

Symbolizing Maps using Parallel Line Patterns: What the Cartographic Designer Should Know

Clifford H. Wood
Department of Geography
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X9 CANADA
Fax Number: 709 737-3119
E-mail address: chwood@mun.ca

Abstract. More than 30 years ago, Castner and Robinson (1969) published the definitive study on dot patterns. *Dot area symbols in cartography: the influence of pattern on their perception* provided the cartographic designer with knowledge regarding the character of dot patterns. In that publication, the authors make the point that basic research in the role of patterns in cartographic design is relatively rare compared to applied research (Castner and Robinson, 1969:7). Furthermore, they observed that repetitive marks or patterns were commonly used design choices in thematic cartography. Yet, little was known about them, or how the eye and mind reacted to them, or what made one dot pattern different in appearance from another, and any liabilities or assets that patterns had for cartographic communication (Castner and Robinson, 1969:7). As far as research on other patterns is concerned, nothing seems to have changed much in the last 31 years. Take the case of parallel line patterns.

As a symbol option in map design, parallel line patterns are used less frequently than dot patterns. The reason for their less frequent use is that some parallel line patterns present a number of problems for the map reader. Some of these problems include involuntary eye movements that cause the line patterns to “shimmer”; some contribute to the presence of “subjective colors”; some may be easier to look at when placed horizontally rather than vertically, and so on. While a great deal of research about the characteristics of dot patterns has been published, little research has been conducted on parallel line patterns. As a result the cartographic designer has few if any objective guidelines for parallel line patterns that can be applied with confidence. And yet, cartographers continue to use them for area symbolization with varying success.

It is generally accepted among cartographers (Robinson et al, 1995; Cuff and Mattson, 1982; Dent, 1996; Castner and Robinson, 1969; Monmonier, 1993; Keates, 1989; and

Campbell, 1991) that line patterns used to differentiate areas on maps create visual discomfort and can induce involuntary eye movements. Line patterns are sometimes described as “hard to look at”. In part, this visual irritation is thought to occur when the eyes trace the paths or orientations of lines. While acknowledging the visual problems of line patterns, little has been published that would identify the root causes, or provide empirically tested means to facilitate their use in a cartographic context.

In a cursory examination of several cartography texts, one recurring suggestion to moderate the visual irritation was to use horizontal rather than vertical line patterns. Robinson et al (1995:396) for example, stated in the caption of an illustration that parallel line patterns, particularly in a vertical orientation, can be irritating to the eyes. Monmonier (1993:74) stated that to lessen the visual irritation associated with parallel line patterns, one should avoid vertical line patterns that “dazzle” the eye. He suggested that horizontal line patterns are less irritating. No substantive explanation or citation of source for this suggestion was offered by either author. No hint at the physiological underpinnings of their recommendations is available in their works.

Other authors of cartography texts advised against using parallel line patterns unless they were modified to make them less visually irritating. For example, Robinson et al (1995:318) stated that “whatever the reason, the effect (visual irritation) is somewhat reduced if the lines, regardless of their width, are separated by white spaces greater than the thickness of the lines”. Monmonier (1993:74) and Cuff and Mattson (1982:10) suggested cross-hatching them. Keates (1989:32) and Dent (1996:143) suggested screening them to lessen the contrast with the background. Keates (1989:32) and Campbell (1991:128-129) suggested using fine lines as opposed to coarse lines. Missing from these works is any reference to the desirability of using horizontal versus vertical line patterns, nor any suggestion as to which orientation is less visually irritating, as well as a lack of any definitive guidelines for their usage.

This paper explores a number of issues surrounding the use and perception of parallel line patterns. Some preliminary research results will be presented that may offer some useful guidelines. If cartographic designers are expected to achieve the best possible results, they must have information about the ways they can use patterns to make areas visually distinct while avoiding unwanted visual effects.

