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The Efficacy of Small Multiples in the Visual Language of Instructional Designs

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The Efficacy of Small Multiples in the
Visual Language of Instructional Designs

Douglas B. Stringham

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

The Efficacy Of Small Multiples In The Visual Language Of Instructional Designs

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The visualization strategy of *small multiples* (Tufte, 1983, 1990, 1997) is not merely the clever or ordered arrangement of similar and personable images; small multiples—purposeful compositions of similarly sized, repeated illustrations—contain a great deal more than the sum of their respective parts. The purpose of this study is to define a set of objectives and guiding tactics for using small multiples in the visual language of instructional designs. This study aims to (1) compile a targeted literature review cataloging the historical treatment of small multiples and their pedagogical and cognitive virtues and (2) analyze examples of small multiples usage in visual design artifacts to determine efficacious and expansive applications of this technique.

Key words: small multiples, Edward Tufte, instructional design, cognition, illustrations, visual representation, visual design, objectives, guiding tactics

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Chapter 1: Introduction

A single image is okay. But that same image, when multiplied a number of times, is often irresistible. —Bob Gill

A Medieval Pedagogical Tale

One of the legacies of the influential English Benedictine monk Bede was *De computo vel loquela per gestum digitorum* (“On Calculating and Speaking with the Fingers”), first published in 725 AD. Actually a prelude to his larger work, *De temporum rationae*, Bede’s dactylogical system contains the only complete manual counting system in existence (Menninger, 1992) and for nearly eight hundred years, its instruction remained only accessible in its original textual form:

¶ Here foloweth the table of the arte of the hande

In which as you may se 1 is expressed by ye lyttle fynger of ye lefte hande closely and harde croked.

2 is declared by lyke bowynge of the weddyng fynger (whiche is the nexte to the lyttell fynger) together with the lyttell fynger.

3 is signified by the myddle fynger bowed in lyke maner, with those other two.

4 is declared by the bowyng of the myddle fynger and the ryng fynger, or weddyng fynger, with the other all stretched forth.

5 is represented by the myddle fynger onely bowed.

And 6 by the weddyng fynger only crooked: and this you may marke in these a certayne order. But now 7, 8, and 9, are expressed with the bowyng of the same fyngers as are 1, 2, and 3, but after an other fourme.

For 7 is declared by the bowyng of the lyttell fynger, as is 1, saue that for 1 the fynger is clasped in, harde and rounde, but for to expresse 7, you shall bowe the myddle ioynte of the lyttell fynger only, and holde the other ioyntes streyght.

S. Yf you wyll geue me leue to expresse it after my rude maner, thus I vnderstand your meanyng: that 1 is expressed by crookyng in the lyttell fynger lyke the head of a bysshoppes bagle [crozier]: and 7 is declared by the same fynger bowed lyke a gybbet.

M. So I perceau, you vnderstande it.

Then to expresse 8, you shall bowe after the same maner both the lyttell fynger and the ryng fynger.

And yf you bowe lyke wayes with them the myddle fynger, then doth it betoken 9.
Now to expresse 10, you shall bowe your fore fynger rounde, and set the ende of it on the
hyghest ioynte of the thombe. (The arte of nombrynge by the hande, 1916)

The reader here may find, in an attempt to parse Bede's instructions, that he or she is tempted to reproduce the pronunciation of the described handshapes. Bede's original system, while an important step in connecting the cognitive and physiological, lacked an integral component to its instructional design: a visual representation layer (Gibbons, 2003). How are these descriptions of handshapes to be executed? How would one know if there was error in their articulation? Bede's method was reproduced in 1494 by Italian mathematician Luca Pacioli (*Summa de Arithmetica*, 1494; Figure 1), again in the 18th century by German physicist Jacob Leupold (*Theatrum arithmetica-geometricum*, 1724; Figure 2), and finally in an unattributed 20th century mathematics compendium (*The arte of nombrynge by the hand*, 1916; Figure 3). Notably, however, these reproductions did not rely solely on Bede's original text, but instead added diagrams to their interpretations of the original dactyological system.

These reproductions of Bede's original written system are highly significant. His original system and descriptions become much more salient when they are replaced by (or at least paired with) visual representations that help reduce the amount of memory capacity required to learn and store the information (van Merriënboer & Sweller, 2005). These diagrammatic approaches are superior for at least two vital reasons. One, they reduce extraneous cognitive load (additional required cognitive processing because of the manner in which instruction is presented; discussed in greater depth in Chapter 2), or remove irrelevant barriers that are "imposed purely because of the design and organization of the learning materials rather than the intrinsic nature of the task" (Sweller & Chandler, 1994, p. 192). In other words, a difficult-to-parse textual description is replaced with an at-once perceptible visual representation of the task or process.

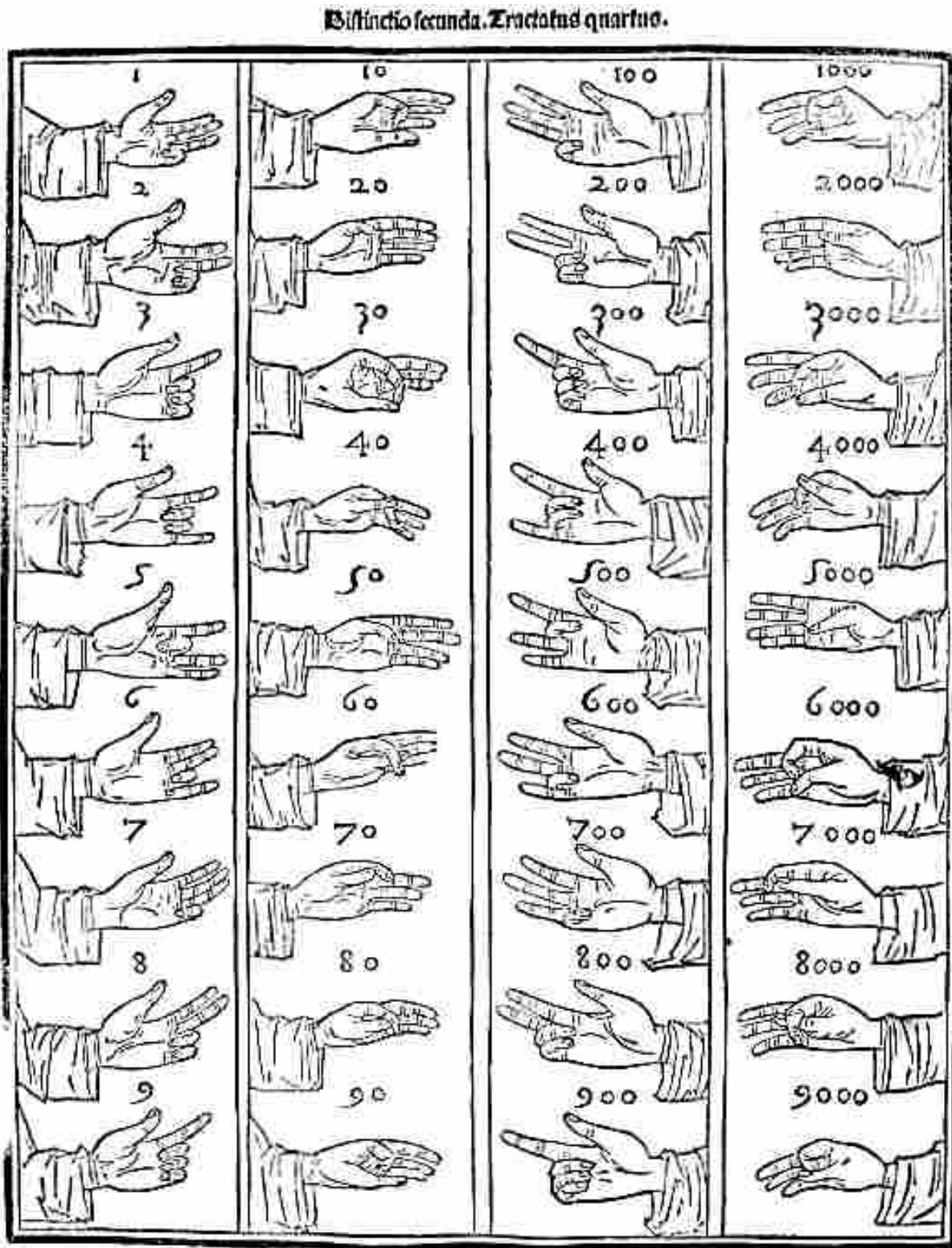


Figure 1. *Distinctio fecunda tractatus quartus* in *Summa de Arithmetica*, Luca Pacioli (1494).

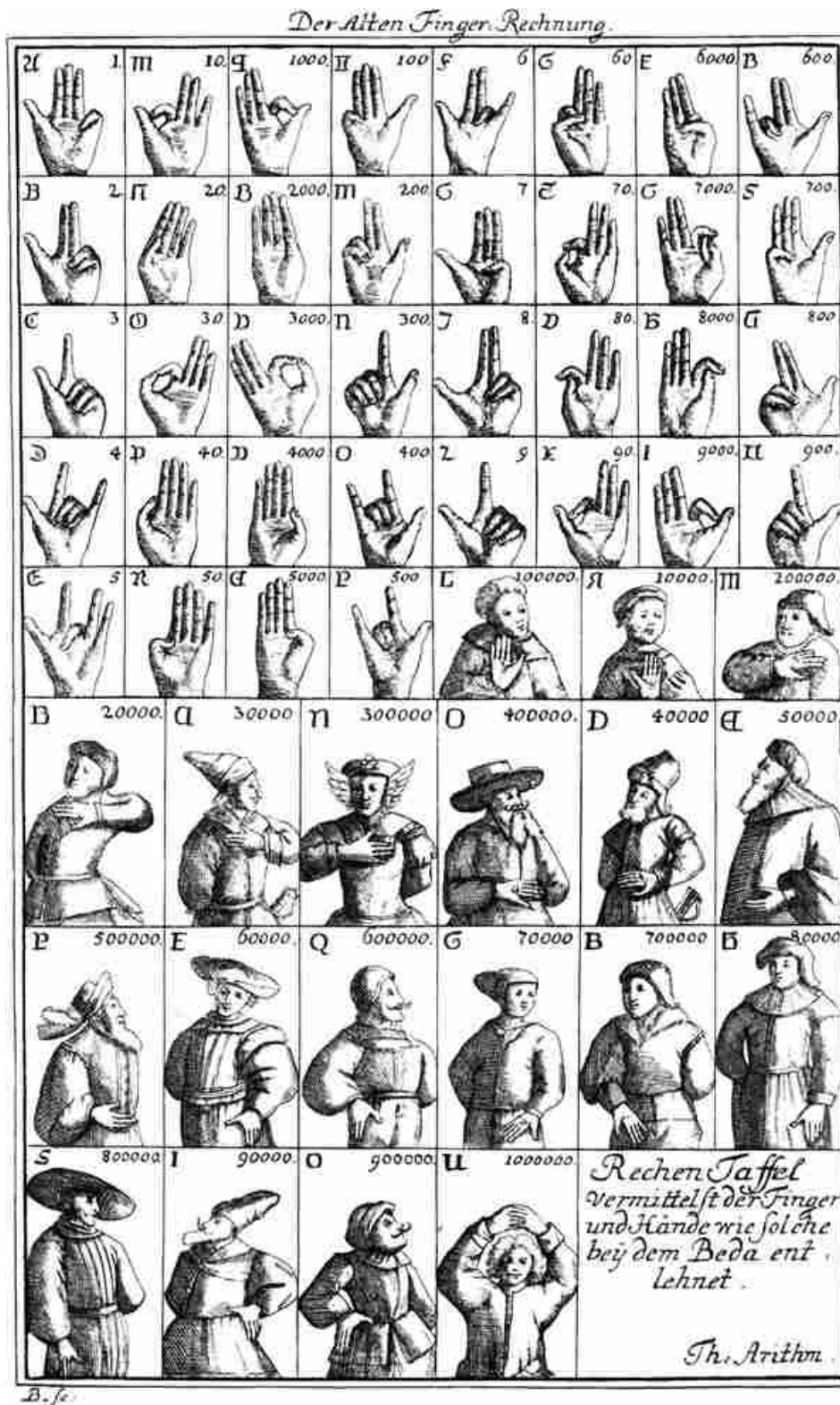


Figure 2. Der alten finger rechnung in *Theatrum arithmetico-geometricum*, Jacob Leupold (1724).

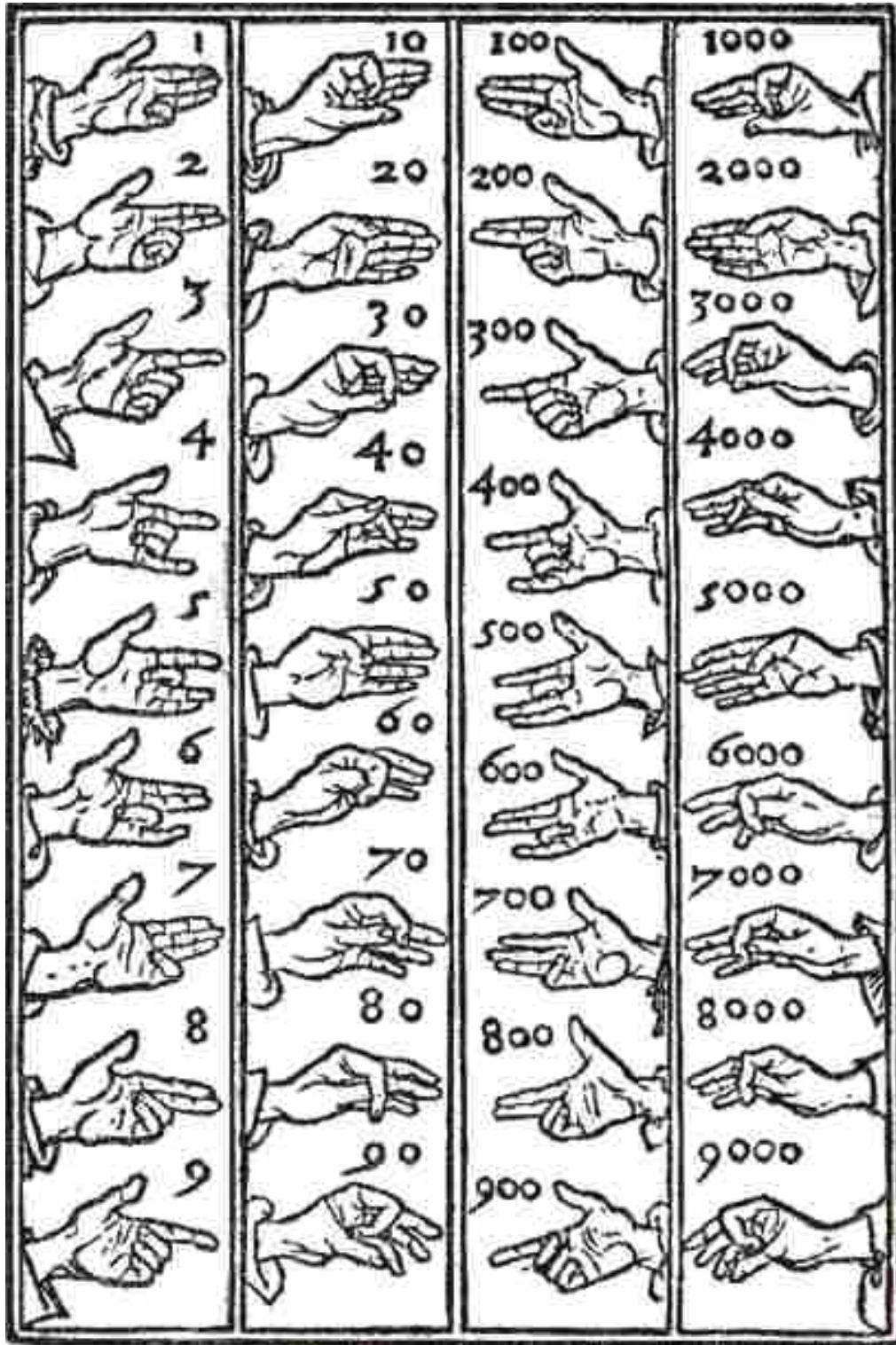


Figure 3. The arte of nombrynge by the hande, Unknown (1916).

Two, and most notably for this study, the illustrations are arranged in such a way as to saliently indicate the rhetorical differences between each of the dactyological positions.



In which as you may see 1 is expressed by ye lyttle fynger of ye lefte hande closely and harde croked.

2 is declared by lyke bowynge of the weddyng fynger (whiche is the nexte to the lyttell fynger) together with the lyttell fynger.

3 is signified by the myddle fynger bowed in lyke maner, with those other two.

4 is declared by the bowynge of the myddle fynger and the ryng fynger, or weddyng fynger, with the other all stretched forth.

5 is represented by the myddle fynger onely bowed.

Figure 4. A recomposed small multiple comprising images from *The arte of nombryng by the hande* and text from Bede's *De computo vel loquela per gestum digitorum*.

In Figure 4, '1' is understood as different than '2,' '3,' '4,' or '5' because they are visually distinct yet spatially relevant; the linear and spatial proximity of the images creates a before-and-after experience where a learner comes to understand that "'1' looks like this and '2' looks like that; therefore, these must be different." This instructional strategy of clarifying and defining the rhetorical relationships of objects by using numerous similarly sized comparative illustrations is called *small multiples*.

Questions Addressed In This Study

This study seeks to answer questions posed by instructional designers about the identity and utility of small multiples in instructional designs.

What are small multiples? Small multiples are not just an arranged series of personable images; they are, quite literally, packed with far more than the sum of their respective parts. Small multiples might be more clinically defined as a holistic (or Gestaltian) visual representation tactic

constructed of multiple homogeneous units arranged to reveal salient comparisons in data presentation, visualization, and pedagogy:

At the heart of quantitative reasoning is a single question: *Compared to what?* Small multiple designs, multivariate and data bountiful, answer directly by visually enforcing comparisons of changes, of the differences among objects, of the score of alternatives.... Constancy of design puts the emphasis on changes in data, not changes in data frames. (Tufte, 1990, p. 67)

Small multiples are most recently and famously discussed in data scientist Edward Tufte's work on information design and visualization techniques (Tufte, 1983, 1990, 1997). Most notably, in each volume, Tufte reinforces that small multiples help readers and learners focus on the pedagogically-rich crevasses *between* data images: the patterns and changes and rhetorical differences between data points. In short, the real value of small multiples lies not in the actual images themselves—the *what* and the *when*—but in the differences between the images—the *how* and the *why*:

An economy of perception results; once viewers decode and comprehend the design for once slice of data, they have familiar access to data in all the other slices. This constancy of design allows viewers to focus on changes in information rather than changes in graphical composition. (Tufte, 1990, p. 29)

All small multiples at their very essence, then, are comparative devices, and are used (unwittingly or purposefully) in many familiar and common visual representations. To wit: the five-day forecast and the baseball scorecard.

The five-day forecast. Since the 1970s, viewers of television news programs have watched (and arguably, shaped) the presentation of visual weather pattern predictions.



Figure 5. An example of modern five-day forecast television graphic, depicting meteorological conditions and high/low temperatures (in °F).

Through the use of a simple small multiple representation, meteorologists and visual information designers have evolved what used to be a lengthier recitation of potential weather conditions into an easily and visually processed two-minute visual soundbite known as the five-day forecast. This small multiple-based pictorial depiction of weather is far more efficacious than a traditional serial outlining of data because

- cognitively, presented data are reduced to the minimum linguistics needed to communicate expected conditions, and consequently, the data representation is more concise and less hampered by additional cognitive load (cf. Sweller, 2002);
- learners see data contextualized in both a familiar (timeline) and desired (“What do I need to know for Wednesday?”) temporal presentation of events;

- learners can make inferences about adjacent changes (e.g., comparisons) in weather events (“What was the weather like before X and what will it be like after Y?”) and can construct contingencies for their behavior;
- renderings of the meteorological pictograms communicate implicit rhetoric about and juxtaposition within the conditions; in traditional color psychology, orange and yellow communicate happiness and warmth (doubtless because of their physical inspirations) while blues and grays communicate water, coolness, and quiet.

Though five-day forecast visuals may vary in temporal, picto-iconic, and other constituent considerations, their operational small multiple principles win out in providing cognitive advantage while maintaining instructional density.

The baseball scorecard. Invented in 1863 by baseball writer and marketer Henry Chadwick (Dickson, 2007), scorecards are baseball’s Rosetta Stone; scorecard code linguists can operationally trace and retrace the steps in any baseball narrative. Indeed, in the absence of video or audio ubiquitous in the 21st century, any game—the mundane or thrilling alike—can be codified and recreated using small multiples.

In this case, these small multiples visually recreate the afternoon’s hidden narrative; a reader of the scorecard in Figure 6 can deduce that the Oakland team started the game with very little result and progress but, as visually noted by the density and similarity of the multiples captured in the fourth, fifth, and sixth innings, this flurry of activity resulted in six runs for the home team. Similarity and adjacency in the representation of each step help the viewer perceive, unpack, and then recreate high-context temporal narrative and progress.

No.	ATHLETICS	POS.	1	2	3	4	5	6	7	8	9
18	Kendall	C	X	◇	◇	6-3	◇	21 BB 21	4-3	◇	◇
21	Kotsay	CF	LG	◇	◇	◇	22 BB 22	◇	◇	6-3	◇
22	Bredley	RF	K	◇	◇	◇	25 BB 25	◇	◇	◇	◇
35	Thomas	DH	◇	8	◇	3	◇	◇	◇	K	◇
16	Payton	LF	◇	9	◇	◇	◇	◇	4-3	◇	◇
33	Swisher	1B	◇	K	◇	X	K	◇	◇	F9	◇
3	Chavez	3B	◇	◇	◇	◇	◇	◇	◇	◇	◇
19	Scutaro	SS	◇	◇	F3	6-3	◇	K	K	◇	◇
14	Ellis	2B	◇	◇	DP 5-4-3	◇	5-3	4-3	◇	◇	◇

Figure 6. Detail of Oakland A's team scorecard, Toronto Blue Jays at Oakland A's, July 29, 2006. ©boxscorejr.com via Creative Commons BY-NC-SA 2.0.

How do small multiples function? Research into the use of graphics in instructional designs clearly shows that instructional (and visual) designers cannot effectively create designs without understanding how visuals syntactically fit into their pedagogical aims (Winn, 1989; Englehardt, 2002). That is, semantically, how do images and graphics fit into the visual linguistics of instructional designs? Small multiples not only visually command cognitive load, they also grammatically function as adpositionals in a visual language: they identify, differentiate, and make visually explicit the relationships of learning objects to each other. Chapter 2 of this study explores how small multiples have had historical efficacy in instructional graphics and imagery as well as how small multiples can leverage pedagogical, psychological, and cognitive advantages in contemporary instructional designs.

Why should instructional designers care about small multiples? Figures 1 through 6 demonstrate the potential to strengthen pedagogical effectiveness not only by proactively using visuals in (cf. Duchastel, 1980; Pettersson, 2002) (or, in some cases, even in place of) text, but also by using visuals in specific arrangements to encourage specific outcomes. Though small multiples have been rigorously discussed and applied in other fields (cartography: MacEachren, 1995; interaction and user experience design: Tidwell, 2006, 2011; and geology: Clary, 2003), historically, the visualization strategy of small multiples (Tufte, 1983, 1990, 1997) has been typically used only to identify a genre of illustrative display. There continues to be, however, a dearth in the instructional and instructional message design literature concerning the cognitive and pedagogical benefits of using small multiples in the visual representation of instructional materials.

Drawing, then, on a critical review of literature and author analysis, this thesis aims to construct a set of tactics for small multiples usage that instructional designers can use in their work to decrease cognitive load, improve learning material aesthetic, and enhance learner perception and comprehension of instructional content and subject matter. These tactics can be constructed by culling the existing literature and better understanding how small multiples have historically been referred to and implemented in academic and nonacademic applications and how small multiples are cognitively processed and interpreted.

Chapter 2: Literature Review

In order to help existing references to and historical usage of small multiples to be more easily and cogently digested, five broad categories of literature—historical references of small multiples, usage of graphics in instructional situations, cognitive load and cognition, Gestaltian theory and saliency, and animation—are proposed for consideration. These groupings help designers and researchers see strengths and weaknesses of small multiples application as well as help them capture salient purposes in these devices: historical treatment (and mistreatment), pedagogical and cognitive advantages, and psychological and graphical advantageousness.

Historical Examples Of Small Multiples

Instructional designers can learn about the strategic and tactical benefits of small multiples by observing examples of this technique in historical contexts.

Classic depictions of small multiples. Certainly scholar and educator Edward Tufte is credited with coining the contemporary moniker small multiples (Tufte, 1983, 1990, 1997). However, this type of visual approach is not a novel discovery or phenomenon only discovered in the 20th century. With the invention of relief (or woodblock) printing in the late 14th century, illustration styles shifted from a traditional Medieval iconic flat two-dimensional light-and-shadow modality (Figure 7) to that of functional—and instructionally-motivated—monolithic line art (Figure 8). The repeatable offset printing processes invented by Gutenberg, et al. in the mid-15th century fueled an increased demand for literacy, and, as a result, rudimentary instructional texts began to emerge, composing explanatory texts with, for the first time, inline illustrations (Meggs, 1983).

The result is a visually distinctive, unambiguous, and easily accessible communication of information. These first “block books” simply yet visually instructed learners about topics such as

death preparation, religious doctrine, and trade performance. Initially these books were single-pane, still life renderings, but as demand for instructional communication increased and information design became more sophisticated, illustrators endowed their images to capitalize on the ability to display multiple tasks in multiple frames, and the flat icon style of the pre-1400s gradually faded from popularity (Meggs, 1983). Artistic, interpretive depictions gave way—for a time, at least—to information design.



Figure 7. Folios 9 (verso) and 10 (recto) of the Stockholm Codex Aureus (Codex Aureus of Canterbury), mid-eighth century.

Figure 8. *Formschneider in Ständebuch*, Jost Amman (1568).

Macvlæ in sole apparentes observatae. Pacioli (1494) and Leupold's (1724; cf. Tufte, 1990) small multiple renderings of Bede's eighth-century manual counting system have been chronicled in Chapter 1. Two pre-Renaissance representations of small multiples can be found in Christopher Scheiner's *Macvlæ in sole apparentes observatae* (1612; Figure 9) and Christiaan Huygens' *Systema Saturnium* (1659; Figure 10). Scheiner's 1612 rendering chronicles sunspot activity and their relative composition over a 37-day period from October to December 1611.

The first row of ten images in Schreiner's small multiples portrayal impressively depicts not only the rotation of the sun during this period (as seen by the slight successive horizontal movement of the sunspot groupings), but also the relationship, variability, and overall trace placement of the other observed spots.

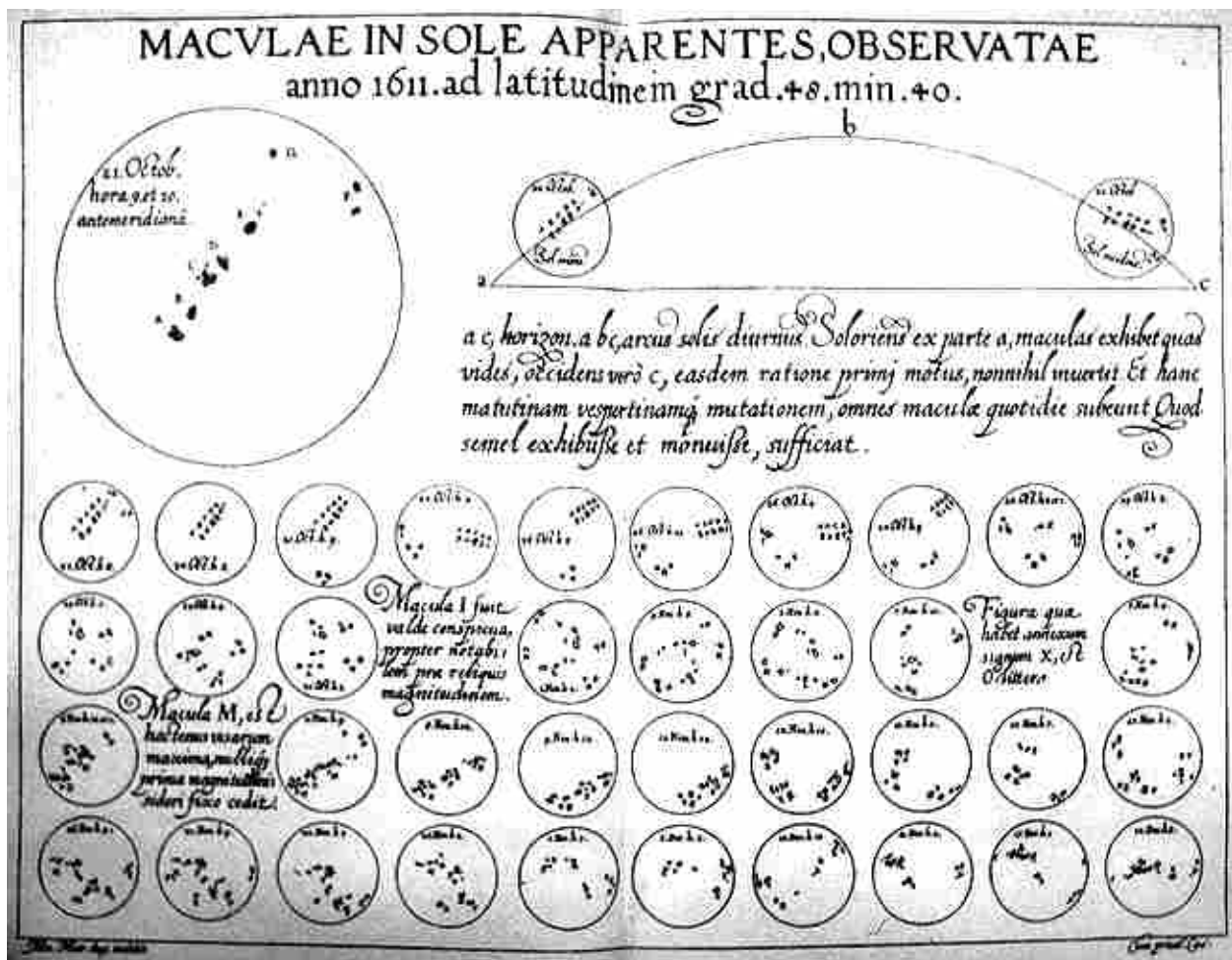


Figure 9. *Maculae in sole apparentes observatae*, Christopher Scheiner (1612).

