History on the Line: Time as Dimension

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Introduction

In 1753, Jacques Barbeu-Dubourg wrote a pamphlet accompanying a timeline of history, his *Chronography or Depiction of Time*.[1] In it he compared the visualization of past time unfavorably with the visualization of distant countries. Geography he found easy, attractive, and highly memorable while chronology was "laborious, unforgiving, offering nothing to the mind but repellent dates."[2] A solution seemed to present itself:

> Geography has as its object the extent of the earth; Chronology has as its object the succession of time. May not duration be imitated and represented as effectively to the senses as distinctly as space, and may not intervals of time be as easily counted in degrees?[3]

In this way Barbeu-Dubourg offered his rationale for one of the earliest timelines: a representation mapping time arithmetically to graphical space rather than presenting events in a list or table (see Figure 1).[4] His publication was followed in 1765 by Joseph Priestley's *Chart of Biography* (see Figure 2).[5] One of Priestley's innovations was the use of actual graphic lines to represent the life duration of individuals.[6]

In some ways, little has changed since Barbeu-Dubourg contrasted the state of the art in geographic and temporal visualization. Admittedly, many charts—some of them sophisticated—have mapped *quantities* against time: Quantitative visualization took off shortly after Barbeu-Dubourg and Priestley's innovations and was partly based on their work. But the visualization of historic lives, events, and artifacts and the relations between them—of categorical rather than quantitative information about the past—is rarely given serious consideration as either a design or historiographic problem. As a result of long and intense research and development, geographic maps do their job well, and a wealth of experience is applied to their design, supported in these days by significant innovations arising from digital capabilities. Controversy rages over the respective merits of the Mercator, Gall-Peters, and other projections, with a clear understanding

1 Stephen Ferguson, "The 1753 Carte Chronographique of Jacques Barbeu-Dubourg," *Princeton University Library Chronicle* (Winter 1991). http://www.princeton.edu/~ferguson/PULC_1991_duBourg.pdf (accessed December 17, 2011).

2 Jacques Barbeu-Dubourg, *Chronographie, ou Description des Tems* [Chronography, or Depiction of Time], trans. Stephen Boyd Davis (Paris, 1753 [2009]), 5. http://goo.gl/vNhN (accessed December 17, 2011).

3 Ibid.

4 Jacques Barbeu-Dubourg, *Chronographie Universelle & Détails qui en Dépendent pour la Chronologie & les Généalogies* (Paris: Barbeu-Dubourg, Lamote, Fleury, 1753). Princeton University Library Rare Books: D11 .B37 1753.

5 Joseph Priestley, *A Chart of Biography* (London, 1765). British Library: 611.l.19.

6 The two inventors shared a connection: Benjamin Franklin was a mutual friend and sent Barbeu-Dubourg a copy of Priestley's timeline, to which Barbeu-Dubourg responded with the gracious remark, "I have received with gratitude and viewed with pleasure the biographical chart of Mr. Priestley which is in truth made on almost the same principles as my own, without plagiarism on either side, as I in no way claim primacy on account of the date." He may have known from Franklin that Priestley had been making charts for some time to assist in his teaching at the Warrington Dissenting Academy before he began to publish them. (Jacques Barbeu-Dubourg to Benjamin Franklin, May 8, 1768, in *The Papers of Benjamin Franklin*, http://franklinpapers.org/franklin/yale?vol=15&page=112a&ssn=001-78-0029 (accessed December 21, 2011).

Figure 1
Detail of Barbeu-Dubourg's 1753 *Carte Chronographique*. Time runs from left to right. The other axis is used for states and kingdoms, with two bands near the bottom edge for notable events and individuals. This detail shows the lowest band for the period from about 1693AD to 1728AD. Rare Book Division, Department of Rare Books and Special Collections, Princeton University Library. Reproduced with permission.

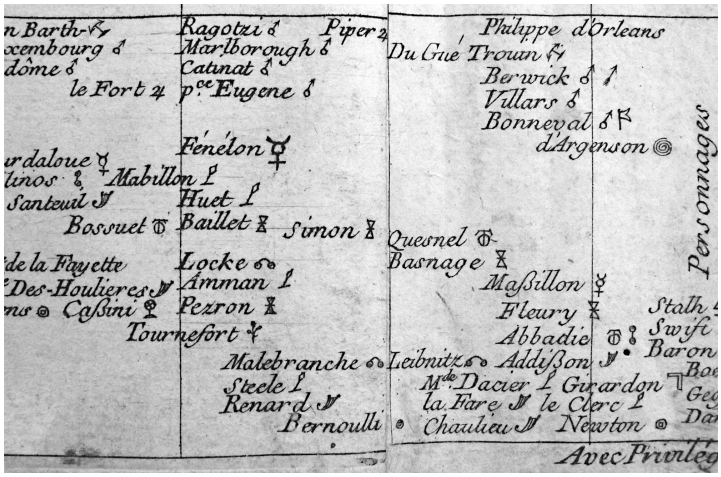
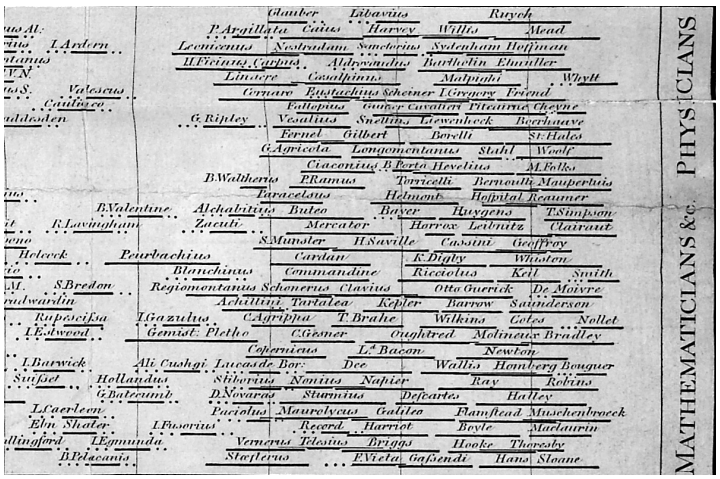


