The Standard Celeration Chart (SCC)

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What is now known as the Standard Celeration Chart (SCC) did not begin with any reference or understanding of celeration. Instead, the essential elements developed by Ogden Lindsley and his students were those that standardized the display of data. A desire for efficient visual analysis and data sharing inspired the original standards of the SCC. The discovery of the magnificent utility of celeration and the quantification of change came as a result.

In the 1960s, most people who set out to apply the discoveries from behavioral science came from experimental backgrounds where cumulative recorders were standardized. Anyone who could read a cumulative record was able to understand any of them. There were few variables (e.g., speeds at which the rollers traveled), but the equipment that produced them was standard. Apart from equipment standardization, the earliest compilations of research on human behavior, such as the work of Ullmann and Krasner (1965), had a variety of data displays of human behavior. The range of graphics was produced as the pioneers of "behavior modification" tried to find a way to show new single-case designs while displaying data that did not have shared conventions. The fact that those data were not automated as they had been with laboratory work was one contributing complication. Inspired by the cumulative recorder's elegance, Lindsley and his students set out to eliminate the problems of infinite display types. In doing so, they developed standard data displays that communicated data quickly and efficiently with minimal variation across collections (Lindsley, 1992).

The birth of the standard chart

In September of 1967, the "DG-5," or Daily Graph iteration five, was printed by Behavior Research Company. It was the first mass-produced chart that conformed to the standards of standard graphs that would later be known as the SCC. It had 6 multiply cycles on the vertical axis and was divided by 20 major gridlines along the horizontal axis.[1] The grid of the DG-5 was 7.9 inches wide by 5.25 inches tall. The ink was Pantone® 310, a light blue. The chart also had a header and footer that remained relatively standard after 1967. The header contained chart naming information. The footer contained a fixed location for label blanks to list team members who worked on the project and a designated area for the "movement cycle" measured. Lindsley and colleagues had experimented with all these attributes on earlier prototypes and iterations through 1966 and 1967. Following the DG-5, all SCCs maintained these features almost uniformly.[2]

The standards were so consistent that in one of Lindsley's last publications (Graf & Lindsley, 2002) 35 years later, the standards that the authors still included are as follows:

- 6 cycles
- Multiply scale in base 10
- Real time across the bottom on an "add" scale
- Celeration periods represented by 21 "ticks" denoting 20 celeration periods

On the following page of the publication, Graf and Lindsley emphasized the importance of the 6-cycle vertical axis:

> **"Always six cycles up the left"** (p. 62)

Another standard feature of the standard celeration chart: Frequencies "up the left" (i.e., the vertical axis) always cover 6 cycles of "times ten." Nonstandard charts change the up the left from one chart to another to allow the behavior to stretch the entire length of the chart" (Graf & Lindsley, 2002, pp.61–62, emphasis in original).

Primary rationale for development of the SCC

The SCC was developed with fixed 8-in. × 5.25-in. axes and standardized labels to facilitate communication and comparison of data sets (Lindsley, 1990b). Standard chart researchers have demonstrated that data analysis is faster (Mawhinney & Austin, 1999), more

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[1] The periods that the 20 major vertical axis gridlines created would come to be known as "celeration periods" once the concept of celeration was revealed and emerged as a common focus for what had been the DG-5. For consistency, these 20 periods will be called "celeration periods" in this article, although the term *celeration period* did not appear in common usage until the 1980s.

[2] In 1973, the grid for the family of charts changed to 8 in. × 5.3 in. In 1998, all standard chart families were changed to an 8-in. × 5.28-in. grid. However, in publications and presentations, Lindsley referred to the dimensions of all these charts as 8 in. × 5.25 in. The configuration of the header and footer also varied slightly over the years, with chart blanks and chart names taking on slightly different forms across versions

accurate, and more accessible with an SCC than other traditional methods in the field of behavior analysis (Lefebre et al., 2008). While a standardized rate of change is essential, one of the valuable products of a standard number of multiply cycles vertically and time periods horizontally is that an experienced analyst can quickly identify absolute frequencies (Sepler, 1979). A chart reader only has to determine a single value on the vertical axis. Vargas (2009) described the situation:

> The Standard Celeration Chart was born from a need. Lindsley was teaching an off-campus course for practicing teachers. Like a good behavior analyst, he had his students doing projects back in their schools. Each week the students shared the progress on their students' performances. Lindsley noticed that in presenting their graphs, most of the time was taken up describing the method of graphing, not with what the graphs revealed about behavior. Teachers needed a standard graph. (p. 127)

Lindsley, in an email (personal communication, February 13, 2001), described a similar case:

> A strong want galvanized me into action in 1966, when a schoolteacher, a student in my graduate class, spent over 30 minutes describing her class project chart projected on the wall to the 28 other students in the class. Then another class member asked how old the child was, and the teacher answered, "That isn't the child's behavior. That's my behavior!"
>
> Sitting in the back of the room, I thought, Wow! Thirty minutes and we don't even know whose behavior it is! There is no way we can have chart-based teaching using self-made charts! We have got to have a standard chart! And SOON! Or, this class will disintegrate!
>
> That night, after the class that met from 4:30 pm to 7:30 pm, I drew up the first standard behavior chart.

In the same 2001 communication, Lindsley emphasized the need for standardization of the peripheral labels in the footer: "The location and presence of the name and behavior blanks were as important as the 6 multiply cycles up the short side of the paper."

The 8-in. × 5.25-in. ratio was *not* distinct to ratio displays

There is a misunderstanding that Lindsley et al. solely developed the "standard" in the SCC to display data on a 6-cycle by 20-celeration period axis. Lindsley appeared on various television programs and educational films in the late 1960s, showing *add–subtract* data on 8-in.

× 5.25-in. grids using an overhead projector and other methods [Perspective: Pinpoint, Record, and Consequate (1967a), Perspective: The Sunday Box (1967b)]. Lindsley and colleagues retained this ratio even when not displaying data on 6-cycle by 20-celeration period axes. For example, in March 1968, Behavior Research Company printed a “comparison index” chart with equal intervals along the vertical axis from −1.00 to +1.00 (Figure 1) (Lindsley, 1956-1971). In 1970 and 1972, Behavior Research Company published two runs of an add–subtract chart with 20 periods across the horizontal axis and 10 major gridlines up the vertical axis (Lindsley, 1967-1973) (Figure 2). All of these charts featured the same 8-in. × 5.25-in. frame as the SCC.

Lindsley et al. developed the SCC to avoid “stretch-to-fill” displays and facilitate comparing and sharing data

One of Lindsley’s primary frustrations was with “stretch-to-fill” charts. Lindsley discusses his dislike in numerous publications, most exhaustively in *Skinner on Measurement* (1992). The effect of “stretch-to-fill” practices was the accidental (or intentional) amplification of effect sizes based on the ratio of the horizontal axis to the vertical axis. A typical convention was the arbitrary “decapitating and depodiating” (Lindsley, 1992, p. 51) by setting the top of the vertical axis and the bottom of the vertical axis such that the data leave little white space on the display. Similar strategies are used along the horizontal axis. Decades before, journal editors had insisted on massaging submitted cumulative records, something about which Skinner (1989) lamented in *Recent Issues in the Analysis of Behavior*. Subsequently, editors did the same for the SCC.