Systema Saturnium. Dutch astronomer Christiaan Huygens' *Systema Saturnium* actually demonstrates *two* sets of small multiples: an inner ellipse, which shows, over the course of 16 undetermined time periods (perhaps lunar months or a zodiacal correlation), how Saturn appears

to an earthbound viewer; and an outer ellipse which depicts how Saturn looks from deeper space. Tufte (1990) has remarked that this small multiple design is “superior” (p. 67) because it depicts not only 32 Saturn images but also their individual rhetorical relationships to each other.

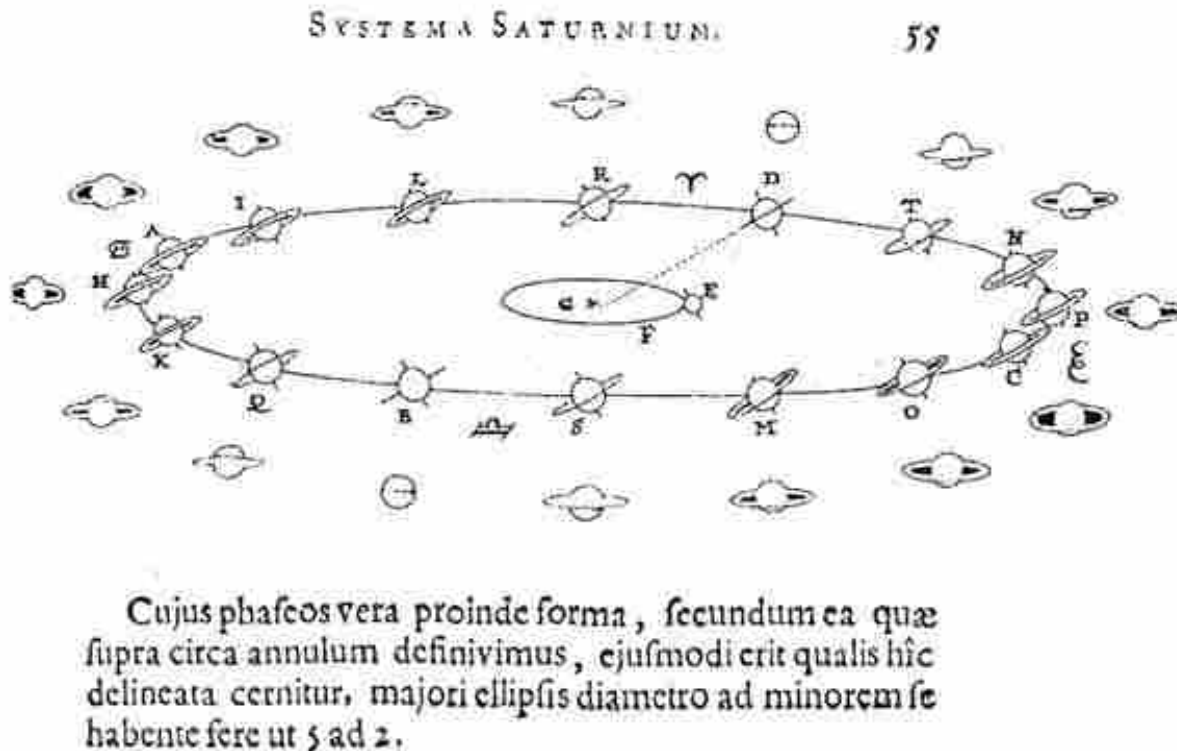


Figure 10. *Systema Saturnium*, Christiaan Huygens (1659).

Tufte (1997) also points out that Huygens’ multivariate diagram “depict[s] motion” (p. 108). Because each rendering represents snapshots in an uninterrupted series, the reader is left to “interpolate between images, closing up the gaps” (p. 108). Herein lies their efficiency to prompt higher-order thinking: small multiples leverage learners’ abilities to make inferences and create connection between snapshots.

Atlas universel d’histoire et de géographie. One of the more visually striking historical examples of small multiples is found in French scholar Henri Duval’s 1834 *Atlas universel*

d'histoire et de geographie anciennes et modernes, de mythologie, des religions, d'astronomie, de physique, de geologie, de histoire naturelle, de grammaire, de rhetorique &c. Duval packed a wealth of general world knowledge into a collegiate textbook/atlas, but he visually arranged the information using small multiples techniques. Two plates in particular depict (like Huygens) astronomical views of the Earth and moon relative to the larger bodies they orbit, and a remarkable color plate of the relative sizes of 51 winged insects and multipedes. While the *Tableau d'Astronomie et de Sphère* displays expected rhetorical, positional, temporal relationships between astronomical objects, it is the *Tableau d'histoire naturelle* which is unique in its use of small multiples.

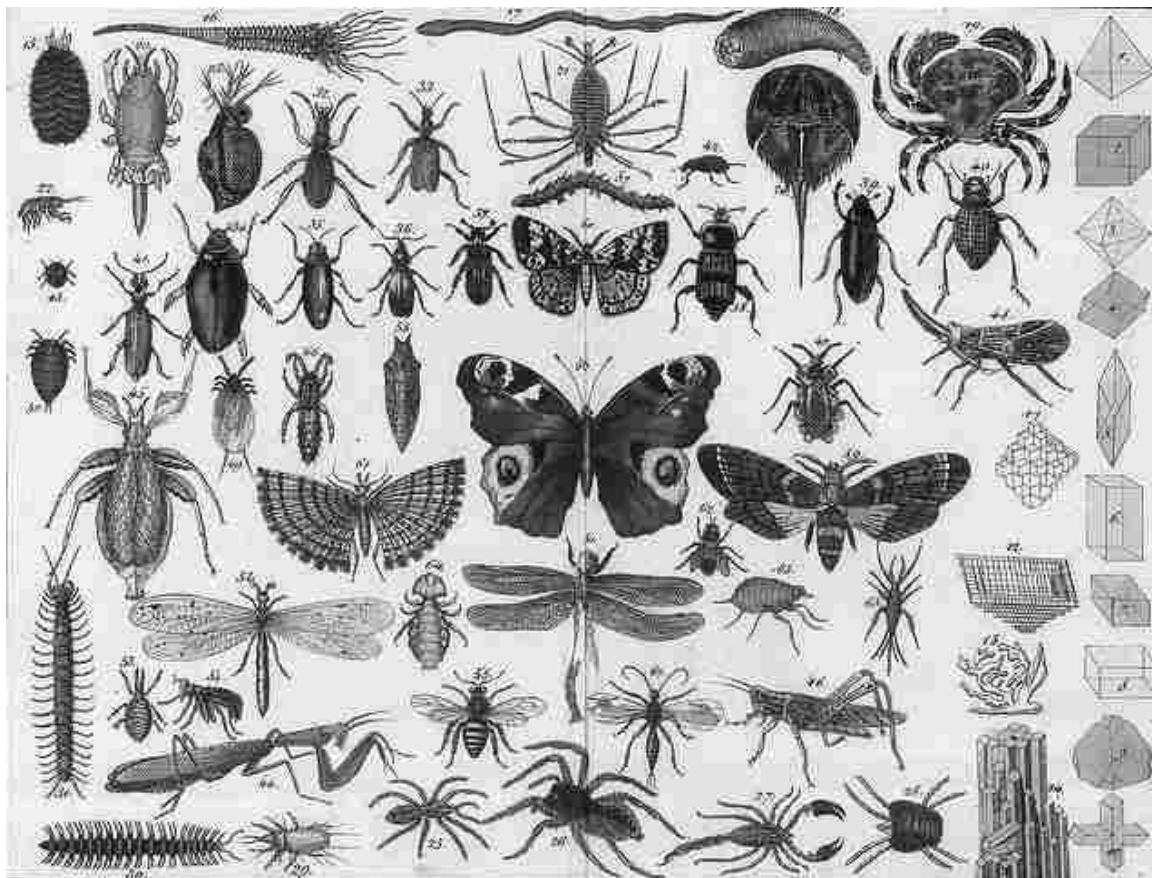


Figure 11. *Tableau d'Histoire Naturelle: Annelides, Crustaces, Arachnides, etc.* (detail), Henri Duval (1834). David Rumsey Map Collection.

Figures 9 and 10 display multiple images of homogenous sizes; Pacoli's dactylogy, the five-day forecast iconography, and Schreiner's sun renderings all show images that are near to exact the same dimensions, the more orthodox interpretation of Tufte (1990). Figure 11 from Duval (1834), however, successfully uses heterogeneously sized small multiples to interpret the explicit rhetorical relationships of the insects.

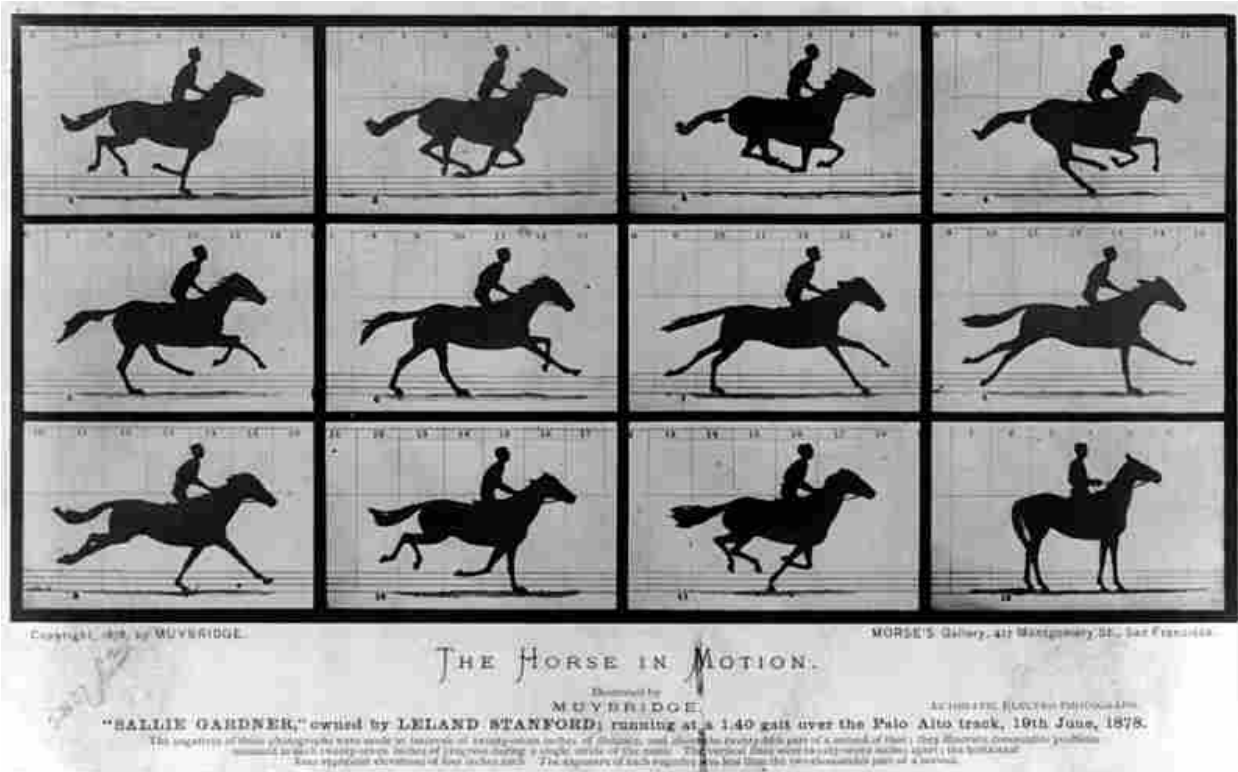


Figure 12. "Sallie Gardner at a Gallop," or "The Horse in Motion," Eadweard Muybridge (1878).

Sallie Gardner at a Gallop. Arguably one of the most iconic small multiples of the past 150 years is the photographic series captured in 1878 by Eadweard Muybridge entitled "Sallie Gardner at a Gallop," or "The Horse in Motion." Enlisted to settle the then-popular dispute over whether a horse, in full gallop, was ever truly aloft, Muybridge devised a clever rigging of wires and a dozen cameras to capture multiple images of a horse's locomotion (Leslie, 2001).

The resulting image from Muybridge's "Gallop" rendering (as well as the lesser-known 1887 Daisy Plate 640 photograph) is a classic small multiple. To be sure, only one photograph (top row, second or third from left) was needed to simply answer the question: "yes, at some point, all four legs are clearly elevated." But this comparative composition of 12 sequential and adjacent images not only provides the scientist with rhetorical salience—that X shares some kind of relationship with Y—it also yields the viewer a pedagogical experience: *how* and *why* and *when* X and Y are related.

Although de Souza & Dyson (2007) counter that "Gallop" may offer some images that are too similar in nature (that is, some of the differences and comparisons in the 12 images are perhaps too discrete, e.g., plates seven and eight and one and ten), they still concede that "Gallop" explicates adjacency, trace, and procedure in a way that "make[s] instruction easier to understand" (p. 4).

A case of mislabeling. Prolific 19th-century geologist and cartographer Henri de la Beche produced dozens of illustrations for numerous European periodicals, government documents, and field notebooks (Clary, 2003) from 1819 to 1855. Many of his works were explicitly detailed and multivariate; de la Beche's renderings are considered a watershed moment in the visual representation of geological concepts.

Although Clary labels these representations "small multiple formats" (Clary, 2003, p. 170) and even qualifies Plate 3 (Figure 13) as a "pseudo small multiple format" (p. 175), here Clary's identification of the images as small multiples is in error because de la Beche's renderings deviate from the Tufian definition of small multiples in at least two respects:

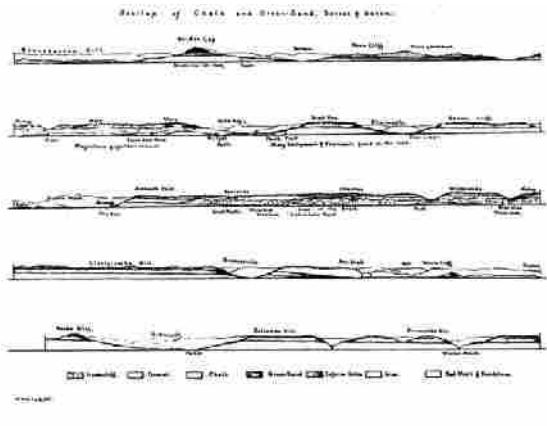


Figure 13. “Plate 3” from *Sections and views, illustrative of geological phænomena*, Henri De la Beche (1830).

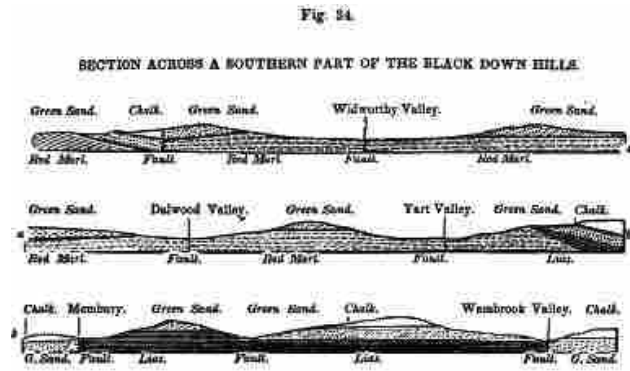


Figure 14. “Figure 34: Section Across a Southern Part of the Black Down Hills,” *Researches in theoretical geology*, Henri De la Beche (1837).

1. though it can be argued that the illustrations are multivariate (there is taxonomy, as evidenced by the bottom-anchored color legend, and hierarchies of labeling) and indeed “small” and “multiple,” the renderings do not demonstrate trace or adjacency, important for drawing comparisons and rhetorical relationships—as evidenced in the Muybridge sample—between X and Y.
2. most importantly, the renderings neither reference nor compare the same subject matter. Figure 34 from de la Beche (1837) more closely implies that the subject matter is similar in rendering style and label placement. (On closer inspection, however, the reader will discern three discrete geologic examples.)

While de la Beche’s works are not as orthodox to the Tufian small multiples definition as Pacioli (1494) or Scheiner (1612), they might be arguably closer to Duval’s (1834) *Tableau d’histoire naturelle* methodology: arranging heterogeneously-sized and/or heterogeneously-semantic concepts can still produce a small multiples-like representation. However, this

misunderstanding of de la Beche's work as small multiples "formats" (Clary, 2003) is typical of similar contemporary representation styles ("this illustration uses *several small* images, therefore, these are *small multiples*") and is symptomatic of the periodic misuse of this device (see Russell, 2002 below).

Contemporary depictions and applications of small multiples. Similar to their historical counterparts, modern-day visualization practitioners also routinely use small multiples in their data displays.

Cartographic data consumers. Researchers working with geographic visualization (GViz) tools and representation often cite the use of small multiples as effective comparative devices in map creation and review. Although MacEachren (1995) and other colleagues somewhat demur over the effectiveness of small multiples in the specific display of multivariate global model-derived data, they do concur that small multiples are almost always cognitively beneficial for users and scientists of cartography. "Side-by-side compar[ative] map pairs" (p. 402), as MacEachren terms them, are particularly suited to parsing "size and color value variation[s] at fixed locations" (p. 402) and viewing larger four-by-four matrices of controlled multivariate data points.

Similarly, Fabrikant et al. (2008) refer to several studies that analyze the effectiveness of animation and small multiples, particularly Slocum, et al. (2004) who found that

map animations and small multiples are best used for different tasks. The former are more useful for inspecting the overall trend in time-series data, the latter for comparisons of various stages at different time steps (p. 202).

Fabrikant, et al. argue for a concept of *inference affordance* in the measurement of effectiveness of visual displays. Inference affordance mingles assessments of diagrams' *informational equivalence* (that information from one illustration can be concluded from another

like illustration) and *computational equivalence* (that information from one illustration can “easily and quickly” be inferred as with another like illustration) as identified by Simon and Larkin (1987). When compared with animation displays, for example, Fabrikant et al. found that, contingent on the design and arrangement of the frames, small multiples are very effective in helping readers and viewers draw accurate inferences about the data they hold.

Interaction and user experience practitioners. Professionals working in interaction design (IxD), human-computer interaction (HCI), user experience (UX) design, and information architecture (IA) have routinely advocated for small multiples—under a variety of names and labels: “thumbnails,” “grid view,” among others—on websites and visualizations that visually taxonomize multiple products or multiple categories of like information.

Alongside several online interaction design pattern repositories (welie.com, developer.yahoo.com/ypatterns, ui-patterns.com, and others), Tidwell (2006, 2011) extols the virtues of small multiples as efficient organizational, display, and compositional devices for use in interactive (i.e., web- and app-based) applications. In Tidwell (2011), at least seven interaction design patterns—Picture Manager, Sequence Map, Grid of Equals, Thumbnail Grid, Carousel, Filmstrip, and Thumbnail-and-Text List—are, in actuality, simply expanded variations of small multiples. Tidwell recommends that the “grid of equals,” for example, be used when a

page contains many content items that have *similar style and importance*, such as news articles, blog posts, products, or subject areas....[this presents the] viewer with rich opportunities to *preview and select* these items. [italics added] (p. 149)

Additionally, Tidwell comments on the aesthetic appeal to small multiples, explaining that designers should “use a consistent, richly-styled template for all the items in a list....Grids look neat, ordered, and calming. That may suit the style of your site or app” (p. 149).



Figure 15. Example of “Grid of Equals” interaction design pattern. ©2011 Jenifer Tidwell.

Marginal (and/or unsound) references to small multiples. Other professions and areas of study also mention small multiples in their proposed visualization techniques but they typically do so either parenthetically or, as discussed earlier in the case of de la Beche’s renderings (Clary, 2003), inaccurately.

Business data. To his credit, Brath (1999) dedicates a fair amount of time in suggesting small multiples as a visualization strategy in displaying business (financial and economic) data, including a handful of Tufte’s definitions of the device as guideline. Brath recommends that small multiples, “at least for simple generalized forms, have the capacity to rapidly convey existence or omission of a feature” (p. 113) (a strategy also raised in this thesis). Brath, however, in making the case for effective business visualizations, reminds and explains not much more than that one should “use small multiples to visually convey multivariate data” (p. 152). Interestingly, the diagrams that Brath uses to demonstrate small multiples, while they do contain multivariate components, are very liberal interpretations of the device. Several diagrams have occluded or

unparsable data (compounded by complex z-index layering) and do not create favorable conditions for comparison, adjacency, or rhetorical juxtaposition.

Scientific data. Wimsatt (1990) posits that, because it is often more compelling to see examples than try to describe them, “data in science” (p. 111) would benefit greatly from targeted visualization efforts. He suggests a scaled taxonomy of five approaches—ranging from simple nonvisual examples to multiple dimensional views of phenomena (or “chaos”)—including an approach that visualizes “multidimensional heuristics of the visual system” (p. 113). Among other suggested “multidimensional heuristics,” representation devices such as Chernoff face matrices (Chernoff, 1973) and motion lines on stick figures (based on Marey, 1895) are small multiples. Wimsatt plainly describes these as “small graphs [that] are ordered in a row or rows according to the values of one or two additional parameters” (p. 115) and then displays one small multiples image (from Tufte, 1983, p. 42). (Interestingly, before moving to the next approach in his taxonomy, Wimsatt suggests that an alternative use of the images would be to animate them in a flipbook or multicell style. Animations and their cognitive impacts are discussed later in this chapter.)

Computer science and software development. Conway (2007) suggests the use of small multiples “in data or charts or other forms [as] promoted by folks like visualization guru Edward Tufte” (p. 1). Additionally, he references “data visualization guru” Stephen Few’s definition of small multiples as “a series of small graphs that can be used to make comparisons without resorting to 3-D graphs, which are difficult to read” (p. 1; cf. Brath, 1999). It is peculiar that, in every case in Conway’s paper, he demonstrates the result of his proposed programmatic small multiple solutions only as a series of five bar or line graphs, each with at least twelve variables, never deviating.

Military. A unique reference to small multiples is found in Russell (2002). In a display of multivariate data from a network designed to “analyz[e]...communication time delays (communications latencies) inherent to...simulated JDN [joint data network] message traffic” (p. 1) of a missile defense system, Russell suggests showing data using small multiples because, according to his reading of Tufte (1983), “graphics can be shrunk way down” (p. 1).

(It should be noted here that, although this is exactly what Tufte *says* (p. 169), this is not to what he is *referring*. Tufte uses this language to explain an axiom he entitles “The Shrink Principle.” He postulates that “many data graphics can be reduced in area to half their current published size with virtually no loss in legibility and information” (p. 169). However, at this point in his text, Tufte has not even discussed small multiples; he uses this “shrunk way down” language to explain how to maximize data density in a graphic, not to comment on the economy of small multiples.)

Russell’s proposal contains seven pages of time delay data arranged in eighty-percent sized box plot charts, but doesn’t give any indication to their relevance or relationship to each other. It might be surmised that the chart comparisons may already be contextualized for this audience, but the reader is left to wonder the reasoning behind citing small multiples as an efficacious display technique for the data.

Summary. This review of historical references illuminates three important observations: (1) while small multiples do have historical precedent (that is to say, their efficiencies are notably useful); (2) many contemporary references to small multiples largely tout their notion but not their function; and (3) consequently, there is a need to promote best practice applications of small multiples in pedagogical materials.

Graphics And Visuals In Instructional Situations

Certainly as a reaction to evolving learning styles of the past thirty years, both psychology and instructional message design literature support the competent use of illustrations in instructional materials.

Advance organizers. Ausubel (1960, 1963, 1978a, 1978b) and Mayer (1979) are responsible for much of the seminal writing on comparative and advance organizers. Lidwell, et al. (2003) efficiently describe Ausubel's notion of advance organizers as representations—or “chunks”—of information which enable learners to schematize new materials. These “chunks” can be written, spoken, signed, or illustrated and differ from simple abstracts or synopses of information in that they chronologically provide a very broad perception of a schema *before* details are given. Further, Ausubel identifies that advance organizers can be identified as *expository* (used when materials are novel for learners) and *comparative* (used when information is familiar or can be made relatable to learners' existing schema). Despite early outcry against this pedagogical approach, Ausubel deftly defended against critics of advance organizers in pedagogy, citing empirical studies that chronicle measurable increased mean learning scores and mean concept transfer scores with children (1978b).

Graphic organizers. An important subset of advance organizers are *graphic organizers*, “displays that make relationships more apparent between related facts and concepts” (Dexter, 2010, p. 82) and visual representations of Ausubel's expansive, detail-light ‘schema.’ Although more recently graphic organizers have become narrowly depicted by educators in the presentation and instruction literature as knowledge maps, concept maps, network trees, cycle diagrams, or Venn diagrams, graphic organizers are of much greater benefit to instructional and visual designers when they are more broadly recognized as “visual and graphic display[s] that depict the

relationships between facts, terms, and/or ideas within a learning task” (Hall & Strangman, 2002, p. 1). Graphic organizers are also shown to increase learner performance “across grade levels with diverse students, and in a broad range of content areas” (IARE, 2003, p. 2). Specifically, graphic organizers help learners with retention and schema and cognitive load management and have been shown to increase factual recall and higher-level inference skills in learning disabled students (Dexter, 2010).

Illustrations, graphics, and diagrams in instructional texts. Though cognition through textual means has been debated in greater detail than visual learning, there is a considerable body of writing regarding the inclusion of graphics in instructional texts. It is not the intent of this thesis to provide an entire literature review chronicling the amount and varieties and purposes (cf. Pettersson, 2007) of mentions of illustrations in instructional texts. However, over the past 30 years, research has been focused on the efficacy of graphics in pedagogy (Duchastel, 1980; Merrill & Bunderson, 1981; Mandl & Levin, 1989), their function (Duchastel & Waller, 1979; Parrish, 1999), their placement (Lyons, 2004), their genre (Schumacher, 2007; Mayer, 2009; Mayer, 2005), and their semantics (Waller, 1985; Winn, 1991). Additionally, there is growing evidence for the copresentation of text and illustrations in Waddill, McDaniel, & Einstein (1988), Bernard (1990), Reed & Beveridge (1990), and Glenberg & Langston (1992).

What makes a “good” illustration? Mayer (1990) recapitulates several criteria for “good” and “effective” illustrations in aiding retention and comprehension in scientific texts. Outside of text that requires qualitative reasoning, performance that measures qualitative reasoning, and learners that are inexperienced in the materials, illustrations must be explanative, and “help the learner build a runnable mental model of the system” (p. 716).

Identifying the function and purpose of illustrations. “Educational technologists rarely seem to venture into the world of the image....Rarely are illustrations in text ever considered as important instructional variables” (Duchastel, 1978, p. 37). Duchastel argues that visuals should be perceived by instructional designers in a *functional* (rather than decorative) framework: what function will an image or diagram perform in a pedagogical text? Visuals can fluidly and adroitly affect *attentional* purposes (how can instruction be made more aesthetically appealing?), *retentional* purposes (how can instruction be made less susceptible to cognitive decay?), and *explicative* purposes (how can instruction be made more parsable and multifunctional?) in instruction.

In fact, illustrations in instructional texts are not only desirable, in certain contexts, they're expected. Duchastel & Waller (1979) remind practitioners that, historically, the instructional message design literature has considered images and diagrams merely to (1) “enrich” instructional texts for decorative or “optional” purposes and (2) that, in subject matter that is considered more technical (sciences, technologies, et al.), imagery is expected but in “areas such as the humanities, education, and social sciences[, images] have basically a literary [non-visual] tradition” (p. 20). Duchastel & Waller counter that deciding whether to use an (or any) image solely based on aesthetic considerations is not “usefully considered in assessing the value of [an] illustration in text” (p. 21). The decision to include illustrations in instruction should be decided far less on its morphological merits, but on *functional* (or semantic and objective-based) grounds.

As discussed, Duchastel (1978) defines that imagery serves an attentional, retentional, and, most importantly, explicative purpose in instructional materials; Duchastel & Waller (1979) identified seven important explicative functions of illustrations, four of which—descriptive,

expressive (i.e., rhetorical), functional, and data-display—correlate with and support the proposed arguments in this thesis for the use of small multiples in instructional materials.

Lyons (2004), like Duchastel & Waller (1979) prompts instructional designers to revisit their instructional purposes as they consider graphics in their designs. Broadly speaking, if a designer's aims are towards immediate performance versus long-term memory capture, teaching procedures and processes, or principle-based tasks, choosing an appropriate graphic type is vital. Interestingly enough, in each of these three categories of objectives, Lyons encourages designers to incorporate “visual instructions...[which] depict the steps” (p. 19), “graphics that demonstrate the task in easily digestible chunks” (p. 20), or the “use [of] several examples” (p. 20), all objectives which are accomplished by the use of small multiples in an instructional design.

Winn (in Mandl & Levin, 1989), uses Reigeluth's (1983) ‘methods, outcomes, and conditions’ instructional design decision-making approach as a framework for instructional graphic choice; images, illustrations, and visuals should be specifically chosen to support instructional design objectives. Clearly, Winn reminds that, instructional designers must use or explicitly teach the graphic conventions they use (cf. “graphicacy,” [Balchin & Coleman, 1965]), but there are behavioral and statistical advantages to using a variety of graphic *methods* (comparisons, hierarchy creation, and grouping) that encourage learner *outcomes* (identification, classification, mental model creation, reduced cognitive load). Small multiples, by their definition and makeup, replicate these type of methods and can help accomplish designer outcomes.

Contemporary applications of instructional graphics. King-Gordon (2001) has written about the radical change in magazine and periodical visual design in the latter half of the 20th century, noting its rather dramatic change from longer-form prose-based page design to creative and visual interpretations of article content:

A visual society erupted with the onset of television, and, as new generations of readers came to expect the same three-dimensional eye candy fed to them by the new medium, magazines responded in kind. (p. 9)

In response, a new contemporary media and generational content consumption model has induced learners to (re)process information in smaller sizes and more concise chunks (Lupton & Miller, 1999) and attend to reduced information in a Gestaltian composition of “bite-size, non-linear nuggets surrounded by pictures” (Cart, 2002, p. 399). News and information digestion has been re-pioneered in the television space (and now, even more recently, in the Internet space). Fully reported (i.e., textual- or oral-based) stories have nearly completely given way to a competitive culture of soundbites and all-day broadcast newscycles.

Design case: USA Today. Lupton & Miller (1996) and Leslie (2003) note the causal relationship between television-based information and printed media, observing that

the authoritative condensed speech of the TV anchor begot the style of *USA Today*. A ring of authority comes from minimizing details and eradicating qualifying or parenthetical statements. (Lupton & Miller, 1996, p. 144)

Television news reporting began adding “colorful graphics and photography [to the] news presentation” (Leslie, 2003, p. 23); *USA Today* and other news periodicals reciprocated to this shift by “ritually purg[ing stories] of detail and intimacy, [and rendering] information graphics...with gratuitous color and illusionistic tonal gradations” (Lupton & Miller, 1996, p. 148). Graphic designers have rejoined (or have been forced to rejoin by consumers and editors) these changes by creating ‘visual soundbites,’ or visual design that consolidates schemas into clever infographics popularized by designers like Nigel Holmes, and lamented by infopurists like Tufte.