Figure 2
Priestley's 1765 *Chart of Biography* (detail). Time extends from left to right. This detail shows the period 1300AD to 1800AD. The other axis is divided into horizontal bands, here Mathematicians and Physicians. Reproduced with the permission of Chetham's Library, Manchester.



that each presents a different world view and that these differences matter.[7] The mapping of time, by contrast, has made only modest intellectual progress since it was invented 250 years ago: The choices to be made by the designer are assumed to be straightforward and incite no debate. Twyman has pioneered timeline scholarship from a typographic and graphical point of view, while the recent survey by Rosenberg and Grafton is scholarly, comprehensive, and highly visual.[8] Rosenberg's extensive article on the timelines of Joseph Priestley is also a major contribution to the subject.[9] However, this fine scholarship has been applied to recovering the lost history of chronographics rather than to extracting key principles that might help us design new ones. I hope to make the latter contribution in this article. Doing so involves asking what we are mapping and how. I draw on psychological and anthropological sources and on my own historical investigations into early timelines and their authors. Crudely, one could say that the eighteenth-century pioneers had subtle ideas but not the technology to implement them, while now we have technologies that they sorely needed but less critical thought. Apart from imaging

7 See Denis Wood and John Krygier, "Critical Cartography," in *International Encyclopedia of Human Geography*, eds. Rob Kitchin and Nigel Thrift (Amsterdam: Elsevier, 2009), 340-44.

8 See Michael Twyman, "Articulating Graphic Language: A Historical Perspective," in *Towards a New Understanding of Literacy*, eds. Merald E. Wrolstad and Dennis Fisher (New York: Praeger, 1986), 188–251; Michael Twyman, "Textbook Design: Chronological Tables and the Use of Typographic Cueing," *Paradigm* 4 (December 1990); and Daniel Rosenberg and Anthony Grafton, *Cartographies of Time: A History of the Timeline* (New York: Princeton Architectural Press, 2010).

9 Daniel Rosenberg, "Joseph Priestley and the Graphic Invention of Modern Time," *Studies in Eighteenth Century Culture* 36 no. 1 (2007): 59.

the past, timelines are an important component of many digital tools for planning projects—for creating music, animations, movies, and multimedia—and for representing processes at a range of scales from nanoseconds to the geological and cosmological. If we can think intelligently about mapping time to graphical space in the domain of history, this capacity will benefit other fields as well.

Time as Dimension

This article focuses on one issue—the orientation and direction of the time axis—to the exclusion of many others; for example, it touches only briefly on the closely related questions of scale and calibration. In addition, even the earliest chronologies showed a strong awareness of the usefulness of being able to look at simultaneous events, "across" time, as well as to displaying their date order, but the design and use of these non-time axes is a topic for another day. What follows is also confined to mapping time to a *straight line.* This model is of course just one possibility, often contrasted with cyclic or circular models allegedly held by, for example, Greek, Asian, or any non-Judaeo-Christian cultures. Such binary contrasts have been rejected as simplistic by Feeney, Goody, and Gould.[10] In fact, in any culture we seem to operate comfortably with switchable concepts of time. In the words of Möller and Luraghi, "most people perceive time in different ways according to their context or situation, with the result that any one culture is characterised by a range of different perceptions of time."[11]

The Uses of Timelines

We cannot begin to look at the form of the timeline without considering its purpose. What is the objective when historical time is mapped on a surface—whether page, exhibition board, or digital display? What are such maps of time meant to achieve? Potentially, they share the benefits of any well-designed data visualization, enabling users to spot patterns, trends, clusters, gaps, and outliers—in short, to make sense of data.[12] Visualizations are not only for the benefit of other people; authors themselves might also benefit. These representations serve the social reproduction of knowledge *and* they constitute tools for thinking.[13] When applied to historic data, specific insights include spotting connections through and across time, identifying clusters and lacunae, and understanding the context of individual events, actions, and artifacts. Such benefits have been claimed from the earliest days of use. Priestley argued that users would be able to see how individuals "stand related in point of time to one another," get "a clearer idea of the time in which they lived," understand "the state of their co[n]temporaries," assess the "relative length of their lives," and perceive "the intervals of time which elapsed between them and their predecessors and successors."[14] A subtle and insightful man,

10 See Denis Feeney, *Caesar's Calendar: Ancient Time and the Beginnings of History* (Berkeley: University of California Press, 2007), 3; Jack Goody, *The Theft of History* (Cambridge UK: Cambridge University Press, 2006), 18; and Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge, MA: Harvard University Press, 1987).

11 Astrid Möller and Nino Luraghi, "Time in the Writing of History: Perceptions and Structures," *Storia della Storiografia* 28 (1995), 7.

12 For a useful synthesis of the literature, see Stuart K. Card, Jock D. Mackinlay, and Ben Shneiderman, eds., *Readings in Information Visualization: Using Vision to Think* (San Francisco: Morgan Kaufmann, 1999), 16.

13 Matthias Schemmel, "Medieval Representations of Change and Their Early Modern Application," Preprint 402. *TOPOI – Towards a Historical Epistemology of Space* (Max Planck Institute for the History of Science, 2010), www.mpiwg-berlin.mpg.de/Preprints/P402.pdf (accessed December 17, 2011).

14 Joseph Priestley, *A Description of a Chart of Biography* (Warrington: Eyre, 1764), British Library: 611.d.30, 3.

Figure 3
A timeline as public exhibit in the Cartoon Museum, London, UK, 2007. In this example, the items are packed, with no attempt to plot events arithmetically. Sequence is clearly represented, but interval and scale are not. Homer Creative Limited, Birmingham. Used with permission. Photo: Stephen Boyd Davis.