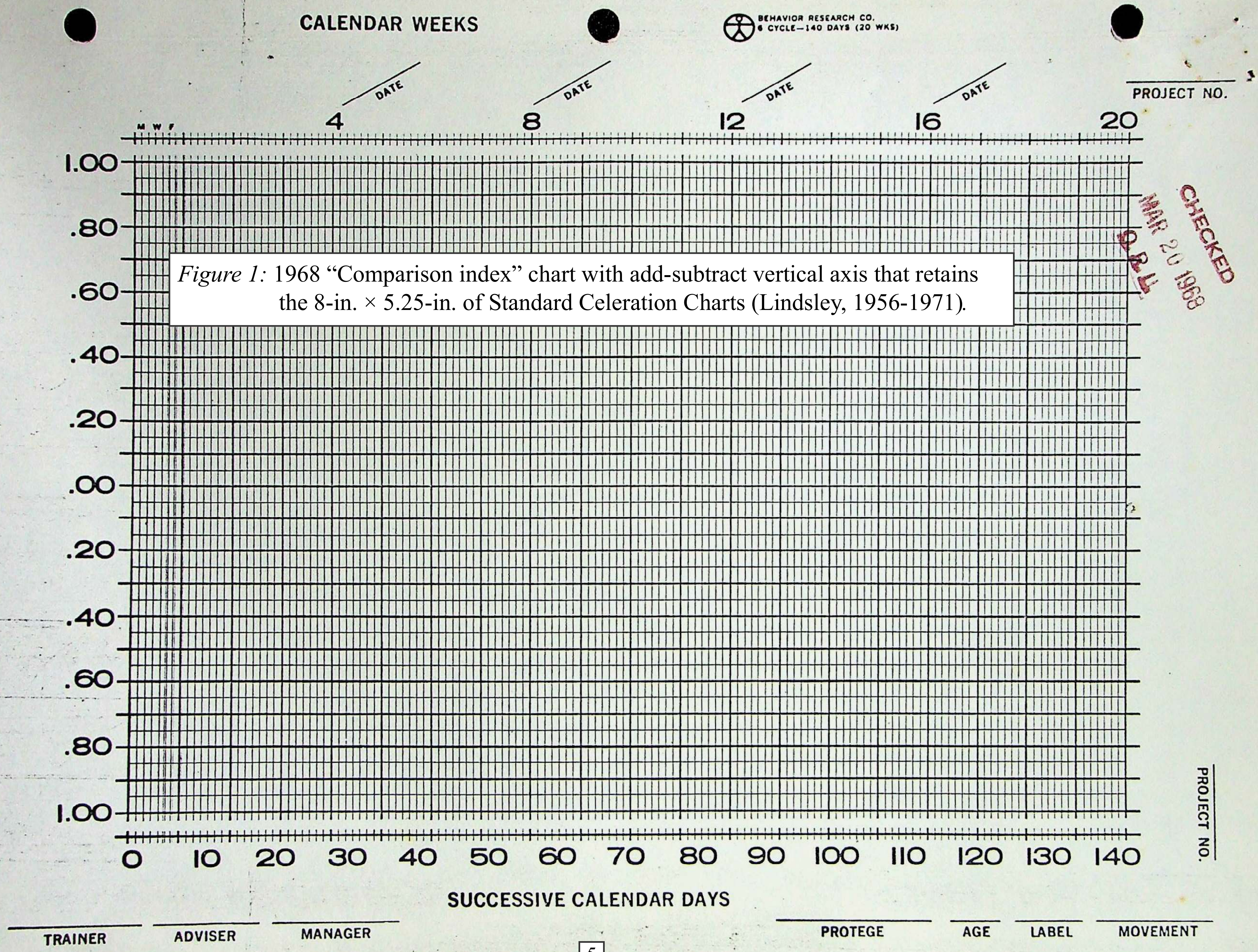

Figure 1: 1968 “Comparison index” chart with add-subtract vertical axis that retains the 8-in. × 5.25-in. of Standard Celeration Charts (Lindsley, 1956-1971).

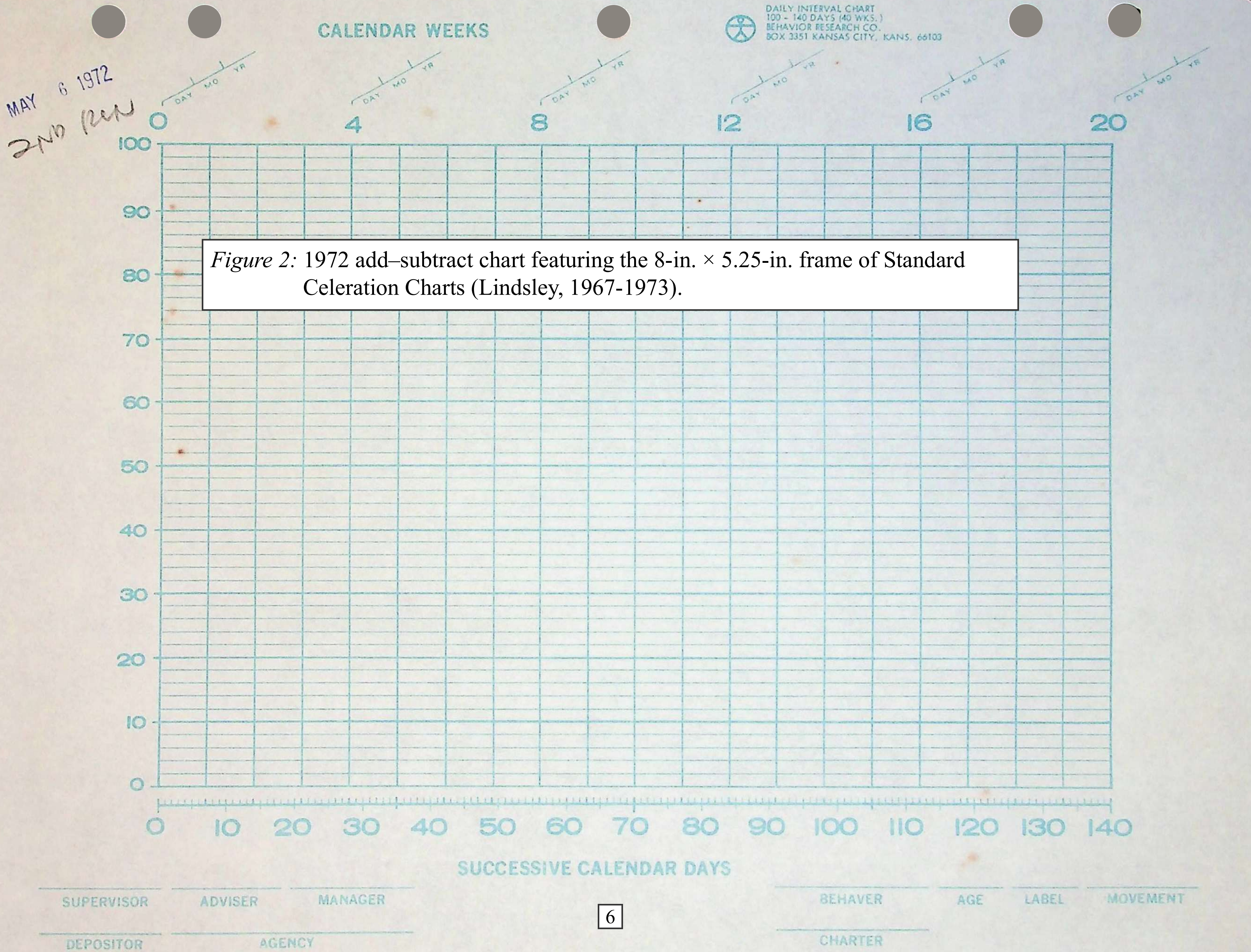

Figure 2: 1972 add–subtract chart featuring the 8-in. × 5.25-in. frame of Standard Celeration Charts (Lindsley, 1967-1973).

