Purkinje 66)

Purkinje not only studied the influence of flicker on closed-eyed-vision, he also observed its effects on more conventional perception, with eyes opened. Instead of using his hands as a shutter mechanism, he constructed his own phenakistoscope in 1840 - following Faraday, Roget, Plateau and Stampfer. He named it the phorolyt, and used it to demonstrate motion found in nature - as well as toyed around with it for fun: ‘Purkinje used his phorolyt to produce dynamic images of a range of natural movements generated from a sequence of static drawings. These ranged from the pumping action of the heart to the walking movements of newts; he also used it to display his own rotating posture.' (Wade 40) (fig. 7)

Crary places Purkinje in line with investigators like Goethe, Plateau and Fechner, engaging in 'the kind of self-observation [...] in which the changing conditions of the observer's own retina was (or was believed to be) the object of investigation.' (111) The altering ideas about the nature of visual perception, along with the changing outside world, led to new investigations. Subjective perceptual phenomena such as the afterimage were given a new priority. Fertile soil for inventions such as the phenakistoscope.

To briefly return to the naming of the phenakistoscope: the changing world and altering views of human vision resulted in scientific enquiries that made a parallel invention of a phenakistoscope / stroboscope (and later also a phorolyt) more likely. But what accounts for the catchy names such as 'Magic Wheel', 'Kaleidorama' or 'Magic Panorama'? Names like these are telling for the intersection between science and popular culture. After invention within the scientific field, the phenakistoscope 'wasted no time in making the leap to popular entertainment.' (Dulac 228)

In some cases, the inventors themselves played a role in the commercialization of their devices (fig. 8). Purkinje sold his phorolyt under the name 'magic disc' (Wade 40). Plateau even illustrated the discs for his first six phenakistoscopes to be sold as toys. His father was a landscape and flower painter who originally enrolled him in the Acadamy of Design in Brussels, and even though Plateau directed his attention towards science, he maintained an interest in art (Leskosky 180). One of Plateau's designs showed a dancer making a pirouette, another a bee flying towards a flower. They were sold commercially as 'phantasmascopes', and later 'fantascopes'.

Often times the animations were reminiscent of the 19th-century phantasmagoria (fig. 9). Olive Cook describes a selection of discs in her history of pre-cinematic devices: 'A phenakistoscope roundel owned by John and William Barnes is decorated with the exaggerated features of a human face in such a way that as it revolves the mirror flings back a preposterous animated image of enormous bespectacled eyes shifting rapidly from side to side, while a prim mouth opens to swallow an endless procession of rats', and: 'Fantastic ogre heads approach the centre of the disc, growing larger and larger, then suddenly recede' (125). Rats seem to be a returning theme on phenakistoscope discs. The painter and lithographer Thomas Mann Baynes illustrated one showing an infinite number of rats climbing out of holes near the centre of the disc, running towards its edge, then seemingly maneuvering towards the spinners' hand. More innocent images were shown as well. A lady and gentleman waltzing, a woman sewing, a dog jumping, etcetera. (Dulac 229)

It should be noted that the phenakistoscope is one of in a line of so-called ‘optical’ or ‘philosophical’ toys - animation apparatuses with scientific origins that subsequently became popular entertainment. Their history has mostly been studied from the field of film studies and therefore, understandably, from the perspective of what they contributed to the ‘final form’ that is cinema. The phenakistoscope, then, is preceded by the thaumatrope and followed by the zoetrope. Popularized in the 1820s, the thaumatrope (fig. 10) is a small disc with strings on both ends. Both sides have an illustration on them and when one spins the disc rapidly using the strings, the drawings merge. One side shows a tree in winter with bare branches, the other its foliage, and when spun one conjures up a tree in leaf. Likewise, a bald man on one side and his hair on the other, or a bird on one side and a cage on the other. Associated with the invention of the thaumatrope are amongst others John Herschel, an astronomer who named seven moons of Saturn, and Charles Babbage, conceiver of the computer. ‘What we're really dealing with here is a fairly close-knit group of gentlemen scientists’, Chanan points out. ‘They obviously amused each other in their social chit-chat with anecdotes and puzzles which issued from their scientific work; much as computer scientists today [1980] might describe to each other games which can be invented for the computer to play.’ (60)

