Luminance & Line

Lessons from the past in perception–based communication

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Introduction

Grant's Atlas of Anatomy [1] is a historically significant textbook, notable for its image-dominant, systemic orientation, originally published by Williams and Wilkins in 1943. The University of Toronto is home to the original illustrations, which were completed in the 40s and 50s by a small group of Canadian medical illustrators. A major digital archiving project is currently underway to preserve these original illustrations, and it has provided an opportunity for us to revisit the representational techniques used by these illustrators—based on years of training and apprenticeship-derived design heuristics—in the light of a modern understanding of perceptual design. This poster highlights two of these representational strategies: the primacy of luminance-dependant representations of form; and the deployment of linear depiction in specific contexts.

Historical context

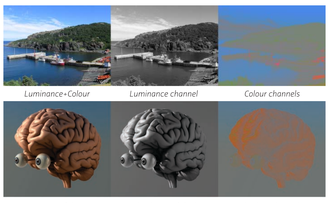
In the period before the Second World War, North American medical schools relied primarily upon the English translations of two German anatomical atlases: Spalteholz's *Atlas of Human Anatomy* (1895-1900) and Sobotta's *Atlas of Human Anatomy* (1906) [2, 3]. Wartime events—a business interruption at one European publisher, the bombing of another, and wartime trade restrictions—meant that these books became unavailable in North America. Dr. John Charles Boileau Grant, a renowned teacher of anatomy at the University of Toronto, visited the Philadelphia offices of Williams and Wilkins in 1941, and proposed a new atlas [4]. This atlas would take a novel approach: much less text; English rather than Latin terminology; a regional rather than a systemic approach (more appropriate for dissection); a single volume; and non-idealized illustrations based closely on individual dissections. He brought with him a group of sample illustrations created by Canadian illustrators working with Maria Wishart, director of the university's Medical Art Service. By 1943, the first edition of *Grant's Atlas of Anatomy* was available. Maria Wishart had trained with Max Brödel, who had founded the first school of medical illustration at Johns Hopkins in Baltimore in 1911 [5]. The illustrators who worked on the atlas included Dorothy Chubb, Elizabeth Blackstock, Eila Hopper-Ross (also student's of Brödel), and Nancy Joy (a student of Tom Jones at the University of Chicago).

Luminance vs colour

Most of the illustrations for *Grant's Atlas* were originally created in grayscale (crude colour overlays were used in some of the images to isolate major structures such as veins and arteries, and in recent editions the illustrations have been colourized for market reasons). Despite the fact that many competitor atlases were full-colour, *Grant's* continued to sell well after WWII (to the surprise of its publisher [3]). Why do the illustrations work so well with such a limited palette?

Vision research shows us that the luminance channel provides virtually all the information necessary to decode complex real-world scenes [6]. Luminance changes allow us to detect object boundaries, object shapes, spatial position and orientation, and object motion (see comparison illustration below). Colour alone can do none of these things.

Colour is not without use in anatomical representation; it can aid in the segmentation of complex scenes, and the categorization of structures. But, as in black and white photography and cinematography, colour is not essential in providing a richly informative two-dimensional representation.



A comparison of the representational richness of the luminance and colour channels, in a real-world scene (top) and a synthetic scene (bottom). From left to right, full-colour images (luminance + Colour), luminance channel only, and colour channels only.

Linear depiction

The *Grant's* artists used line drawings in two primary modes: as keys to tonal depictions of structure, and as schematic representations of structure-function relationships.

Linear depiction is a special case in visual perception. Real world scenes don't resemble line drawings, yet human beings have little trouble interpreting them. Developmentally, we all start to draw using lines, and line drawings are recognizable even in cultures that have not previously been exposed to them [8, 9]. Strong evidence supports the notion that the ability to understand line drawings is somehow inherent to visual and spatial perception, not learned [10, 11]. There is even evidence that line drawings are faster to interpret than realistically shaded scenes in many circumstances [12, 13, 14]. As the cognitive scientist Julian Hochberg noted:

> *"In line drawings, the artist has not invented a completely arbitrary language: instead, he has discovered a stimulus that is equivalent in some way to the features by which the visual system normally encodes the images of objects in the visual field..."* [7]

Linear depiction remains a preferred mode of communication in many forms of technical documentation (how-to manuals, patent applications, etc.). Skilled illustrators use various techniques to extend the expressive range of line drawings (see the call outs at right).

Comparative strengths

In a number of instances, both tone and line are used in *Grant's* for the same specimen or subject. How these illustrations are labelled provides clear evidence of the perceived strengths of each visual approach. In these posterior views of the posterior cranial fossa, the tone illustration (image 3) is labelled mostly with surface features of the cranium, while the line drawing (image 4) is labelled to demonstrate important internal features, especially the small foramina that are functionally important transcranial routes for blood vessels and nerves.

Tone is never used in the atlas when:

- The image is schematic (i.e. scale varies across the illustration)
- The image is conceptual (e.g. representations of opposing surfaces "opened up" and laid flat with a the graphic guide of a surrounding open-book motif).
- Multiple layers are represented simultaneously (images incorporating elements made see-through or transparent for didactic purposes) as in image 2.