Tailoring displays to specific data sets has many commonly identified drawbacks. Lindsley and his students identified this as one inspiration for standardizing the axes of the SCC (Lindsley, 1992). Changing scales to fit data can affect the data interpretation (Huff, 1954; Tufte, 2001). Individualizing displays also makes it challenging and time-consuming to compare data collections (Datchuk & Kubina, 2011). These drawbacks were a primary rationale for the standardization of the SCC and the methods for sharing them within the standard charting community. From Lindsley (1997):

> If stretch-to-fill charts were used in animal pictures, an elephant would look like a long-nosed, hairless mouse! They both would appear the same size because they had been stretched to fill the same size rectangle. (p. 530)

The 6-cycle × 20-celeration period, 8-in. × 5.25-in. format was a stipulation for all charts developed by Lindsley et al.

When Lindsley designed the comparison index chart, he made notes insisting that it follow the exact frame of the recently finalized DG-5. For example, Lindsley's development notes stamped "Mar 20 1968" include large scrawls of "Check to be sure of exact size as 6 cycles × 140 days" and "All other printing should superimpose 6 cycle × 140 days graph" (Lindsley Graph Paper History binder; how to cite?). Lindsley prototyped a large number of charts, laboring to make sure that they could fit into a 6-cycle × 20-celeration period format with the 20 horizontal periods fitting standard time values. These charts included, but were not limited to, charts where each line represented decades, years, months, weeks, days, 4-hour periods, hours, 10-minute periods, minutes, 10-second periods, and seconds (Lindsley, 1967-1973). In fact, on a prototype for a Minute per 10-minute chart stamped "Sep 26, 1969," Lindsley omitted the horizontal axis lines on the bottom two cycles of the chart (there could not be frequencies lower than .1 per minute), but left the frame of the chart consistent with the 6-cycle grid in order to preserve the ratio (Figure 3).

Celeration was a *product* of displaying data on a grid with a fixed width × height ratio

By 1968, the dominant chart used by Lindsley, and colleagues was the 8 × 5.25 ratio displaying daily data using 6 vertical base-10 multiply cycles by 20 fixed horizontal periods. The emphasis was not on quantifying change but rather on standardizing display. Between 1969 and 1971, Lindsley and colleagues made the radical discovery that behavior changed logarithmically and that their fixed chart structure allowed them to quantify and compare change along straight lines. By doing so, they were able to predict future behavior rates (Koenig, 1972). Without standardizing a display and the "massive amounts of easily compared data," this "counter-intuitive," the inductive discovery of celeration and the accompanying tools of analysis and quantification that this discovery revealed may not have emerged (Lindsley, 1990a, p. 7). The first documented use of the term *celeration* was not until James Morrey's dissertation in 1970.

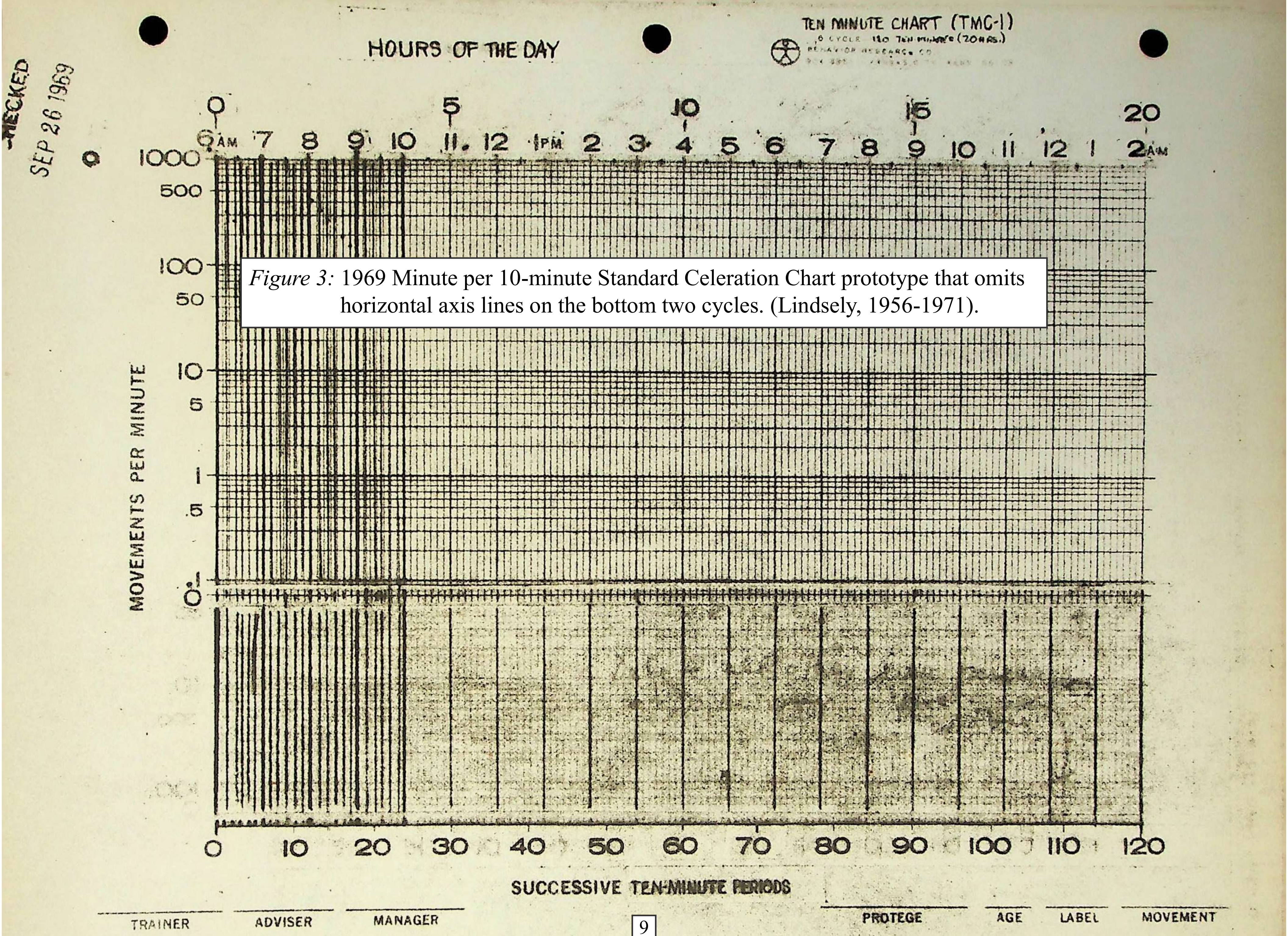

Figure 3: 1969 Minute per 10-minute Standard Celeration Chart prototype that omits horizontal axis lines on the bottom two cycles. (Lindsely, 1956-1971).