Psychologists’ early work with line patterns. “It has long been known that certain

perceptual changes occur as a consequence of continuous observation of ‘geometrically periodic patterns’ ” (Wade, 1977:407). According to Wade (1977) Purkinje, in 1823, was probably the first to describe visual distortions while viewing finely ruled gratings or line patterns. Purkinje attributed this effect to an overlap of an afterimage of the lines with a displaced image (Wade, 1977:407). Brewster also noted problems in viewing line patterns in 1825. In 1832, Brewster and Wheatstone reported the dazzling effect caused by line patterns, as well as the appearance of subjective colors in the white spaces between black lines (Wade, 1983). Fechner observed the appearance of subjective colors associated with a rotating disk in 1838. Other early observers of visual distortions associated with line patterns included Helmholtz in 1860, Hensen in 1865 and 1867, Fleischel in 1883, and Schilder in 1912. A variety of early explanations for the phenomenon were based either on the fineness/coarseness of the grating, the “grain of the retinal mosaic”, “retinal irradiation”, “interference fringes on the retina”, or some combination, but in 1977 Wade maintained that the cause for the apparent waviness remained unresolved (1977:407).

While developing a reliable method for demonstrating the influence of illumination-intensity upon visual efficiency, Luckiesh and Moss (1933), using a test graphic consisting of diagonal parallel lines, also found that the pattern produced involuntary eye movements and subjective colors. They attributed them to “rapid eye-movements over the stationary black and white pattern” (Luckiesh and Moss, 1933:137). In 1939, Erb and Dallenbach conducted their own experiment using a similar image as Luckiesh and Moss, but with five different line widths (.002, .004, .008, .016, .024) and spaces (.004, .010, .020, .028, .035). They found that narrow lines and spaces produced both “phenomenal (eye) movements” and subjective colors. Effects were less pronounced when either narrow lines and wider spaces, or wider lines and narrower spaces were used. And, broad lines and broad spaces produced neither reaction among the observers (Erb and Dallenbach, 1939:239-241).

An equally robust experiment was carried out by Wade (1977), who used four gratings consisting of black, parallel lines .010 inch in thickness with white spaces measuring .010, .020, .040, and .080 inches, viewed at normal reading distance. The patterns were presented on a disk measuring 1.256 inches in diameter and were oriented at 0, 45 and 90 degrees. The author reported waviness and oscillation associated with prolonged viewing, followed by disappearance of the pattern, only to re-emerge as scintillating colored dots (Wade, 1977:417). Those patterns with the smallest spaces disappeared more quickly than those with wider spaces, and the vertical gratings were more resistant to disappearances than other orientations.

Wade (1977:413) asked the question: what effects would the small involuntary eye movements over parallel line patterns produce? He suggested that the lines would be shifted continuously over the retina that could trigger the scintillating effect, either by varying stimulation of the “on” and “off” units somewhat analogous to flicker, or by stimulating directionally sensitive units, as reported by Hubel and Wiesel (1959, 1962, 1965, 1968). Wade concluded that apparent waviness is not due to pattern lines that are finer than the retinal mosaic as had been suggested earlier, or by direction-sensitive

neurons, but rather by small involuntary eye movements that lead to effects similar to flicker.

Although Wade seemed to have isolated the response to “geometrically periodic patterns”, their physiologically-based cause remains unknown, at least to me. There is a body of psychology literature that I have not yet had time to devour, so perhaps I will find the root cause for the phenomenon. But now, back to the question of horizontal versus vertical parallel line patterns.

I mentioned earlier that contemporary authors of cartography texts seem to accept the notion that parallel line patterns with a horizontal orientation are “easier” to read than when placed vertically. This notion seems to be based on opinions expressed by Boring in 1942 and experiments conducted by Brandt in 1945.

Boring (1942) cited work by Wundt in 1858 while discussing the Helmholtz square illusion. The illusion is one where a set of horizontal, parallel lines appear shorter than a set of vertical parallel lines, although the lines are the same length. Wundt had concluded that judgments of extent were based on eye movements, and the reason for the illusion was due to the notion that vertical eye movements were more difficult to make than horizontal ones because of the arrangement of the eye muscles. This notion was largely discarded during the twentieth-century (Boring, 1942: 240).

Brandt (1945) conducted a series of experiments, one of which was to assess how subjects observed designs mounted in both horizontal and vertical positions. In his concluding remarks, Brandt states:

In computing the relative excursions made by subjects when observing designs mounted vertically or horizontally it is apparent that significantly more excursions are made when the eye is permitted to move laterally. This might imply that less aesthetical satisfaction accompanies an ocular performance when an excess of vertical eye movements is necessitated due to the character of the composition Brandt, (1945:180).