Design case: The rise of children’s pedagogy as literature. Likewise, *Children’s Software Revue* (CSR) (1997) and Gillieson (2001) observe that a major content and visual shift has

occurred in children's literature over the past forty years. Book titles by Britain's Dorling Kindersley and Usborne imprints, and France's Gallimard Jeunesse publishers, among others, parlayed technological (personal computer as design and compositional engineer) and educational (increasingly more stringent curriculum standards) advents into popular "non-fiction books on science, not to be confused with textbooks" (Gillieson, 2001, p. 27). Peter Kindersley, art director-turned-publisher, explains that the development of this new genre of literature came about through the exploration of a "missing link" (CSR, 1997, p. 1) between text and image:

One of the problems with words is they're incredibly slow, while pictures are incredibly fast. When you put them together, they work in completely different ways. We needed to find ways in which we could slow down the pictures and speed up the text. (CSR, 1997)

With this unwitting (yet market-driven) recognition of dual coding behavior (Paivio, 1986), publishers like Kindersley and other instructional designers created a new genre of children's literature where the traditional children's book experience (Figure 16) gave way to a responsive approach, "entirely unlike reading the continuous, linear text of a novel...; the vigorous patchwork of a highly illustrated layout suggests a particular type of interaction from the reader" (Gillieson, 2001, p. 32; cf. Figure 17). Kindersley claims that children now have a "democratic learning style," to

experience information from their own particular point of view. So you, as a learner, have a choice...you can either start with the text and work toward the picture, or you can start with the picture and work into the text (CSR, 1997).

Among the visual and instructional design approaches that children's publishers like Dorling Kindersley employ in producing these neo-children's pedagogical materials (Figure 17) are layered, "patchwork," *USA Today*-like layouts which include small multiples.

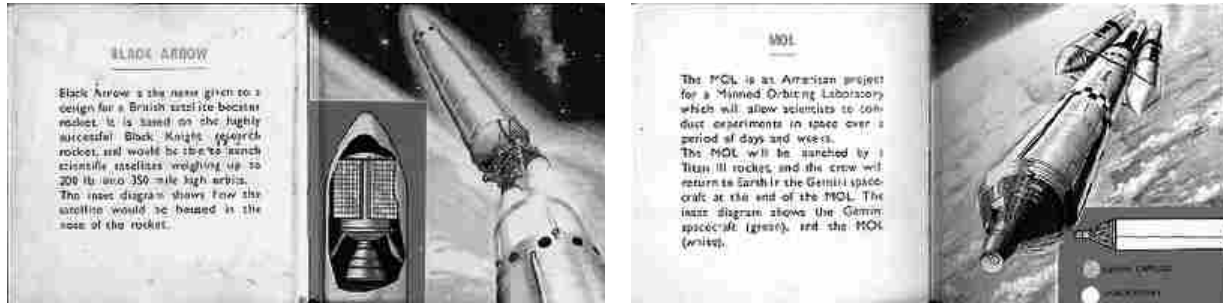


Figure 16. “Black Arrow” and “Mol” from Rockets and Spacecraft, Book One and Two (1966). ©1966 Collins.

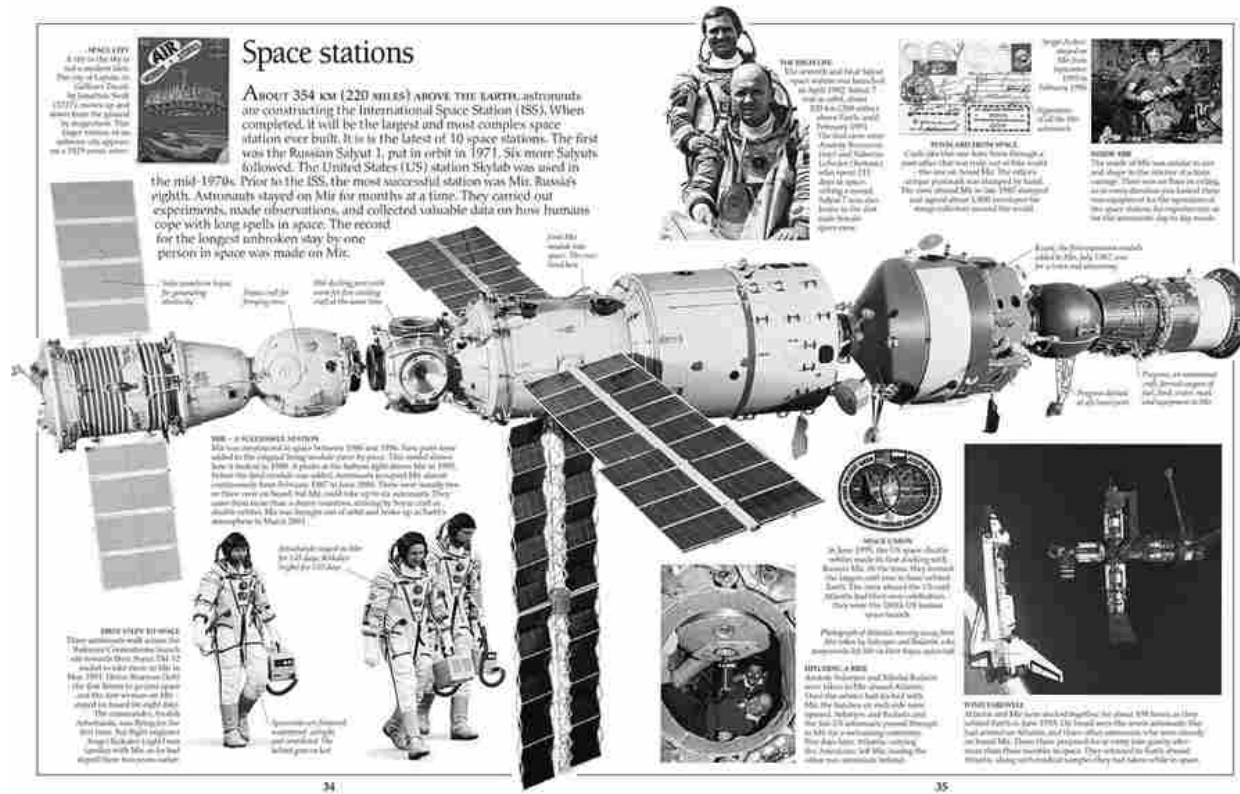


Figure 17. “Space Station” layout in Space Exploration (Eyewitness Series). ©2010 Dorling Kindersley.

Summary. Despite the earlier findings of instructional scientists like Ausubel and Mayer, graphics and imagery, although represented, have historically been minimized in pedagogical materials. Similarly, though instructional-specific texts have used illustrations as decoration, they also have been perceived as having more of a pedagogical and conceptual value than their cousins in general teaching materials. As information has become more institutionalized in the 21st century, contemporary instructional materials have adapted to this change and are more evident now in traditional learning arenas such as current news and children's publications.

Small Multiples And Their Impact On Cognition

As explained previously, illustrations and images in instructional texts do not merely decorate but promote cognition. As an increasing tide of information continues to press, learners will be confronted with greater competing demands on their cognitive load (Sweller, 2006; van Merriënboer, Kirschner, & Kester, 2003; van Merriënboer & Sweller, 2005; Mayer & Moreno, 2003; Paas, Renkl, & Sweller, 2003). Consequently, instructional designers are faced with needing to understand how to construct their designs to both minimize pedagogical demand and maximize communicative efficiency. Understanding how small multiples impact learner cognitive load, dual coding processing ability, and overall cognition assists designers in choosing advantageous supporting visual materials in their designs.

Cognitive load theory and learning. Cognitive load theory is concerned with identifying the amount of control over information structures that are presented in a learner's working (née "short-term"; cf. Miller, 1956) memory (van Merriënboer & Sweller, 2005). Developed and expanded in the 1980s, cognitive load theory informs the practice of instructional designers by helping to manage—and, where possible, minimize—the amount of cognitive noise or distractions (cognitive load) in learning situations.

Cognitive load has further been taxonomized into types based on their inherency to the learning event:

- *intrinsic* cognitive load refers to memory load that is, because of the event, ‘built-in’ or has an already inherent complexity in the event
- *germane* (or relevant) *cognitive load* is purposeful mental work added to the learning event by instructional goals, designers, or instructors; “load imposed by instructional methods that lead to a better learning outcome” (Clark, Nguyen, & Sweller, 2006)
- *extraneous* (or irrelevant) *cognitive load* refers to mental load or distraction that is not natural to the event and is typically caused by additions by a content developer, producer, or instructor

This combination of intrinsic, germane, and extraneous cognitive load is a relative equation based on the learning event, however, *element interactivity* (how much or how many concepts are being processed and cross-processed) also affects these proportions in theoretically setting a finite limit of cognitive load in a learning system. This is not to say that cognitive tasks have quantifiable measurements attached to them, i.e., brushing one’s teeth does not rank a ‘19’ while learning Chinese ranks a ‘320’ (although Paas & van Merriënboer [1993] did attempt to create an index of cognitive load). It does reinforce, however, that the amount of intrinsic, germane, and extraneous cognitive load (and resulting element interactivity) are abstractly but proportionally related in a given task.

Additionally, a learner’s amount of knowledge in a given task or schema also impacts the amount of cognitive load in a learning environment. The amount of cognitive load in an HTML programming task might be very high for an eight-year-old but very low for a seasoned Web developer. Consequently, instructional designers are interested in the relationship between the

inherency of a task's particular load: if a learning event's intrinsic cognitive load is low, how much extraneous cognitive load can feasibly be added and still keep the task within a learner's working memory load? Conversely, if a task's intrinsic cognitive load requirements are high, what amount of extraneous cognitive load must be reevaluated and/or reduced to keep the event within a learner's acceptable level of mental work?

Visual instructional effects that reduce extraneous cognitive load. Sweller (2002) and Sweller, van Merriënboer, & Pass (1998) correlate instructional and visual design decisions with increased cognition and decreased working memory load. Sweller (2002) gives important context to how visual design considerations impact and help learners manage cognitive load. The skillful and appropriate integration of visuals (and indeed, small multiples) are likely to help leverage intrinsic and germane loads while also reducing extraneous load. Sweller identified five different effects that visualizations may have on the cognitive load of an instructional design:

- *The split-attention effect.* Cognitive attention is required to both interpreting a visual as well as searching for and creating schema for information associated with the visual. Memory load “can be reduced by physically integrating diagrams and statements” (p. 1504). In praxis, this effect is found in *worked examples* (step-by-step displays which show how one performs a task [Clark, Nguyen, & Sweller, 2006, p. 190]); Chandler & Sweller (1992) suggest that the purposeful composition of worked examples—integrating text and image in single or multiple frames—also helps reduce extraneous cognitive load. (Small multiples may be effective as solely images, solely text images, or a combination of both, provided there is good contiguity.)
- *The modality effect.* Research has shown that working memory ability may be extended by presenting information in two modes, e.g., pairing chunks of instruction (that are related

to each other) in both a visual modality (visuo-spatial) and an auditory modality (spoken text or music) (p. 1506). (Small multiples may be effective in learning events like kiosks, which provide an on-screen visual experience coupled with a spoken narrative track.)

- *The redundancy effect.* Neither the split-attention nor the modality effects are present “if the diagram is fully intelligible and fully provides the information needed” (p. 1506). In this situation, if either text or image are self-explanatory, then the other is unnecessary and its removal may enhance learning. Redundancy may be manifest as mental versus physical activity (learning how to perform a task by both reading and doing), summary versus detail (learning a task both by synopsis and full background), and auditory versus visual (learning a task by both hearing and seeing the information) (p. 1506). (Because small multiples have tacit abilities such as demonstrating ordinal and narrative relationships and steps in a task, redundancy may be eliminated by their usage.)
- *The element interactivity effect.* As explained previously, this effect occurs because of the number or amount of structures that require processing. If, to the learner, a task presents a low mental load, this effect may not be present (p. 1507). (Small multiples typically contain singular elements, thus reducing the amount of needed interactivity.)
- *The imagination effect.* “To attain relatively high levels of expertise, further learning will need to include automation of the previously acquired schemas” (p. 1507). One way to accomplish this automation is to perform the task repeatedly; another method to automatizing skills is to mentally recreate or imagine performing the task. A previous study by Cooper, Tindall-Ford, Chandler, & Sweller (2001) found that learners who visualized a set of tasks performed better than those who were merely given a set of

instructions. Visuals (such as small multiples) can provide learners with better context to perform more effectively (p. 1507).

Mayer & Moreno (2003) suggest that when “one or both channels [are] overloaded by essential and incidental processing (attributable to confusing presentation of essential material)” (p. 46), because readers tend to read text and then scan its associated image (Hegarty & Just, 1989), images and text should be composed more contiguously (the “spatial contiguity effect” [p. 46]), in some cases, even moving the text inside the bounds of the image, if appropriate (p. 49).

As Duchastel (1978) has mentioned, illustrations in instruction serve a *retentional* purpose, and more specific to this segment of the literature review, illustrations help learning stay both relevant and ordered in both working and archival memory. Gagné (1985) posits that the graphical representation of information or schema functions as a “pointer” (Parrish, 1999). Pointers act as a type of mnemonic device or proxy for several related concepts so that all of the concepts do not have to be held in working memory. An image of an apple, for example, may represent exactly what it purports to be, but in additional contexts (and even in a larger abstracted small multiples composition), an image of an apple may represent a larger genus of ‘fruit’ (bananas, grapes, et al.).



Figure 18. How *pointers* (Gagné, 1985) are created by purposeful representation of schema. Apple, ©giniger via Creative Commons BY-NC-SA 2.0.

On the left, a singular image of an apple, without comparison or shared context, stands simply as ‘apple.’ In the second grouping, the images represent individual and discrete elements (‘apple,’ ‘broccoli,’ and ‘cheese’), although shared context and proximity may imply that these images might be functioning as “pointers” (Gagné, 1985) in representing larger collective noun groups. Finally, on the right, and combined with added textual context, the three images assume the additional representational responsibilities of acting as pointers for food groupings (fruit, vegetables, and dairy).

Another example of how visuals (and small multiples) can act as pointers and offload mental work is found in the diagrammatic representations of Bede’s dactyological system in Figures 1, 2, and 3. Bede’s original textual descriptions require a much higher intrinsic cognitive load because the reader is both required to comprehend the written description as well as reinterpret the text in a physiological manner without fully understanding if his or her rendering is accurate. The recreation of the series as visuals minimizes much of the intrinsic load (comprehension and articulation guesswork) and adds germane load (re-rendering as immediately parsable visuals in a small multiple composition to add tacit rhetorical differences between handshapes) to create a more effective learning event.

Small multiples and dual coding theory learning. Two other areas of cognitive load research are particularly relevant to a discussion of small multiples: dual coding theory and the Contiguity Effect.

Dual coding theory. Dual coding theory, also theorized by Paivio (1971, 1986; and expanded upon by others [Mayer & Sims, 1994; Mayer, 1994]) suggests distinct ecologies for processing verbal and auditory input and processing pictorial and visual input. Additionally, these systems are separate and limited as to how much information a learner can take in and

singularly process; this question of capacity is at the root of efforts surrounding managing cognitive load and working memory in instructional designs (Mayer & Moreno, 2003). While agreeing with the basic definition of dual coding, Mayer (1994) found that learners not only need “referential connections” (p. 135) to information in each channel, but to increase task performance, learners also needed these referential connections between the information in the visual and verbal channels.

Small multiples and the Contiguity Effect. Small multiples are often found as multimodal compositions, which comprise images accompanied by verbal (textual) instructions in close proximity (cf. Figures 19 and 20). Mayer & Sims (1994) found that these integrated verbo-visual configurations lead to more efficient problem-solving transfer for higher-spatial learners. They also identified that *performance* (“learner’s response to tests of retention and transfer” [p. 390]) is dependent on the learner’s ability to create *visual* (comprehension of image), *verbal* (comprehension of text), and *referential* (comprehension of the congruency of the two) connections. Although information is presented in two distinct modes, through a cognitive phenomenon called the Contiguity Effect,

inexperienced students were better able to transfer what they had learned about a scientific system when visual and verbal explanations were presented concurrently [...].increas[ing] the likelihood that [they are] able to build connections between...visually and verbally presented explanations. (p. 399)

“Examples in view” and learning by making comparisons. Advanced cognition can be helped along by leveraging multiple means of composition, however. Winn (1993b) posits that conceptual complexity can be illustrated through “use of multiple representations of that concept” (p. 245). Multiple analogies and/or multiple models allow learners to process concepts in layers; interconnecting these multiple representations (via direct and indirect connections) are



Figure 19. Instructions for eight brocades Qi Gong form exercise.

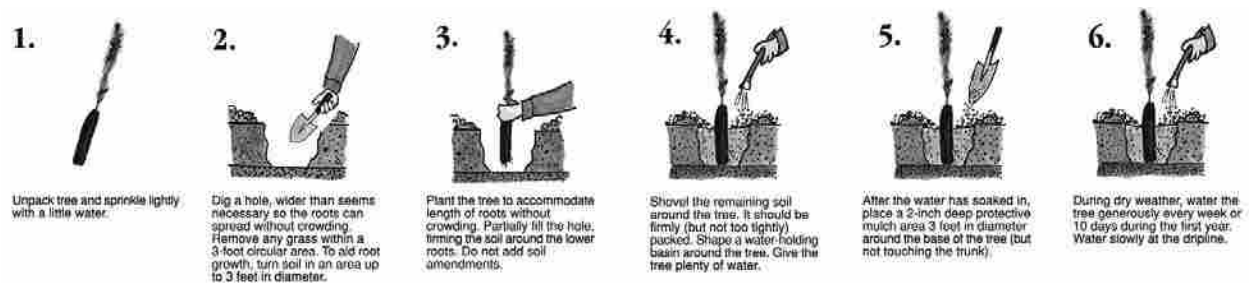


Figure 20. Gift tree planting instructions. ©2011 Arbor Day Foundation.

necessary to close the instructional loop. In a direct nod to reducing cognitive load, Winn suggests that instructional designers should “leav[e] examples in view,” (p. 245) as opposed to presenting novel examples acontextually, which forces learners to remember “all previous

examples for comparison with each new one” (p. 245). Small multiples tacitly present learners with several related and multiple examples.

Summary. Although there is greater overall access to technology and tools in the creation of instructional materials, often the undisciplined application of these aids can result in increased cognitive load in these materials. If managing cognitive load is an obstacle to providing more efficacious instructional design, then illustrations may serve as the antidote. Duchastel (1979) has pointed out that illustrations aid in the retention of materials; Gagné (1985) has shown that images are conceptually responsible for a greater amount of information than what is perceived on the surface. Small multiples can reduce extraneous (and germane) cognitive load by being applied to work *with*—rather than serially or against—the other components in a design.

Gestaltian Theory As Small Multiples Architecture

Small multiples uniquely capitalize on Gestaltian artistic principles (Wertheimer, 1923; Moore & Fitz, 1993) to create more meaning in their sum than among its individual parts. Indeed, as explained above, an understanding of how similar yet multivariate components create local and meta meaning is vital in creating guidelines for their production.

Schemas: building blocks of information. Lawson (2004) chronicles the usage of *schema* by Bartlett (1932), a Gestaltian psychologist, who (though reluctantly) redefined and developed the concept as an internalized reactive mental image:

For this combined standard, against which all subsequent changes of posture are measured before they enter consciousness, we propose the word ‘schema.’ By means of perpetual alterations in position we are always building up a postural model of ourselves which constantly changes. Every new posture of movement is recorded on this plastic schema....(199) ‘Schema’ refers to an active organisation of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response. (201)

Making order of schemas. Wurman (1990, 1997) and Shedroff (1994) outlined taxonomies of how to saliently classify and arrange schema, or constructs. Wurman champions neatly categorizing information by use of the acronym LATCH: arrangement by location, alphabet, time, category, and/or hierarchy. To wit, *commuter* train schedules are best arranged by *location* (Portland, Salem, and Eugene) and *time* (12:45 pm, 3:20 pm, and 4:15 pm), but not necessarily by *hierarchy* (passenger, freight, or non-ticketed railcars). (This is, of course, if the intention of the information is for passenger travel; if the information were to intended to communicate the movement or quantity of railcar types, grouping by location and time would be less effective methods.)

Shedroff decided that seven categories was more effective; while keeping location, alphabet, time, and category, he added ‘continuums,’ ‘numbers,’ and ‘randomness’ to his taxonomy. Irrespective of a designer’s architectural preferences, Wurman’s and Shedroff’s solutions are well-suited to grander, meatier schema organization; are these principles applicable on a more local scale and with more local finite graphical units?

Principles of Gestalt. Gestaltian—or ‘whole form’—psychology of the early 20th century, besides its study of philosophy and epistemology, also branched into how one’s worldview is perceived and, by extension, defined by the grouping of visual objects in one’s environment (schemas). Gestalt principles, then, applied to the visual, identify and define how objects are grouped and therefore interact with one another. An important subset of Gestaltian compositional principles are called *prägnanz*, or means that define the properties of object interactivity; *prägnanz* comprises six axioms (Figure 21).

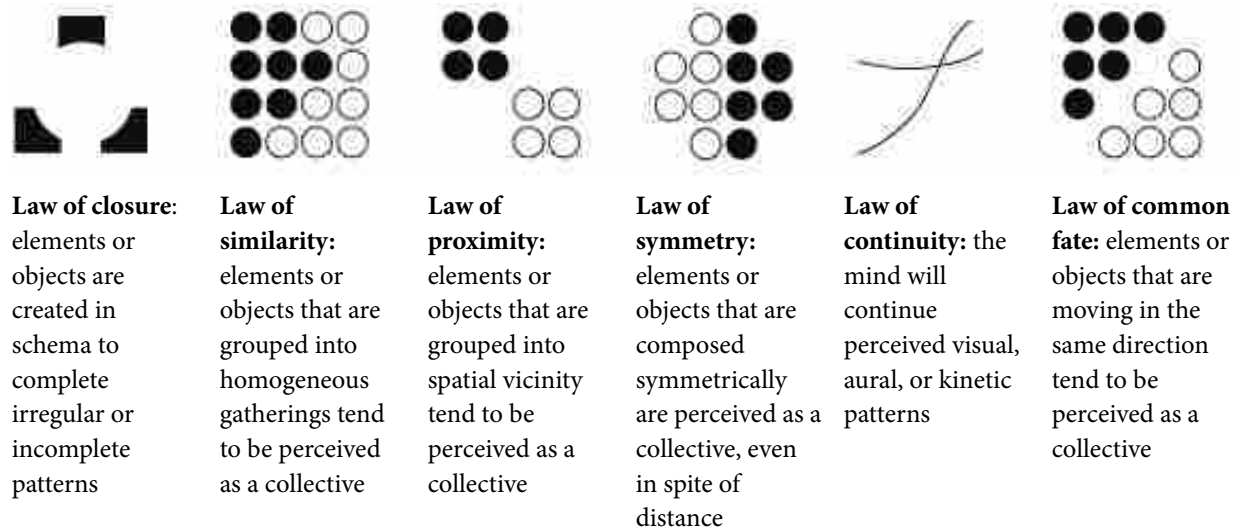


Figure 21. The six axioms of Gestaltian compositional principles, or *prägnanz*.

Small multiples heavily—and implicitly—capitalize on the laws of similarity and proximity, allowing a viewer or learner to understand that while a *single* graphic object may qualify a certain measurable schema, the combination of the schema, rhetorical relationships, and perceived aesthetic of *multiple* objects is far more efficacious to the instructional designer. Tacit to the makeup of small multiples is their efficiency in the laws of similarity and proximity.

Similarity of graphical units. Moore & Fitz (1993) remind that the Gestaltian law of similarity explains that viewers will see objects that are similar (“style, location, size, orientation, color, and so on” [p. 149]) as having a rhetorical connection; conversely, objects that do not share similarity will be perceived separately. Moore & Fitz point out that typography is also perceived in this way as well (p. 149; cf. Waller, 1985). Wong (1993) defines fundamental perceptions of similarity of graphical and visual concepts, or unit forms. Similarity is most salient when it refers to shapes; “forms can hardly be regarded as similar if they are similar in size, color, and texture, but different in shape” (p. 69). Small multiples capitalize on shape differences to explicate

narratives and steps in a process; purposeful proximity and composition multiply the value of tacit comparisons to make them effective instructional tools:

Sometimes similarity can be recognized when the forms all belong to a common classification. They are related to one another not so much visually as perhaps psychologically. (p. 69)

Similarity is achieved in shapes that have association, variant imperfection, spatial distortion, union/subtraction, and tension/compression (pp. 70–71).

Wong hypothesizes that visual elements, when composed, generate a *similarity structure* (which, admittedly, lack a certain empirical rigidity and regularity). Similarity structures may consist of *subdivisions* which create a greater structure (or, what Winn [1993a] calls *macroconfigurations*), or, more relevant to small multiples, create a *visual distribution*:

Unit forms are positioned within the frame of reference of the design, visually, without the guidance of structural lines. Visual distribution in this case should allow each unit form to occupy a similar amount of space as judged by the eye. (p. 71)

Repetition of graphical units. When similar unit forms are used plurally, the compositional effect is repetition. Where similarity defines ‘small,’ repetition defines ‘multiples’; globally, repeated unit forms produce patterns while locally, they may generate something of a narrative or rhythm of a design.

Repetition is achieved in unit form shape, size, color, texture and direction, and, importantly, in position and space (p. 51). Unit forms can also be repetitively composed in linear, rectangular, rhombic, triangular, and circular (arcic or complete) manners. Applying this principle to small multiples, while multiple unit forms which are arranged in non-linear compositions might demonstrate similarity, such a presentation does not effectively illustrate

steps, process/progress, trace, or narrative, and likely complicates any intended rhetorical relationships.

Precedent for Gestalt in instructional designs. Moore & Fitz (1993) point out that little research has been conducted evaluating the application of specific Gestalt principles in the visual layer of instruction design. Guiding principles of Gestalt composition have historically lacked in the visual component of instructional design, but, suggest the authors, “might be very informative, and...would go a long way towards presenting a few easily understood strategies for improving the visual design of instructions” (p. 138).

Macroconfigurations. Winn (1993a) outlines very salient principles which define the Gestaltian view that macroconfigurations of multiple instructional objects (in this case, “meaningful visual units” [p. 61]) are treated by learners as single perceptual units in a phenomena called *emergent property*.

The idea of “emergent property” (Rock, 1986) comes very close to the Gestalt psychologists’ principle of “Prägnanz” (Wertheimer, 1938), or parsimony, in perceptual organization....If tokens can therefore be configured to form a single perceptual unit, perceptual processes will tend to “see” the unit rather than its parts. (p. 61)

A macroconfiguration consists of several meaningful visual units. In analyzing the five-day forecast graphic (Figure 5), for example, a configuration might contain of

- a minor typographical element (the day)
- a semiotic illustrative or *pointer* (Gagné, 1985) element (a sun or clouds or lightning)
- a major typographic pairing element (high and low temperature predictions)
- grounding graphical elements (background colors, a bounding box, and other additional law of closure tactics)

Further, Winn stipulates that emergent property is heavily influenced by the proximity and common fate (additional Gestaltian propositions) of the visual units. Small multiples, inherently defined by their linear proximity, can be perceived by learners both individually *and* holistically. Because of the composition and configuration of the five groupings in the forecast graphic, not only is the viewer made aware of the potentially novel conditions of each day, but the viewer also perceives a tacit narrative: “this week, the weather will be sunny, then stormy.”

So what do learners see first: “the details and then synthesize them...; or does the perceiver see the ‘big picture’ first, analyzing it into its component parts?” (p. 63) Winn (and Navon, 1977) explains that viewers tend to create salience globally to locally. However—and this is important for instructional designers—depending on how learners approach these macroconfigurations of imagery, they will first access their perceived median of detail and then process cyclically, either working outwards toward less-salient information or working inward towards “finer and finer detail” (p. 64). Importantly for the inclusion of small multiples in instructional designs, then, (1) linear compositions (but not diagonal) and (2) “the size of images relative to the visual field” (p. 64) are variables that visual designers can manipulate to increase the chances that a learner will start at the instructional designer’s intended median of detail.

Frameworks of visual organization. Instructional designers should understand frameworks which define how macroconfigurations might be organized or classified.

Rhetorical compositions. In their work on formulating a model of document layout genre, Delin, Bateman, & Allen (2002) juxtapose what a document’s (i.e., instructional) form should look and/or behave like with the types of discursual forms it contains, because, plainly, “they are intended to do different things” (p. 55). Delin, et al. propose a framework of five longitudinal levels of description and three latitudinal usage constraints (canvas, production, and

consumption constraints); resultant types of document genre may be identified based on how the design incorporates and leverages data in these areas. Viewing small multiples in this theoretical framework provides information about how and why they may be a very efficient modality in communicating certain document semantics (e.g. instruction, explanations, storytelling, data visualization, infography, etc.). Delin, et al.'s framework asks designers to consider:

- *content structure* (structure of the information to be communicated)
- *rhetorical structure* (rhetorical relationships between content elements; how the content is argued)
- *layout structure* (appearance, and position of communicative elements on the page)
- *navigational structure* (ways in which the intended modes(s) of consumption of the document is/are supported)
- *linguistic structure* (structure of the language used to realize the layout elements) (p. 36)

This framework provides a helpful template, then, for instructional designers to make efficient use of small multiples in satisfying learning objectives.

Visual linguistic compositions. Another valuable framework for understanding the value of Gestaltian macroconfigurations (Winn) and subdivisions (Wong) is Engelhardt's (2002) schema of visual linguistic composition (and decomposition) of graphic elements and graphic syntax (Figure 22). Graphic compositions and schemas can be linguistically decomposed into syntactic units (e.g., phonological, morphological, lexical) called *elementary graphic objects*, and, if made grammatical, can be interpreted and de/reconstructed to help designers, then, to produce more semantically accurate representations.