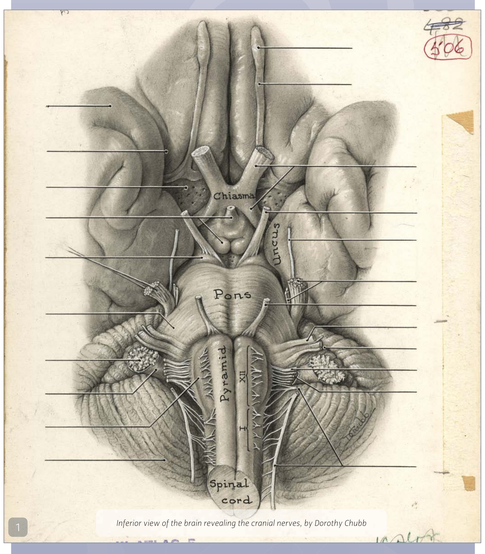
Thus, tone illustrations become, through the force of a consistent visual rhetoric, the "evidence" in the Atlas. The tone illustrations, specifically designed to be the core of a book meant to be used in a cadaver lab, represent what the student *might see* at dissection. Line illustrations were free to include not only what the student might see, but also what they *should know*. In many circumstances, line drawings also provide visual scaffolds that would allow students to form the proper conceptual models of the structure-function relationships in the human body.

Conclusion

Grant's Atlas of Anatomy has had an enduring impact on anatomical teaching, and remains is use around the world. It employed an image-centric regional approach to anatomy, making it especially useful in the context of the dissection lab. The illustrators of *Grant's* (Dorothy Chubb, Nancy Joy, Elizabeth Blackstock, and Eila Hopper-Ross) were skilled visual communicators, whose training reflected decades of received wisdom from the pioneers of medical illustration, and from academic schools of art.

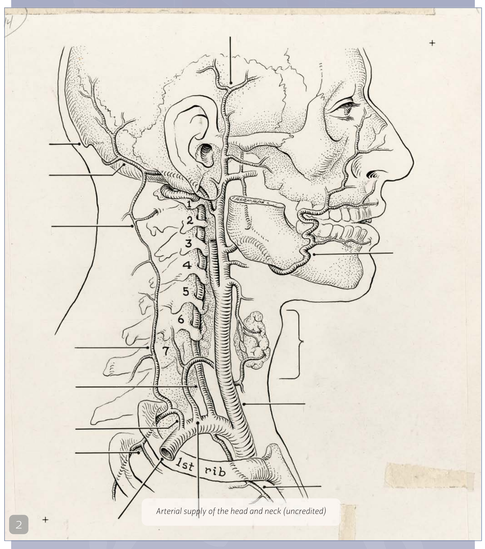
Many of the design heuristics used by these illustrators can be supported by recent research in visual perception. Understanding these lessons of the past, and their perceptual bases, may help influence the form taken by future education-oriented visualizations.

Luminance

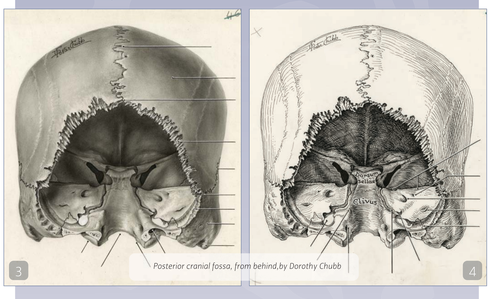


1 *Inferior view of the brain revealing the cranial nerves, by Dorothy Chubb*

Line



2 *Arterial supply of the head and neck (uncredited)*



3 4 *Posterior cranial fossa, from behind,by Dorothy Chubb*

Contrast effects

The illustrators of *Grant's Atlas* selectively amplified the luminance contrast along object edges, in order to enhance the illusion of depth. This technique exploits a powerful perceptual depth cue described only relatively recently: edge contrast at object boundaries, and its relative sharpness or blurriness, will strongly affect the perception of depth discontinuities [15].

Texture gradients

Texture gradients are represented by patterned luminance changes that vary in scale and orientation with the angle of the surface relative to the observer [6]. These surface patterns help to convey the complex three-dimensional morphology of the anatomical subjects.

Cast shadows

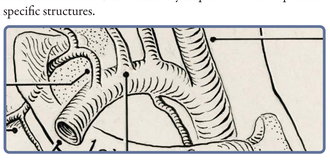
Cast shadows, another powerful depth cue, are frequently used to convey shape as well as the spatial interrelationships of objects. Note the use of an upper-left light source, a convention of medical illustration (and of classical art training).

Occlusion

Occlusion, where a nearer object overlaps a more distant object in the visual field, is the most powerful depth cue. The illustrators of *Grant's Atlas* would selectively enhance the occlusion effect by breaking the contours of more distant objects as they intersected the silhouette lines of nearer objects.

Line weight

Line weight may be used to denote various kinds of contours; among them: silhouettes; depth discontinuities; and surface discontinuities. In establishing a hierarchy of line characteristics, the illustrator can assist the viewer's reconstruction of the three-dimensional form [16], and selectively emphasize or de-emphasize specific structures.



Linear patterns

Varied patterns of thin-to-thick-to-thin lines are used to indicate shading and describe the form of the anatomical structure. The resulting pattern forms a type of linear texture gradient. This technique is termed eyelashing among medical illustrators.

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