A ×2 Celeration requires a visual anchor to be functionally standard

As celeration emerged in the years leading up to Carl Koenig's dissertation in 1972, Lindsley and colleagues realized that immediate visualization of *times two of how many and for how long* was an essential gift of the SCC (Koenig, 1972). With elastic axes, viewers must spend time examining the axes rather than the data to know the values involved (Lindsley, 1992; Vargas, 2009). One of the standard charting community's precepts is that a ratio measurement has little value on its own. Without a count, a ratio is the equivalent of a dimensionless quantity. A ratio of 3 out of 4 is a very different number when considering 12 things as distinct from 2000 things. Modifying both axes of a celeration display makes this mistake. Standardizing only the ratio of the dimension of the graph was not enough of an anchor when viewing displays on an SCC (see demonstration document).

Displaying data on a grid with a fixed width × height ratio allowed for immediate consumption of complex data, regardless of display size

The standardization of the 8-in. × 5.25-in. ratio and the 6 × 20 grid promoted methods for training people how to do chart analysis and "learning pictures" with practice materials as small as postage stamps. Practice sheets used representations of charts as small as approximately 8 mm × 5 mm for identifying frequencies, celeration values, bounce values, types of celeration changes, probability of outliers, celeration types, and other analysis tools (Lindsley, 1993). On grids 10 across and 10 deep, a fluent charter could identify the approximate value of a data point faster than one per second (Lindsley, 1992 Figures 4 and 5). Graf and Lindsley (2002) included flashcards the size of business cards which displayed record floors with values that charters could identify at similar frequencies (Figure 6). The materials were possible only with the standardization of the number of cycles and number of celeration periods within a frame with a standard width-to-height ratio.

Summary

Based on the rationales summarized above, if a person wishes to claim to be using a SCC, the user must maintain 6 base-10 multiply cycles on the vertical axis, 20 celeration periods along the horizontal axis, and the grid measurement ratio of 8 × 5.25.

Name ____________________ Date _______

Point Say the outlier probability as one out of a (thou, mill, bill, trill).

OutlierProb x1c3b
Shuffled after 2, Page 1
Pics = 8

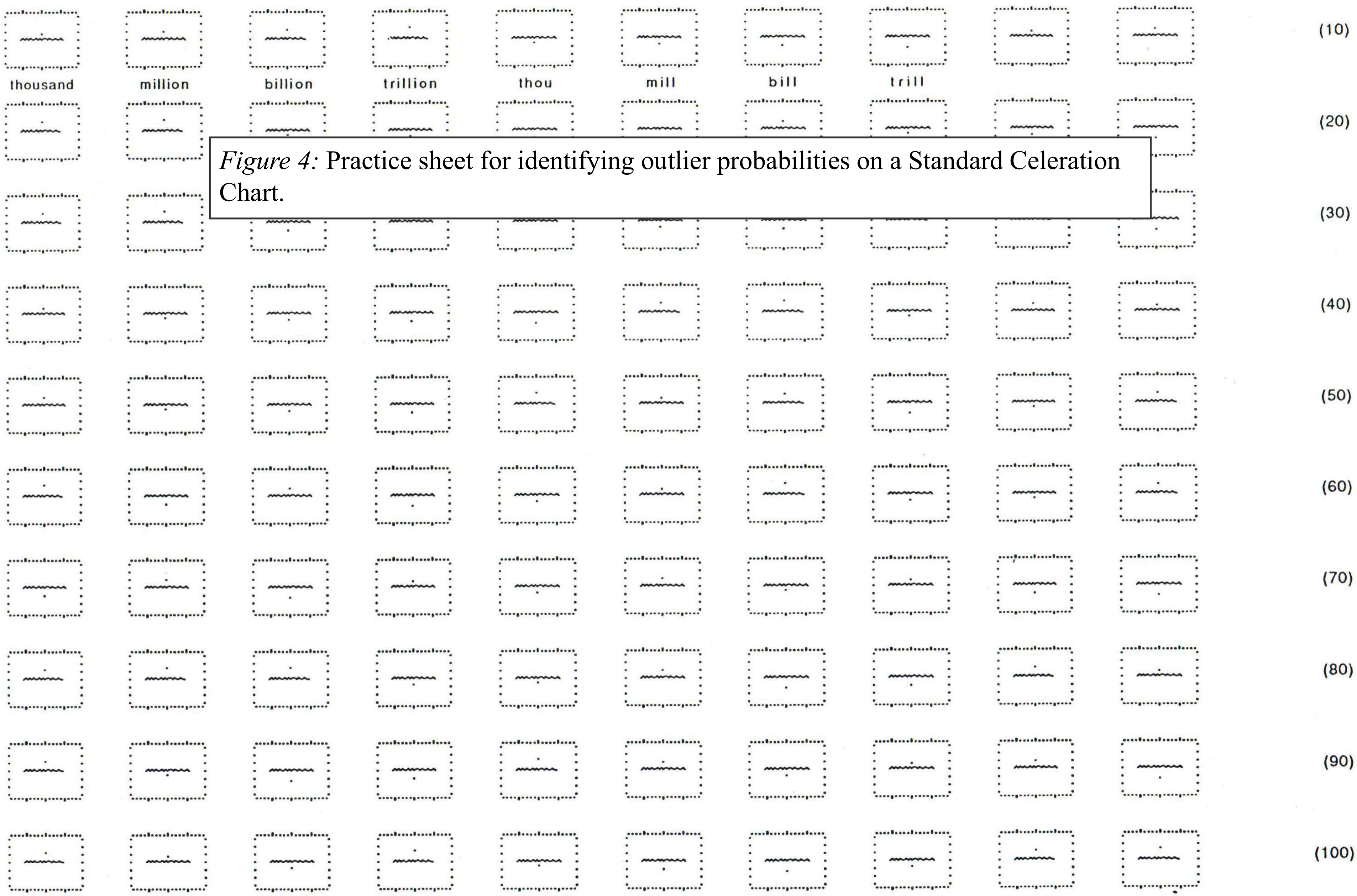

Figure 4: Practice sheet for identifying outlier probabilities on a Standard Celeration Chart.

READING-21A

Name ________________________ Date _______

Point Say the frequency of each dot on the SCC: (one per minute, ten per minute).