The thaumatrope doesn’t demonstrate the principle of animation but of superimposition – it was the phenakistoscope that showed the first animated sequence. The daedaleum (fig. 11), invented by W.G. Horner in 1933 and popularized under the name zoetrope, is a small alteration of the phenakistoscope, though with notable consequences. The images between the slots are folded 90 degrees up, as it were, and the resulting drum-like structure is loosely mounted on a base, so that it can spin. Horner describes the device in his paper ‘On the properties of the Daedaleum, a new Instrument of Optical Illusion’, published in the London and Edinburgh Philosophical Magazine of January 1834:

> The apparatus is merely a hollow cylinder, of a moderately high margin, with apertures at equal distances, and placed cylindrically round the edge of a revolving disk. Any drawings which are made on the interior surface in the intervals of the apertures will be visible through the opposite apertures, and if executed on the same principle of graduated action, will produce the same surprising play of relative motions as the common magic disk does when spun before a mirror. But as no necessity exists in this case for bringing the eye near the apparatus, but rather the contrary, and the machine when revolving has all the effect of transparency, the phenomenon may be displayed with full effect to a numerous audience. I have given this instrument the name of Daedaleum, as imitating the practice which the celebrated artist of antiquity was fabled to have invented, of creating figures of men and animals endued with motion. (Horner 37)

Emile Reynaud modified the zoetrope, taking away the slots, adding mirrors in the center of the drum, and naming it the praxinoscope (fig. 12). The mirror mechanism made it possible to show more detailed illustrations and was less tiring to the eye. From this point on, histories of the invention of film usually go into the motion studies of Etienne-Jules Marey and Muybridge, on to Edison's Kinetoscope and Les Frêres Lumieres' Cinématographe, briefly mentioning dead media like the mutoscope.

Here is not the place to go deeper into this interesting history, but what is of note is the influence of the form of the device on the imagery that is shown on it. Through comparison, this can shed light on the inherent singularities of the phenakistoscope. In their comparison of the phenakistoscope to the zoetrope, Nicolas Dulac and André Gaudreault ask themselves: 'Don't all apparatuses impose a way of conceiving the subject they depict?' (232) Of course there is common ground between the phenakistoscope and the zoetrope: inherent to both of them is the brief repetition of action: 'narrative had no place in such an apparatus, because of the programmatic limitation of the dozen images engraved on the disk, images condemned to turn endlessly, to perpetual movement, to the eternal return of the same.' And therefore: 'the subjects are like Sisyphus, condemned ad infinitum to turn about, jump, and dance. In another sense, the figures are machine-like: untiring and unalterable, they are 'acted-upon' subjects rather than 'acting-out subjects.' (232)

But then there are also differences. In the phenakistoscope 'the radial arrangement of the images ensured that they were invariably organized in relation both to the center and to the edge of the disk. Centrifugal and centripetal forces reigned there equally, along with a sense of movement beyond the confines of the disk.' Therefore: 'The phenakistoscope functioned according to both *ex*plosion and *im*plosion. Like the kaleidoscope, the phenakistoscope belonged more on the side of the cosmic, of the big bang, and of the expansion and contraction of the universe.' In comparison, the zoetrope is much closer to the 'terrestrial': 'Here animated pictures lost a large part of their propensity to fly off in all directions. [...] they were brought back, neither more nor less, to terra firma, where they moved laterally, a common enough kind of movement for terrestrial animals. Moreover, in these scenes the ground was often depicted as part of the 'decor', at the bottom of the strip, where it should be, without the troubling curvature it had in the phenakistoscope.' (Dulac 235)

Between all these optical toys – the thaumatrope, the zoetrope, the praxinoscope, etc. – the phenakistoscope holds a special place. It was the first instrument to show full animation, and it does so in the most elementary way. It is therefore pre-eminently this device that gives rise to the question: why is it that we see one moving image, when what we perceive are in fact separate still images?