Priestley realized that gaps are meaningful: "The thin and void places in the chart are, in fact, not less instructive than the most crowded." The combination of detail and context was important to him: "It is a peculiar kind of pleasure we receive, from such a view as this chart exhibits, of a great man, such as Sir Isaac Newton, seated, as it were, in the circle of his friends and illustrious co[n]-temporaries. We see at once with whom he was capable of holding conversation…."[15] All this would be "particularly useful to students in Chronology, History, and Biography."[16]

The Emergence of Modern Chronographics

In the mid-eighteenth century, a shift from typographic, tabular layouts of events to truly graphical time-maps illustrated a changing model of time exemplified by the ideas of Descartes and Newton.[17] The event-based model meant that earlier chronologies had almost always packed each tabular entry close upon the previous one. Blair complained that they have "all of them made one great and fundamental Mistake […] contracting History into as little Room as they could…."[18] Admittedly, Helvicus had created tables using equal space—in his case, equal pages—for equal time, but another 140 years elapsed before historic time was mapped arithmetically to space on a continuous substrate, rather than table-wise in pages.[19] Just like those pre-eighteenth century tables, the majority of current "timelines" are really lists in which each item is allotted just enough space for its name or description—especially on the Web, where the limitations of early versions of HTML tended to encourage the production of packed lists and tables rather than anything graphically sophisticated. Event lists can be given a graphical treatment, as shown in Figure 3, but

15 Ibid., 24.

16 Ibid., 4.

17 Stephen Boyd Davis, Emma Bevan, and Aleksei Kudikov, "Just in Time: Defining Historical Chronographics," in *EVA London 2010: Electronic Visualisation and the Arts:Proceedings of a Conference Held in London* (London: British Computer Society, 2010), 355-362. www.bcs.org/content/conWebDoc/36111 (accessed December 17, 2011).

18 John Blair, *The Chronology and History of the World, from the Creation to the Year of Christ*, 1753 (London, 1754). British Library 1852.c.9.

19 Christophorus Helvicus [Christoph Helvig], *Theatrum Historicum* [Historical and Chronological Theatre], (Giessæ Hessorum, 1609). British Library 747.c.22.

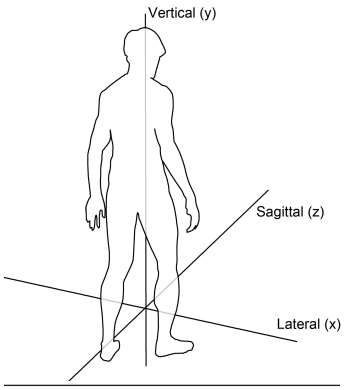


Figure 4
Axes relative to the perceiving subject, labeled according to their relation to the body and with the conventional Cartesian x, y, and z.

time here is just an ordering principle rather than a dimension. Such treatments convey information about sequence but not about interval or scale.

Time as Dimension: Orientation and Direction

Whether we can think about time without using metaphors from other domains is questionable.[20] Gentner emphasizes the sheer utility of mapping time to space: Location captures elements and their relations; dimension shows duration; it is an eminently usable analogue of an abstract concept.[21] However, if time is mapped to a line, on which axis of the graphic surface should it lie?[22] And in which direction should later times lie in relation to earlier: What is the direction of travel? Can we identify an answer to these questions that is the most natural, the best, or simply right?

Often in tabular layouts of history, two directions are used together to represent successive times. In the West, this orientation is usually left-to-right and top-to-bottom, following standard reading practice—characterized by Twyman as "linear interrupted."[23] The page is divided into vertically sequenced rows representing events or years, while successive pages, turned horizontally, represent larger increments of time, as in a diary. When time began to be fully mapped to space, there were thus already tabular precedents for considering both left-to-right and top-to-bottom as the "right" way for time's flow. But beyond the graphical domain, language and gesture both give clues as to how time may be conceived or experienced as directional. Interestingly, the evidence from language and the evidence from gesture are in conflict.

Direction in Verbal and Gestural Metaphors for Time

The significance of verbal metaphors was noted by Priestley, who argued that line-length is an appropriate representation because both lines and time can be described using the words "short" and "long."[24] He did not discuss the appropriateness of any particular direction. Traugott was one of the earliest researchers to ask why verbal metaphor prefers some directions to others.[25] Lakoff and Johnson cite examples in English where the future lies in front of the observer (e.g., "the weeks ahead of us"), where time is moving toward the observer, and where the observer is moving through time.[26] All these are sagittal metaphors: Time is aligned front to back relative to the observer's body (see Figure 4). Alverson found that metaphors of the observer moving through static time and of time flowing around the observer occur in many languages.[27] Not only is the sagittal axis preferred in verbal metaphor, but so is one direction along that axis. Núñez and Sweetser conclude that all documented languages, with the apparent exception of Aymara in the Andes, map future events onto spatial locations in front of

20 Lynn Avery Hunt, *Measuring Time, Making History* (Budapest: Central European University Press, 2008), 3 passim.

21 Dedre Gentner, "Spatial Metaphors in Temporal Reasoning," in *Spatial Schemas and Abstract Thought*, ed. Merideth Gattis (Cambridge, MA: MIT Press, 2003), 203-22 at 221.

22 Tversky cites a number of arguments for preferring the cardinal axes, to which the present discussion is confined. See Barbara Tversky, "Spatial Schemas in Depictions" in *Spatial Schemas and Abstract Thought*, ed. Merideth Gattis (Cambridge, MA: MIT Press, 2003), 79-112 at 99.

23 Michael Twyman, "A Schema for the Study of Graphic Language," in *Media, Knowledge and Power*, ed. Oliver Boyd-Barrett and Peter Braham (London: Croom Helm, 1987), 201-25.

24 Priestley, *A Description of a Chart of Biography* (1764), 7.

25 Elizabeth C. Traugott, "Spatial Expressions of Tense and Temporal Sequencing: A Contribution to the Study of Semantic Fields," *Semiotica* 15 no. 3 (1975): 207-30.

26 George Lakoff and Mark Johnson, *Metaphors We Live By* (Chicago: University of Chicago Press, 1996), 41-45.

27 Hoyt Alverson, *Semantics and Experience: Universal Metaphors of Time in English, Mandarin, Hindi, and Sesotho* (Baltimore: Johns Hopkins University Press, 1994).

speakers, with past events behind them;[28] however, evidence has recently emerged of another rare model that orients time-ordered objects not relative to the observer but relative to the world.[29]

Although verbal metaphors for time are dominated by the sagittal, some evidence of vertical language concepts also emerges. Mandarin describes earlier events as "shàng" or "up," while later events are "xià" or "down." French uses the terms *remonter* (travel (back) up) for looking back to early events, and *descendre* (descend) for passing down the generations. English, of course, uses the French-derived word *descendant*. Boroditsky, Fuhrman, and McCormick suggest that Mandarin has more vertical examples than English because the language is traditionally written vertically, top to bottom.[30] However, even in Mandarin, horizontal metaphorical use outnumbers vertical.