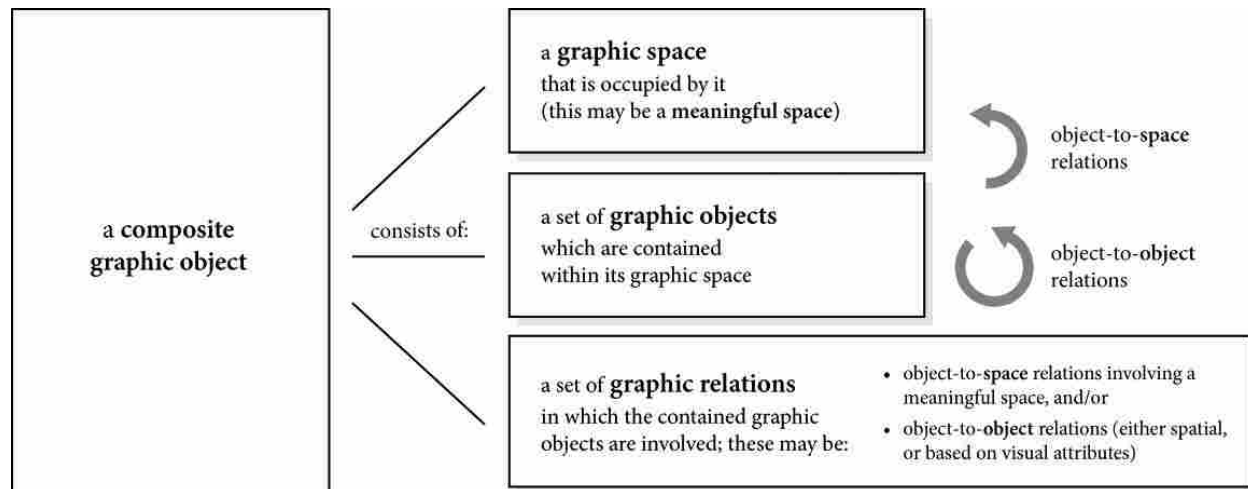


Figure 22. The syntactic decomposition of graphic compositions. ©2002 Yuri Engelhardt. Redrawn from original.

As has been shown previously, and is highlighted here again by Engelhardt, the execution and rhetorical relationships of a 'composite graphic object' (cf. small multiples) is just as worthy (if not more so) of consideration as the raw content of the object. Several elementary and composition graphical objects are defined and grammaticized in this work, including symbols, link diagrams, and grouping diagrams, all which share morphologies with small multiples. However, of additional interest in Engelhardt, graphic objects have salience in both three-dimensional/heterogeneous-plane spaces and two-dimensional/homogeneous-plane spaces. This consideration is important in analyzing when and how small multiples can be rendered in three-dimensional spaces.

Saliency in small multiples compositions. Machin (2007) argues that calculated and purposeful spatial compositions result in salience, information value, and framing (p. 130). Visual elements are made competitive by altering their size, color, foregrounding, overlap, repetition, and linear relationships. The body of anthropological research is broad regarding the

symbolism and importance of left-to-right relationships (Copeman, 1919; Hertz, 1960; Needham, 1973; Halliday, 1985; van Leeuwen, 2005); to a large constituency of 21st century learners, however, timelines, given-and-new structures, cause-and-effect relationships, processes, and ordinal relationships are all based in left-to-right schemas. Conversely, top-to-bottom, while also communicating cause-and-effect-like structures, communicate power structures and juxtapose idealism against realism (p. 145).

Synoptic versus discrete image compositions. Twyman (1985) defines compositional types as *synoptic* (a variety of separate, unrelated elements composed in a singular representation) or *composed of discrete elements* (much like a Muybridge layout, consisting of multiple diverse images). Twyman reminds that a discrete element composition, like the *Time* magazine layout in Figure 23, might require the “interpretation of different styles and conventions of representation” (p. 270), making it challenging for a learner to process not only the elements but also the relationships between the elements. Creating more homogeneity and minimizing the differences in representation, then, should reduce parsing difficulties and load; this is, by definition, the economy of small multiples.

Its potential complexity aside, Twyman recommends compositions of discrete images to learners and instructional designers because of their tacit effectiveness:

After all, a synoptic image cannot reveal those parts of the world it depicts that have to be seen from other viewpoints. When making a choice within this dimension of pictorial language, much will clearly depend on purpose, information content, users, and circumstances of use. (p. 271)

Unique saliency: multi-panel series and triptych compositions. Practically speaking, *triptychs*—panels or segments consisting of (at least) three representations—leverage the benefits

of serial schemas and effectively demonstrate sequences, processes, and narrative; to wit, the comic strip (Figure 24) or multipanel instructions (Figure 25).

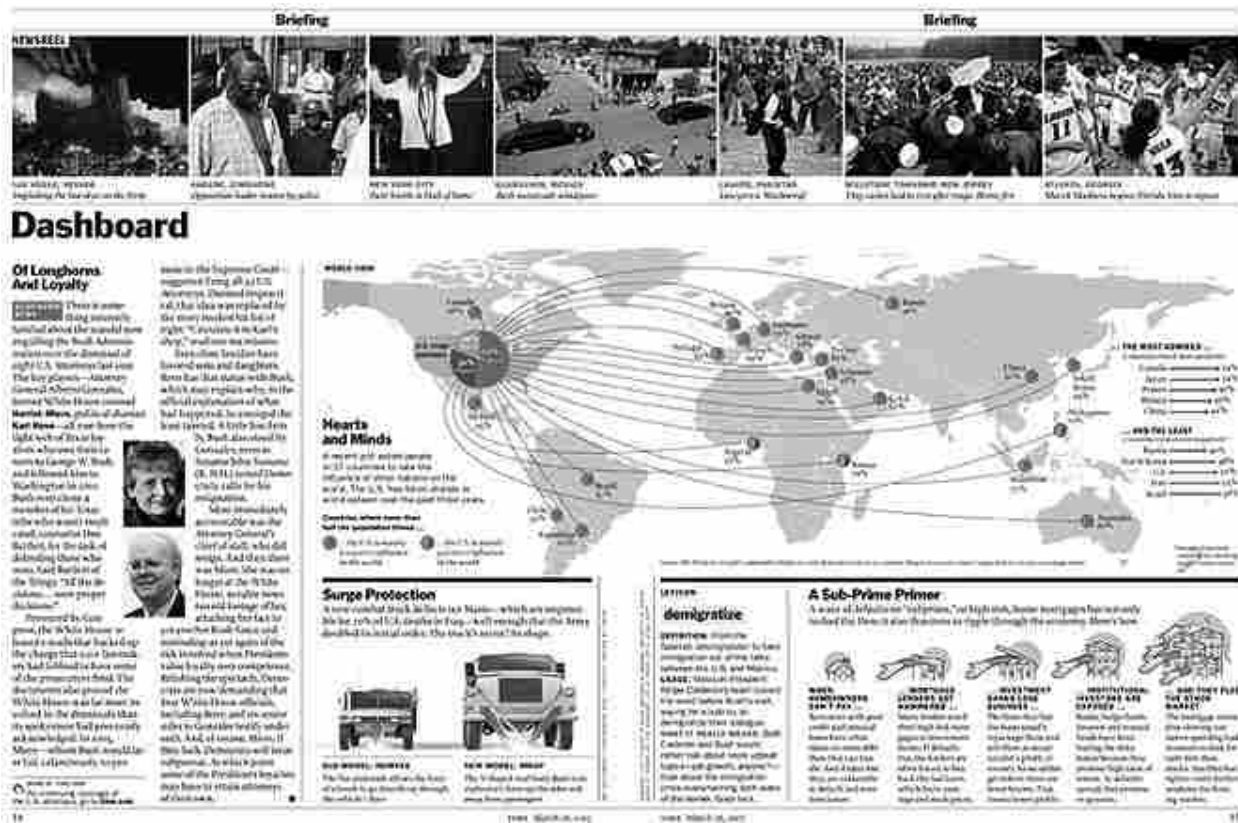


Figure 23. Editorial layout from Time, “Briefing: Dashboard” (March 18, 2007). ©2007 Pentagram.



Figure 24. Peanuts comic strip (Original publish date April 6, 1963). ©1963 Go Comics/Universal Click/Charles Schulz.

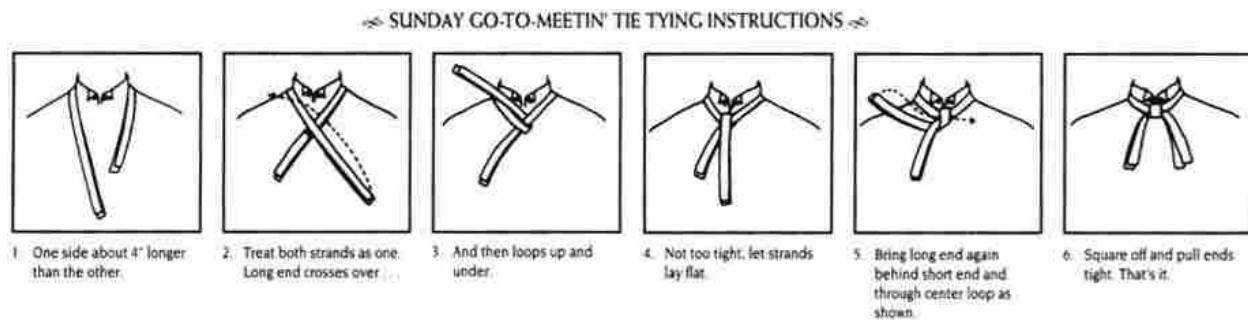


Figure 25. Sunday Go-to-meetin' tie tying instructions. ©2011 Cattle Kate.

A modified triptych composition can be a highly salient instructional tool, however:

In centre and margin compositions, as in the triptych, it is the central element that gives the meaning to the other elements around it. This gives them their meaning and coherence. But...rather than three vertical or horizontal sections there is a central feature that can be surrounded. This can be found, for example, in a schoolbook where an animal is placed in the centre of the page, [and] images of its habitat, things it eats, its offspring, etc. [are] placed around it. The central element gives meaning and coherence to those in the margin (Machin, 2007, pp. 147–148).

An example of this unorthodox triptych composition is shown in the page layout “Inside the Numbers: Healthy Living” (Figure 26). This layout not only highlights Delin, Bateman & Allen’s (2002) concept of document layout genre but it also effectively demonstrates how surrounding *images* (couple riding tandem bicycle, swimmer, pie chart, and series of exercise types) and *typography* (“#1,” “Top 10 Exercises for Kids,” “How Many Calories Do You Burn While;” etc. and various captions; cf. Waller, 1982, 1985 below) are given additional saliency by the contiguous presence of a central element, in this case, the woman demonstrating an exercise technique.

Creating salient compositions and affordances with small multiples. Interaction and user experience designers maintain that not only is the content of imagery important to the conversion of a site’s goals (historically the graphic and visual designer’s domain), but also the

Inside the Numbers

Healthy Living As Latter-day Saints, we are promised great blessings if we abide by the Word of Wisdom. And, though members of the Church do live healthier lifestyles than many, the ability to "run and not be weary, and...walk and not faint" doesn't always come easily. Like with any blessing, the real joy comes with real effort.

► Results of a 2002 U.S. study of the percent of adults (18 and over) who engaged in regular leisure time physical activity.

▼ **Top 10 Exercises for Kids**
Soccer, playing tag, running, swimming, hopscotch, jump-rope, biking, rollerblading, walking the dog, and even yoga.

#1
In 2000, *Self* magazine ranked Provo/Orem, Utah as the No. 1 healthiest city in the country for women. The article claimed the "Mormon influence" was the reason for low rates of cancer, smoking, drinking, violence, and depression among women. (Provo/Orem "dropped" to #2 in the 2003 study, behind Lake Champlain, Vermont.)

► **Top 10 Healthiest U.S. States**

1. New Hampshire	6. Utah
2. Vermont	7. Nebraska
3. Hawaii	8. Massachusetts
4. Iowa	9. Maine
5. Minnesota	10. Connecticut

2004 STUDY BY MORIGAN QUINT CITY RANKING SERVICE, BASED ON 21 HEALTH FACTORS, INCLUDING MORTALITY, DISEASE, AND SUBSTANCE ABUSE.

► **BYU leads the nation...again**
The 2005 rankings of *The Princeton Review's* "The Best 357 Colleges" are in: Brigham Young University is the No. 1 "Stone-Cold Sober School," No. 1 in "Scotch And Soda, Hold the Scotch," No. 1 in "Got Milk? (not a beer, on the party scene)" and No. 12 in "Everyone Plays Intramural Sports." These top rankings serve as evidence that the Saints are holding to healthy principles, in line with the Word of Wisdom.

▼ According to the U.S. Center for Disease Control (2001), the median life expectancy of **77.2** years (and individual rates for men and women) are at their highest levels ever.

♂ 74.4 yrs ♀ 79.8 yrs

85-88 yrs

▲ A 1997 UCLA study tracked the mortality rates and health practices of nearly 10,000 LDS California males and found that Latter-day Saints enjoy a life expectancy **8 to 11** years longer than that of the general white population of the U.S.

#1
The National Institute of Mental Health ranked Utah No. 1 for lowest per-capita alcohol consumption.

HOW MANY CALORIES* DO YOU BURN WHILE:

45 Sleeping	72 Watching television	150 Vacuuming or mopping	216 Playing with kids	240 Golfing	360 Doing yoga	405 Playing half-court basketball	441 Biking (no hills)	549 Playing tennis	740 Skiing
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*APPROXIMATE CALORIES PER HOUR; NUMBERS ESTIMATED FOR A 150 LB. PERSON

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Figure 26. Inside the Numbers: Healthy Living. ©2005 LDS Living/Doug Stringham.

composition of imagery in these presentations. Nielsen's (2010) usability study, analyzing a photo-as-content strategy, found that learners "pay attention to *information-carrying* images that show content that's relevant to the task at hand. And users ignore purely decorative images that don't add real content" [italics added] (Nielsen, 2010). Nielsen's study compares eyetracking samples of users' fixations on popular e-commerce web pages (Figure 27); sites which display images of substantive interest command the most attention while users also quickly identify filler images for their vapidness.

What is interesting to note here, specifically, is how the use of a grid of equals (Tidwell, 2011) or small multiples visual structure creates affordances for users as they make comparative purchasing decisions. In Figure 27, the eyetracking image on the right demonstrates that, although the designers have employed a grid/small multiples composition approach, sitegoers use the textual cues on the page to ascertain comparative differences; the images of the television sets are nearly all homogeneous and provide no "compared to what?" (Tufte, 1990) information. Conversely, the image on the left shows how consumers at a different site use not only the inherent grid/small multiples information design structure to compose available products, but also create salient affordances for them to identify which products they want.

Treating typography as salient graphic objects. Much has been made of *graphic objects*, *instructional objects*, and *unit forms* as illustrations or diagrams in instructional materials, and most often, these elements are expected to be traditional photographs or assume a graphic organizer diagram aesthetic. However, *typography*, carefully and purposely composed, may also serve as instructional diagram and illustration (Waller, 1985). Waller (1982) categorized several typographic conventions as interpolation (explicitly calling out salience from a larger textual component), delineation, serialization, and stylization.

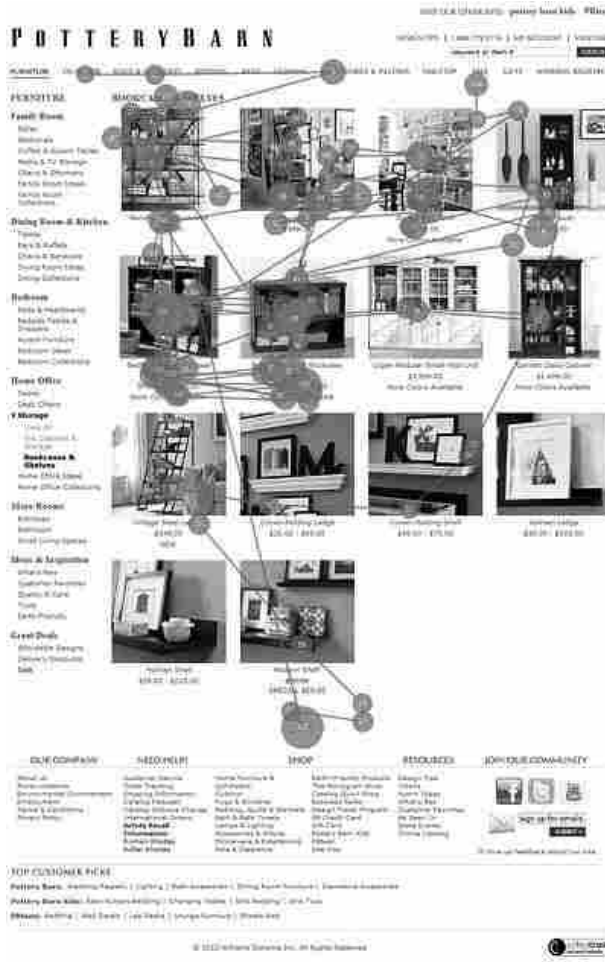


Figure 27. Comparative eyetracking studies showing how a grid/small multiples structure are helpful in assisting purchasing decisions. ©2011 Nielsen Norman Group.

Renowned San Francisco-based graphic and information designer Kit Hinrichs crafted a unique and award-winning (and much widely thereafter duplicated) aesthetic which treats typographic elements and blocks as instructional objects. Hinrichs' style leverages all four of Waller's (1982) categories in instructionally dense ways (Figure 28).

The Sacred Trees layout from the 1984 Potlatch Annual Report uses typography in atraditional ways; it is clear from the layout that certain types of prosaic text ("body copy") are visualized not as page-wide block paragraphs to be parsed but rather as *serialized* and *stylized* (Waller, 1982) similarly sized blocks of information to be learned. The off-white container in the top middle of the right page contains both *delineated* (marking beginning of the text) and *interpolated* (clarified, set apart) textual images. Numbers are deftly treated as graphic images both *serialized* (ordinal numerals) and *stylized* (large sized). Hinrichs visually interprets traditional text as graphical object (indeed, as a graphical organizer), small multiples, and gives the data an instructional aesthetic.

The two-page layout from the Corporate Design Foundation's quarterly magazine *@Issue* (Figure 29), also designed by Hinrichs, treats the photos' text captions as graphical objects that, here satisfy Waller's four categories of

- *interpolation* (juxtaposed and clarifying marginalia)
- *delineation* (create and use idiosyncratic space)
- *serialization* (similarity)
- *stylization* (use of red coloring and stylized alignment)

and therefore function as small multiples. The left column of the *Freedom Festival Magazine* page (Figure 30) displays a vertical timeline of American history mileposts. Captions related to the thumbnail photographic images consistently depict the associated year in red while

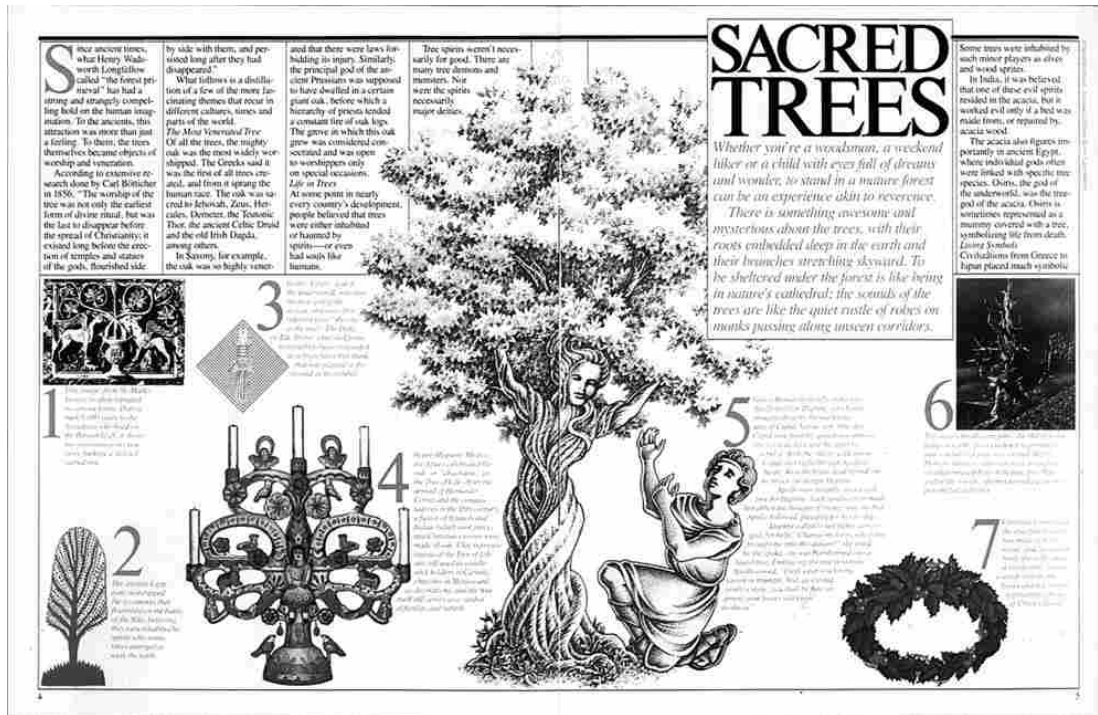


Figure 28. "Sacred Trees" layout in 1984 Potlatch Annual Report. ©1984 Kit Hinrichs.



Figure 29. "Mercedes Benz" layout in @Issue (Vol. 2, No. 2; 1996). ©1996 Kit Hinrichs.



Figure 30. "Festive Findings" page layout in Freedom Festival at Provo Magazine. ©2004 America's Freedom Festival at Provo/Doug Stringham.

years not associated with images are rendered in grey; all years, however, are enlarged and function as graphic typographic elements.

Summary. While small multiples make good cognitive sense, they also exhibit expert fidelity to long-held principles of visual design and composition. Gestaltian axioms of similarity, repetition, proximity, and common fate make up the semantic building blocks of this visual grammar system. Importantly, these components and methods, bundled into compositions and macroconfigurations, become small multiples that instructional designers can use to create saliency in their designs.

Small Multiples Versus Animation: Which Is More Efficacious?

A discussion about small multiples must engage an exploration and comparison to animated displays. Morphologically similar (both comprise a series of typically smaller, multiple, visually parsable images) yet geographically distinct (images in an animation share an asynchronous overlapping z-index whereas small multiples have a common synchronous horizontal y-axis), animations and small multiples have a cognitive and familial resemblance.

Patterns in the literature on animation. As considered instructional approaches, healthy debates about the efficiency of small multiples arise in the literature regarding their comparison with animated displays. So as to not belabor the efficacies of one over the other (each study gathered on this topic expresses very homogeneous results and conclusions), it should be noted that, in most of the animation-versus-static-image research, each article promotes the ability of animations to outperform static images in dynamic display, and then in the same breath, claims the inconclusivity of their author's findings.

Designers and implementers of animated graphics benefit from a general perception that, tacitly, these visuals exhibit a sense of novelty (Morrison & Tversky, 2000) but that they also

mimic a sense of realism and seem “natural for conveying concepts of change, just as [using] space in graphics is a natural for conveying actual space” (p. 2). Although Matuk & Uttal’s (2008) study of using animations to educate museum goers about evolutionary concepts leaves no doubt as to the novelty (viz. their “humour” and “appeal” [p. 1]) of this type of display, their work asks more questions than it answers, chiefly, does an animated display’s ability to rapidly visualize through geologic time distort a user’s perception of the evolutionary processes? And does the narration, paired with the animated display, result in misleading cognition? (p. 2)

Assumptions aside, while much of the literature on animation as an instructional design device is favorable, it is also inconclusive; also borne out in Chan & Black (2005) and others who have written on using graphics in instruction, the argument is not “should they or should they not be used?” but “what is the instructional purpose and context of their inclusion?”

Considerations of using animation. Morrison, Tversky & Betrancourt (2000) conclude that animation, despite its popularity, (which, alone, makes it slightly more compelling than a small multiples display) is not any more cognitively productive than the use of static illustrations or diagrams. Animations, they surmise, *should* be more efficacious in showing processes (“such as...the circulatory system or the mechanics of a bicycle pump” (p. 2).) And more specifically, animations are superior (as also identified in Thompson & Riding [1990]) in showing the microsteps of a process—the in-between parts or the information that must be inferred between steps that a static (small multiple) display might not show. The challenge in this—and other experiments comparing animation and static (small multiple) displays—is in the “lack of comparability among conditions” (Morrison, Tversky & Betrancourt, 2000, p. 5).

While sometimes the modality is common (e.g., a web page which allows for both two- and four-dimensional imagery), often times the modality is *not* common (e.g., an animated

display cannot function in a printed or two-dimensional environment). Additionally, the *perception* of animation by some learners may be that an animation is merely showing the distinct steps of a process or comparative situation: “If motion is conceived of in discrete steps instead of continuously, then the natural way of conveying it may be to portray it in discrete steps rather than in a continuous animation” (p. 6). In certain cases, then, animations are more efficacious in showing the microsteps of a process, but in other cases where an animation is used to demonstrate an already asynchronous set of tasks, animated displays cognitively fail their users.

Similarly, in another experiment contrasting static images and animation, Morrison & Tversky (2001) found that animation (as an instructional graphic), particularly with participants who demonstrated a low spatial ability, is more effective than text alone, but not because of its ‘animation-ness.’ Morrison & Tversky posited that animation might be more efficient because of the Conceptual Congruence Hypothesis: “graphics should be effective in conveying concepts that are literally or metaphorically spatial [and] by extension, animated graphics should be effective in conveying change in time” (p. 377). Although they recognized—as had Winn (1989, 1993a, 1993b), Mayer (1990, 1994), Duchastel (1978), and Duchastel & Waller (1979)—that graphics and text are more effective than text alone, they also found that the use of an animated graphic did not better participants’ cognitive performance.

Tversky, Morrison & Betrancourt (2002) even go so far to say that animations, hastily employed (cf. with little regard to the “what is the instructional purpose and context of their inclusion?” question previously asked), will fail learners. Animated displays sometimes demonstrate steps (and microsteps) too quickly to be parsed, too inaccurately (‘if they’re already steps, why am I seeing an animation?’), and too interactively (extraneous cognitive load may be expended on tracking forward and backward through an animated searching for salience).

In their evaluation of a geovisualization spatiotemporal data software application, Slocum, Sluter, Kessler, & Yoder (2004) also found that animated displays, 'change maps' (small multiples of maps indicating change), and small multiples were most efficient in instances where their inherent benefits were being leveraged. Specifically, their study looked at, in the context of the software (MapTime), how useful were animations compared to small multiples? (p. 44) Each display type (animation, change map, small multiples) resonated with participants, but for very different reasons. Animations, study participants related, helped them to see "general trends" in the data and "provid[ed] a sense of change over time" (p. 63). However, when looking at an animation comparing temporal changes, the display required a higher cognitive load and failed users: "with animation, you would have to keep a picture in your head in order to do the comparison" (p. 58). Additionally, animations created challenges because of

(1) the inability to compare arbitrary time periods (because it would require remembering a spatial pattern) and (2) the difficulty of recognizing when population decreases occurred. (p. 59)

Small multiples, however, allowed participants to "compar[e] arbitrary time periods" (p. 63) and "multiples of change maps...show[ed] the actual change[s]" (p. 63). Overall, participants were favorable to the small multiple of change maps because they allowed for comparison of temporal changes and the demonstration of the actual change the displays purported to show.

A small multiples analog: static animation. de Souza & Dyson (2008) suggest that motion can be depicted in various compositions of series of serial images (small multiples). Microsteps are not necessarily the *missing* images between static images, but they *are* the salient static images, or "moments" (p. 3) that other authors have claimed make animations more efficacious. de Souza & Dyson claim that small multiples may exist in various compositions such as a *composite* image ("a set of discrete images...organized in a 'linear interrupted

configuration” (p. 4), cf. Winn, 1991) and a *synoptic* image (different events composed in a single composite image).

Importantly, however, de Souza & Dyson recommend the tactic of overlapping multiples, “a special type of synoptic image in which transitional pictures of a moving object lie adjacent to or on top of each other” (p. 11). Overlapping multiples are highly efficacious in communicating change and comparison to learners because the subject’s multiples move (or change) on a path that is simple to infer.

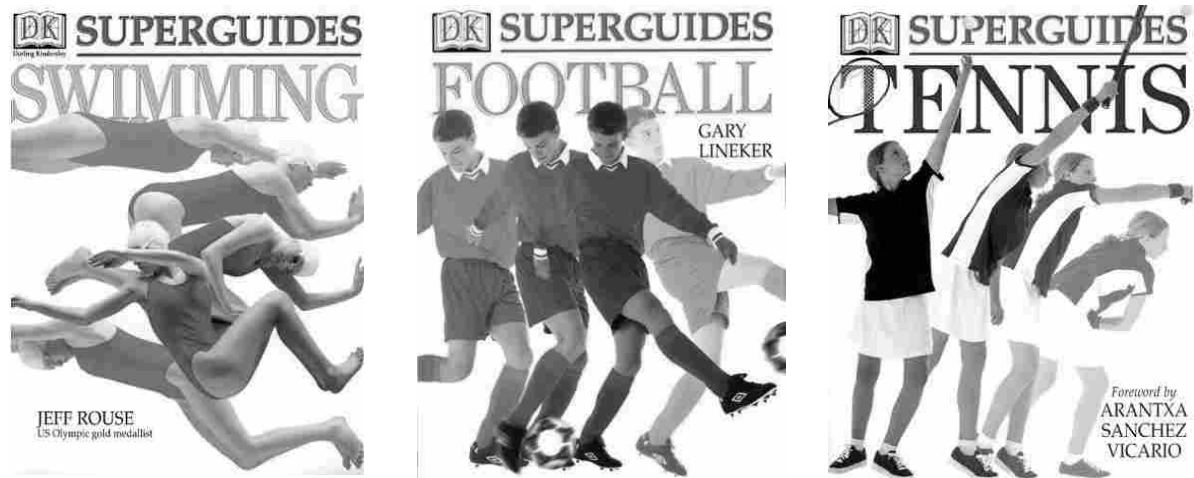
In their work to demonstrate various semiotic characteristics of graphics and imagery, Wong (1993) and Leborg (2006) outline taxonomies of various ways graphics are depicted. Many of them Gestaltian in nature, *repetition* is a salient attribute to both animated displays and small multiples. Their taxonomies are compared in Table 1.

Design case: Static animation in DK SuperGuides. In 1995, UK publisher Dorling Kindersley began marketing a series of books designed to encourage young British readers to participate in a variety of sports (golf, riding, rugby, English football [soccer]); in 2000, this original *DK Young Enthusiasts* series was rebranded as *DK Superguides* and titles about ballet, basketball, snowboarding, and fishing were added for the domestic US children’s market. While internal page layouts are treated with the same signature Dorling Kindersley information graphic style (Figure 17), the covers (Figures 31, 32, and 33) provide an excellent example of a series of pedagogical static images (de Souza & Dyson, 2008) which create the appearance of motion. These discrete and synoptic (Twyman, 1985) macroconfigurations (Winn, 1983) take advantage of repetition and similarity in color and transparency and opacity (Leborg, 2006, p. 32 and 75) and overlapping (Wong, 2003, p. 127) to create salient static animations. These ‘animations’ make explicit salient steps of the displayed skill (task analysis) and adjacency or progress/process.