More recent research on the superiority of horizontal orientations over vertical ones has called into question the earlier results of Boring and Brandt. In 1958, for example, Ogilvie and Taylor tested the visibility of a fine wire displayed in 18 orientations. They reported that the visibility of the wire in the horizontal and vertical meridians was much the same (Ogilvie and Taylor, 1958:629). Rock reminds us that based on experimental evidence from Attneave and Olson (1967), it is known that human beings and some animal species find it far easier to discriminate a vertical line from a horizontal line than to discriminate clockwise from counterclockwise oblique lines (Rock, 1973:16-17). Rock further states: “... it is known that visual acuity is superior along vertical and horizontal directions compared with oblique directions” (Rock, 1973:96). This statement is further substantiated by the work of Higgins and Stultz (1948, 1950), Liebowitz (1953) and Taylor (1963), all of whom reported that visual acuity associated with parallel line patterns was better when the patterns were oriented either horizontally

or vertically, than when positioned diagonally.

Although Hubel's work in the 1950s and 1960s to establish the presence of directionally sensitive neurons in animals is not without merit, their presence in the human visual system is only supposition. But, it is commonly accepted. Kelsey, for example, noted that the human eye does not detect horizontal and vertical lines or features with equal sensitivity. He demonstrated this difference using a simple test, the results of which he then stated as direct evidence of the presence of some sort of feature detection system in the visual process (Kelsey, 1997:37). These feature detectors are thought to be a group of specialized nerves that fire only when excited by a particular color, a certain form, a vertical line, an angled line, a circular blob, or upon perception of motion in a specific direction. There is no evidence yet, however, that these detectors function better for one orientation than another, *i.e.*, a preference for horizontal over vertical orientations.

Campbell and Robson (1968) suggested that the human visual system is composed of sets of neurons, each capable of responding to targets over only a narrow range of spatial frequencies. These preferred frequencies vary from one set of neurons to another. The authors further suggested that the sensitivities of these frequency-tuned neurons, or channels, determine the overall contrast sensitivity function of the individual. During viewing of a pattern, however, an individual will experience adaptation to a particular spatial frequency, fatiguing those visual neurons that respond to its frequency (Movshon and Lennie, 1979; Albrecht, Farrar and Hamilton, 1984). If one of the channels is fatigued by adaptation, that channel will not respond as strongly when its preferred spatial frequency is presented again (Blakemore, Muncey and Ridley, 1973). This selective adaptation means that the visual acuity for a particular line pattern may be adversely affected, that is to say, its contrast will be decreased. Albrecht, Farrar and Hamilton (1984) further suggested that selective adaptation likely occurs in visual cortical cells. Such cells are indeed selective for spatial frequency (size), but they are also selective for orientation. As a result, one would expect pattern adaptation to be selective for both orientation and spatial frequency (size). Thus, adapting to a horizontal orientation would have no effect on vertical orientations, regardless of similarities in spatial frequency – implying that the cells fatigued by the horizontal pattern are not at all involved in seeing vertical patterns (Sekuler and Blake, 1985: 166-167).

Where does this leave us in the pursuit to understand the nature of parallel line patterns? At this stage, I have yet to discover, or perhaps understand, the physiological basis for the disturbing, involuntary eye movements some patterns produce. Yes, the presence of direction-sensitive neurons in the human visual system does likely account for the detection of various pattern orientations. That, however, does not account for the disturbing nature of many parallel line patterns, and it doesn't shed much light on the question of whether horizontal line patterns are easier to view than vertical ones. The search for understanding continues.

In the final analysis, what is needed is a robust research program into the nature of parallel line patterns similar to that of Castner and Robinson's work on dot patterns. Cartographers should have information that will allow them to make sound design

decisions, including the use of parallel line patterns, thereby eliminating the trial and error approach. This knowledge set might include the establishment of line weight and line spacing thresholds that separate visually disturbing line patterns from those that are not. Cartographic designers would then know which combination of weights and spaces to avoid. Knowledge of the perceptual value of various line patterns along with percent area inked should be available. Such knowledge may lead to the development of a gray scale for parallel line patterns. The question whether horizontal line patterns are superior to vertically oriented patterns should be settled. I would further suggest that eye movement recording during this extended experiment might provide objective measures to various experimental conditions.

If this research leads to some reliable, basic knowledge regarding parallel line patterns that will reduce or eliminate the trial and error approach now used in cartographic design, I will consider it time well spent.

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