Work on metaphoric gesture adds weight to the evidence for spatial and directional models of time. However, it also adds a complication. We have seen that language metaphors for time are sagittal or vertical. Verbal left-right expressions for time are "virtually non-existent,"[31] and we do not say that someone did X "to the left of" Y to mean that someone did X before Y.[32] However, *gestural* metaphors are often lateral. A detailed study of one French speaker by Calbris reveals extensive use of the left and right hands to denote the past and future, respectively, which she believes is inspired by reading direction.[33] Cienki also reports a gestural pattern with prior time to the left and later time to the right and agrees on the influence of writing.[34] Cooperrider and Núñez discerned five distinct temporal gestures, in all of which the transverse rather than the sagittal axis is dominant.[35] On the basis of such evidence, the "right" direction for time could be lateral, flowing left to right—but only in cultures where this orientation maps to the reading direction.

Direction in Graphical Representations of Time

If we try to make a drawing of the sagittal timeline evoked by verbal metaphor, the problem is an obvious one: The graphic surface is normally orthogonal to our line of sight; we look more or less flat-on at a piece of paper, exhibition board, or digital display. Thus, a transformation is required to translate the sagittal axis to one or another of the axes of the graphic surface. We rotate the sagittal z axis to the lateral x or vertical y. Alternatively, we try to present the sagittal line using some kind of perspectival depiction of an imaginary z axis that the user looks along. In physical media, this solution tends to be impractical; it has really only started to come into its own with animated, interactive digital representations.

When we look on a scene, the more distant parts of the observed world generally end up higher in our view than the nearer.[36] Applying this perspective to the graphic surface suggests

28 Rafael E. Núñez and Eve Sweetser, "With the Future Behind Them: Convergent Evidence from Aymara Language and Gesture in the Cross-Linguistic Comparison of Spatial Construals of Time," *Cognitive Science* 30 no. 3 (2006): 401-50.

29 Lera Boroditsky and Alice Gaby, "Remembrances of Times East: Absolute Spatial Representations of Time in an Australian Aboriginal Community," *Psychological Science* 21 no. 11 (2010): 1635-39.

30 Lera Boroditsky, Orly Fuhrman and Kelly McCormick, "Do English and Mandarin Speakers Think About Time Differently?" *Cognition* (2010). http://psych.stanford.edu/~lera/papers/mandarin-time-2010.pdf (accessed December 19, 2011).

31 Traugott, "Spatial Expressions of Tense and Temporal Sequencing," 214.

32 Alan J. Cienki and Cornelia Müller, "Metaphor, Gesture and Thought" in *The Cambridge Handbook of Metaphor and Thought,* ed. Raymond W. Gibbs (New York: Cambridge University Press, 2008), 492.

33 Geneviève Calbris, "From Left to Right…: Coverbal Gestures and Their Symbolic Use of Space" in *Metaphor and Gesture,* vol. 3 of *Gesture Studies,* ed. Alan J. Cienki and Cornelia Müller (Amsterdam: John Benjamins, 2008), 27-53.

34 Alan J. Cienki, "Metaphoric Gestures and Some of their Relations to Verbal Metaphorical Expressions" in *Discourse and Cognition: Bridging the Gap,* ed. Jean-Pierre Koenig, (Stanford, CA: Center for the Study of Language and Information, 1998), 189-204.

35 Kensy Cooperrider and Rafael E. Núñez, "Across Time, Across the Body: Transversal Temporal Gestures," *Gesture* 9 no. 2 (2009): 181–206 at 188.

36 James J. Gibson, *The Perception of the Visual World* (Boston, MA: Houghton Mifflin, 1950), 137-44.

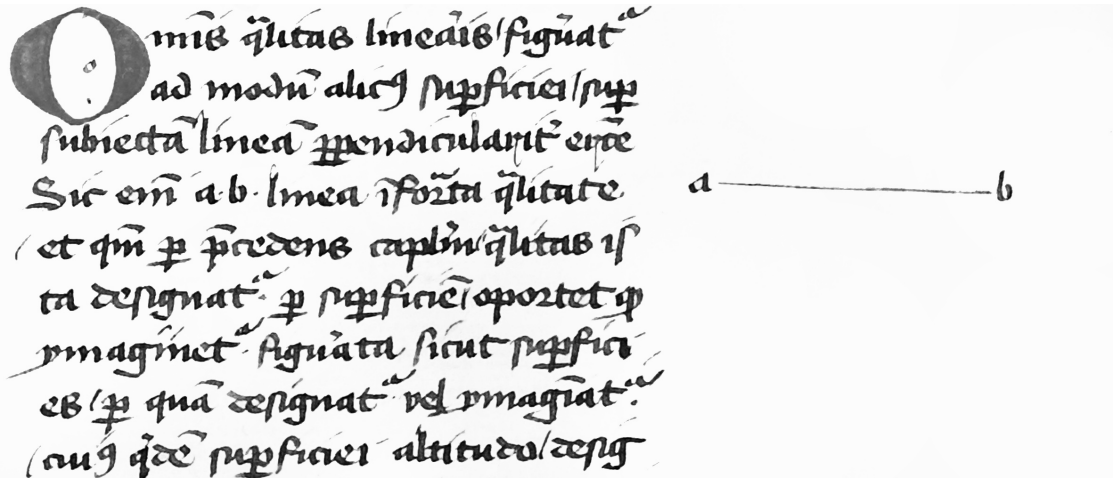


Figure 5
A detail from Oresme's *Tractatus de Configurationibus Qualitatum et Motuum* (A Treatise on the Configurations of Qualities and Motions). This copy in the British Library is from 1428, but the original was probably made in the 1350s. The line *ab* represents time, against which qualities and motions (i.e., quantitative variables) may be perpendicularly plotted. Nicole Oresme, *Tractatus de Configurationibus Qualitatum et Motuum, cum prologo.* 159-94. © The British Library Board (Manuscript Sloane 2156).