Persistence of Vision

The question of how we see motion in separate still images is usually asked in relation to cinema. It is therefore a good idea to briefly look at the workings of the movie projector. When a film is projected, the strip doesn't simply slide through the projector - this would result in a blur. Instead, a mechanism briefly stops every frame, much like a sewing machine stops the fabric from moving when the needle pierces through. The moment the frame is moving in place, the light beam is cut off by a circular shutter. Film, like the phenakistoscope, functions using of a shutter mechanism.

Hugo Münsterberg, psychologist and author of the first scientific inquiry into film ('The Photoplay: a psychological study' published in 1912) traces the question of why we can see film back to the time of optical toys: 'The problem did not arise with the kinetoscope only, but had interested the preceding generations who amused themselves with the phenakistoscope and the stroboscopic disks or the magic cylinder of the zoötrope and bioscope. The child who made his zoötrope revolve and looked through the slots of the black cover in the drum saw through every slot the drawing of a dog in one particular position. Yet as the twenty-four slots passed the eye, the twenty-four different positions blended into one continuous jumping movement of the poodle. [...] What objectively reaches our eye is one motionless picture after another, but the replacing of one by another [...] cannot reach our eye at all.' It made Münsterberg wonder: 'Why do we, nevertheless, see a continuous movement?' (71)

The routine answer to this question within the field of film studies is 'persistence of vision'. The idea of persistence of vision is simple: the spectator sees a rapid succession of slightly different images, and because the eye is a bit sluggish there is a brief period during which each image, after its disappearance, is still 'imprinted' on the retina. This persistence allows the image to blend smoothly with the next one, forming one fluid moving image. The notion of persistence of vision is ubiquitous in film studies. André Bazin, to name one example, wonders how it is possible that cinema 'took so long to emerge, since all the prerequisites had been assembled and the persistence of the image on the retina had been known for a long time.' (19) But, as Joseph and Barbara Anderson straightforwardly point out, persistence of vision is a myth: 'The proposed fusion or blending of images could produce only the superimposition of successive views, as in Marcel Duchamp's painting "Nude Descending a Staircase" or a frame from Norman McLaren's "Pas de Deux". The result would be a piling up of images, or at best a static collage of superimposed still pictures, not an illusion of motion.' (1993, 4)

The origins of the notion of persistence of vision are strongly tied to the inquiries into movement by Faraday, Roget, Plateau, etcetera. Anderson & Anderson briefly sum up how the term came into being:

> In 1926 film historian Terry Ramsaye attributed the discovery of persistence of vision to the English-Swiss physician Peter Mark Roget and reported that Roget presented his finding before the Royal Society in a paper entitled 'Persistence of Vision with regard to Moving Objects'. Thirty years after Ramsaye, another film historian, Arthur Knight, provided the identical citation and recounted the spread of Roget's theory throughout Europe. He listed a number of parlor toys that served to establish the 'basic truth of Roget's contention that through some peculiarity of the eye an image is retained for a fraction of a second longer than it actually appears', and went on to assure us that 'upon this peculiarity rests the fortune of the entire motion picture industry.' (Anderson 1993, 4)

Roget never wrote a paper with this title, and Ramsay and Knight are actually referring to his study mentioned earlier named 'Explanation of an Optical Deception in the Appearance of the Spokes of a Wheel when Seen Through Vertical Apertures', in which Roget describes the wheel with curved spokes that, although it is moving laterally, doesn't seem to rotate. He explains the phenomenon by noting that the spokes, in passing the vertical apertures 'leave in the eye the trace of a continuous curved line, and the spokes appear to be curved'. He compares it to what one sees when a bright object is quickly circled around. A line forms behind the bright object, making it possible to 'draw' a full circle - as we do in photography when playing with slow shutter speeds.