Table 1.

Comparison of Leborg (2006) visual grammar characteristics and Wong (1993) repetition characteristics

Leborg (2006)	Wong (1993)
<ul style="list-style-type: none"> • abstract/structures: formal structures, informal structures, visual distribution • concrete/objects: form, size, color • concrete/structures: visible structures, active structures • activity: repetition, frequency, rhythm, form, size, color, direction, rotation, movement, direction • relations: attraction/distance, static, groups (linear), position, amount/dominance, coordination, variation, transparent/opaque, overlapping 	<ul style="list-style-type: none"> • repetition of <i>shape</i> (shape is always the most important element) • repetition of <i>size</i> (is possible only when the shapes are also repetitive or very similar) • repetition of <i>color</i> (all the forms are of the same color but their shapes and sizes may vary) • repetition of <i>texture</i> (all forms can be of the same texture but they may be of different shapes, sizes, or colors. In printing, all solidly printed forms with the same type of ink on the same surface are regarded as having the same texture) • repetition of <i>direction</i> (possibly only when the forms show a definite sense of direction without the slightest ambiguity) • repetition of <i>space</i> (all forms can occupy space in the same manner. In other words, they may all be positive, or all negative, or related to the picture plane in the same way.)



Figures 31, 32, 33. Covers of *DK Superguides* Swimming, Football, and Tennis. ©2000 Dorling Kindersley.

Overlapping. The four or five images in each photographic series significantly overlap each other. It might be suggested that the page dimension has forced this composition, but, pedagogically, it appears that the visual and instructional designer aimed for something more intentional (otherwise, the images could have been made smaller and more independent).

Overlapping is an important form relationship:

In a flat space situation, forms can meet one another by touching, interpenetration, union, subtraction, intersection, coinciding, or just be in detachment, but they can never meet by overlapping. Overlapping suggests that one form is nearer to our eyes than another, thus rendering the space illusory to some extent....Space is illusory when all the forms seem not to lie on or be parallel to the picture plane. Some forms may appear to advance, some to recede, some to present their frontal views, and some to show their oblique views. The forms themselves may be flat or three-dimensional. The design area opens up like a window or a stage where the forms are displayed in varying depths and/or at different angles. When one form overlaps another, it is seen as being in front of or above the other. The flat forms may have no appreciable thickness at all, but if overlapping occurs, one of the two forms must have some diversion from the picture plane, however slight the diversion may be (Wong, 1993, p. 127–129).

By overlapping the images, each image is given a space in time in which to exist.

Physically speaking, the swimmer or football player or tennis player cannot exist in a different state or task at the exact space in time. According to Machin (2007), overlapping also creates *saliency*:

Overlapping is like foregrounding since it has the effect of placing elements in front of others. [Referring to an advert for cameras,] In the Panasonic advertisement, the woman with the camera overlaps everything else in the composition. She overlaps the borders, the page edge, and the photograph above. This puts her at the front of the composition, thus indicating that she is the most salient element in the composition. (p. 138)

The reader is assisted by the application of full opacity (or *color* or *saturation*) assigned to one of the images to designate ‘active’ or ‘current’; interestingly enough, the last image (of a left to right flow) is not always the state that is ‘active.’ In this way, the *tense* of entire set of tasks—or at least a segment of them—can be shown: past, present, and future.

Opacity, color, or saturation? Are these covers, then, demonstrating opacity or color (tone) or saturation? Leborg references Itten’s seven kinds of color contrast (Itten, 1967) devised to create color combination. Of note, “(p. 6) Contrast of saturation” (Leborg, 2006, 32) refers to the addition of white, black, and/or grey to a color to lower its saturation. That contrast of saturation is interpreted by the eye and brain as to be situated in the rear of a three-dimensional space: fully saturated colors advance to the foreground, while muted colors appear to recede to the background.

The saturation levels of the images plus the captured-space-in-time character of the overlapped figures allow the designer to accomplish small multiples in a smaller compositional space while also accomplishing the display of steps of a skill, adjacency in process, and consistency of object size. Though space and compositional efficiency is reached in these *DK*

Superguides covers, this approach is still effective without overlapping the figures. In an effort to create an animation using static images, saturation and overlapping adds another dimension to small multiples, especially where task description and/or adjacency in process are desirable to demonstrate.

Summary. Genetic cousins to small multiples, animations truly are highly efficient in instructional events where novelty is important and providing an understanding of change over time is desired. de Souza & Dyson (2007) submit (and Leborg [2006] and Wong [2003] corroborate), however, that composite images—overlapped multiples of a learning event—not only depict adjacency and trace, but also narrative in communicating instruction.

Conclusion

This review of literature has explored five principal areas of research and application: (1) historical references of small multiples, (2) usage of graphics in instructional situations, (3) cognitive load and cognition, (4) Gestaltian theory and saliency, and (5) animation. Exploring each of these domains not only helps to uncover and identify strengths and weaknesses of small multiples within each of these contexts, but also to capture principles that might be operationalized in the creation of a set of guidelines and criteria for using small multiples in instructional events.

A literature survey of both historical and contemporary samples demonstrates that the use of small multiples has precedent in its utility; more recently, however, this approach has sometimes been marginally or erroneously applied. Instructional and visual designers would benefit from a taxonomy that had explored previous cases so as to capitalize on the best possible applications of this approach.

The review in this chapter of the changes in the consumption of media by 21st century learners forces forward-thinking instructional and visual designers to reassess how their pedagogy will not only be processed but applied. Tendencies to marginalize illustrations in instructional materials are far less efficacious now than even ten years ago; a set of guidelines which promotes small multiples as a tactic would profit designers.

The use of any tool for learning can have both positive and negative results on the cognitive load of the outcome. Although the advent and ease of computers has served as a tactical advantage for instructional and visual designers, efficient germane load can often be offset (or upset) by extraneous load—the well-intentioned yet practically deficient execution—into a learning event. The review of literature demonstrates that small multiples can soak up cognitive load excess and work as efficient tactical partners in instructional designs.

Just as world-class instruction should have fidelity to principles, so too the representation layer of an instructional design (Gibbons, 2003) should adhere to frameworks that promote established visual design principles such as composition, balance, alignment, and layout. This chapter has shown that small multiples have their primordial beginnings in Gestalt philosophy and centuries-old artistic fundamentals; their considerate conceptual and cognitive application would help both instructional and visual designers in creating saliency in their designs.

In praxis, instructional designers may consider animations to be efficient ways to depict information. Certainly the literature bears out that they may win the day in novelty and certain displays of change over time. Not to be shortchanged, though, instructional designers would benefit from understanding how other visual displays may be better at satisfying instructional goals. Small multiples excel at their display of trace and adjacency, not to mention ordinal and

task relationships. Designers would benefit from a set of guidelines that helped them understand when X might be better than Y, or vice versa.

Chapter 3: Methodology

Gibbons & Bunderson (2004) posit that knowledge may be produced by *exploring* (devising hypotheses based on observations), *explaining* (determining the why and how of research), and *designing* (applying principles to shape criteria). In an attempt to contribute additional and expansive theory in instructional message design while also proposing a practical set of guidelines for using small multiples in instructional designs, this study intends to

1. identify common instructional design challenges that can be solved by small multiples by compiling a literature review that catalogs historical and modern treatment of small multiples and their pedagogical, psychological, graphical and cognitive values;
2. demonstrate cases (Boling, 2010; Smith, 2010; Baxter & Jack, 2008) of small multiples usage in design artifacts to identify how they satisfy purposeful instructional objectives (discussed in Chapter 4) through an expertise-oriented evaluation approach of connoisseurship (Eisner, 1972, 1975, 1991a, 1991b; Fitzpatrick, 2004; Chapman, 1978; Visscher-Voerman & Gustafson, 2004).

Analysis Of Literature

The literature review in Chapter 2 is vital to this thesis because it represents much of the actual data to be studied and analyzed. That is, principles, theory, and praxis gathered from sources that document artistic, aesthetic, informational, and psychological principles show not only how small multiples are processed and interpreted but also how they can effectively accomplish the instructional designer's cognitive, aesthetic, and pedagogical goals. References in this thesis are drawn from sources in the instructional message design, psychology, cognitive science, and visual design literature. Because there is paucity in the instructional design literature regarding small multiples, the literature review in Chapter 2 focuses on how small multiples can

tactically resolve instructional design challenges while examples of small multiples and how they support instructional objectives are demonstrated in Chapter 4.

Choosing A Data Evaluation Method

In the case of qualitatively evaluating the efficacy of visual design elements as in this study, Robbins (2006) has suggested that traditional statistical experimental methods of determining reliability, the rejection of hypotheses, etc. “are not appropriate for a connoisseurship model of assessment” (p. 4); numerical data answers other specific questions (not raised in this study) and provides limited access to other questions proposed by the data in the study. Indeed, the purpose of this thesis is not to defend a proposed quantifiable experiment, but instead to illuminate the efficacy of a visual and psychological design technique applied to instructional designs, a question that requires an expertise-based evaluation method.

Connoisseurship as a data evaluation method. Though debated by some as less valid or non-empirical, an evaluation model that requires a researcher’s connoisseurship and expertise is well-established in the evaluation literature and, in some assessment and research circles, has a long tradition of use (Robbins, 2006). Stanford education and art professor Eliot Eisner has used the term *connoisseurship* (1991b) to describe the ability to evaluate some thing based on the assessor’s expertise in the thing’s domain, “so that others not possessing his level of connoisseurship can also enter into the work” (Eisner, 1975, p.1). Robbins (2006) elaborated on the assessment form of connoisseurship as:

- assessment by a qualified person who is a member of a community of practice and whose authority as an expert in their field and as a connoisseur is recognized both within and outside of that community;

- the exercise by a connoisseur of critical faculties based on knowledge both within their field of expertise and as an assessor, that has been acquired, at least in part, by forms of apprenticeship;
- purposes for the assessment that are shared and agreed both within and outside of a community of practice. (p. 2)

As discussed previously, perceptions of visual design artifacts have been historically resistant to empirical measurements and judgment. Identifying and describing cases and samples of small multiples artifacts through Eisner's lens of connoisseurship and expertise-oriented evaluation will not only allow the reader to understand them in light of the principles uncovered in the literature review, but also the evaluator to analyze them given his acquired knowledge and proficiency with these types of artifacts.

Credibility and trustworthiness of data and findings. Vars (2002) explains Eisner's terms for connoisseurship evaluation credibility as "*structural corroboration* (triangulation), *consensual validation* (agreement among 'competent others'), and *referential adequacy* (the extent to which criticism reveals what might otherwise be overlooked)" (p. 70). Structural corroboration is reached in this thesis by demonstrating how the collected data are shown to both resolve instructional design challenges (discussed in the literature review in Chapter 2) and to satisfy instructional objectives (evidenced in Chapter 4). Prolonged engagement, referential adequacy, and consensual validation are accomplished in that the author of this thesis has worked with and studied the effects of small multiples both

- *academically* (exploring and applying the use of small multiples as a visual design tactic on work conducted during undergraduate and graduate design degrees) and

- *vocationally* (using and advocating for the use of small multiples in marketing, instructional, informational, and editorial projects. Over a nineteen-year professional career in visual design, the author has won several industry awards while working in both visual design and advertising agencies and internal corporate communications departments as a marketing communications designer, copywriter, senior art director, and user interface and experience designer.)

Although there is only one researcher for this study (additional researchers were not available), consensual validation is achieved by referencing and triangulating collected data back against the findings presented in the literature review in Chapter 2 and are discussed in depth in Chapter 4.

Data Collection And Evaluation Approach

Despite historical attempts to view them in the microscope of assessment, representations of art and visual design have been resistant to the scientific, statistical, and disciplined nature of evaluation theories and approaches. Hegel (1975) explains that these types of objects “present [themselves] to sense, feeling, intuition, imagination; [they have] a different sphere from thought, and the apprehension of its activity and its product demands an organ other than scientific thinking” (p. 5). Redefining methodology in the context of connoisseurship and criticism, then, evaluation becomes object criticism:

“The evaluator is the ‘instrument,’ and the data collecting, analyzing, and judging are largely...within the evaluator’s mind....As a consequence, the expertise...of the evaluator is crucial, for the validity of the evaluation depends on his perception.” (Fitzpatrick, 2004, p. 121)

Because this study focuses on showing how small multiples can make instructional designs more efficacious, several historical and contemporary examples of small multiples

representations from across a variety of genres and media are sampled in this thesis. Stake (1995) does caution against a tendency to represent findings of a few cases across all theoretical instances; “case study research is not sampling research,” (p. 4) he warns. However, it is beneficial to highlight and examine descriptive (describing a phenomenon and the real-life context in which it occurs; Yin, 2003) or instrumental (the case itself is not at issue, but it provides insight and/or helps refine theory; Stake, 1995) cases and samples in order to produce arguments for the proposed categories of small multiples.

Identifying and creating design cases. Boling (2010) and Smith (2010) have detailed the concept of a design case as a critical form of studying any “real artifact or experience that has been intentionally designed” (Boling, 2010, p. 1). Creating and reviewing design cases, then, contribute to precedent (Lawson, 2004) that a designer (or other designers) may use, connect with, associate, or even improve on in creating designs. Design cases should not be confused with design research, formative evaluation, design and development research, or design-based research approaches, but instead can benefit designers in two important ways. First, design cases are intended to be pedagogical in nature, they should

offer in-depth explanations of design rationales, rich and multi-dimensional descriptions of designed artifacts and experiences, and full reflection on design processes [that] have the potential to offer teaching and learning opportunities that are difficult to find. (Boling, 2010, p. 6)

Second, creating, evaluating, and sharing design cases allows for cross-disciplinary and operational applications; the idea of cases in medicine and law not only encourages rigor (Smith, 2010) but also

benefit[s] students of design across multiple fields. Sharing these cases across fields of practice exposes the languages and assumptions in use by designers, encouraging cross-

fertilization of ideas and perspectives...[P]ublic explanations and reflections will improve the knowledgeable appreciation of design across specialties. (Boling, 2010, p. 6)

Collecting evidence and data. Over 70 examples of small multiples were originally considered for this study (Appendix A), however, only 17 were chosen for analysis and discussion in this thesis. Data have been collected avocationally for the past 10 years and aggressively (in focused preparation for this thesis) over the past three. Examples were chosen by employing a naturalistic maximum variation sampling approach (cf. Lincoln & Guba, 1985; Patton, 1990) in an attempt to identify “common patterns that emerge from great variation” (Patton, 1990, p. 172); in turn, this kind of sampling, “yield[s] detailed descriptions of each case,...identifying shared patterns that cut across cases” (Hoepfl, 1997, p. 52). Samples in this study, then, were taken from a wide variety of archived museum collections; existing printed books, reference materials, periodicals, annual reports, and informational handbills; novel hand-created drawings and sketches; broadcast television graphics; and various Internet webpages, subpages, and page renderings.

As the researcher analyzed the collected evidence and data, seven notable themes and patterns—called *objectives*—began to emerge across the design cases. In each of these seven objectives, at least two or more sample small multiples were identified, described, and then triangulated back against principles found in the literature review.

Deciding the number of representative samples. Several of the examples satisfy features and characteristics of one or more objectives, however, final included design cases were selected on the researcher’s connoisseured and critical view of their fidelity (“how well and how universally does this example best demonstrate the proposed instructional objective?”) to the definition and instructional purposes of small multiples. Table 2 outlines how many cases were

considered for each objective and how many actual design cases were ultimately examined. (In the case of one example, though conceptually a better fit for the argument, the collected sample had to be discarded because the copyright owner would not consent to its usage in this study.)

In the cases of objectives 1–4, three examples were judged to be representative (two were too few and four were too many); in the cases of objective 6 and 7, two examples were deemed sufficient to illustrate the objectives' guiding tactics. Because defining the various relationships of learning objects (objective 5) is a much broader task, four samples of small multiples were chosen. All examples have been rendered here as electronic files for the ease of transfer, duplication, and reproduction.

Table 2.

Number of considered design cases versus number of examined design cases.

Identified objective	Number of considered design cases	Number of examined design cases
Objective 1	12	3
Objective 2, 3, 4	21	6
Objective 5	20	4
Objective 6	18	2
Objective 7	9	2

Chapter 4: Findings

Observations From The Literature Review

The intents of this study have been to (1) identify common instructional design challenges that small multiples can overcome and (2) show examples in existing design artifacts. Based on the literature review conducted in the previous chapter and an analysis on over 70 examples of small multiples, a set of seven objectives and associated guiding tactics emerged of how small multiples may objectively benefit the intentions of instructional and visual designers.

Objectives Of Small Multiples In Instructional Designs

Instructional designers can use small multiples in their designs to:

1. Define and explicate the steps of a skill/task (task analysis)
2. Define and explicate ordinal relationships
3. Define and explicate adjacency and trace
4. Define and explicate progress and process
5. Define and explicate the rhetorical heterogeneity of objects
6. Define and explicate the various steps of a story or implied narrative
7. Create an instructional or information design aesthetic and/or metavoice

Indeed, these objectives assume fine distinctions between their definitions. While many of the examples in this chapter likely have ingredients or components that fluidly bleed over into other categories (e.g. “can a small multiples display help a learner understand the steps of a narrative while also defining ordinal relationships?”), the 17 design cases presented here are intended to be representative of the objectives they model.

Objective One: Define and explicate the steps of a skill/task. Arguably the most critical part of the instructional design process (Jonassen, Tessmer, & Hannum, 1999, p. vii), designers

perform a *task analysis*, identifying and prioritizing overall goals or learning outcomes for what is to be taught or trained, and subdividing those requirements into manageable action items.

In helping learners understand how to perform various tasks, instructional designers (and learners alike) often want to have separate task items made explicit. Certainly, task instructions have historically often been explicated in prose form (cf. Bede's *De computo vel loquela per gestum digitorum*, explained in Chapter 1) and can be given to learners as lists. However, as shown in Chapter 2, visuals help learners better understand instruction (cf. Dexter, 2010; Machin, 2007; Duchastel, 1978; Paivio, 1971) and manage cognitive load (Sweller, 2002; Sweller, van Merriënboer, & Pass, 1998). Because small multiples are, by their morphology, "comparisons of changes, of the differences among objects" (Tufte, 1990, p. 67), they are natural visual methods that instructional designers can use to demonstrate steps in a task.

Guiding tactics. Instructional and visual designers may want to explicitly demonstrate the steps of a task but not necessarily highlight or make salient the rhetorical relationships between the tasks. Small multiples are efficient in accentuating steps in a task provided that

1. theoretically, the nature of the task(s) to be demonstrated is general and, other than the unavoidable tacit perception of left-to-right as chronology (Machin, 2007), rhetorically "neutral." (A designer may wish to be more specific or use a more specific genre to define the steps in a task, such as when an instructional designer intends for tasks to have more specific rhetorical requirements [e.g., more decisively ordinal or adjacent relationships]; these specific rhetorical requirements are discussed in a separate objective below.)
2. typically only one frame (i.e., photograph or illustration) of the task is shown at a time
3. individual frames, however, may function as a pointer (Gagné, 1985), representing a handful of salient microsteps or subtasks within the task

4. the images may be situated closer or further apart from each other on the y- or horizontal axis; that is, small multiples A and B may enjoy a relationship of anywhere from $y = 0$ (“directly on top of”) to $y = n$ (where n represents a measurement that image B is to the right of image A; “image B is a half inch to the right of image A” or “image B overlaps image A by three millimeters”)
 - a. if multiples overlap, they become *synoptic images* (Twyman, 1985), and, for all frames to be visible (i.e., comparative) and to indicate accepted norms of ‘before,’ ‘now,’ and ‘after,’ must display a degree of transparency (Leborg, 2006; Wong, 2003)

In this objective, three examples are used, specifically to demonstrate how small multiples can effectively (and/or be used to better) illustrate the steps or skills of a task.

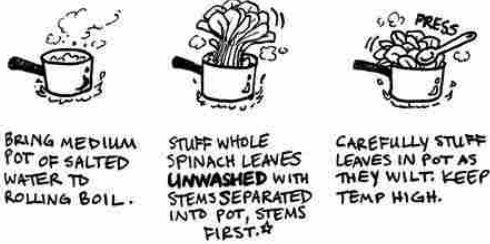
Design case: Spinach ban-chan diagram. In an attempt to capture her mother’s nondocumented bespoke family recipes, former cartoonist Amy Kibuishi created a series of visual recipe cards to accompany the tasks:

I spent last Sunday going to my mom’s unofficial Korean cooking class where she taught me several of her homemade recipes for ban-chan and fish. [I drew] a sort of instructional recipe comic...so I could remember exactly what to do, as she is sort of self-taught. Her way of teaching is to simply make the thing and I watch.” (Kibuishi, 2011)

The first task, “Blanch and Shock the Veggies,” (Figure 34) is visualized in nine steps, their left-to-right arrangement tacitly presuming chronology (Machin, 2007). Kibuishi’s renderings are sketched and extemporaneous (as exhibited in her comments about her illustrations), reinforcing the general nature (or her perception of the general nature) of the task. Additionally, each main

SPINACH BAN-CHAN

① BLANCH AND SHOCK THE VEGGIES:

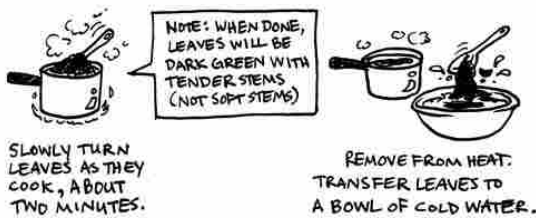


BRING MEDIUM POT OF SALTED WATER TO ROLLING BOIL.

STUFF WHOLE SPINACH LEAVES UNWASHED WITH STEMS SEPARATED INTO POT, STEMS FIRST.*

CAREFULLY STUFF LEAVES IN POT AS THEY WILT. KEEP TEMP HIGH.

* IF LEAVES ARE WASHED, THEY WILL TASTE LIKE GRASS WHEN COOKED.



SLOWLY TURN LEAVES AS THEY COOK, ABOUT TWO MINUTES.

NOTE: WHEN DONE, LEAVES WILL BE DARK GREEN WITH TENDER STEMS (NOT SOFT STEMS)

REMOVE FROM HEAT. TRANSFER LEAVES TO A BOWL OF COLD WATER.



LIFT LEAVES OUT OF WATER AND PLACE IN RINSED POT.

THOROUGHLY RINSE DIRT FROM BOWL. REFILL WITH WATER.

TRANSFER LEAVES FROM POT TO COLD WATER BOWL.

REPEAT RINSING PROCESS 5-6 TIMES UNTIL NO DIRT IS FOUND AT BOTTOM OF BOWL.



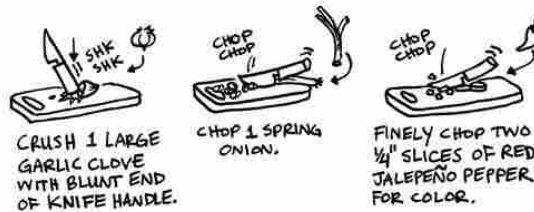
WHEN FINISHED, SQUEEZE EXCESS WATER FROM LEAVES IN LARGE HANDFULS. FORM INTO BALL.



CUT SPINACH BALL INTO QUARTERS. SET ASIDE IN LARGE MIXING BOWL.

NOTE:
1 bunch of spinach = 1 handful = 1 household serving.

② PREPARE DRESSING



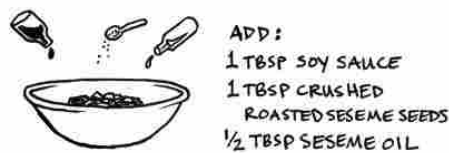
CRUSH 1 LARGE GARLIC CLOVE WITH BLUNT END OF KNIFE HANDLE.

CHOP 1 SPRING ONION.

FINELY CHOP TWO 1/4" SLICES OF RED JALEPEÑO PEPPER FOR COLOR.



ADD TO MIXING BOWL WITH SPINACH.



ADD:
1 TBSP SOY SAUCE
1 TBSP CRUSHED ROASTED SESEME SEEDS
1/2 TBSP SESEME OIL

③ MIX



Toss lightly until fully coated. Adjust seasoning to taste.

TIP: FOR A DIFFERENT VERSION, ADD A SPOONFUL OF DWENJANG (KOREAN MISO) INSTEAD OF SOY SAUCE.



SERVE COLD AS A SIDE DISH TO ANY TRADITIONAL KOREAN MEAL. STAYS GOOD REFRIDGERATED FOR 3-5 DAYS.

Figure 34. Visual instructions for how to make spinach ban-chan (original image vertical; recomposed here for ease of viewing). ©2011 Amy Kim Kibuishi.

task is accompanied by motion lines and multiple puffs of steam or drops of water. McCloud (1993) has explained that these motion lines are tactics that cartoonists and graphic novelists use to “represent the paths of moving objects through space,” (p. 111) certainly congruent with how Kibuishi employs them to represent the dripping, steaming, and rearranging movements of the spinach and water.

Design case: Carpentry for Children. Figure 35 is typical of the over 30 hand-rendered illustrations found in architect Lester Walker’s simple book of do-it-yourself projects for kids (Walker, 1982). Walker provides readers with a series of visual to-do lists either for how to use certain tools or how to create projects.

While admittedly, this figure does incorporate ordinal numbers and might arguably be better data for objective 3 below, this sample was chosen for this objective because of its incongruencies with the principles outlined in this section, viz.

- although five steps are outlined, only two frames are used to explicate the steps
- none of the steps really function as pointers
- the frames and their related captions are not associated with a y-axis

Though a good example of visual learning, the last incongruency—not associating images and/or captions with the same y-axis—makes the overall composition more challenging to parse (Winn, 1993b). Figure 36 proposes a version of Figure 35 that has been realigned and redesigned to leverage the guiding tactics of this objective and to focus more on change in data and less in presentation (Tufte, 1990):

- each step now has an associated image which allows for comparison “before” and “after”
- each image now functions more as a point for all of the microsteps surrounding each task

The Brace and Bit

Below are the five steps taken to drill a perfect hole with your brace and bit. Step five is particularly important because it shows you how to drill without breaking through the wood at the bottom of the hole, which leaves a ragged, splintered edge. Also, you may have trouble drilling a straight hole. This problem can be easily solved by asking a friend to stand back and line you up as you drill.

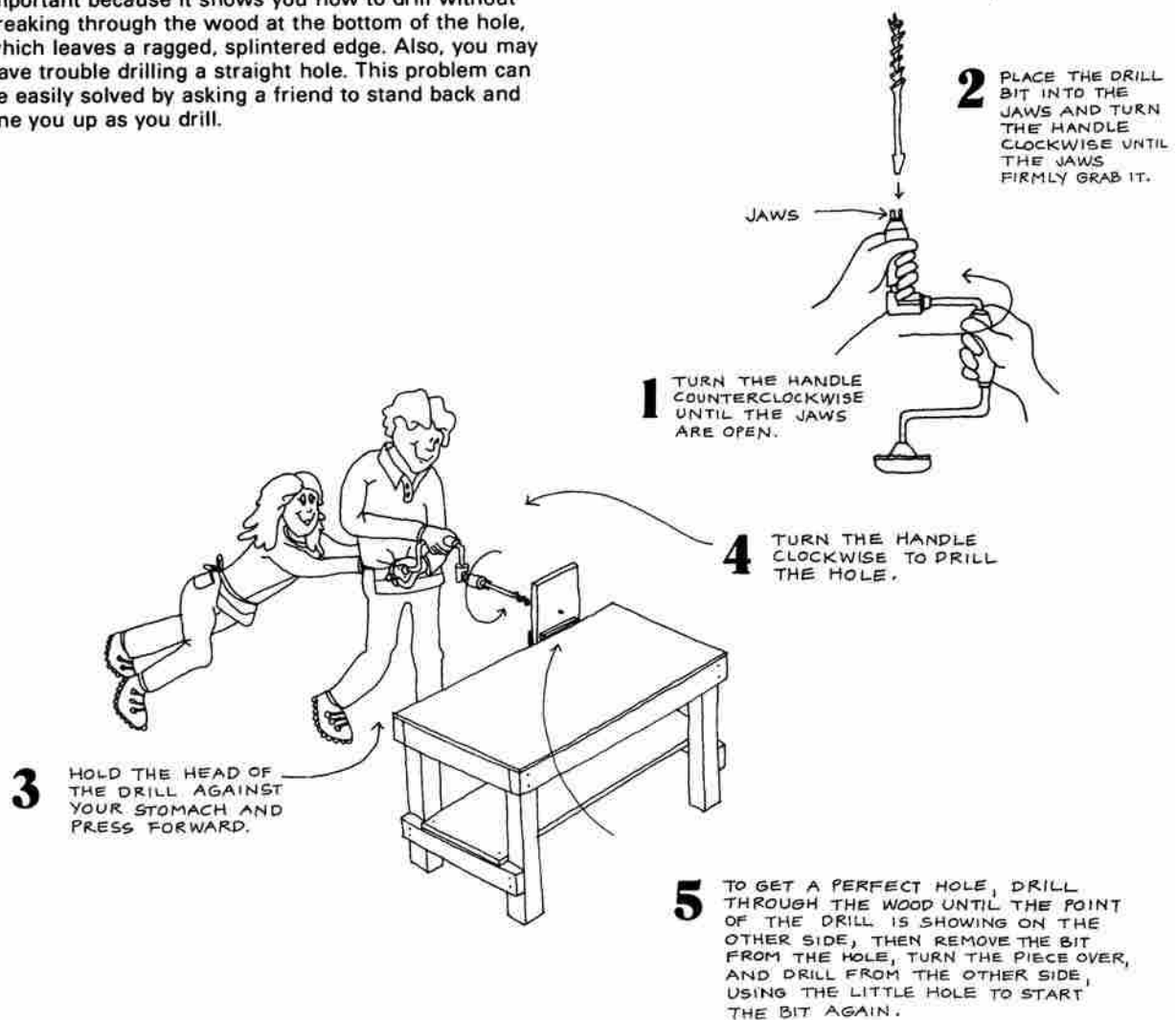


Figure 35. "The Brace and Bit," from *Carpentry with Children* (1982). ©1982 Lester Walker.