Ref.Freqs. x10

Num Ord, Page 1

Pics = 7

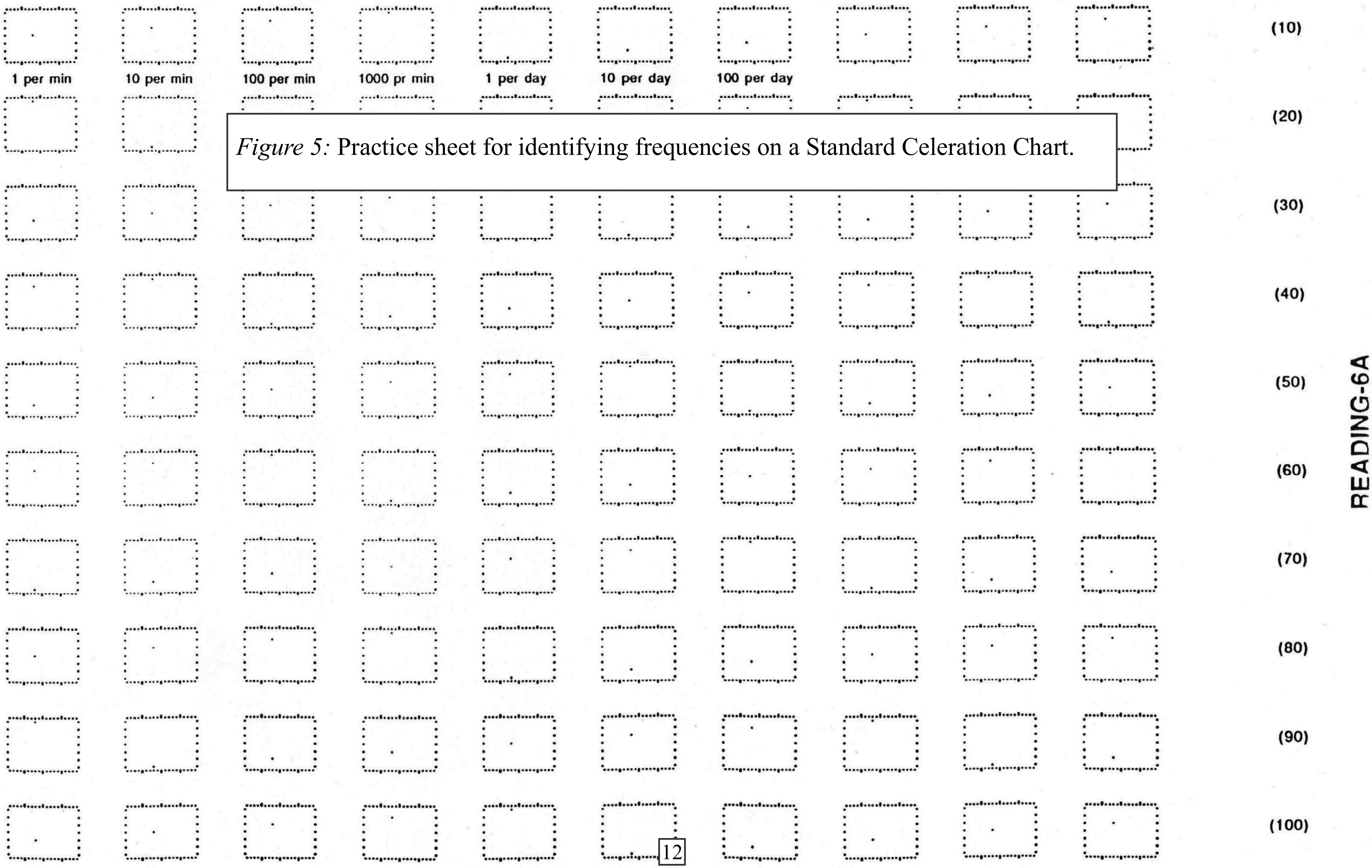

Figure 5: Practice sheet for identifying frequencies on a Standard Celeration Chart.

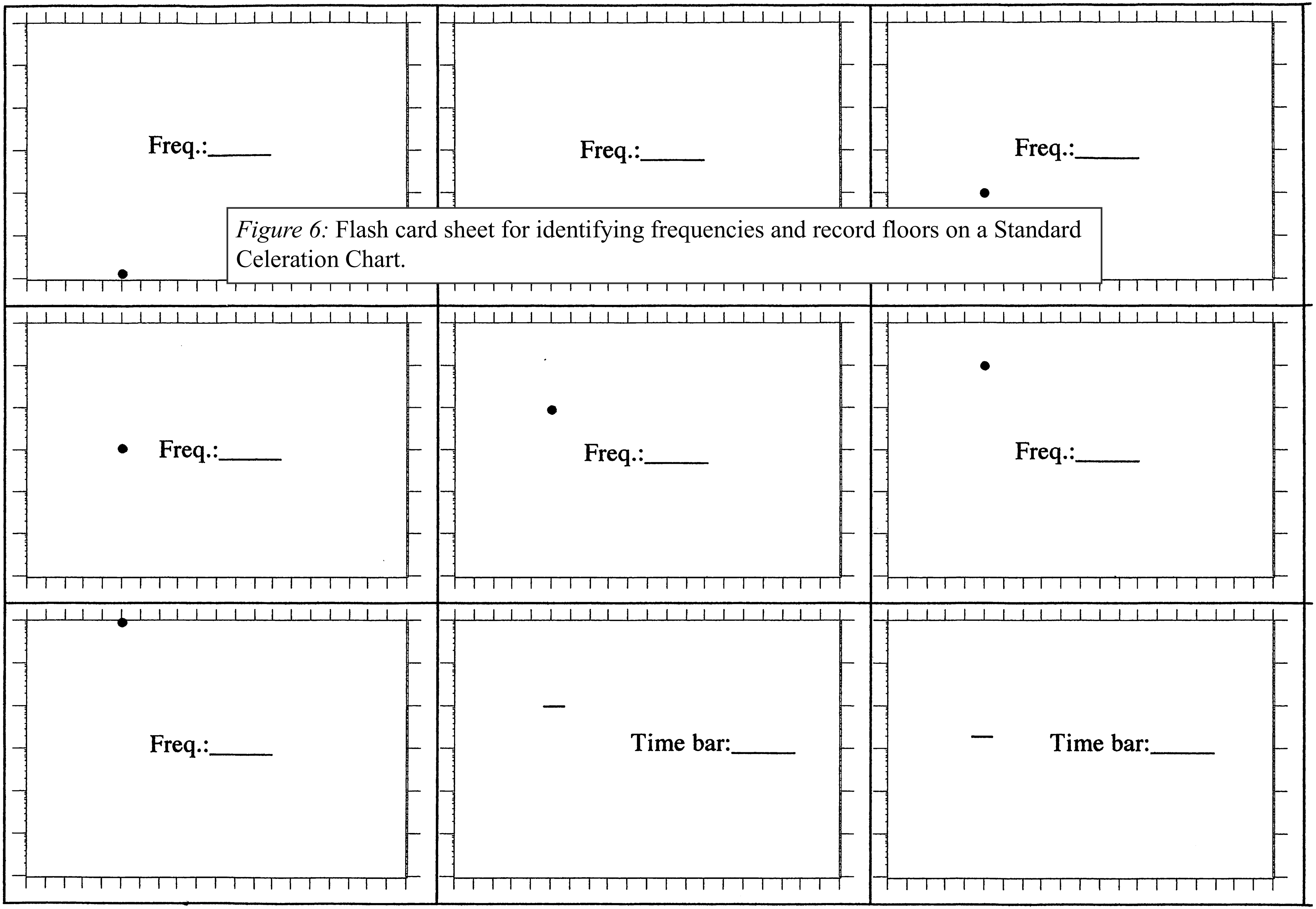

Figure 6: Flash card sheet for identifying frequencies and record floors on a Standard Celeration Chart.

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Perspective: Pinpoint, Record, and Consequate (1967a)

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Demonstration document

Interested readers wanting in-depth visual demonstrations of the problems with reading and using charts with varied multiply cycles and celeration periods can refer to the demonstration document that follows.

Members of the charting community have produced and used displays of celeration that vary from the Standard Celeration Chart for various reasons. For example, some authors have said that publications have required them to use segments of SCCs rather than SCCs standardized as described in this document. Some members of the charting community are unaware of the empirical rationales for preserving the Standard Celeration Chart's axes. The reader is left with no visual anchor for the eye to have visual perspective common across charts in these cases. For example, the next four data displays sets all have ×2 celeration lines of 33.52 degrees (Figures 8 and 9). Among other things, it is impossible to know the multiples by which the data have changed without a considerable orientation to the axes.