Anderson & Anderson note that nowadays [1993] this illusion wouldn't be explained as merely taking place 'in the eye'. But more importantly: 'the illusion with which Roget was concerned was not an illusion of apparent motion; to the contrary, it is an illusion in which a wheel in real motion appears to stand still, and yet it is on the basis of this explanation that many film scholars accounted for the illusion of motion in a motion picture.' (1993, 5)

Plateau is also frequently credited as having discovered the principle of persistence of vision. Initially, his significance was pointed out by French film historian George Sadoul in his 'Histoire Génerale du Cinéma', published in 1946. In explaining the workings of the phenakistoscope, Plateau said: 'If several objects, progressively different in form and position, are presented to the eye for very short intervals and sufficiently close together, the impressions they make upon the retina will join together without being confused, and one will believe one is seeing a single object gradually changing form and position.' (Doane 71)

Plateau therefore speaks of a fusion taking place within the eye. Anderson & Anderson place his view of perception within the context of then-contemporary psychological inquiry: 'Indeed, a generalized notion of "fusion" was applied to the illusion of motion by a host of psychologists working in the latter part of the 19th century, including William Stern, Karl Marbe and Ernst Durr.' But: 'The generalized and imprecise use of the term “fusion” in these theories renders equally problematic the recurrent explanations of persistence of vision in film literature.’ (Anderson 1993, 7) And from 1900 onwards, the literature of psychology treated perception of movement as processed principally in the brain and the central nervous system, instead of in the eye.

Interesting is that the notion of persistence of vision is accompanied by ‘an insistent vocabulary of deception and failure’, as Mary Ann Doane observes. The word phenakistoscope itself means ‘deceptive view’. Furthermore: ‘Frederick A. Talbot elaborated upon the way in which the cinematographer exploits a “deficiency” of the human eye: “This wonderful organ of ours has a defect which is known as visual persistence”. The concept of persistence of vision presupposes that a delayed image (an afterimage) blurs empirical distinctions between imperceptible stages of movement in time. Hence the afterimage is the symptom of a failure in human vision that is re-inscribed in the very technology of the cinema. The afterimage points to a flawed temporality. [...] The thaumatrope, the phenakistiscope, the zoetrope, and finally the cinema are all said to “work” because of a defect, a deficiency of the human body.’ (Doane 72) Film historian Raymond Spottiswoode speaks of persistence of vision as ‘a sort of mental hangover, [which] prolongs the image of what the eye is seeing’ and reinforces that ‘if the eye were entirely sober, there would be no movies.’ (Anderson 1978, 3)

In his book ‘The Working Brain’, neuropsychologist Alexander Luria reflects on the difference between 19th and 20th century psychology. In the 19th century, visual perception was considered as a ‘passive imprint made by external stimuli on the retina, and later in the visual cortex.’ By the 20th century, visual perception became ‘an active process of searching for corresponding information, distinguishing the essential features of an object, comparing the features with each other, creating appropriate hypotheses, and then comparing these hypotheses with the original data. [...] This process of selection and synthesis of the corresponding features is active in character and takes place under the direct influence of the tasks which confront the subject.’ (Chanan 57)

Although writing in the very beginning of the 20th century, Münsterberg clearly sees perception as this active process. On persistence of vision and afterimages he said: ‘The [positive afterimages] are sufficient to bridge the interval between the two slots in the stroboscopic disk or in the zoötrope, the interval in which the black paper passes the eye and in which accordingly no new stimulus reaches the nerves. The routine explanation of the appearance of movement was accordingly: [...] the afterimages were responsible for the fact that no interruptions were noticeable, while the movement itself resulted simply from the passing of one position into another.’ Münsterberg notes: ‘This seems very simple’, but: ‘it was slowly discovered that the explanation is far too simple and that it does not in the least to justice to the true experiences.’ (Münsterberg 73)

Münsterberg names a few examples of these experiences, the first being motion aftereffects: 'We look from a bridge into the flowing water and, if we turn our eyes toward the land, the motionless shore seems to swim in the opposite direction.' It is an experience of movement that is 'evidently produced by the spectator's mind and not excited from without.' (Münsterberg 74) Another example is given by the experiments of gestaltist Max Wertheimer: 'If a flash of light at one point is followed by a flash at another point after a very short time, about a twentieth of a second, the two lights appear to us simultaneous. [...] If now, in the same short time interval, the first light moves toward the second point, we should expect that we would see the whole process as a lighted line at rest [...] But the experiment shows the opposite result. Instead of the lighted line, we see in this case an actual movement from one point to the other.' (Münsterberg 74)