- all of the frames/captions are placed on the same y-axis, also allowing for comparisons “before” and “after”
- though each image is not a chronological iteration (in size, shape, repetition) of surrounding images, it is more closely approximating and incorporating small multiple

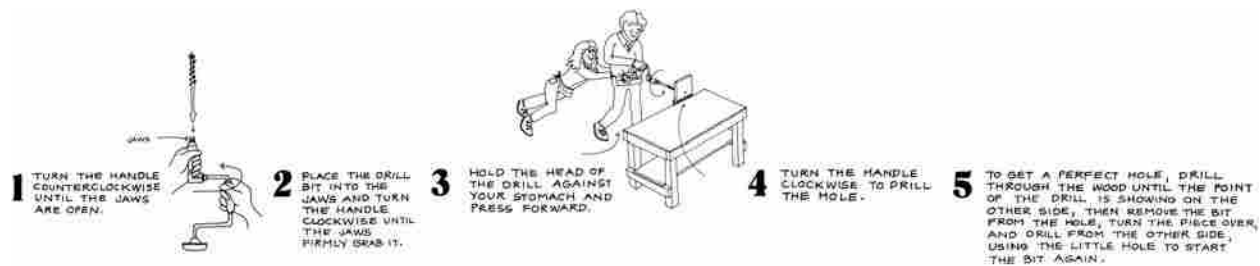


Figure 36. “The Brace and Bit,” reenvisioned in a horizontal and temporal composition to purposely leverage temporal and chronological differences between tasks.

Design case: $y = 0$: Fritz Hirn and *The Deafmutes Sign Language in Finland*. The design case of the Dorling Kindersley *Superguides* covers (Figures 31, 32, and 33) illuminates how steps-in-a-task images can be made transparent, overlap by very small measurements, and create a series of salient small multiples. Figures 37 and 38 are pages and insets from *The Deafmutes Sign Language in Finland*, edited and published by Finnish educator Fritz Hirn and his son Julius (Jantunen, 2002) in 1916. Originating in the mid-1800s, signed language dictionaries, at first, were not much more than lists of textual descriptions of handshapes and movements (cf. Brown, 1860). An important instructional milestone, however, is found in Long’s (1909) photographic signed language dictionary, the first text to add (1) black-and-white plates of single-frame images of various signs and (2) superimpose arrows on the image in an attempt to instruct readers on how to articulate various signs.



Figure 37. *The Deafmutes Sign Language in Finland*, plates 204, 205, 212, 213, 228, and 229. Courtesy Gary A.K. via Creative Commons BY-NC-SA 2.0.



Figure 38. *The Deafmutes Sign Language in Finland* (“1. III hæfte”), plates 289–308.

Hirn's work takes a slightly different approach to demonstrating the steps in the task of producing a sign: present are the single-frame images and superimposed white arrows, but also added (in frames 204, 228 [Figure 37] and 293, 296, 298, 303, 305, and 306 [Figure 38]) are (rather cleverly yet strangely) "more" of Hirn's arms and hands and heads. These eight images are composites of a collapsed y-axis (or $y = 0$), resulting at first in what appears to be a peculiar arrangement, because, as was shown in the Dorling Kindersley covers, varying 'layers' or differences in transparency implicitly communicate chronology and currency. In other words, why does Hirn have three functioning arms and hands? Fully opaque images convey currency or immediacy, while transparency communicates "before" or "after." That Hirn's disembodied arms and head are fully opaque (largely due to production constraints of the early 20th century) initially creates an odd image, but in actuality, results in a fairly salient small multiple.

Objective Two: Define and explicate ordinal relationships. While it might be argued that defining ordinal relationships is merely just a subset of (or even the same as) objective One, this objective is heterogeneous enough that, even in its nuance, it represents an approach where instructional and visual designers can add value.

As was stated in objective One, the unavoidable tacit perception of a lateral (and, to a certain extent, vertical) composition is as chronology (Machin, 2007). However, there are instances, as are demonstrated in this objective, where designers desire to make the ordinal relationships between learning objects explicit. To wit, in Figure 39 (as opposed to Figure 35 above) the instructional and visual designer(s) purposefully decided to clarify the ordinal positions of each respective task. While some of the examples in this objective do share a conceptual overlap with other stated instructional objectives, they apply here because of their overt demonstration of these purposes.

Guiding tactics. Instructional designers may want to emphasize the ordinal nature of how to do or complete a task. Ordinal relationships may be defined as identifying the *when* of learning objects; ordinal relationships are subtly differentiated from the steps-in-a-task objective in that

1. the nature of the tasks are discrete enough so as to not focus more on adjacent or trace relationships than on the step or the task (cf. Muybridge, 1878)
2. the ordinal nature of the tasks are supremely important to the instructional goal(s); in other words, although it may be assumed that any task order is always ordinal ('X,' 'Y,' and 'Z'), the designer deems it absolutely requisite that the ordinal nature be made explicit (first, 'X'; second, 'Y'; and third, 'Z') (Duchastel & Waller, 1979; Lyons, 2004)
3. the representation often includes explicit graphical numeral systems to clearly explicate between steps

Design case: Tennis Magazine. These editorial spreads (Figures 39 and 40) from *Tennis* demonstrate how small multiples can be used to support this type of instructional goal. New York design agency Pentagram partner Luke Hayman and *Tennis* art director Gary Stewart redesigned the magazine in 2009 to “reconnect [*Tennis*] with a young energetic audience, but [not] look like a kids’ magazine” (Pentagram, 2009). Additionally, the designers purposely redirected the photography to be both “dramatic” and “dynamic” while also recognizing the instructional and editorial goals of certain sections of the magazine. Hayman and Stewart’s team expressly leveraged images that exhibited

silhouetting and clipping, mixed with technical info-graphic overlays, clarify[ing] the imagery while eliminating redundant and distracting background elements, emphasizing the...*focus as a player’s manual* [italics added]. (Pentagram, 2009)

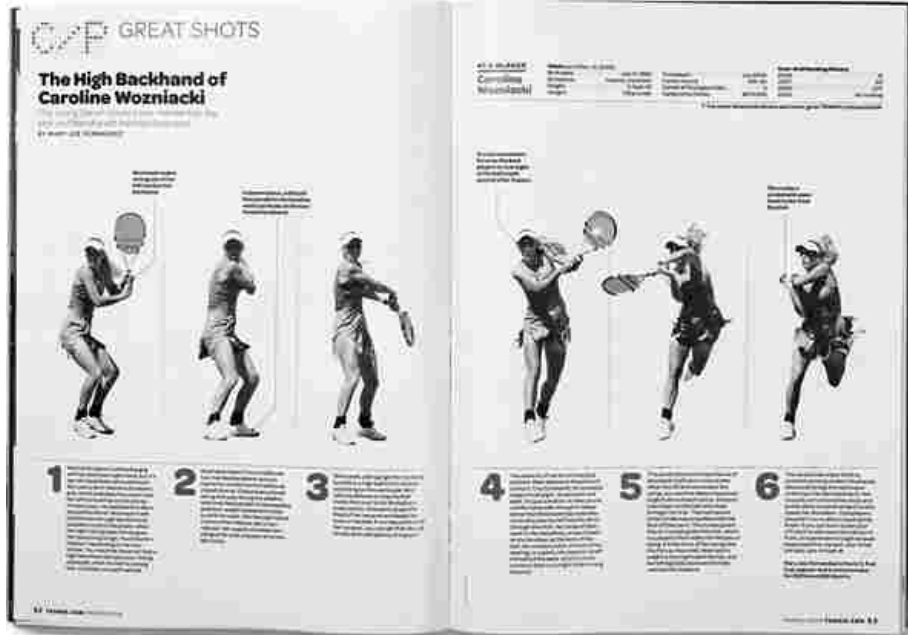


Figure 39. Editorial layout from *Tennis*, “The High Backhand of Caroline Wozniacki,” March 2008, p. 52–53. ©2008 Pentagram.

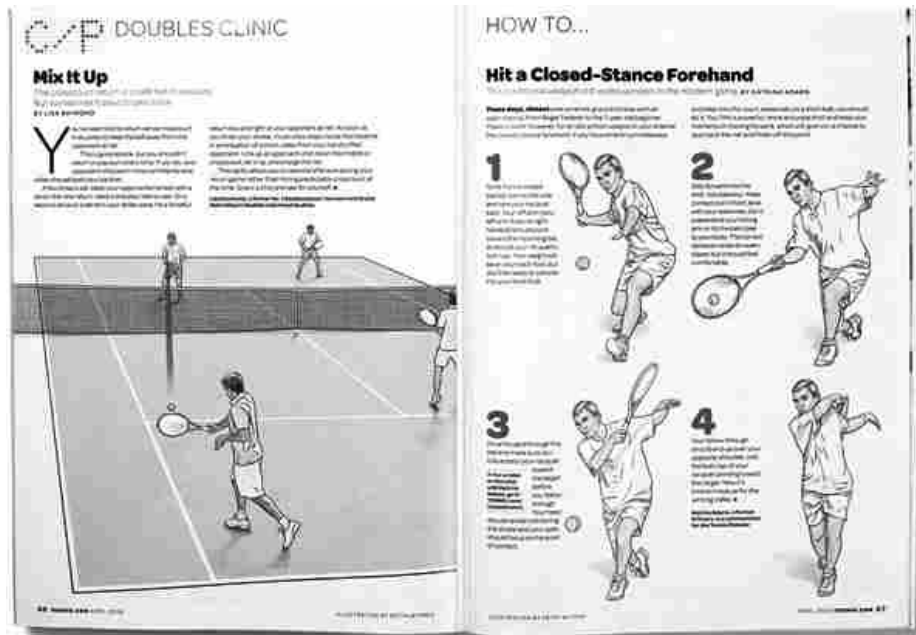


Figure 40. Editorial layout from *Tennis*, “Hit a Close Stance Forehand,” April 2008, p. 67. ©2008 Pentagram.

The March and April 2009 layouts from the "Complete Player" section feature visual design decisions which complement the instructional goals as previously described:

- In either layout ("The High Backhand..." or "Hit a Closed-Stance..."), albeit fairly closely-timed, both sets of visuals array images are discrete enough to identify several salient parts of the snapshot or task. All six images in "The High Backhand..." are accompanied by a lengthy descriptive paragraph about the athlete's task or step and/or an additional caption, which elaborates on another observation in the still image.
- It could be argued that these images could be placed in a non-chronological order and could be redesigned as something like "Steps You Should Include In Your High Backhand Stroke." However, the graphic and instructional designers here have purposefully emphasized a 'first, second, third' goal, and the visual design complements this.
- Arguably the most salient and visual element on the page are the bright red numbers (in juxtaposition to the purposeful monotonic rendering of the photography) which accompany each step. These (typo)graphic organizers function as Waller (1982) suggests by *interpolating* (explicitly calling out salience from a larger textual component) and *delineating* (marking beginning of the text), and satisfying *serialized* (ordinal) and *stylistic* (red, oversized) requirements.

Design case: skype.com. This webpage (Figure 41) gives learners a classic small multiples composition in which it frames a help system. Each image is homogeneously-sized and guides the user to compare his or her next task with the previous one. This design, provided for users who download Skype's video and voice calling software application, also complements the site instructional designer's goals of (1) simplifying the download and installation process while also (2) attempting to minimize customer service requests:

- Each task is uniquely discrete and ‘skips’ several potential hypothetical ‘frames’ understood by the user in the process (in the case of these instructions, most Apple Macintosh users are familiar with the in-between steps of locating the downloaded file, viewing a user interface ‘processing’ element, launching an application, etc.)
- Unlike the *Tennis* magazine layout where, theoretically, the images could be conceptually reordered, the instructional/visual designer purposely displays these four images in this linear order (Machin, 2007).
- Each macroconfiguration (Winn, 1993) is led by a numeral system, in this case, overtly as “Step X.”

Need some help installing Skype?



Figure 41. How to install Skype (from <http://www.skype.com/intl/en-us/get-skype/on-your-computer/macosx/downloading>). ©2010 Skype.

Objective Three: Define and explicate adjacency and trace. Gestaltian psychologists posited that, because human beings are wired to recognize and to rely on patterns for learning (Wertheimer, 1923), repetition is a staple visual approach for designers, instructional and/or visual. Gibbons (2006) has called these patterns in the representation layer of instructional designs *traces*, or “visible or audible contrails of captured experience created as events unfold” (p.

9). Traces help designers display chronology and help learners unpack implicit ideas to become explicit; cause and effect, prediction, trajectory, comparison, and cloze are all pedagogical antecedents to visualizations that highlight adjacency and trace. Small multiples complement these aims; as has been previously outlined, much of contemporary media

provid[es] information in a graphical form that shows multiple influences on trends and allows multiple comparisons. Through the manipulation of time and space with traces, we make it possible for the learner to see new contrasts and new structures. (p. 10)

Instructional designers may require a visual approach that emphasizes several *spatially* or *geographically* closely-related salient points in a given task and not the discrete ordinal nature of steps or a task, as shown by the ‘ordinal relationships’ objective. This is, perhaps, the most orthodox of the interpretations of small multiples (Tufte, 1990) as many of the instances he uses in his work heavily validate this point. It is likely the most explicit way to demonstrate “changes in data” (Tufte, 1990, p. 67). An example of this strategy is Muybridge’s 1878 “Horse at a Gallop” and “1887 Daisy Plate 640 renderings” discussed in Chapter 2. While de Souza & Dyson (2007) express uneasiness with the homogeneity of Muybridge’s images, they still admit the efficacy of its pedagogy.

Guiding tactics. Small multiples in adjacency and trace relationships are efficient in both showing the existence of *spatial* rhetorical relationships—identifying the *where* of learning objects—between X and Y and also *how* and *why* X and Y are related:

1. The comparable relationship of tasks or steps are barely discrete enough so as to require several salient static images, or “moments” (de Souza & Dyson, 2007, p. 3; cf. Muybridge, 1878)
2. Because of the quantity of required images

- a. the representation typically includes several small multiples in order to create enough data for the learner to compare but not more than can be perceived in a single view
- b. it is expected that the small multiples will be sized “relative to the visual field” (Winn, 1993a, p. 64) and that a learner can view all of the frames globally (as a macroconfiguration), and then rapidly and repeatedly parse them individually (64); the ordinal nature of the tasks are therefore assumed to be ‘X,’ ‘Y,’ and ‘Z’
- c. the representation should be horizontally composed (never diagonally nor vertically; cf. Winn, 1993a, p. 64) because the strategy is to compare and/or contrast and/or predict over many salient frames (almost approximating animation)

Design case: *The Hitchhiker*. Sixtiescity.com is a UK-based website which documents British popular culture of the 1960s. The site contains pages dedicated to English television programming, music, and trendy dance moves and styles of the period. Among other single image snapshots of dance steps and several paragraphs of acontextual instructional text, Figure 42 demonstrates the then-popular ‘hitch hike’ dance style, “a craze started by [R&B singer] Marvin Gaye’s 1962 tune “Hitch Hike” (Pagett, 2008, p. 39), using a small multiples, filmstrip-type composition.



Figure 42. Flipbook/image strip of The Hitchhike dance move. Courtesy Clint Hough/sixtiescity.com.

Further up on the webpage, the ‘hitch hike’ moves are textually described over five paragraphs. Figure 42, however, displays 12 chronologically spaced images with a modicum of

instructional text. The images efficiently showcase the subtle but salient rhetorical relationships X and Y (physical dance positions) and the macroconfiguration (Winn, 1993a) is just wide enough to completely be perceived in the learner's peripheral vision. Halving and stacking two images might arguably reduce the cognitive impact a larger, more horizontal (and therefore, more procedural) image like Figure 43 would have. Like when a piano player has to interrupt the flow of note reading to turn pages of the sheet music, viewing only six (or half a move) of the twelve steps interrupts the flow of learning and recreating all movements in the dance.

Design case: "Juan Marichal, born 1938." In 1966, artist Gerald Gooch painted a three-row triptych visually documenting the windup and delivery of then-heralded San Francisco Giant baseball pitcher Juan Marichal (Figure 43). Marichal exhibited a unique and harried windup-and-catapult style at which National League hitters feared and spectators marveled. Gooch's "Juan Marichal, born 1938" was *Time Magazine's* June 10, 1966 cover and displayed an adjacency and trace visual design problem solved with small multiples.



Figure 43. "Juan Marichal, born 1938." ©1966 Gerald Gooch. Image used with permission of the National Portrait Gallery, Smithsonian Institution, Washington, D.C.

The technique was actually rather informative for Marichal's fans; Gooch explained that the three vignettes running diagonally from top right to lower left summarized what most fans saw when Marichal pitched. The action in the other vignettes, he said, passed too fast for the eye to see. (Barrett, 2004, p. 38)

Constrained by the vertical format of a magazine cover, the nine images had to be configured more vertically and a true small multiples lateral configuration had to be avoided. Additionally, Gooch's proposed path of salience—"running diagonally from top right to lower left" (p. 38)—may arguably make sensemaking of the image a bit more challenging. But the rendering clearly demonstrates the power of traces in the visual design of pedagogy; Marichal's signature wide windup (top row, center) and exaggerated stretch catapult throwing style (center row) are easily identified and mimicked in the image. How could the same images be reimaged to instruct in a different way? An interesting experiment can be had in Figure 44, where the image is de/reconstructed and spatially and laterally realigned to simulate an animation-like representation.



Figure 44. "Juan Marichal, born 1938" reenvisioned in a horizontal composition to purposefully depict adjacency in each of the pitching positions.

Objective Four: Define and explicate progress and process. Still yet, instructional designers may require an approach that explicitly demonstrates the *procedural* and *chronological* (or temporal) relationships between objects or steps in a task. An instructional designer may use this option to, in teaching the parts of an endeavor, help the learner understand what happens

before or after a step; the intention is not to instruct about its ordinal nature, but to define how a step influences other steps (and especially proximate steps) in a process. These types of relationships are similar to the display of ordinal or trace relationships in that they are typically horizontally-composed and implicitly demonstrate an "X, then Y" aesthetic.

Guiding tactics. Progress or procedural relationships—relationships that identify the *how* of learning objects—keenly differ from ordinal relationships or trace in that

1. the nature of the demonstrated steps or tasks is specifically to explicate causal or derivative relationships; Y comes after X
2. temporal saliency is more important than, as with adjacency/trace, spatial considerations
3. the comparable relationship of tasks or steps in a process are discrete enough so they can act as “moments” (de Souza & Dyson, 2007, p. 3) or pointers (Gagné, 1985) yet not too discrete that drawn comparisons are too vast in the skill or task
4. changes in the representative images differ very little from each other except to compare the greatest amount of preferred change by the instructional and/or visual designer
5. the representation is optimally a laterally-rendered composition (never diagonally nor vertically; cf. Winn, 1993a, p. 64) because the strategy is to compare the “stopping” point of the last frame with the “starting” point of the next frame
6. the representation may include additional graphical elements such as directional lines and/or arrows (Krull & Sharp, 2006)

Design case: Men’s Health “All-Star Power” four-step workout. This instructive process diagram from the June 2010 issue of *Men’s Health* magazine (“train your muscles to work together for more explosive and effective movement,” the caption at top right claims) depicts four distinct tasks and related subtasks in an exercise regimen (Figure 45). (Parenthetically, this diagram is a

fairly comprehensive representation of how all of the above objectives—ordinal relationships, adjacency and trace, and progress/process—can be employed in one visual design.)

In each of the four synoptic small multiples in this diagram, figures and progress are distinguished by color, lateral (y-axis) location, directional arrows, or combinations of all three. The black (darkest) image represents the first step in the process; subsequent small multiple steps or tasks are represented in blue (lighter), but also made discrete by the location of directional arrows. Because of the complexities in each configuration, the visual designer has opted to use space in differing ways.

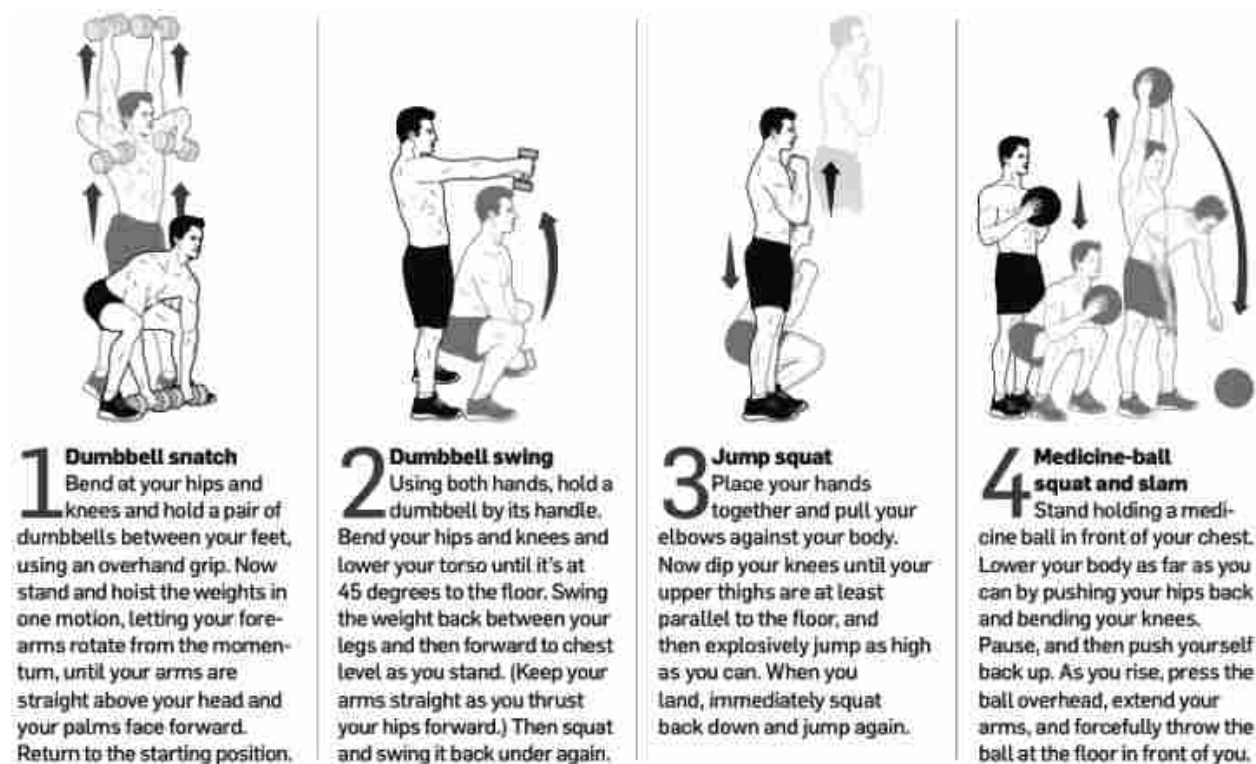


Figure 45. *Men's Health* magazine layout, "All-Star Power," four-step workout, June 2010, p. 52. ©2010 *Men's Health*/Rodale.

In Task 1 (utilizing the large numerals as labels), the task is broken down into three tasks: (a) crouching, (b) standing, and (c) raising arms. Crouching is rendered in black (although there

is no overt visual legend to explain the color system, the reader is left to use cloze skills to determine the order of the movements and the directional arrows are pointed vertically upwards, indicating the person's movement) while the two subsequent 'standing' and 'raising arms' subtasks are rendered lighter, and appear 'behind' the darker, black-lined image.

Interestingly, the visual designer did not opt to draw subtasks (b) and (c) laterally on the y-axis, but instead chose to render them in position. This decision can be juxtaposed against Task 4, where although each of the subsequent three subtasks are shown slightly to the right of the initial (black) task, their z-index placement ($z = 1$) is inconsistent with how Task 1 shows subsequent subtasks ($z = 0$). This is likely because the amount of tasks would be prohibitive to place in the same $y = 0$ space. (Task 3 does depict subtask (a) in the same $y = 0$ position and move task (b) slightly to the right because it would physically occur this way, but Task 4 could not depict its movements in the same way and maintain saliency; the images would all completely overlap each other.)

The other important graphical element is the use of the directional arrows to indicate movement. While these arrows certainly do highlight the instance of trace, they more importantly indicate the relationship of a procedural subtask to the next (e.g., morphologically, that subtask Y comes after the performance of subtask X). Fortunately, these arrows help explicate process in Task 2, which inexplicably, appears to invert the conventions employed in the other tasks. According to the legend used in Tasks 1, 3, and 4, black images are supposed to represent the first step in the process, however, Task 2 shows these reversed. The directional arrows salvage a potential misunderstanding and explicate the subtasks in the overall task.

Design case: US Historical Flags—United States of America. An interesting progress/process example can be found in Figure 46, "US Historical Flags—United States of America." This

representation depicts 39 chronological iterations of the national flag of the United States, however, it lacks any contextual instructional or visual design elements to help the learner understand the significance or relationship of the flags. Indeed, because of the lack of disparity in the stripes (creating an overwhelming amount of extraneous cognitive load) and higher-contrast differences in the Union (the blue field in the upper left corner), the viewer really only sees the 39 union images. In this case, although the image creator attempts to use small multiples to achieve a progress/process objective, the overall effect lacks instructional context. Could this illustration be made clearer and more tactical?

Initially, it would be helpful to understand the instructional objectives of the display; is the intention of the image to

1. individually and wholly depict all 39 flag iterations?
2. individually and wholly depict all 39 flag iterations and add brief related factual information?
3. individually depict just the Union differences with related factual information? (the stripes never change in any of the iterations)
4. display only major mileposts during the two-hundred thirty-plus years of the flag's usage?

If the use of small multiples is about answering “compared to what?,” “visual[ly] enforcing comparisons of changes,” and “put[ting] the emphasis on changes in data, not changes in data frames” (Tufte, 1990, p. 67), then, in revising Figure 49, the reexamined instructional objectives will be to (1) depict 39 iterations, (2) add brief related factual information, and 3) focus on the changes in data (the blue Union field, with slight context of the stripes added).

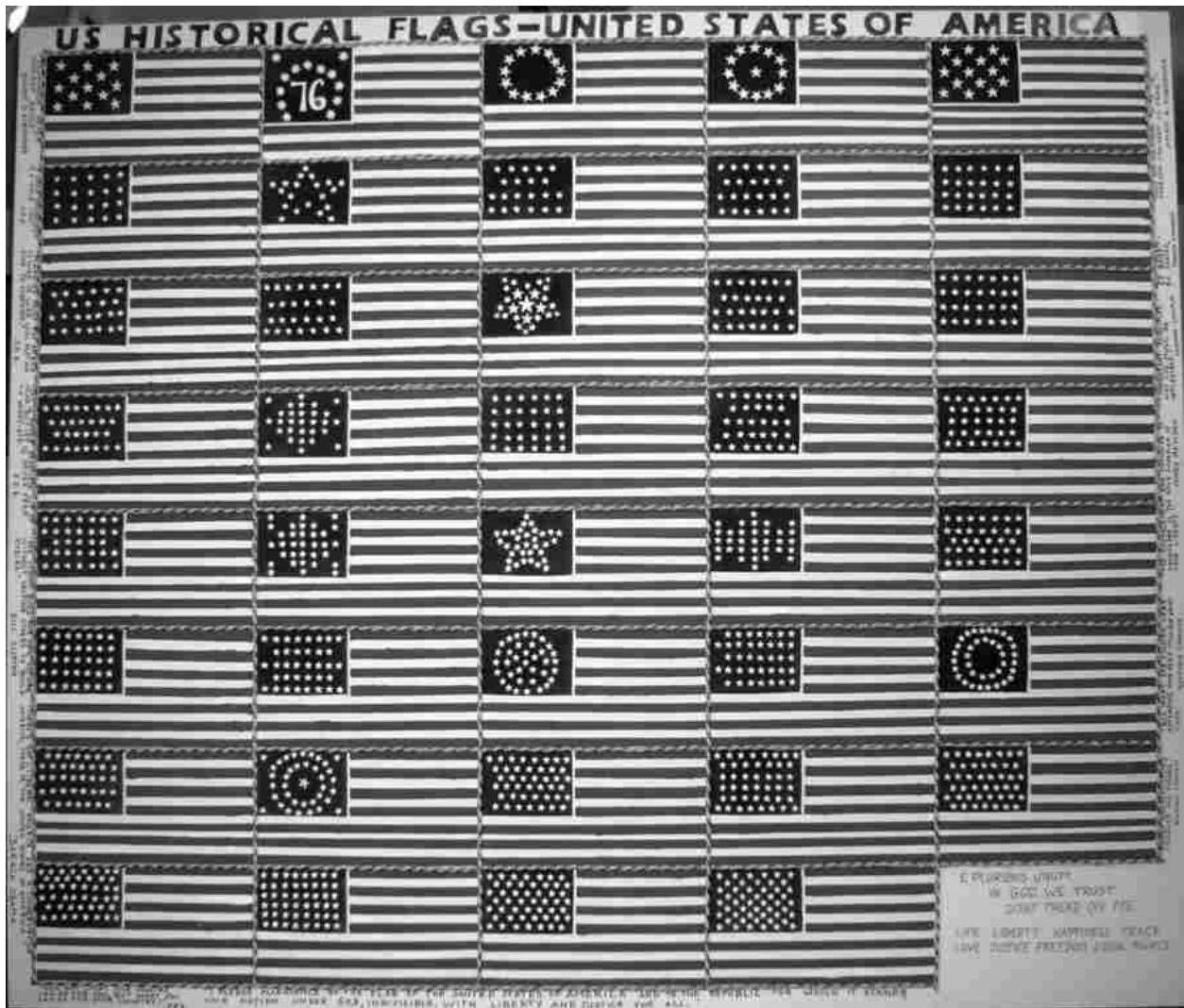


Figure 46. US Historical Flags—United States of America. Courtesy Zimand via Creative Commons BY-SA 3.0.