Figure 8: Four different data displays without cycles or celeration periods marked:

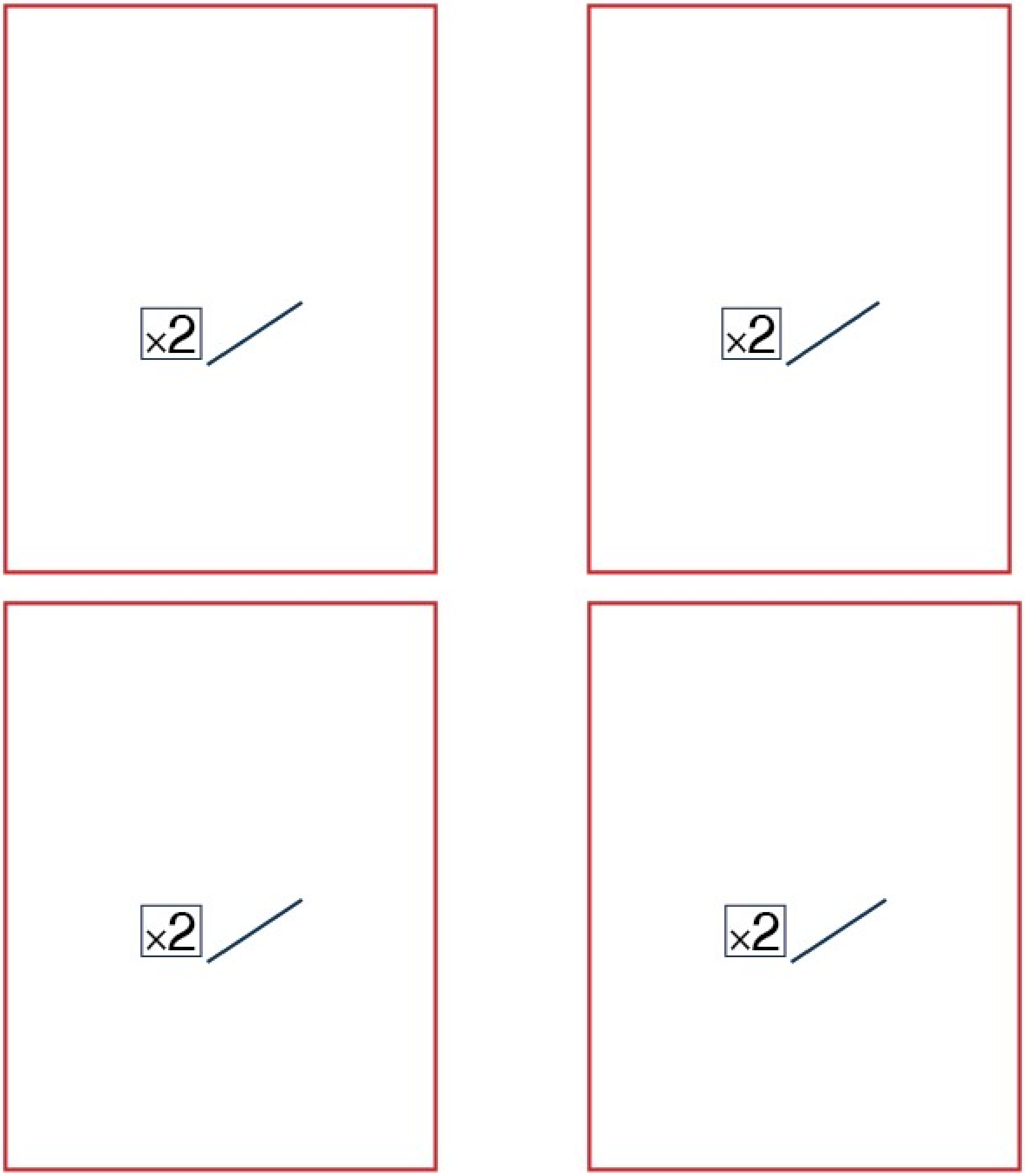
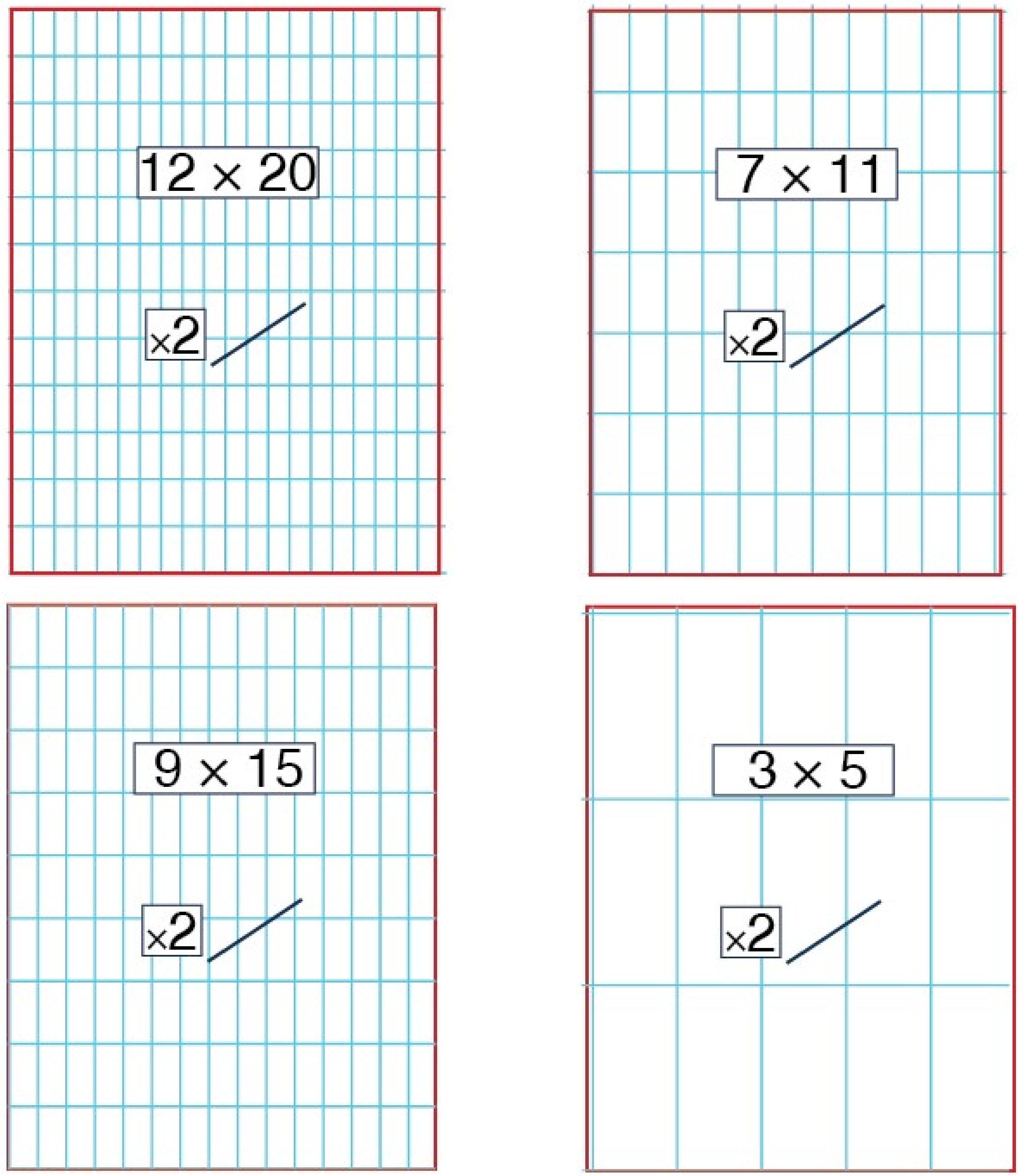


Figure 9: Four different data displays with cycles and celeration periods marked:



The following series of graphics, show one arrangement of dots spaced similarly on different charts varying from the standard axes of the SCC. Example 8a shows the two dots on a traditional 6 × 20 SCC with the first cycle's value starting at one. Those familiar with the SCC will identify the approximate values of the two dots (100 and 1000). Knowledgeable charters will know, with or without a labeled axis, that the upper dot is ten times that of the lower. This analysis is possible without referring to the axes because of the familiar 6 × 20 ratio. More experienced charters would even be able to identify the celeration period in which the dots reside.