Münsterberg sees perception as a process of 'filling in', pointing to the wider workings of the mind: 'Everybody knows how difficult it is to read proofs. We overlook the misprints, that is, we replace the wrong letters which are actually in our field of vision by imaginary right letters which correspond to our expectations.' In the same way, our mind 'fills in' movement: 'the movement is [...] not really seen from without, but is superadded, by the action of the mind, to motionless pictures.' (Münsterberg 76) This doesn't really answer the question of how it is that we can see films though, and he is aware of that: 'the statement that our impression of movement does not result simply from the seeing of successive stages but includes a higher mental act into which the successive visual impressions enter merely as factors, is in itself not really an explanation. We have not settled by it the nature of that higher central process.'

There would be time for that, though. Strangely, of all the starting points of research offered by Münsterberg, none was to be picked up within the study of film up until about 80 years later, in the 1990s. In his book 'The Reality of Illusion', Joseph Anderson gives a brief history of film studies, showing what did happen in the subsequent years. The study of film started with the empirical inquiries of Münsterberg and the classical theories of André Bazin and Sergei Eisenstein, who devoted their writings to the defense of film as art. Then, in the 1950s, 'Cahiers du Cinema' and the auteur theory that posited the director as 'auteur' and the films as 'oeuvre', on to the 1960s, semiotics and film as a system of signification, on to the 1970s and 'what must seem to the non-initiate as a most bizarre program derived from a marshaling of Freudian psychoanalysis in support of an academic strain of Marxism' (Anderson 1996, 6) in which the role of the film theorist was to expose hidden agendas of to be found within the film, on to the 1980s and postmodernism - 'The attitude is one of self-absorption, and the perspective is elitist [...] Any view that is nonreflexive or nonironic is characterized as naive' (Anderson 1996, 7). All the while, no attempts where made to answer the basic questions posed in 1915 - Why do movies seem so real? How do we see depth in a flat surface? Why do we see uninterrupted movement?

This changed in the 1990s. As Anderson points out: 'Scholars from such diverse fields as perceptual and cognitive psychology, linguistics, artificial intelligence, neurophysiology, and anthropology, who have confidence in the scientific method and an interest in understanding the workings of the human mind, are sharing information in pursuit of their common goal. They have spawned what has been called the *cognitive revolution*.' (1996, 8)

Anderson himself, in attempting to answer the basic questions of film perception, works from what he calls an 'ecological metatheory'. The word 'metatheory' meaning a theory that can serve to encompass other – more specific – theories. And the word 'ecological' being borrowed from a study by psychologist J. J. Gibson named 'The Ecological Approach To Visual Perception'. In this study, 'ecological' stands for the world in which we find ourselves, and that shapes and has shaped us:

> We are and always have been part of a larger ecology. In this interlocking relationship with the larger ecological setting, we developed, through eons of evolution, elaborate and sophisticated capacities to gain information. Today, we interact with the synthesized images and sounds of a motion picture, but we have no new capacities for gaining information from them. We have only the systems developed in another time, in another context, for another purpose. We must process the images from the glass-beaded screen and sounds from the metal speakers with the same anatomical structures and the same physiological processes with which we process scenes and sounds from the natural world. To ask how we process continuity and character and narrative in motion pictures is to ask how the forces of evolution equipped us to know where we are in space and time, to make rapid judgements of character, and to narratize the events of our existence. (Anderson 1996, 15)

In explaining how we can see motion in separate still images, then, Anderson breaks the question down into two phenomena. The first one being flicker fusion, the second being short-range apparent motion.