US Historical Flags—United States of America

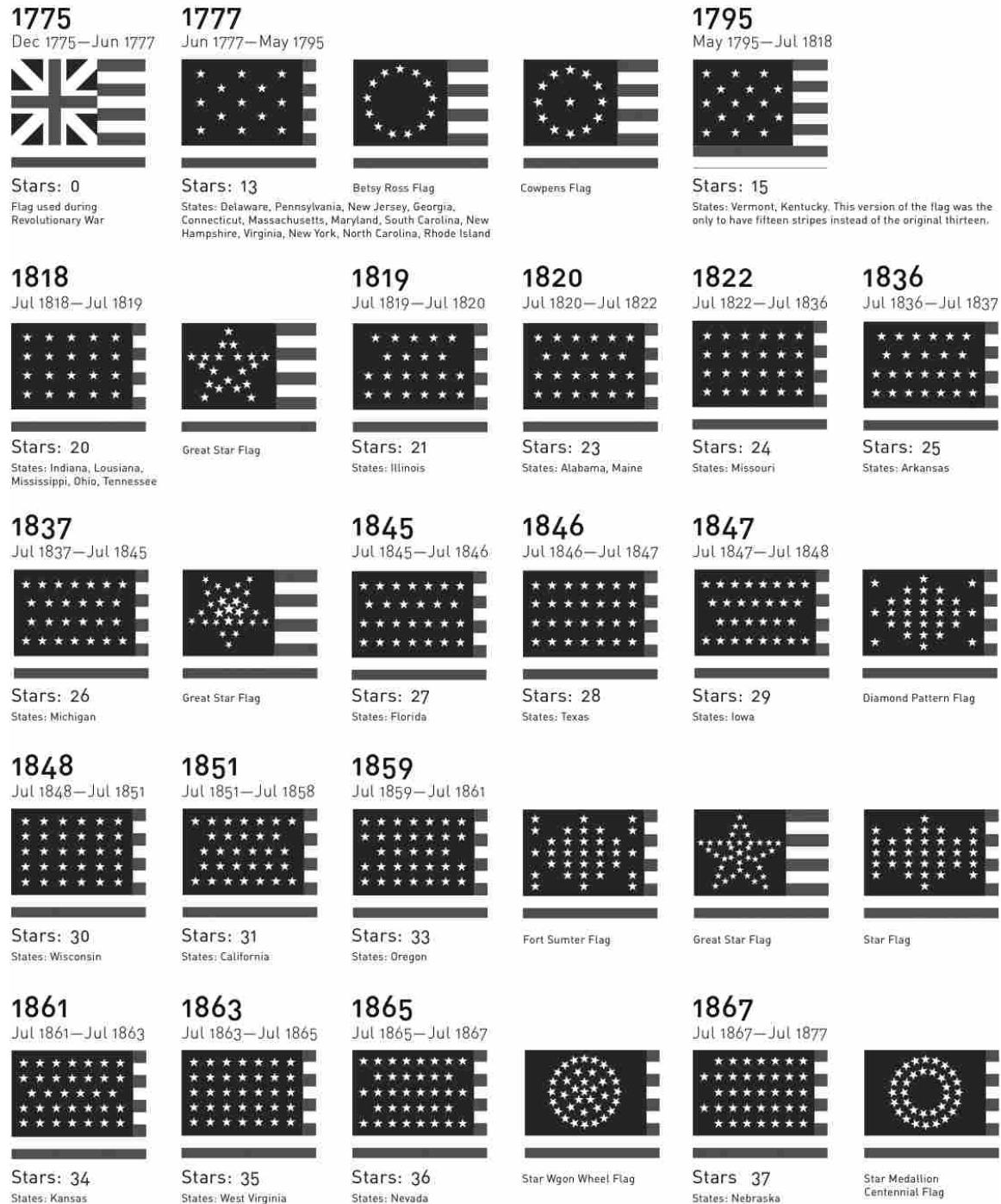


Figure 47. Reenvisioned US Historical Flags—United States of America diagram (detail) utilizing small multiples, less focus on flag stripes and more focus on iterative changes in the flag Union.

In Figure 47, individual flag ‘macroconfigurations’ (consisting of several ‘meaningful visual units’ [Winn, 1993a]) are reimagined and arranged in a horizontal small multiples composition. Each configuration now contains a year (if there was more than one flag produced in a year, then the year is omitted), a flag image, a caption or subordinate textual information, and clear and defining space around the configuration. The flag image has been reenvisioned to keep the emphasis on displaying the differences in the Union (additionally cleaning up some of the production inconsistencies of the original) while subtly maintaining its visual context within the flag shape and the striped field. Obviously, a long horizontal configuration is impractical with 39 iterations, but salience is created by grouping similar dated configurations together.

Objective Five: Define and explicate the rhetorical heterogeneity of objects. While objects in a small multiple may not be related by ordinal or task-based steps, they may be related simply by size or content or shape. While, as described in objectives Two, Three, and Four, representations of ordinal, adjacency, or progress/process small multiples may be arguably the most orthodox utilization, small multiples are still efficacious simply in highlighting rhetorical differences from one data item to another.

Guiding tactics. Instructional designers may want to simply but explicitly highlight the purposeful differences (or rhetorical heterogeneity) between objects. The purpose of using small multiples in this objective is to contrast the differences in learning objects:

1. while objects or image frames can (and must; cf. Tufte, 1990) be heterogenous, they should belong to the same or very similar object genres so as to have fidelity to the definition of small multiples as “changes in data”
2. objects or image frames might, in an effort to explicate any rhetorical relationship between the objects, deviate in size

Because the depiction of rhetorical relationships of similar objects is a fairly desired instructional objective and because the nature of those relationships is very broad and can be shown across a wide spectrum, a variety of examples are demonstrated in this objective.

Design case: “Bread and Better.” In the September 2007 issue of *Parents*, a one-page layout outlines novel and healthy sandwich options for children, touting that “kids love PB&Js...but there are tons of other fun sandwich combos” (Plant & Berg, 2007, p. 260). The layout (Figure 48) features nine different variegated open-faced sandwich options, arranged in a three-by-three grid composition, with short associated captions.

The “Bread and Better” composition does not purport to depict skills in a task; explicate ordinal, trace, or progress relationships; nor tell a narrative. Yet it clearly fits the Tuftean definition of allowing learners to “focus on changes in information rather than changes in graphical composition” (Tufte, 1990, p. 29). Rhetorical relationships between instances are clearly defined (“this piece of bread has X ingredients and another similar piece of bread has Y ingredients”) and have saliency because of the repetitive nature of the images (Wong, 1993; Leborg, 2006). (Parenthetically, the images themselves, assisted by the subordinate captions, function as quasi-*pointers* or recipes. Because of the tacit assembly—viz., the z-index of ingredients on any sandwich, for example, bread [$z = 0$], spread [$z = 1$], and toppings [$z = 2$]—depicted in the images, learners can easily reproduce the sandwiches.)

Design case: *Rancherito’s takeout menu.* A Mexican restaurant takeout menu provides another example of a helpful display of rhetorical relationships. Like the *Parents* layout, Figure 49 does not try to explain tasks nor demonstrate temporal relationships. It is effective, however, in displaying the eighteen combination plate items on the menu by illustrating how each plate is

Bread and Better Kids love PB&Js...but there are tons of other fun sandwich combos.

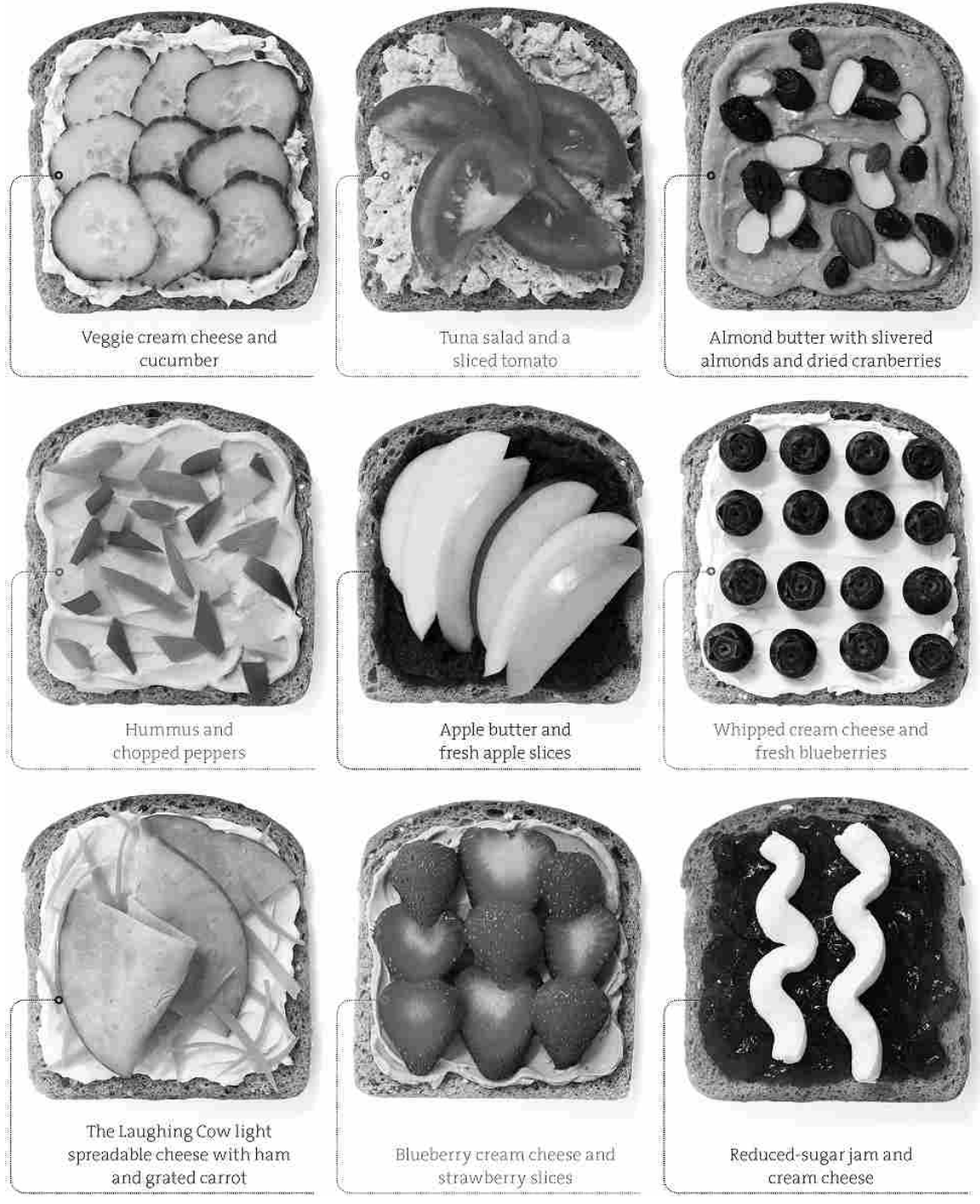


Figure 48. “Bread and Better” (detail), *Parents*, September 2007, page 260. Photography by Paula Hible. Reprinted with permission from *Parents*® magazine. ©2007 Meredith Corporation. All rights reserved.

composed and what each plate is not. That is, Plate 2 is Plate 2 because it is not Plate 1; the small multiples array of menu items clearly delineates the rhetorical differences of the food items.



Figure 49. Rancherito's takeout menu (detail). ©2010 Rancherito's.

Design case: IKEA and Hembakat är Bäst. In September 2010, Swedish furniture and design retailer IKEA commissioned publisher Forsman & Bodenfors (F&B) to create a showbook for IKEA appliances. F&B, constrained by what they felt was the mundane nature and aesthetic of appliances, tried a different approach:

It is really hard to get people excited over things like microwave ovens, fridges, and fans. But if you talk about all the delicious things you can make with kitchen appliances, things like cookies and cakes, people listen. That's why we decided to do a baking book (with kitchen appliances in it). (IKEA, 2010a)

F&B decided to take the concept further by recruiting minimalist photographer Carl Kleiner to reenvision cookbook photography. Traditional cookbook imagery is fairly uniform, the team concluded, and so F&B and Kleiner opted for a unique art direction that was simple and ingredient-focused, inspired by “high fashion and Japanese minimalism” (IKEA, 2010b). The resulting 140-page hybrid catalog/cookbook *Hembakat är Bäst* (*Homemade is Best*) starkly

features dozens of traditional Swedish recipes depicted in their ‘pre-cooked’ states, graphically demonstrating the ingredients’ rhetorical relationships to each other (Figures 50 and 51). The compositions bear striking visual and pedagogical resemblance to Duval’s 1834 *Tableau d’Histoire Naturelle* (Figure 11) which used heterogeneously-sized small multiples to interpret explicit rhetorical relationships of various insect species.

Much like Duval’s work, *Hembakat är Bäst* is, admittedly, a liberal interpretation of small multiples as representation technique, largely because the images are not equally-sized. The composite images do, however, create saliency for the ingredients because of their repetitive nature (Wong, 1993) and focus on changes in information, not composition (Tufte, 1990).

Design case: “Year by Year Summary: New York Mets.” *MLB Game Worn Jerseys of the Double-Knit Era (1970-2009)* by William Henderson is a comprehensive 40-year history and detailed catalog of uniforms worn by all 31 teams who have played in American professional baseball leagues. The work (actually a series of documents indexed on a CD-ROM), in its fifth edition (2011), even includes indices and disparate jersey tagging, patchery, logographic, and typographic considerations of teams’ apparel. Despite its encyclopedic contents, the work is fairly homespun and, by the author’s admission, Henderson, a baseball researcher and collector, intended the compilation only “as a service of sorts for other collectors” (Henderson, 2011).

Of interest to this thesis are the information design styles Henderson employs to compose the massive amounts of imagery and statistical information. In Figure 52, a sample page of the catalog demonstrates challenges to the processing of the information. Aesthetically speaking, the materials contain *heavy extraneous load*: dense spreadsheets with heavy color and line thickness formatting (an inequitable data-to-ink ratio; cf. Tufte, 1983), inconsistent and nonspecialized typesetting conventions and composition, and random photographic arrangements and

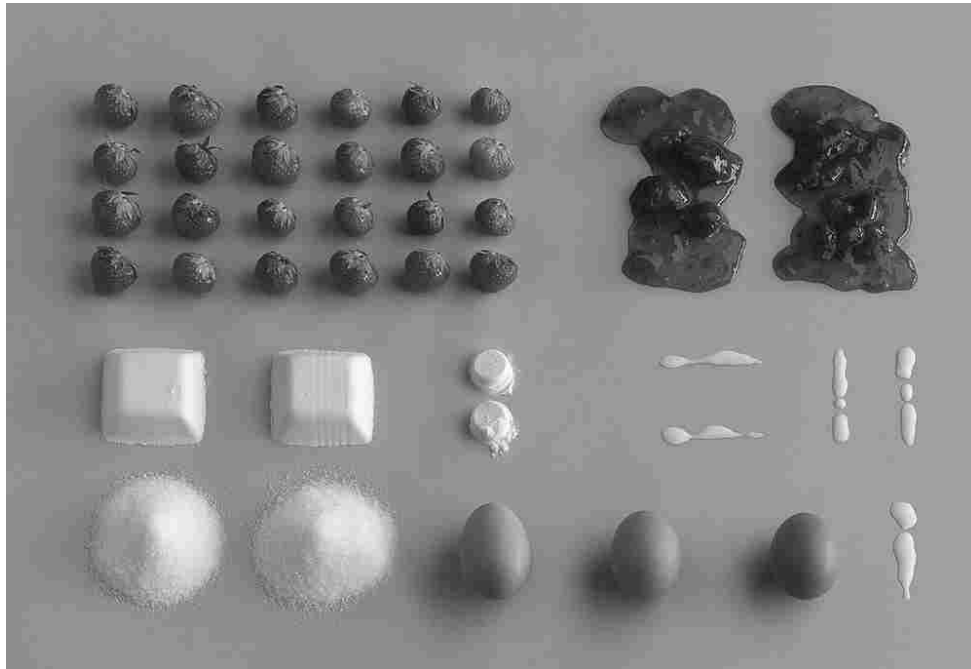


Figure 50. Photographic layout from *Hembakat är Bäst (Homemade is Best)*, Rulltårta.
©2010 Forsman & Bodenfors/Carl Kleiner.

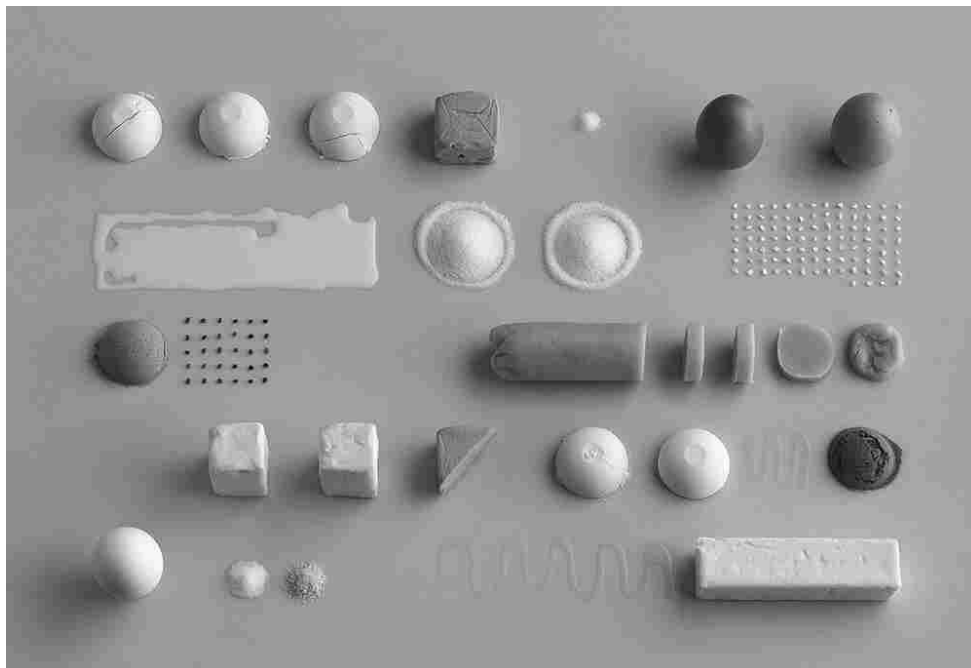


Figure 51. Photographic layout from *Hembakat är Bäst (Homemade is Best)*, Fina kanelbullar.
©2010 Forsman & Bodenfors/Carl Kleiner.

heterogenous photographic editing (e.g., flat objects placed next to three-dimensional objects and on random and variegated backdrops). While visual considerations like these are often overlooked by untrained eyes, they may also be accentuated by a lack of fidelity to instructional objectives and principles; what exactly *are* the pedagogical goals of this material? Could this information be made clearer?

New York Mets

Click on any thumbnail for more detail on that style

Overview of the Era

Mets Game Jerseys

Year	Style	Front Numbers	Back Numbers	NOB	Nameplate?	Left Sleeve	Right Sleeve	Manufacturer
1972	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Varsity 2 color	Varsity 2 color	No	-	Mets Disc	-	Wilson
1973	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Varsity 2 color	Varsity 2 color	No	-	Mets Disc	-	Wilson
1974	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Varsity 2 color	Varsity 2 color	No	-	Mets Disc	-	Rawlings
1975	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Block w/Serifs 2 color	Block w/Serifs 2 color	No	-	Mets Disc	-	Rawlings
1976	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	NL Centennial	Rawlings
	Road Gray	Block w/Serifs 2 color	Block w/Serifs 2 color	No	-	Mets Disc	NL Centennial	Goodman
1977	Home White PS	Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Block w/Serifs 2 color	Block w/Serifs 2 color	No	-	Mets Disc	-	Goodman
1978	Home White PS	Front Block 2 color	Block 2 color	No	-	Mets Disc	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
1979	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
1980	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
1981	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	Mets Disc	-	Rawlings
1982	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
1983	All Blue Home	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
	All Blue Road	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
1984	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
1985	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	-	Rawlings
1986	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	15th Ann Versari	Goodman
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	Yes	-	15th Ann Versari	Goodman
1987	Home White PS	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	No	-	-	Rawlings
	Road Gray	Front Block 2 color	Block 2 color	Block Cond/Cond 2 color	No	-	-	Rawlings

Figure 52. “Year by Year Summary: New York Mets,” *MLB Game Worn Jerseys of the Double-Knit Era*. ©2009 William Henderson.

From viewing the New York Mets’ year-by-year summary, the reader might surmise that the goals of the material might be to

1. show as many pictures of categorized jerseys as possible and/or
2. show as many pictures as possible of or display Henderson's vast personal apparel and patchery collection (a reputational effort to fellow collectors) and/or
3. chronicle temporal or historical changes in the jersey's aesthetics (implied by the title of the book as well as headlines such as "1978–1981 Road Jersey," "1983–1990 Home Jersey," and "1981–1986 Home Batting Jersey" and/or
4. explicate nuances or details of jersey components (tagging, patchery, logography, and typography)

If the instructional objectives of *MLB Game Worn Jerseys* are (1) and/or (2), redesigning the materials to function more like an exhibition or museum catalog, displaying exhaustive imagery banks of inventory, related specification information, and producing a fully cross-referenced index would be more appropriate. However, if (3) and (4) are truly the goals of the material, small multiples are an efficient way to depict the rhetorical differences—temporal, aesthetic, or otherwise—of the data which illustrates each category.

Figure 52 shows page 2 of Henderson's New York Mets section: a large, heavy spreadsheet juxtaposed against eleven thumbnail-sized images of jerseys. There is a laudable effort to use small multiples-like images to demonstrate varying uniform styles, however, the imagery is overwhelmed by the spreadsheet. In actuality, save very slight differences in number styles (columns two and three) and manufacturer (column eight) between 1972 and 1977, and number/name styles (columns two, three, four, and five) and manufacturer (column eight) between 1978 and 1987, there is a very little difference in the presented data. Because of the obvious visual differences (pinstriping, collar piping, and logography) in the jerseys, there is arguably more salience in comparing the first two thumbnails than in attempting to parse the first twelve rows of

the chart. The extraneous cognitive load (cf. van Merriënboer & Sweller, 2005) found in the spreadsheet might easily be reduced and more efficiently managed by showing small multiples of the jersey types. Figure 53 shows this page reenvisioned, using small multiples.

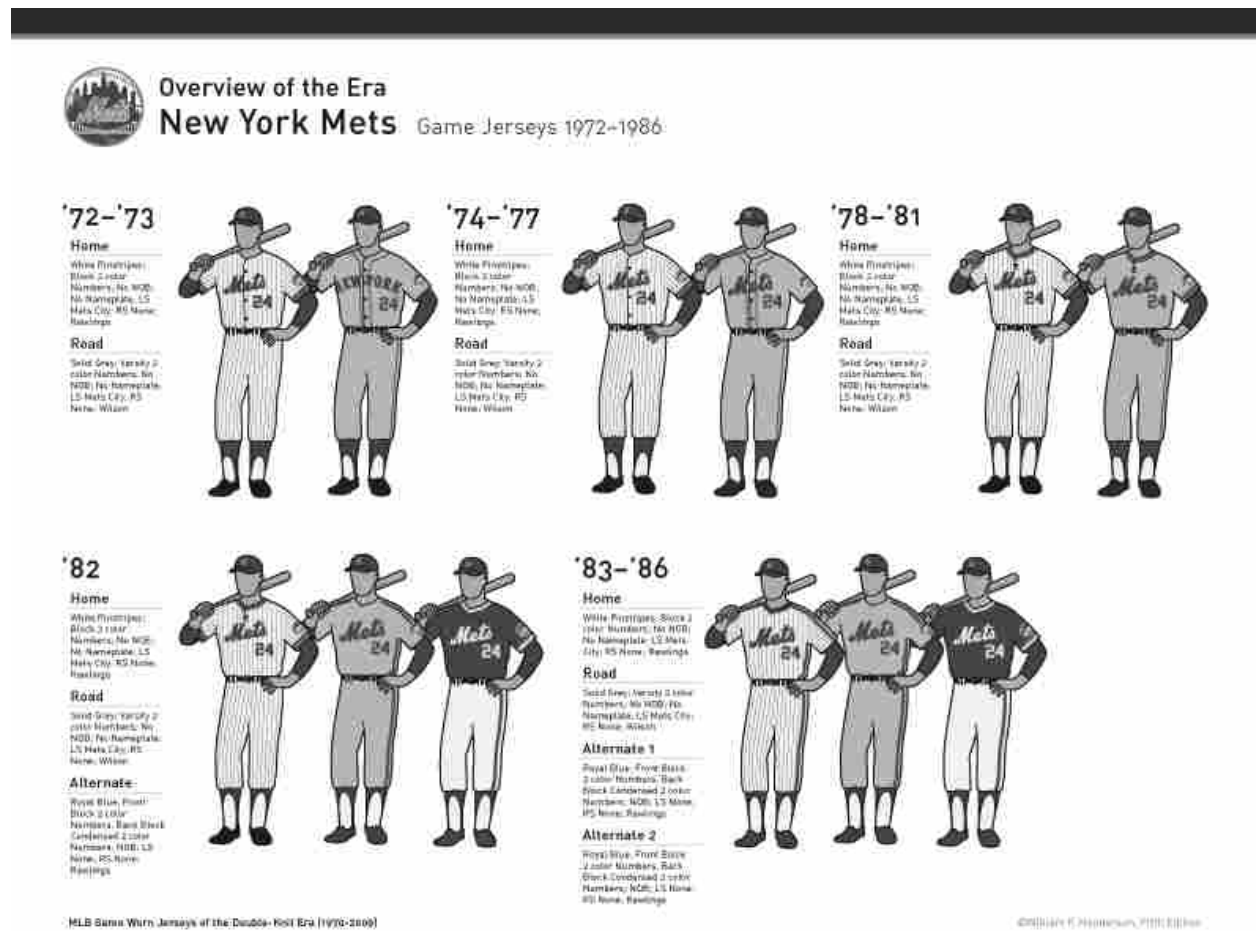


Figure 53. Reenvisioned “Year by Year Summary: New York Mets” utilizing small multiples and chronological groupings; player renderings based on styles by Marc Okkonen.

Photographs are replaced with illustrations, which are easier to keep rhetorically neutral and consistent (or *repetitive*, cf. Wong, 1993) (the variations in photography add to additional unnecessary rhetoric and extraneous cognitive load) and more care has been given to reduce the fundamental unit of comparison to the year and not the novel instance of the jersey. Coloring,

typographical, and logographical considerations have been made primarily visual (by the creation of small multiples) and secondarily textual. Again, if the instructional goal is to depict historical change, then each jersey set needs salience; as Tufte (1990) defined, “compared to what?” Small multiples bring comparisons of change and depictions of difference.

Objective Six: Define and explicate the various steps of a story or narrative. Whether informed by principle or by actual execution, storytelling is an important instructional design strategy. McDonald (2009) has documented how stories motivate behavioral changes and recontext “learned information in real-world environments” (p. 112) and Andrews, Hull, & Donahue (2009) have written about the contribution of storytelling as design practice in case-based, narrative-based, scenario-based, and problem-based instruction (p. 6).

Instructional designers often want to incorporate elements of narrative in their designs. Chapter 1 gave two historical samples of narrative: the five-day forecast (Figure 5) and baseball scorecard (Figure 6). Both cases tell the beginning and end of a story while also incorporating important storytelling principles such as conflict, authenticity, and entertainment (McDonald, 2009). A visual narrative can be a timeline, where several events are made relevant to each other by Gestaltian relationships of similarity, proximity, symmetry, and common fate; adding small multiples to this type of visual design solution enhances its efficiency to highlight related parts of a narrative.

Guiding tactics. Instructional and visual designers may want to explicitly identify steps or parts of a narrative. Because certain canvases (printed material, most webpages) are not inherently capable of conveying animation or time, small multiples can be efficient in defining parts of a story provided that

1. typically only one frame (i.e., photograph or illustration) or snapshot of the narrative is shown at a time
2. individual frames or references, however, may function as a pointer (Gagné, 1985), representing various important frames, scenes, or dates within the narrative
3. while objects or image frames can (and must; cf. Tufte, 1990) be heterogenous, they should refer to the same story or narrative so as to have fidelity to the definition of small multiples as ‘changes in data’
4. objects or image frames typically remain the exact same size

Design case: *Che idea far verde la neve*. Italian art director Francesco Franchi is well recognized for his work on *IL—Intelligence in Lifestyle*, the monthly news magazine of Italian political and economic newspaper *Il Sole 24 ORE*. His visual design approach on *IL* between October 2008 and 2011 is characterized by a crisp unmistakable information design style, combining bold and surgical typography with graphic and diverse illustration styles, tempered dyadic and triadic color schemes, and a strict but playful adherence to a six-column grid system. Many of his compositions generously employ small multiples as comparative, ordinal, and progression devices, however, the morphology of “Che idea, far verde la neve” (Figure 54) parlays the use of small multiples into a dual-layered narrative.

The February 2010 issue of *IL* (entitled *Materia prima*, or “Raw Materials”) contains compositions which deal with the exploration of harvesting sustainable and basic consumable resources. Political topics such as the search for mineral resources and the increasing purchase of land by the Chinese are treated in Franchi’s signature style and framed by area charts crossbred with horizontal timelines, creating a visual narrative of mining and land acquisition efforts over the past decade.

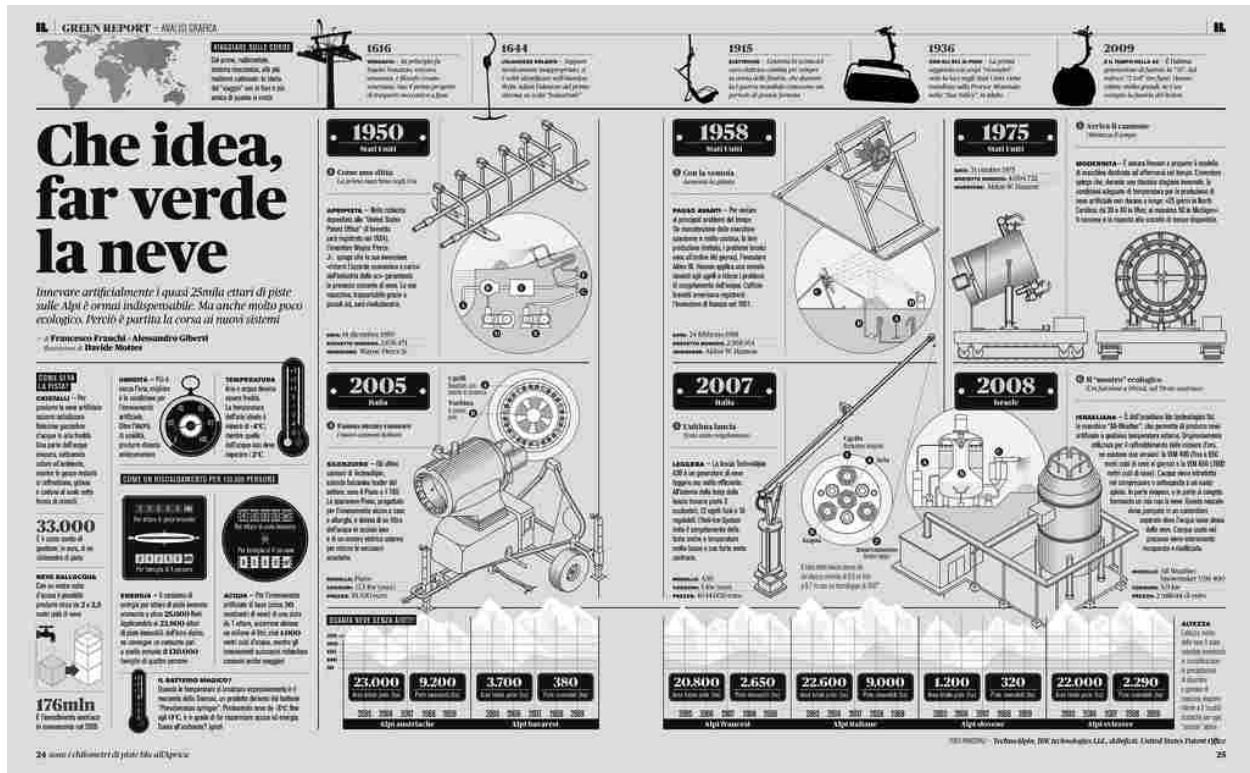


Figure 54. “Che idea, far verde la neve” (“That idea, to make green the snow”), magazine layout from *IL—Intelligence in Lifestyle*, February 2010, pp. 24–25. ©2010 Francesco Franchi.