Figure 9a: Values of 100 and 1000 on a 6 × 20 SCC without gridlines

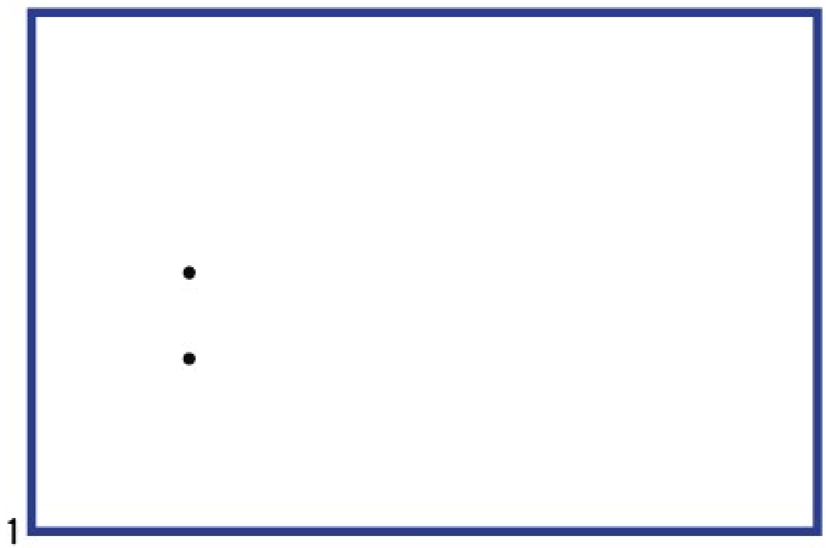
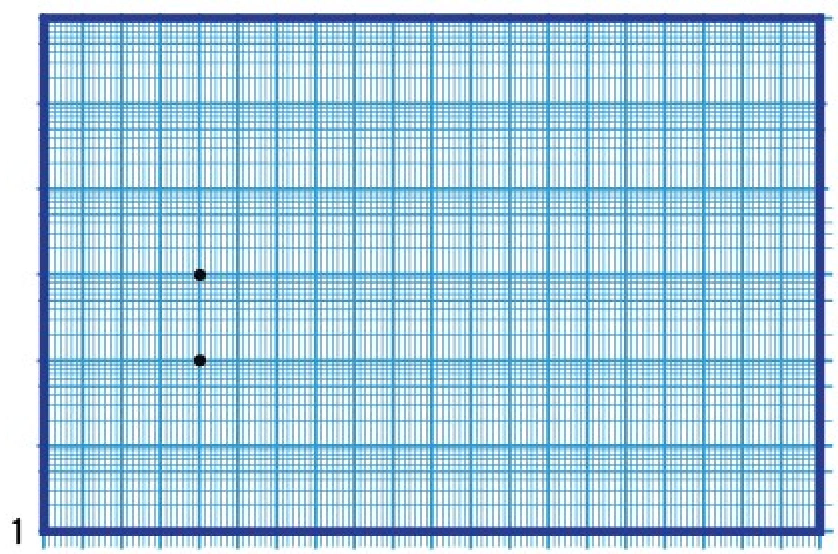


Figure 9b: Values of 100 and 1000 on a 6 × 20 SCC with gridlines



The third example shows the same spacing on a chart without gridlines that is not a 6 × 20 grid, but rather a 3 × 10 grid. Again, an experienced charter will have difficulty identifying the values (10 and approximately 32).

Figure 9c: Dots on a 3 × 10 chart without gridlines

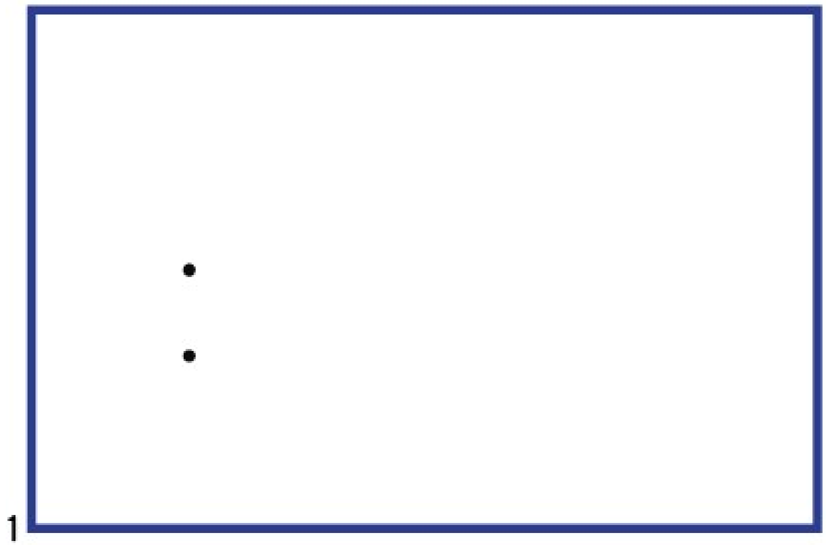
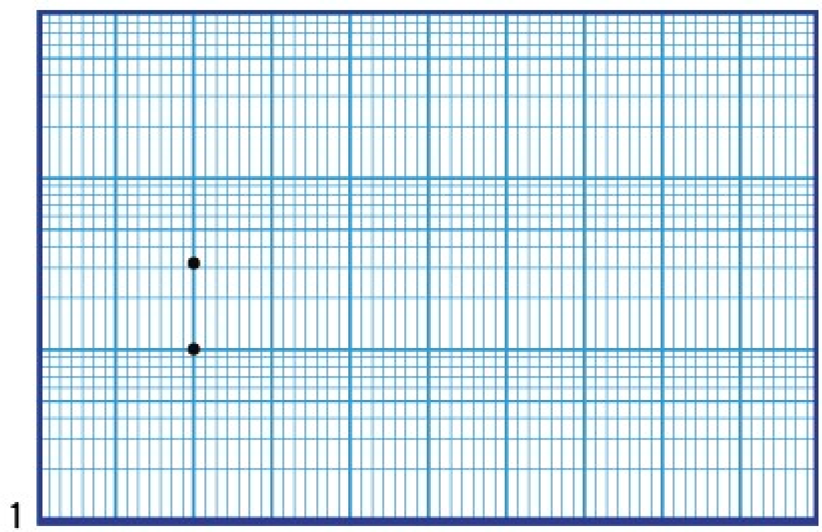
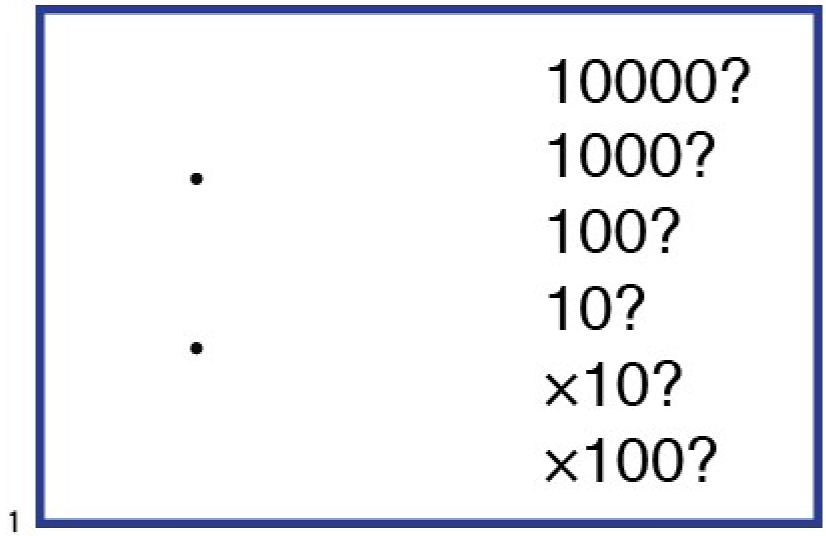