Flicker fusion is the fusion of flashes of light. When one toys around with a stroboscope (as found in discotheques, not the phenakistoscope), one notices that there is a point at which the separate flashes of light are no longer discernible. This point lies around 60 flashes per second (60 Hz.) (Goldstein, 458) In film, there are 24 images in one second, so the image changes at a rate of 24 Hz. This lies rather far below the threshold of so-called *critical flicker fusion*. And this explains cinema's early moniker 'flicks': early film used to run through the projector at a rate of between 12 and 24 frames per second, the flicker being clearly noticeable. (Goldstein, 458)

How is it then that we don't perceive flicker at the movies, even though the film nowadays still runs at 24 frames per second? This is because of the shutter that has been added to the projector. This shutter is a rotating circular disc in front of the light beam, which has been divided into six parts, with the sections alternately opaque and cut away, leaving three opaque blades. It cuts the light when the frame is put into place, thus 'hides' the blurry projection, and then 'exposes' each frame an additional two times. This makes for a flicker rate of 72 Hz., which is above the threshold of critical flicker fusion of 60 Hz. (Anderson 1996, 56) In relation to this flicker fusion, Anderson points out that throughout the development of film, 'It was the human perceptual system that set the limits to which the cinematic apparatus had to conform'. (1996, 55)

How does the phenakistoscope relate to the phenomenon of flicker fusion? Say the phenakistoscope has 12 slots and it turns at a regular speed, about 1,5 times every second, one then has a flicker rate of 18 Hz, so far below the point of critical flicker fusion. And indeed, looking through the phenakistoscope slots at about this speed, I clearly notice a flicker. Looking at the world through the circulating slots, instead of at the disc reflected in the mirror, can prove to be an enjoyable way of passing time. It 'cinematizes' the world, making it feel like a film from the 1910's.

Interestingly, in the SAGE Encyclopedia of Perception published in 2010, Tim Goldstein uses the term *persistence of vision* instead of *flicker fusion*: 'Persistence of vision refers to the continued perception of light - resulting in an "after image" - after the stimulus light has been turned off. [...] Persistence of vision "fills in" the dark interval.' (Goldstein 458) He also notes, though, that flicker fusion, or persistence of vision in this case, doesn't account for the perception of motion. In line with Anderson, he points to another phenomenon: short-range apparent motion. Apparent motion is apparent 'because it is based on static visual information not real motion' (Goldstein 458). In researching apparent motion, two forms have been found: long-range apparent motion and short-range apparent motion.

Long-range apparent motion was first described by gestaltist Max Wertheimer, under the name *beta movement*. Smith explains the phenomenon:

> Long-range apparent motion [...] is perceived when two objects are alternately presented at two different locations around 10 times a second. The two objects are perceived as a single object moving smoothly between the two locations. Because of the slow rate of presentation and the large distances covered by the apparent motion, long-range apparent motions are thought to be processed late in the visual system and require inferences based on knowledge of real motion and the most likely correspondences between objects in the image sequence. (Goldstein 458)

Short-range apparent motions, in contrast, occur when static images depicting only slight differences in object location are presented rapidly, that is, above 13 Hz. Smith points out that: 'short-range motion processing occurs very early in our visual system and does not require perceptual inferences to understand the motion.' Another difference between short-range and long-range apparent motion that reinforces the distinction between the two, is that long-range apparent motion is unable to cause motion aftereffects. (Anderson 1996, 60)

Short-range apparent motion, then, is the system responsible for our perception of apparent movement in film: 'The 24Hz presentation rate used in film is too fast for long-range motion and film frames are too complex, making the task of identifying corresponding objects in subsequent frames too difficult. Instead, apparent motion in film is due to the same short-range motion system used to detect real motion. Motion detectors in the early visual system respond in the same way to the retinal stimulation caused by real motions and by rapidly presented (>13 Hz) static images that depict only slight differences in object location.' (Goldstein 458) Therefore, as Anderson points out, 'the visual system simply fails to detect the real difference between the successive changes in the static frames of a motion picture and the continuous changes of natural motion.' (1996, 61)

Conclusion

The phenakistoscope came to be in a time of rapid industrialization, and this is no coincidence. The spinning cogs and turning wheels of the industrialized world unveiled new forms of movement. Chance observations in this changed world, such as the lateral movement of a wheel through vertical apertures as noticed Roget, or the factory wheels rotating in parallel as seen by Faraday, lead to new investigations into visual perception. These investigations, in turn, brought about the invention of the phenakistoscope. Related to this are the changing views of the human sensorium. Before the 19th century, visual perception was seen as instantaneous and objective, the camera obscura being an analogy. From Goethe's colour studies onwards, seeing became a more subjective matter, taking place over time. Purkinje's in-detail descriptions of self-observed subjective visual phenomena are a vivid example of this, and it is telling that Purkinje, like Faraday and Roget, made phenakistoscopes. The phenakistoscope, then, finds itself at the interesting intersection between 19th-century science and popular culture.