In “Che idea, far verde la neve” (“That idea, to make green the snow”), the efforts of the Italian ski industry to create a more environmentally-friendly artificial snow creation process are depicted. “Innevare artificialmente i quasi 25mila ettari di piste sulle Alpi è ormai indispensabile (The nearly 25 thousand hectares of artificial snow on the slopes of the Alps is now essential),” the subhead reads. “Ma anche molto poco ecologico. Perciò è partita la corsa ai nuovi sistemi (But very little green. Thus started the race for new systems)” (Franchi, 2010). Punctuated by illustrator Davide Mottes’ simple monotone images, Franchi first roofs the composition with a narrative timeline of ski transportation technologies from 1646 to 2009. The five small multiples or macroconfigurations (Winn, 1993a; cf. Chapter 2) comprise

- comparative silhouettes to visually represent the technology
- salient (Waller, 1982) highlighted years
- a half-point dividing line
- a title set in a capitalized sans-serif typeface
- a description of the technology in an italicized serif typeface

A much larger timeline illustrating advances in snow creation technology commands the majority of the layout space and is composed of many of the same elements as the transportation technology timeline:

- a ‘yearplate,’ containing the date and locale (Stati Uniti [United States], Italia, or Israele) of the innovation and additional graphic elements
- a title block, including an ordinal number character, title, and subtitle, and horizontal subdividing one-half point line
- a text block, including a subhead and body copy
- a vertical subdividing one-half point line
- a statistical information block, including creation or first usage date, inventor, development cost, and/or patent number
- an illustration cluster, including an overall rendering of the technology and various insets and details
- in some cases, caption and explanatory text with matching ordinal number characters

Although similar to describing ordinal or rhetorical relationships, both small multiples timelines more pointedly tell a story rather than make comparisons.

Design case: “*Tara Duncan ‘The 4 Parchments’*” animated short storyboards. Like objective Three, storyboard representations may also be considered orthodox interpretations of a

small multiples approach: by definition, storyboard frames are ‘small,’ ‘multiple,’ and inherently convey “changes in data” (Tufte, 1990, p. 67) from frame to frame. Storyboards are narrative, often roughly-fashioned triptychs that can help instructional designers teach sequences and processes while also conveying a metastory.

Originating in early 20th-century animation and film studios, storyboarding became popularized in advertising agencies and especially the defense and aerospace industry of the 1960s as the preferred presentation and proposal development method (Starkey, 2000). Interaction and user experience designers map out *wireframes* or information and behavior flows using storyboards; importantly, contemporary instructional designers use storyboards to, similar to the utility of small multiples, “provide a simple means of understanding the relations of one element to the overall scheme, and how various knowledge elements can become interconnected” (Varvel & Linderman, 2005, p. 1).

Figure 55 is a 36-panel storyboard created for an animated short by French illustrator/artist Jordi Valbuena. The storyboard depicts the actions of the protagonist once she is shrunk down to a small size; of consequence, however, several small multiples relationships are depicted in this storyboard (panel numbers are counted from top-left to bottom-right):

- action (panels 4–7)
- continuity (panels 8–9, 27–28)
- nuance (panels 19–20)
- point of view (panels 22–25)
- “camera” angle (panels 29–32)

Instructional designers may find a helpful confluence in combining objectives One and Six by displaying steps in a task in a storyboard modality.

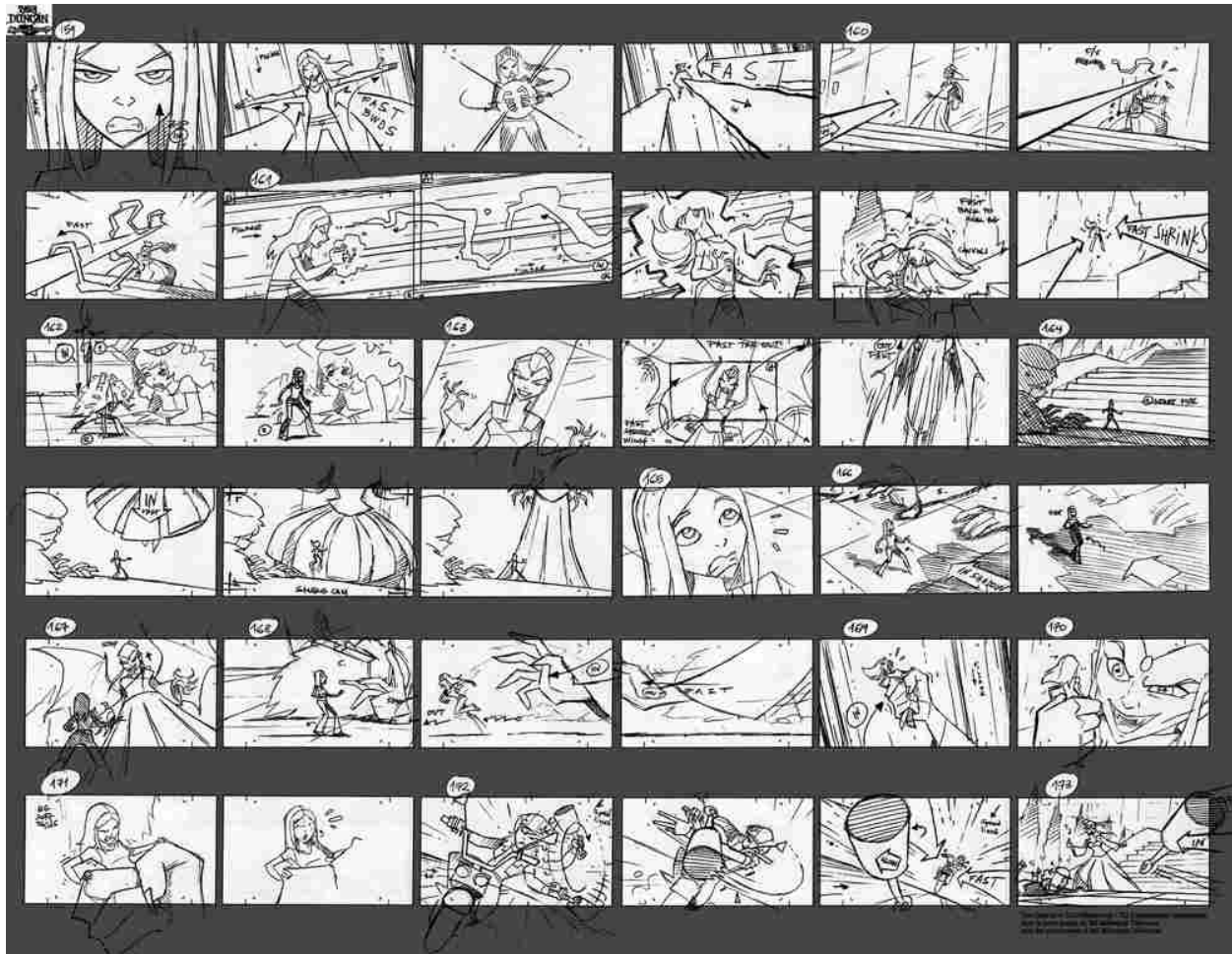


Figure 55. Storyboard for animated short, “Tara Duncan “The 4 Parchments”” ©2010 Moonscoop / DQ Entertainment International, with the participation of M6 Métropole Télévision.

Objective Seven: Create an instructional or information design aesthetic and/or metavoice. Because small multiples have tacit compositional properties of repetition and informational complexity (cf. Franchi, 2010), they tend to be perceived as *information design* or *infographics*. Indeed, a review of information graphics in the 2009 *Communication Arts* Illustration Annual (considered one of the preeminent exhibitions of the year's best illustration work) shows 10 of 22 (or 45%) pieces that include some kind of small multiples display. An evaluation of the American Institute of Graphic Arts' permanent online "Information Graphics: Design of Understanding" collection numbers 24 of 95 (or 25.3%) entrants with some kind of small multiples/grid layout (AIGA, 2011).

While it is arguable that any small multiple composition, at its fundamentals, is about comparing any rhetorical differences between X, Y, and Z, as in objective Five, there are nuances and specialities in rhetorical differences. This objective recognizes the appeal or aesthetic of information design as the aim of an instructional objective.

Grid systems as scaffolding. Although the earliest compositional grid systems date to the Sumerian era (2800 BCE), typographic and other layout grid systems have their first practical etymologies in medieval and pre-Renaissance scriptural and pedagogical manuscripts. Jan Tschichold, Josef Müller-Brockmann, and other neo-Bauhausian International Style and Swiss designers of the 1950s (Meggs, 1983) pushed for predictability and order in mathematical grids and columns and hyperaligned typographic blocks and elements. Vinh (2011) has noted that grid systems are particularly suited to webpages because they give "order, continuity, and harmony to the presentation of information" (9), aid in the prediction of information geography (e.g., 'X' is always found in the top right of the grid), and anticipate scalability behaviors of new items added to the set.

Because grid systems promote Gestaltian compositional principles like repetitiveness, similarity, proximity, and common fate, they are excellent vehicles for small multiples and/or small multiples-like structures.

Guiding tactics. Instructional designers may want their designs to be perceived as informational or infographical. Compositions which leverage several diagrams, charts, graphs, numerical and typographic visualizations—whether or not these elements actually semantically function as any of the six previous objectives defined in this thesis—tend to manifest an instructional aesthetic:

1. objects or image frames may or may not display related concepts (e.g. a horse, a planet, and an insect) but homogeneous sizing of these concepts portrays a Gestaltian aesthetic of common-fate, similar, repetitive, related objects
2. a layout or composition of several (although possibly unrelated) similarly sized, shaped, colored, or semantic objects will benefit from an orderly, navigable configuration

Design case: *Pictorial Dictionary of Eliza Pughe, 1843.* A curious holding at the National Library of Wales is a small 128-page hardbound, hand-drawn pictorial dictionary. Notes (by an unknown contributor) on the inside of the book (Pughe, 1843) identify its creator as “Miss Eliza Pughe, Côch y big, Clynnog” (iii), and (by the book’s donor) “born circa 1831, died 1850” (p. i). This homespun sketchbook is notable for its historical (and posthumous) contribution to early Welsh education (it is evidence that alternative means of education were pursued during a period of active governmental repression of the Welsh language; cf. Jones & Martin-Jones, 2004), but it is also an intriguing use of small multiples as a pedagogical and organizational aesthetic (Figure 56).

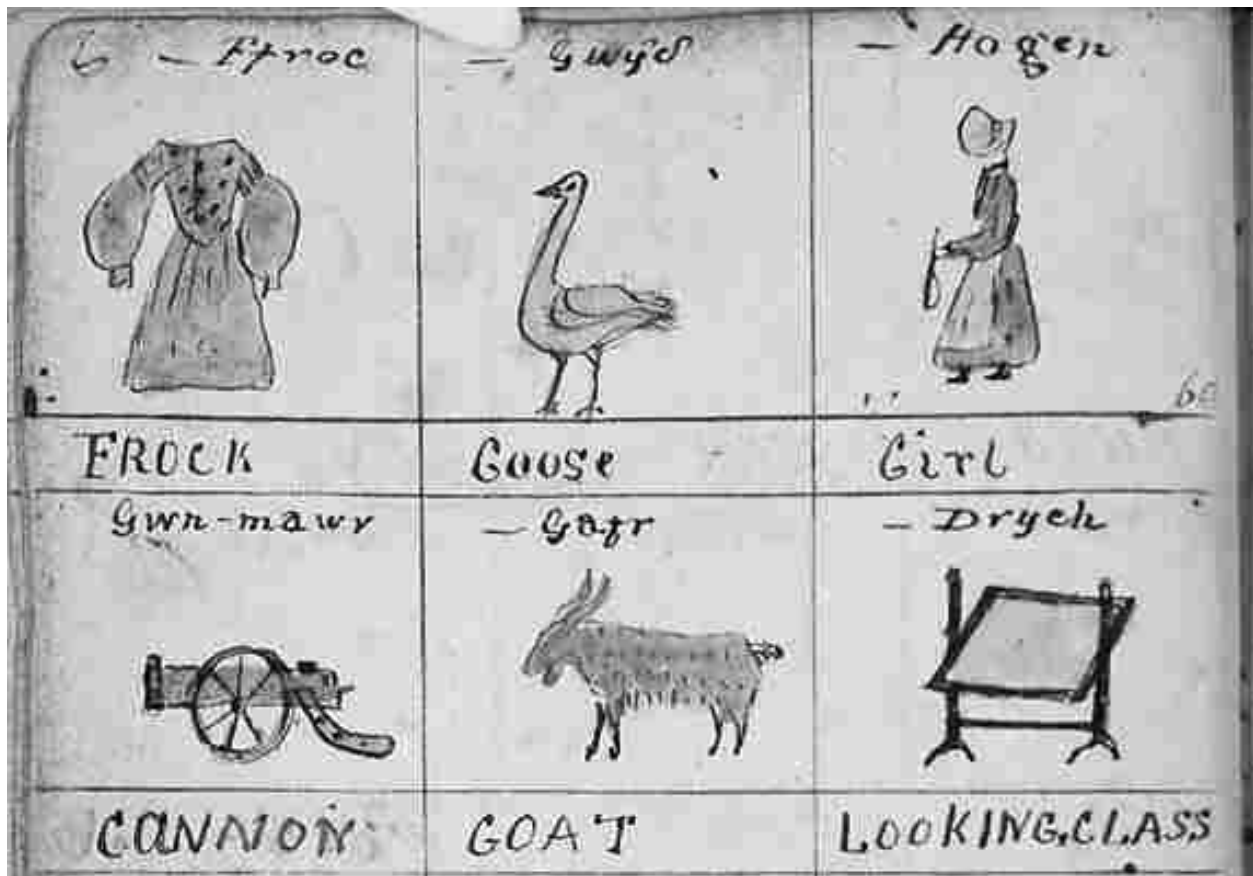


Figure 56. Pictorial Dictionary of Eliza Pughe, page 6 (1843; detail). By permission of The National Library of Wales.

Miss Pughe was deaf (Pughe, 1843, p. i) and was raised in a wealthy family of physicians on the northwestern coast of Wales in Caernavonshire. As deaf (much less any public) education was nearly nonexistent for Welsh children in the mid-19th century, she was likely tutored by governesses and extended family (Green, 2009) on their Clynog estate. Eliza was between 13 and 15 years old when she began her prodigious dictionary, filling it with nearly 1,600 English, Welsh, and visual vocabulary word entries.

The first eight pages of Eliza's dictionary present 81 entries in a mostly alphabetical order (perhaps transferred from a contemporary children's primer or dictionary), playfully yet

rudimentally colored and arranged in a simple three-by-four grid system. The arrangement allowed for “order...and harmony [in the] presentation of the information” (Vinh, 2001, p. 9), referential saliency (‘girl’ or *hogen* is always found in the top row of page six), and scalability as Eliza’s instruction progressed. The remaining pages include 1,500 more entries chronicling her longitudinal lexical and conceptual development (in many cases, pairing indigenous Welsh with English entries) and demonstrates how she may have used related and proximal vocabulary entries to build schema around various conceptual domains.

Design case: Radar magazine. Indicative of a late 20th century layered and informational editorial style made popular by visual designers like Kit Hinrichs, Alexander Isley, and Luke Hayman, *Radar’s* recurring “The List: Random Notes on Modern Life” section includes several small multiples displays. These illustrations are not intended to highlight task steps, ordinal relationships, rhetorical relationships, or narratives at all, but the end intended result is an asemantic parody masked in an informational aesthetic.

The “The List” layout from September 2008 features ten geometrically arranged tongue-in-cheek infographic-looking mini-features built on a six-column grid. Satirical topics range from political figures to sports to federal agencies and are presented using bar charts, histograms, Olympic pictograms, comparative illustrations, mapping, and typography. Each section is identified with an ordinal number, spoofing the informational nature of ordinal lists and figure numbers (e.g. “4.” or “Figure 2.”) while the restrained use of three colors mimics the use of absolute and semantic color labels found in chart legends (e.g., red equals X, blue equals Y). In all, there are no real semantic small multiples displays which define rhetorical relationships in the layout, yet the composition feels like a serious informational graphic.



Figure 57. “The List” from Radar Magazine, September 2008, p. 16–17. ©2008 Pentagram.

Summary

In this chapter, a critical analysis of 17 design cases and artifacts has resulted in the identification of seven instructional objectives that visual and instructional designers may want to accomplish in their designs. A targeted literature review catalogued the historical treatment of small multiples and their pedagogical and cognitive virtues in Chapter 2; observations of design cases and visual design artifacts resulted in seven instructional objectives and associate guiding tactics delineated in Chapter 4. These objectives use small multiples to accomplish their purposes and have overlapping sets of recommended guiding tactics which inform their execution. A consolidated working list of these objectives and their associated guiding tactics is given in Chapter 5.

Chapter 5: Application Of The Findings

This study, through a critical analysis of design cases, identified seven instructional objectives that visual and instructional designers may want to accomplish in their designs (Figure 58). Importantly, these objectives use *small multiples* (Tufte, 1983, 1990) to accomplish these purposes and have sets of recommended guiding tactics which inform their execution.

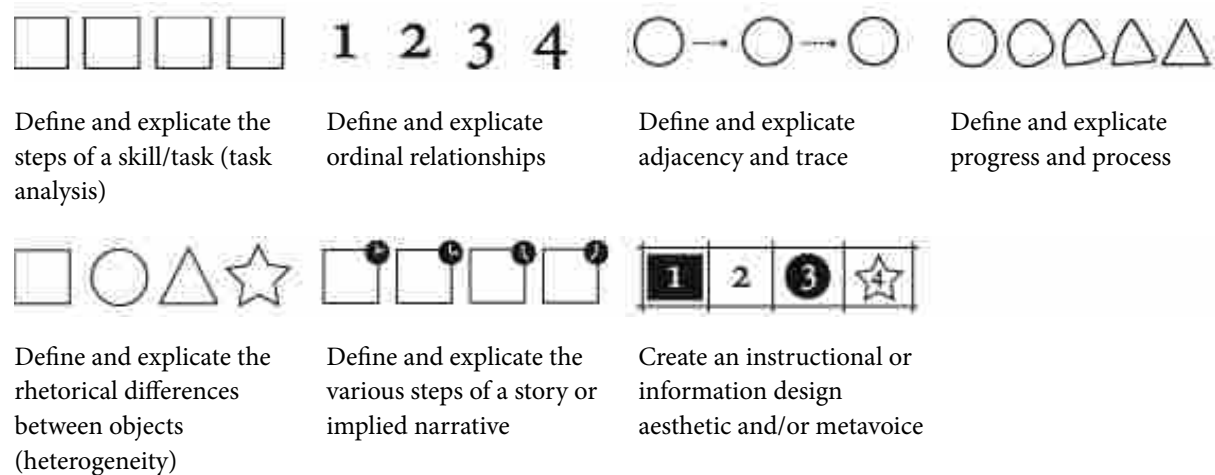


Figure 58. A graphical representation of objectives accomplished by small multiples.

A Working List Of Instructional Objectives And Guiding Tactics For Practitioners

As identified in Chapter 4, each objective can be paired with various tactics that can aid in the execution of a small multiple. This chapter is intended to distill the findings from Chapter 4 into a simpler, easy-to-scan checklist or “cheat sheet” for designers looking to ensure that their objectives can be met by small multiples applications. In this section, *designers* refers to both instructional and visual practitioners.

Objective One: Define and explicate the steps of a skill/task. Small multiples are efficient in helping designers make *how-tos* and *task analyses* visual and tangible. Their natural morphology of non-animated, individual yet comparative representations makes lists of tasks and

skills a natural fit for this technique. Designers should note the guiding tactics in Table 3 if they are designing for this objective.

Table 3.

Objective One (defining and explicating the steps of a skill/task) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate the steps of a skill/task	<ul style="list-style-type: none"> • that the nature of the task(s) is general and (other than the unavoidable tacit perception of left-to-right as chronology), rhetorically neutral • that only one frame of the task should be shown at a time • that an individual frame might function as something that can represent a handful of steps or subtasks within the task • how images might be situated closer or further apart from each other on the horizontal axis <ul style="list-style-type: none"> - if images overlap, for all frames to be visible and to indicate accepted norms of “before,” “now,” and “after,” must display a degree of transparency

Objective Two: Define and explicate ordinal relationships. Small multiples are efficient in helping designers make *ordinal relationships* and *processes* visual and tangible. Though there may be perceived overlap with other objectives, designers can still add value in the nuance of purposefully and explicitly clarifying the overt ordinal positions—the *when* of learning objects—of given tasks or processes. Designers should note the guiding tactics in Table 4 if they are designing for this objective.

Table 4.

Objective Two (defining and explicating ordinal relationships) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate ordinal relationships (the <i>when</i> between objects)	<ul style="list-style-type: none"> • to not focus more on adjacent or trace relationships than on the step or the task • that the ordinal nature of the task is supremely important to the instructional goal(s); in other words, although it may be assumed that any task order is always ordinal (“X,” “Y,” and “Z”), the designer <i>requires</i> that the ordinal nature be made explicit (first must be first: first, “X”; second, “Y”; and third, “Z”) • including an explicit graphical numeral system to clearly explicate between steps

Objective Three: Define and explicate adjacency and trace. Small multiples are efficient in helping designers make *spatial* or *geographical* relationships visual—the *where* of learning objects—(showing the existence of *spatial* rhetorical relationships between X and Y) and tangible (*how* and *why* and when X and Y are related). This is likely the most orthodox interpretation of Tufte’s propositions (Tufte, 1990) because they often show data change in the most obvious way. Designers should note the guiding tactics in Table 5 if they are designing for this objective.

Table 5.

Objective Three (defining and explicating adjacency and trace) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate adjacency and trace (the <i>where</i> between objects)	<ul style="list-style-type: none"> • that the relationship of tasks or steps may require several salient static images; because of the quantity of required images: <ul style="list-style-type: none"> - the representation should include enough small multiples to create enough data for the learner to compare but not more than can be perceived in a single view - that the small multiples should be sized “relative to the visual field” (Winn, 1993a, p. 64) and that a learner can view all of the frames globally, and then rapidly and repeatedly parse them individually; the ordinal nature of the tasks will therefore be assumed to be ‘X,’ ‘Y,’ and ‘Z’ - that the representation should be horizontally composed (not diagonally nor vertically) because the strategy is to compare and/or contrast and/or predict over many frames

Objective Four: Define and explicate progress and process. Small multiples are efficient in helping designers make *procedural* or *chronological* (or temporal) relationships—the *how* of learning objects—visual and tangible. A designer, in an attempt to instruct about the components or steps in a learning system or event, may desire to depict process and progress; this approach helps a learner understand how a step influences other steps (and especially proximate steps) in a process. The serial character of these renderings implies the ‘left-to-right as chronology’ rhetoric inherent in their display (Machin, 2007). Designers should note the guiding tactics in Table 6 if they are designing for this objective.

Table 6.

Objective Four (defining and explicating progress and process) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate progress and process (the <i>how</i> between objects)	<ul style="list-style-type: none"> • that the demonstrated steps or tasks is specifically to show causal or derivative relationships; Y comes after X • that temporal saliency is more important than spatial considerations • that the relationship of tasks or steps in a process are discrete enough so they can represent a handful of steps or subtasks yet not too discrete that drawn comparisons are too vast • that changes in images differ very little from each other except to compare the greatest amount of preferred change by the designer • that the representation should be horizontally composed (not diagonally nor vertically) because the strategy is to compare the <i>stopping</i> point of the last frame with the <i>starting</i> point of the next frame • including graphical elements such as directional lines and/or arrows

Objective Five: Define and explicate the rhetorical heterogeneity of objects. Small multiples are efficient in helping designers make *rhetorical relationships* between objects visual and tangible. In contrast to objectives Two, Three, and Four, where the aim is to demonstrate nuanced difference, objective Five aims to identify the rhetorical heterogeneity of objects in the same composition. Designers should note the guiding tactics in Table 7 if they are designing for this objective.

Table 7.

Objective Five (defining and explicating the rhetorical heterogeneity between objects) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate rhetorical heterogeneity (the different implicit, explicit, neutral purposeful relationships) of objects	<ul style="list-style-type: none"> • that while objects or images should be heterogenous, they should also belong to the same or very similar object genres so they represent “changes in data” • that, in order to define rhetorical relationships between objects, images may deviate in size

Objective Six: Define and explicate the various steps of a story or narrative. Small multiples are efficient in helping designers make *story* or *narrative* relationships visual and tangible. Storytelling is an effective and constructive instructional design strategy (McDonald, 2009; Andrews, Hull, & Donahue, 2009) and, to leverage these benefits, designers may wish to incorporate elements of narrative in their designs. Timelines or storyboards inherently display several events or salient occurrences over a preferred time period and small multiples leverage Gestaltian compositional principles to highlight related parts of a narrative. Designers should note the guiding tactics in Table 8 if they are designing for this objective.

Table 8.

Objective Six (defining and explicating the various steps of a story or narrative) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Define and explicate the various steps of a story or narrative	<ul style="list-style-type: none"> • that only one frame of the task should be shown at a time but that the individual frames or references often represent a handful of steps or subtasks, representing various important frames, scenes, or dates within the narrative • that while objects or image within frames can heterogenous, they should also refer to the same story or narrative so they represent “changes in data” • that objects or image frames should be homogeneously-sized

Objective Seven: Create an instructional or information design aesthetic and/or metavoice. Small multiples are efficient in helping designers make their designs be perceived as *informational* and/or *infographical*. Perhaps a designer doesn't want to prioritize data change or nuance in rhetorical difference; boilerplate compositional principles like alignment, hierarchy, and grid systems along with Gestaltian values of repetitiveness, similarity, proximity, and common fate are natural expressions of small multiples and/or small multiples-like structures. Compositions that include multiple diagrammatic and typographic visuals may be asemantic but still carry a small multiples aesthetic. Designers should note the guiding tactics in Table 9 if they are designing for this objective.

Table 9.

Objective Seven (creating an instructional or informational design aesthetic and/or metavoice) and guiding tactics.

If I want to (<i>Objective</i>)	I should consider (<i>Guiding Tactics</i>)
Create an instructional or information design aesthetic, metaaffect, and/or metavoice	<ul style="list-style-type: none"> • that although objects or image frames may or may not compare related concepts (e.g. a horse, a planet, and an insect), homogeneous sizing and organization of these concepts portrays an aesthetic that looks and feels informational • that a layout or composition of several (although possibly unrelated) similarly sized, shaped, colored, or semantic objects will benefit from an orderly, navigable configuration

Summary And Future Research

The purpose of this study was to identify and demonstrate how the cognitive and visual design tactic of small multiples can be useful in the representation layer of instructional designs. As delineated in the review of literature and data findings, small multiples truly are far more than the sum of their individual components. They decrease cognitive load, improve learning material aesthetic, and enhance learner perception and comprehension of instructional content and subject matter. Additionally, the observed data and analysis here has resulted in seven instructional objectives and related guiding tactics that visual and instructional designers might use to accomplish their designs.

Admittedly, in the definition of these objectives, room for overlap and nuance is observable. Future research in this area might focus on possible additional or subtractive comparative nuances that can be addressed by small multiples or expansive studies on single instructional objectives and/or the efficacy of their related guiding tactics. Another related study might be conducted on how the appeal of collections, collecting behaviors, and grouping theory impact the appeal of small multiples displays for certain learners.

Regardless of the need for further research, small multiples can and will assist design practitioners in creating pedagogical materials that are conducive to an ever-increasingly mature and demanding visual learner.

Appendix A: List of examples of small multiples considered for this study

use?	artifact	task	ordinal, trace, or process	relation- ship	narrative	aesthetic
	Simon Evans “I have everything” blog entry				×	
	baseball scorecard		×		×	
	Muybridge <i>Sallie Gardner at a Gallop</i>	×	×			
	five-day forecast		×	×	×	×
×	Carpentry for Children instructions (+ revise)	×	×	×	×	
×	Juan Marichal Time magcover (+ revise)		×		×	
×	Mets sample chapter (+ revise)			×	×	
	mitts/gloves comparison		×	×	×	×
×	Finnish SL dictionary (incl. overlapping)	×	×			
	David McCaulay		×	×	×	
	tying a tie	×	×			
	tying a scarf	×	×			
	Apple installation magic mouse, trackpad	×	×	×		
	Mendeley installation instructions	×	×			
	01-02-03-04 web layout		×		×	×
	dashboard pattern mobile devices	×		×		
×	skype.com instructions	×	×			
×	<i>Tennis</i> maglayout		×		×	
	Franchi <i>Ultissime</i> maglayout			×		
	Franchi <i>Minstro</i> maglayout			×	×	
×	<i>Men’s Health</i> All-Star Power maglayout	×	×			
	Women's Health page, large numbers		×			
	Questar Gas newsletter					×
	anntaylorloft.com shopping			×		

×	Bread and Better Parents sandwiches maglayout			×		
×	US Historical Flags (+ revise)		×	×	×	
	DK nature			×		
×	Ikea/ <i>Hembakat är Bäst</i>			×		×
×	Rancherito's menu			×		
	Lands' End kids back to school			×		
×	Franchi <i>Che idea far verde</i> maglayout		×	×	×	×
×	Eliza Pughe dictionary					×
	Wildlife Explorer tiger (Owners would not consent to usage; remove)					×
×	Radar Magazine maglayout					×
	Crowder blog reconfiguration			×		×
	AARP timeline maglayout				×	
	FloobyNooby storyboarding				×	
	Franchi <i>Accendi l'Oceano</i> maglayout		×		×	
	tying on dresses image	×		×		
	Mendeley installation screen	×	×			
×	Tara Duncan animated short storyboards				×	
×	The Hitchhiker	×	×			
×	Spinach ban-chan diagram	×	×	×	×	
	Bechers buildings			×	×	×
	Inside the Numbers			×		×

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