a vertical mapping of the sagittal time axis, with distant time at the top and nearer time at the bottom. In dealing with the future, distant future events would be highest. However, in dealing with history, we are visualizing the past: Perhaps we imagine ourselves turning on the spot and looking behind. The recent past is now close and, in landscape terms, should be at the bottom of the view, with the increasingly distant past higher up. It may be that less cognitive load is imposed on the user by such a mapping to the vertical because in some respects it provides a kind of pictorial view of the sagittal axis. Happily, this picture also accords with Western textual conventions, in which earliest dates are listed first and continue down the page. Again, writing direction is formative. In comparing three language cultures, Tversky, Kugelmass, and Winter found strong evidence of its influence on the direction of temporal diagram-making, time being more strongly influenced by writing than were other variables.[37]

Past Struggles with the Graphic Orientation of Time

A remarkable early example of drawing time is Nicole Oresme, whose work in the 1350s anticipates the quantitative time graphics of the seventeenth and eighteenth centuries.[38] His linear drawings of time are perhaps the first, though Oresme himself traces the idea to Aristotle (his *Physics* Book 4).[39] Time is horizontal in all his illustrations, of which the most basic is a single line (see Figure 5). The influence of reading direction is emphasized by the use of textual labels in alphabetic order. Nevertheless, Oresme too seems to have had trouble deciding on the "right" direction. He struggles to say whether the variable quantities mapped against time should be referred to as latitudes or longitudes (Oresme trans. Clagett),[40] opting for "latitudes" even though he then plots them vertically, perpendicular to his horizontal time axis.

In looking at Barbeu-Dubourg's and Priestley's work, no one seems previously to have noticed that they, too, might have struggled with time's direction. Barbeu-Dubourg's chart uses the

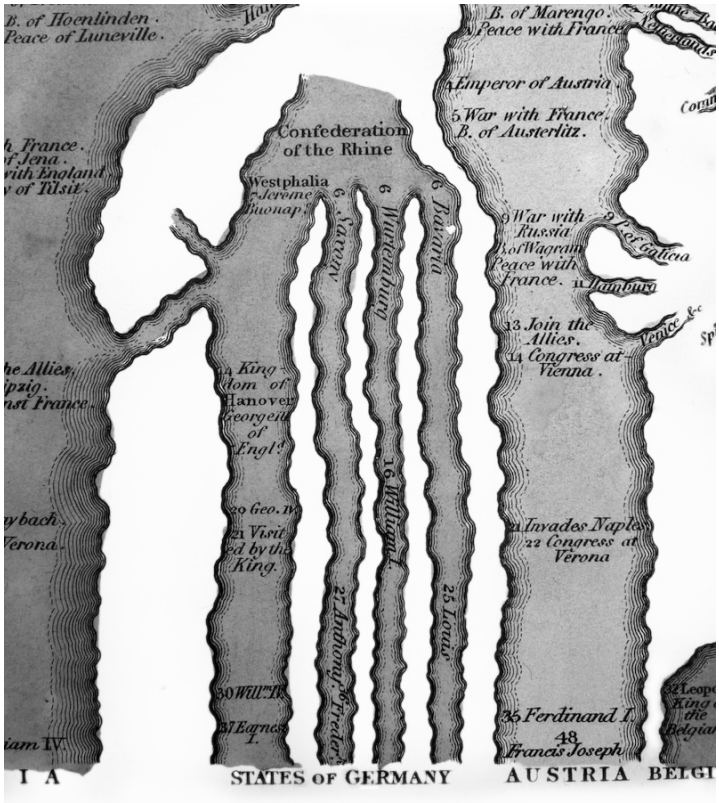
37 Barbara Tversky, Sol Kugelmass, and Atalia Winter, "Cross-Cultural and Developmental Trends in Graphic Productions," *Cognitive Psychology* 23 no. 4 (1991): 515-57.

38 Marshall Clagett, ed. and transl., *Nicole Oresme and the Medieval Geometry of Qualities and Motions: A Treatise on the Uniformity and Difformity of Intensities Known as "Tractatus de configurationibus qualitatum et motuum"* (Madison, WI: The University of Wisconsin Press, 1968).

39 Marshall Clagett, *The Science of Mechanics in the Middle Ages* (Madison, WI: University of Wisconsin Press, 1959), 333.

40 Clagett, *Nicole Oresme and the Medieval Geometry of Qualities and Motions,*169-73.

Figure 6
A detail from Strass, F. 1849. Stream of Time, or Chart of Universal History. 1849. [London]: C. Smith, Mapseller. Note the struggle to squeeze horizontal labels into vertically oriented streams of time. Photo: Stephen Boyd Davis. Collection: Stephen Boyd Davis.



horizontal axis for time and the vertical for categories, assigning states and kingdoms to horizontal bands, with two additional bands below them: one for events and one for individual historical lives (again, see Figure 1). In French a suitable term for these divisions would have been the word *bande* or, if emphasising its horizontality, *rang* (row). Instead, we find the word *colonne* (column), which in the eighteenth century could refer to printed columns of text on a page.[41] Dictionaries of the period give no hint that the term was ever used for horizontal rows. His use of the word strongly suggests that Barbeu-Dubourg originally intended to have time running vertically, with the categories as columns. The term *bande* replaces *colonne* in the posthumous second edition.[42] Priestley's explanation of his own chart shows a similar muddle: The first edition has 32 occurrences of the word *column*.[43] By the seventh edition in 1778, only six occurrences remain, the others having been changed to *division* (20), *space* (4), or *class* (2).[44] By 1800, the last few had been corrected, and the word *column* no longer appears.[45] This evidence surely suggests that Priestley originally had in mind a vertical orientation for time.

We saw that the vertical orientation seems in some ways to be the more direct or natural mapping of the sagittal axis—a potentially less burdensome intervention than rotation to the horizontal. Why did both inventors change their minds? The most likely explanation is pragmatic: Names and labels are longer than they are tall, and fitting them into a vertical design is problematic.

41 *Dictionnaire de l'Académie Française*, 4th ed. (1762) http://artfl-project.uchicago.edu/node/17 (accessed December 20, 2011).

42 Jacques Barbeu-Dubourg, *Chronographie, ou Description des Temps*. (Chronography or Depiction of Time). (Paris, 1838). British Library 798.1.19.