In explaining how it is that we can see separate still images as one continuous moving image, the notion of persistence of vision is a recurrent one. The separate images fly by so quickly that the sluggish retina cannot keep up, and therefore they are merged into one continuous stream of movement. Even though this explanation is used in film studies to this day, it does not do justice to the complexities of moving image perception and contemporary insights from fields such as psychology and neurology. Moving image perception can be split up into two phenomena: flicker fusion and short-range apparent motion. Flicker fusion is the phenomenon by which separate flashes of light are perceived as one continuous light, the point of fusion being at 60 flashes per second. Short-range apparent motion processing occurs early in the visual system, and accounts for how we see movement in daily life. We use the same system in viewing moving images.

Limitations in time and space do bring to mind Münsterberg's earlier citation from 1916: 'The statement that our impression of movement does not result simply from the seeing of successive stages but includes a higher mental act into which the successive visual impressions enter merely as factors, is in itself not really an explanation. We have not settled by it the nature of that higher central process.' (76) There is much left to investigate.

Bibliography

Anderson, Joseph and Barbara Fisher. 1979. "The Myth of Persistence of Vision." *Journal of the University Film Association* 30 (4): 3-8.

Anderson, Joseph and Barbara Anderson. 1993. "The Myth of Persistence of Vision Revisited." *Journal of Film and Video* 45 (1): 3-12.

Anderson, Joseph. 1996. *The Reality of Illusion: An Ecological Approach to Cognitive Film Theory*. Carbondale and Edwardsville: Southern Illinois University Press.

Bazin, André. 1967. *What is Cinema?* Translated by Hugh Gray. Berkeley and Los Angeles: University of California Press.

Cook, Olive. 1963. *Movement in Two Dimensions*. London: Hutchinson and Co.

Chanan, Michael. 1980. *The Dream That Kicks: The Prehistory and Early Years of Cinema in Britain*. London: Routledge.

Crary, Jonathan. 1990. *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century*. Massachusetts: MIT Press.

Doane, Mary Ann. 2002. *The Emergence of Cinematic Time: Modernity, Contingency, the Archive.* Cambridge: Harvard University Press.

Dulac, Nicolas and André Gaudreault. 2006. "Circularity and Repetition at the Heart of the Attraction: Optical Toys and the Emergence of a New Cultural Series." In *The Cinema of Attractions Reloaded*, edited by Wanda Stauven, 227-244. Amsterdam: Amsterdam University Press.

Faraday, Michael. 1831. "On a Peculiar Class of Optical Deceptions." *Journal of the Royal Institution of Great Britain* 1: 205-223.

Leskosky, Richard. 1993. "Phenakistoscope: 19th Century Science Turned to Animation." *Film History* 5 (2): 176-189.

Horner, William. 1834. "On the properties of the Daedaleum, a new Instrument of Optical Illusion." *London and Edinburgh Philosophical Magazine*: 36-41.

Münsterberg, Hugo. 1916. *The Photoplay: A Psychological Study.* New York: Routledge.

Purkinje, Jan Evangelista. 1819. *Observations and Experiments on the Physiology of the Senses: Contributions to the Knowledge of Vision in its Subjective Aspect.* Translated by Nicholas Wade and Joseph Brožek. London: Lawrence Erlbaum Associates.

Roget, Peter Mark. 1825. "Explanation of an Optical Deception in the Appearance of the Spokes of a Wheel Seen Through Vertical Apertures" *Philosophical Transactions of the Royal Society of London* 115: 131-141.Goldstein

Goldstein, Bruce E., ed. 2010. *Encyclopedia of Perception*. Thousand Oaks: SAGE Publications.

Wade, Nicholas and Joseph Brožek. 2001. *Purkinje's Vision: The Dawning of Neuroscience.* London: Lawrence Erlbaum Associates.