43 Priestley, *A Description of a Chart of Biography* (1764).

44 Joseph Priestley, *A Description of a Chart of Biography* (London: Johnson, 1778). British Library: 10602.aa.22.

45 Joseph Priestley, *A Description of a Chart of Biography* (London: Johnson, 1800). British Library: 10604.aaa.29.

Neither inventor could easily have reconciled his wish to label every item with using a vertical time-axis. The vertical charts by others who followed evade this problem by minimizing individual lives and adding labels only to kingdoms and major events. Strass in his *Stream of Time*[46] does try to name every monarch within his drawn tributaries, but the result is very small lettering, broken lines and even broken words—and even then he is at times obliged to rotate the names where the stream is particularly narrow (see Figure 6). At both a pragmatic and a metaphorical level, then, the direction of writing had a powerful influence on the earliest Enlightenment timelines and, through them, on the historical chronographics and statistical charts of others who followed.

To summarize before proceeding further, evidence from psychology and anthropology suggests that time is almost universally mapped metaphorically to space. However, evidence from language and from gesture points, quite literally, in different directions. In addition, whether language or gesture is taken as the model, evidence also suggests that reading direction has a powerful influence, both metaphorically and pragmatically. No single, a-cultural, natural mapping for time exists, either in terms of orientation or direction of travel. At the very least, this has implications for the design of chronographics intended for international or multicultural audiences. From an exclusively Western beginning, the *textual* architecture of the Web now pays significant attention to scripting direction, character sets, ligatures, and other international aspects of the word, but we see little evidence of such enterprise in relation to time.[47] Research questions need to be pursued about the relative cognitive burden of the competing orientations and directions: Although we can make guesses based on the existing literature, such an approach is not really good enough.

Affordances of Timeline Orientations

In addition to issues concerned with cognition, questions arise concerning the differing effects of orientation on the observer. Do the different orientations and directions carry messages? Perhaps the vertical and horizontal offer different affordances? Tversky et al. (1991) point out that in our embodied experience, the vertical dimension is asymmetric, with the down side literally grounded and the up side unbounded.[48] In contrast, the horizontal, they argue, is symmetric. Therefore, thinking of horizontal time as potentially more neutral and less directed seems possible—although the examples of gestural metaphor already cited suggest this neutrality is limited; in particular, loaded terms such as "sinister" and "dexterity," from the Latin for left and right, cannot be ignored. In the timelines I have studied, downward vertical orientation seems particularly popular for religious teleological representations. Perhaps the downward flow of time echoes the "Fall of

46 Friedrich Strass, *Stream of Time, or Chart of Universal History from the German of Strass* (New York: J.H. Colton, 1860) British Library: Maps 999.(74.)

47 See Elika J. Etemad, "Robust Vertical Text Layout," in *27th Internationalization and Unicode Conference* (Berlin, 2005), http://www.unicode.org/notes/tn22/RobustVerticalLayout.pdf (accessed December 20, 2011), and Edward H. Trager, "International Text Layout and Typography: The Big and Future Picture," *Gnome Live Text Layout Summit* (Boston, 2006), http://unifont.org/textlayout/TheBigPicture.pdf (accessed December 20, 2011).

48 Tversky, Kugelmass, and Winter, "Cross-Cultural and Developmental Trends in Graphic Productions," 518.

Man" from an original state of grace in the Judaeo-Christian story. For example, a vertical chart by Denny presents *A Prophetical Stream of Time* flowing downward from God to *The End, or Everlasting State;*[49] meanwhile, Linton's *Chart of Ancient History* similarly traces the Biblical nations from the Creation downward.[50] A glowing orb at the top of Strass' *Stream of Time* gives it a religious aura, although the remainder of the content is secular: It, too, flows downward. Upward flows of time are virtually absent (but they later reappear in another guise, as perspectival sagittal views).

Metaphors in early timelines included branches, chains, streams, rivers, and arrows.[51] One of the striking things about Barbeu-Dubourg and Priestley's charts is the absence of explicit visual rhetoric: They are both content to let the patterning of the data speak for itself. In Tufte's terms, there is no "chart junk."[52] Strass objected to the very neutrality of Priestley's view, favoring an explicitly drawn grouping and linking of currents and tributaries (see Figure 6). As an underlying metaphor, however, rivers are important even to Priestley: In his explanatory *Description,* he invokes them, citing their lack of beginning and end and likening the lives of men to "so many small straws swimming on the surface."[53] His chart bears the motto, *Fluminis ritu feruntur,* evoking Horace's advice to Maecenas to maintain his own position while the world flows around him like a river. With the 1778 edition, he added a quotation to the *Description,* taken from Virgil's Aeneid (I, 118): *Apparent rari nantes in gurgite vasto,* "We see a few swimming in the vast deep," to describe the paucity of men of learning in the Dark Ages.[54] This apparently unitary river metaphor has two alternative affordances. In the *Description,* we seem to stand on the riverbank watching time's flow from outside—it flows past us laterally. Meanwhile, with the Horace quotation on the *Chart* itself, Priestley puts the observer in the river as the waters swirl around him, presumably sagittally.

In relation to the first use, an obvious aspect of most of the chronographics discussed here is that they do indeed provide an overview—a distancing perspective on time. We are familiar now with this idea of visualizations as summary overviews of available data—an approach perhaps most strongly associated with Shneiderman's work at Maryland, repeatedly arguing the value of seeing entire datasets within a single view.[55] This benefit was familiar to Priestley, whose argument is peppered with phrases such as "at a single glance," "at one glance," "the noblest prospect," "a comprehensive view of the succession of great men," and "the contents of the tablet will be fixed in the imagination, not in succession, but at once."[56]

A less obvious potentiality is to create a sense of immersion in the historic moment—a metaphor surely more strongly tied to the sagittal view. We can glimpse this in Priestley's description,

49 Edward Denny, *A chart, illustrated throughout with Pictorial Designs, entitled, A Prophetical Stream of Time; or, an Outline of God's Dealings with Man, from the Creation to the End of all Things* (Bath: Binns and Goodwin, 1849) British Library: Tab.539.c.

50 Henry Linton. [no date]. *Chart of Ancient History.* London: George Philip & Son.

51 See, e.g., Daniel Rosenberg, "Joseph Priestley and the Graphic Invention of Modern Time," *Studies in Eighteenth Century Culture* 36 no. 1 (2007): 55–103; and Davis, Bevan, and Kudikov, "Just in Time."

52 Edward R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, CT: Graphics Press, 1983), 107-21.

53 Priestley, *A Description of a Chart of Biography* (1764), 24.

54 Priestley, *A Description of a Chart of Biography* (1778), 23.

55 See Ben Shneiderman, "The Eyes Have It: A Task by Data Type Taxonomy for Information Visualisations," *Proc. IEEE Symposium on Visual Languages* (Boulder, CO: IEEE Computer Society, Washington DC, 1996), 336-43; Also see Stuart K. Card, Jock D. Mackinlay, and Ben Shneiderman, eds., *Readings in Information Visualization: Using Vision to Think* (San Francisco: Morgan Kaufmann, 1999), 285-305. Chapter 3.3 *Overview and Detail.*

56 Joseph Priestley, *A Description of a Chart of Biography* (1764), 9, 10, 25, 3, and 7, respectively.

Figure 7
BBC timeline, *A History of the World,* Version 1.1 2010. The z-axis, orthogonal to the picture plane, is used for time. In this case, the designers have chosen to put the present time in the far distance, in front of the observer. Behind the observer is the most distant past. BBC Radio 4, A History of the World http://www.bbc.co.uk/ahistoryoftheworld (used with permission).

already quoted, of Sir Isaac Newton in the circle of his friends, but the greater champion of immersion is Barbeu-Dubourg. He inserted his 16.5-meter continuous paper roll of time into a *machine chronographique,* with small crank handles to wind history back and forth: About 150 years are visible at any moment. The machine was enthusiastically described in great detail by Diderot in the *Encyclopédie*.[57] Meanwhile, Barbeu-Dubourg's own pamphlet evokes "a moving, living tableau, through which pass in review all the ages of the world […] where the rise and fall of Empires are acted out in visible form...."[58] Here, the sense of history as immersive experience is uppermost. We should remember that Barbeu-Dubourg almost certainly intended at first that time should flow vertically in his machine. Perhaps vertical orientations afford a stronger sense of immersion than the horizontal, with the more intrusive rotation to the horizontal producing a distancing, objectifying effect. This possibility raises research questions concerned with *affect,* adding to those questions already raised in relation to cognition.

Instead of mapping the sagittal to the vertical or horizontal, the designer can create a perspectival view of time, looking along the sagittal z axis. Here, the immersive aspect is one of the most appealing features: We seem to stare directly through time from a point within it. Such views have become popular in digital media. They tend to sacrifice some of the benefits of overview, not least because as users interact, much of the timeline passes out of view "behind" them. More distant items may be too small to read. The problems of which way time should flow and quite how it should be rendered remain. In a 2010 timeline of historical artifacts for the

57 Denis Diderot, "Chronologique (machine)," *Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts et des Metiers* vol. 3 (400-01), trans. Stephen Boyd Davis, The Encyclopedia of Diderot & d'Alembert Collaborative Translation Project (Ann Arbor: University of Michigan, 2009), http://hdl.handle.net/2027/spo.did2222.0001.081 (accessed December 20, 2011).

58 Barbeu-Dubourg, *Chronographie, ou Description des Tems* (Chronography, or Depiction of Time), 8.

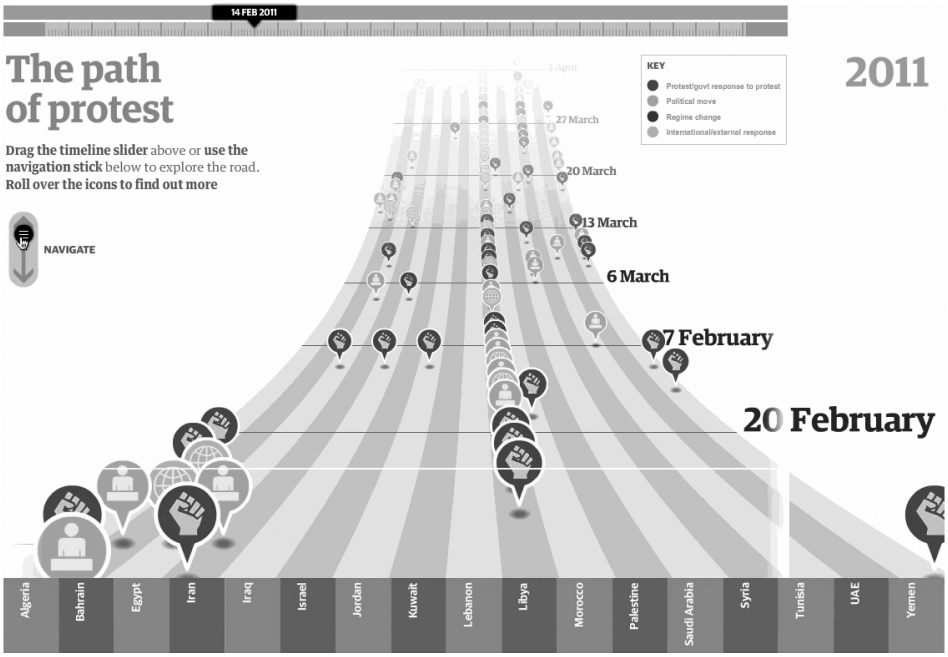


Figure 8
Guardian online newspaper timeline of the "Arab Spring" 2011. Again, the future is ahead of the user, but here time is presented as an incline, a hybrid of sagittal and vertical views. The curvature of the timeline surface helps avoid problems of scale. © Guardian News & Media Ltd. 2011.

BBC (see Figure 7), present time is in the far distance, in front of the user, while "behind" the user and out of view is the most distant past. Clearly this affords a novel view on history: It is unusual to look at the present from the past. A similar approach, also looking toward the future, is offered by recent timelines for the Guardian newspaper website (see Figure 8); but instead of looking into a kind of time tunnel, we now look at time as a curved incline—a hybrid of sagittal and vertical views. This curve has some particular advantages in terms of scale. Instead of distant items becoming illegibly small, the upwardly curved, distant portion of the timeline ensures that they remain visible further into the distance. Note that the perspectival effect allows us to accept the otherwise "unnatural" idea that later times are "higher" than earlier ones; whereas, when time is diagrammatic rather than pictorial, this view is not an acceptable option.

Extrapolating beyond the use of simple, three-dimensional interfaces, the temptation is to look for advantages in virtual environments. In a 3D timeline of photography by Kullberg, individual lifelines are laid out on a virtual surface, while individual photographs stand on these lifelines at the appropriate points in time.[59] Events from contextual history appear on a lower, darker layer. The user can look at time from many points of view and distances. Virtual environment representations for time have been compared against others experimentally.[60] Unfortunately, for some groups of users, a simple horizontal array proved more effective in terms of recall than the virtual 3D space. Further work is needed to discover the determinants of successful design in this aspect of chronographics, as in so many others.

59 Robin L. Kullberg, *Dynamic Timelines: Visualizing Historical Information in Three Dimensions,* MSc Dissertation, MIT, September 1995. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.5178&rep=rep1&type=pdf (accessed December 21, 2011).

60 See, e.g., Nigel Foreman, Stephen Boyd Davis, Magnus Moar, Liliya Korallo, and Emma Chappell, "Can Virtual Environments Enhance the Learning of Historical Chronology?" *Instructional Science* 36 no. 2 (2008): 155-73; and Liliya Korallo, Nigel Foreman, Stephen Boyd Davis, Magnus Moar, and Mark Coulson, "Can Multiple 'Spatial' Virtual Timelines Convey the Relatedness of Chronological Knowledge Across Parallel Domains?" *Computers & Education* 58 no. 2 (2012): 856-62.

Note also how two related issues also impinge strongly on our perception of graphic time: scale and calibration. Barbeu-Dubourg and Priestley both strongly advocated linear mappings, assuming that this presents a *true* impression of time. A tricky epistemological problem arises here: Evidence suggests that the mental models of time we routinely use are non-linear.[61] Drucker and Nowviskie have argued that digital tools should capture the subjectivity of time perception in "elaborate, subjectively inflected timelines."[62] *Continuum,* a project at University of Southampton, demonstrates the benefits of suppressing whole chunks of time so that separate historical periods can be juxtaposed.[63] It also offers multiple views of time on screen at the same moment. Strong arguments can be made both for linear and non-linear views, depending on how we decide time "really is" and what purposes the representation serves.

If western writing direction has often overridden other models of time's flow, this same dominance affects the units and measures of the timeline; nevertheless, there are several reasons why differing measures of time may be needed. One is to reflect the varied cultures of the users. Dershowitz and Reingold list 30 different calendars, including several in current use today and many that are significant in history.[64] Within a single culture, rival dating schemes may be used because of differing scholarly opinion. In addition, having more than one calibration of a chart simply may be useful—for example, dates counted forward from a point in history to our own time, as well as dates counted backward from the present day. The use of multiple and alternative calendars is culturally inclusive, and it is a necessity when dealing with many kinds of history.

Improving the Design of Timelines—and a Research Agenda

Timelines undoubtedly will continue to be seen as useful, and the enhanced capabilities of digital media, in particular for the Web, offer increased roles for design. As new chronographic designs emerge, new discoveries will be made about data. Manovich uses cultural analytics to plot cultural artifacts against time in search of new insights.[65] The *Historical Interactive Timeline* (HiT) allows users to create complex mixed queries to see patterns in a dataset.[66] What new knowledge can be created by advanced forms of chronographic design? Interactivity enables users to make their own choices—but, only if the design supports them. The designer must create flexible solutions that adapt to changing content and context, rather than specifying appearance to the last pixel. Although flexible tools for constructing timelines, such as SIMILE, are becoming more sophisticated, they have far to go.[67] Rather than assuming that designing timelines and other chronographics is unproblematic, we should embrace the often difficult implications for the designer and the researcher. Which are the most effective

61 See Paul Fraisse, "Perception and Estimation of Time," *Annual Review of Psychology* 35 (1984): 1-37; Gal Zauberman, B. Kyu Kim, Selin A. Malkoc, and James R. Bettman, "Discounting Time and Time Discounting: Subjective Time Perception and Intertemporal Preferences," *Journal of Market Research* 45 (2008): 543–56; and Eviatar Zerubavel, *Time Maps: Collective Memory and the Social Shape of the Past* (Chicago: University of Chicago Press, 2003).

62 Johanna Drucker and Bethany Nowviskie, "Speculative Computing: Aesthetic Provocations in Humanities Computing," in *A Companion to Digital Humanities,* ed. Susan Schreibman, Ray Siemens, and John Unsworth (Oxford: Blackwell, 2004) 442-43.

63 Paul André, Max L. Wilson, Alistair Russell, Daniel A. Smith, Alisdair Owens, and m.c. schraefel [sic], "Continuum: Designing Timelines for Hierarchies, Relationships and Scale" in *Proc. UIST* (New York: ACM, 2007), 101-10.

64 Nachum Dershowitz and Edward M. Reingold, *Calendrical Calculations* 3rd ed. (New York: Cambridge University Press, 2008).

65 Lev Manovich, "What Is Visualization?" in *Lev Manovich: Cultural Analytics, Software Studies, New Media, Digital Humanities.* http://manovich.net/2010/10/25/new-article-what-is-visualization/ (accessed December 21, 2011).

66 Davis, Bevan, and Kudikov, "Just in Time," (accessed December 17, 2011).

67 SIMILE Timeline, Massachusetts Institute of Technology. www.simile-widgets.org/timeline/ (accessed December 21, 2011).

models and viewpoints for various users and purposes? Does looking onto time "from the side" have a greater objectifying effect than looking along time? How can problems of occlusion and data density be solved in views that look "along" time? What are the criteria for choosing from among 2D, 2½D, and 3D models? What are the cognitive and affective consequences of different locations of user viewpoint? Which are the best ways of mapping time for particular purposes? Does the user benefit from multiple synchronized views? Is a single zoomable view preferable? How can visual constancy be maintained between views? What use can be made of "intelligent" levels of detail? What about non-linear views, such as fisheye lenses? Can we evaluate experimentally the advantages claimed by Priestley and Shneiderman more than two centuries apart for showing entire datasets in a single view?

In answering such questions, we are not without help from existing research in many fields, but the problem remains of applying this knowledge to the issues I have raised. Exciting opportunities for new research exist, while those interested in these issues can also grapple with them by exploring through designing.

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