Figure 9d: Values of 10 and 32 on a 3 × 10 chart with gridlines



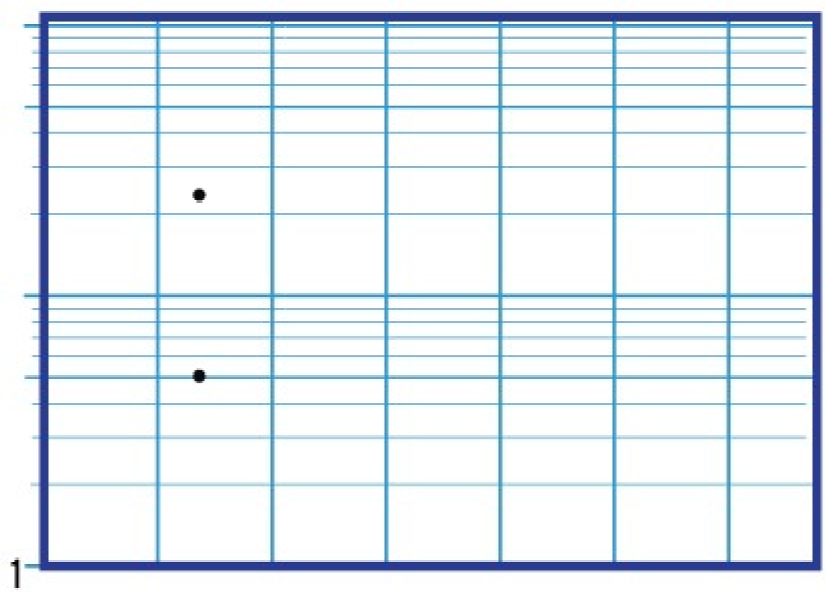
Figures 9e and 9f demonstrate another chart without lines. Before the uncertainty introduced in the previous models, most people familiar with standard charting would have been able to tell you both the approximate absolute values of the two dots and the relative difference between the two. But, without the SCC's standard axes, one now has to ask how many cycles the chart has and how many celeration periods it covers.

Figure 9e: Values of ? and ? on a ? × ? SCC with no gridlines



The values are none of those. Instead, the values are five and approximately 23 because this chart is a 2 × 6.7 chart.

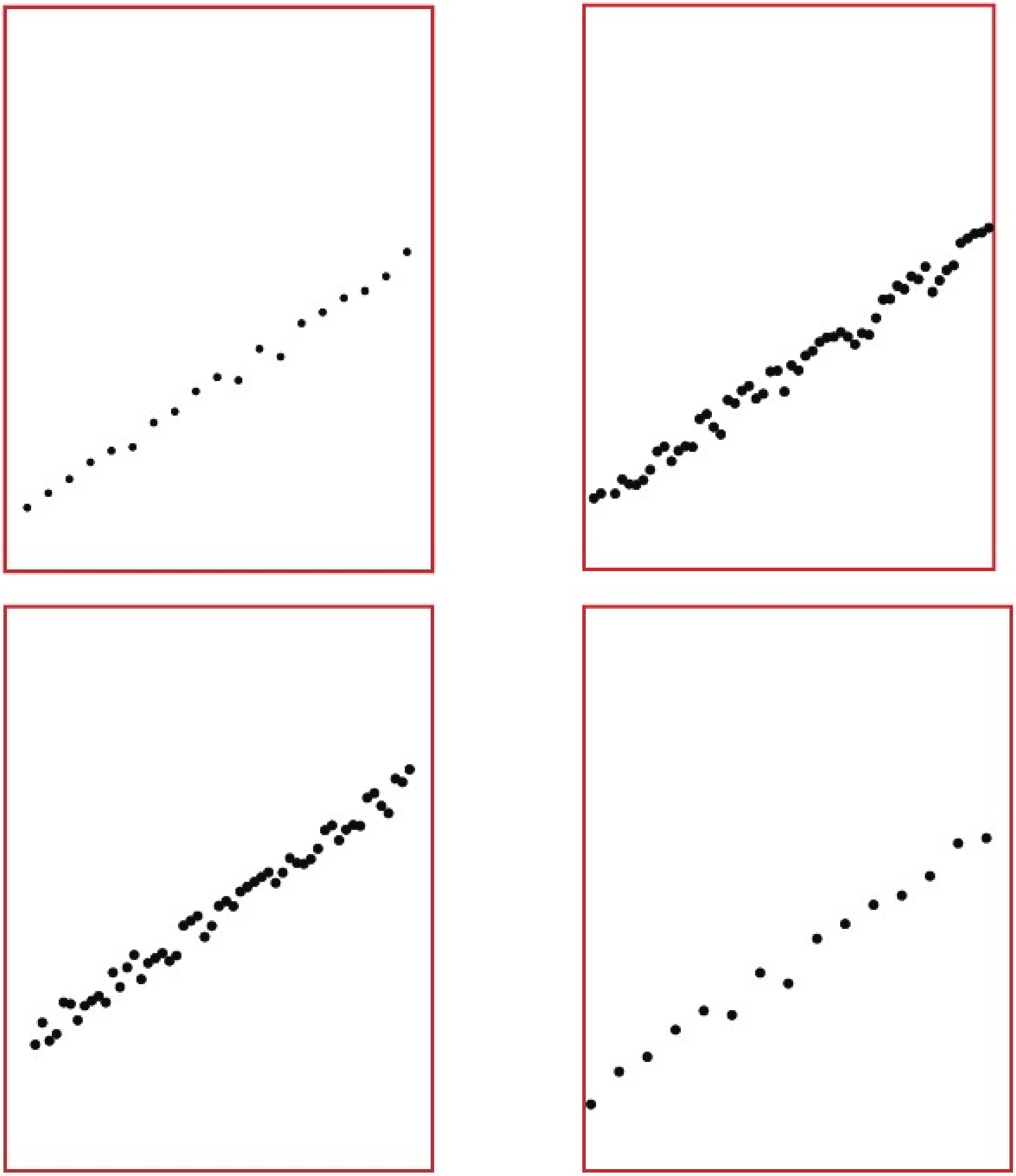
Figure 9f: Values of 5 and ~23 on a 2 × 6.7 chart with gridlines



The final figures are charts showing data on the approximate 34-degree ×2 angle of the SCC. This angle represents data multiplying by two in each celeration period. Thus, all of their frames are the same size yet represent various numbers of base-10 cycles.

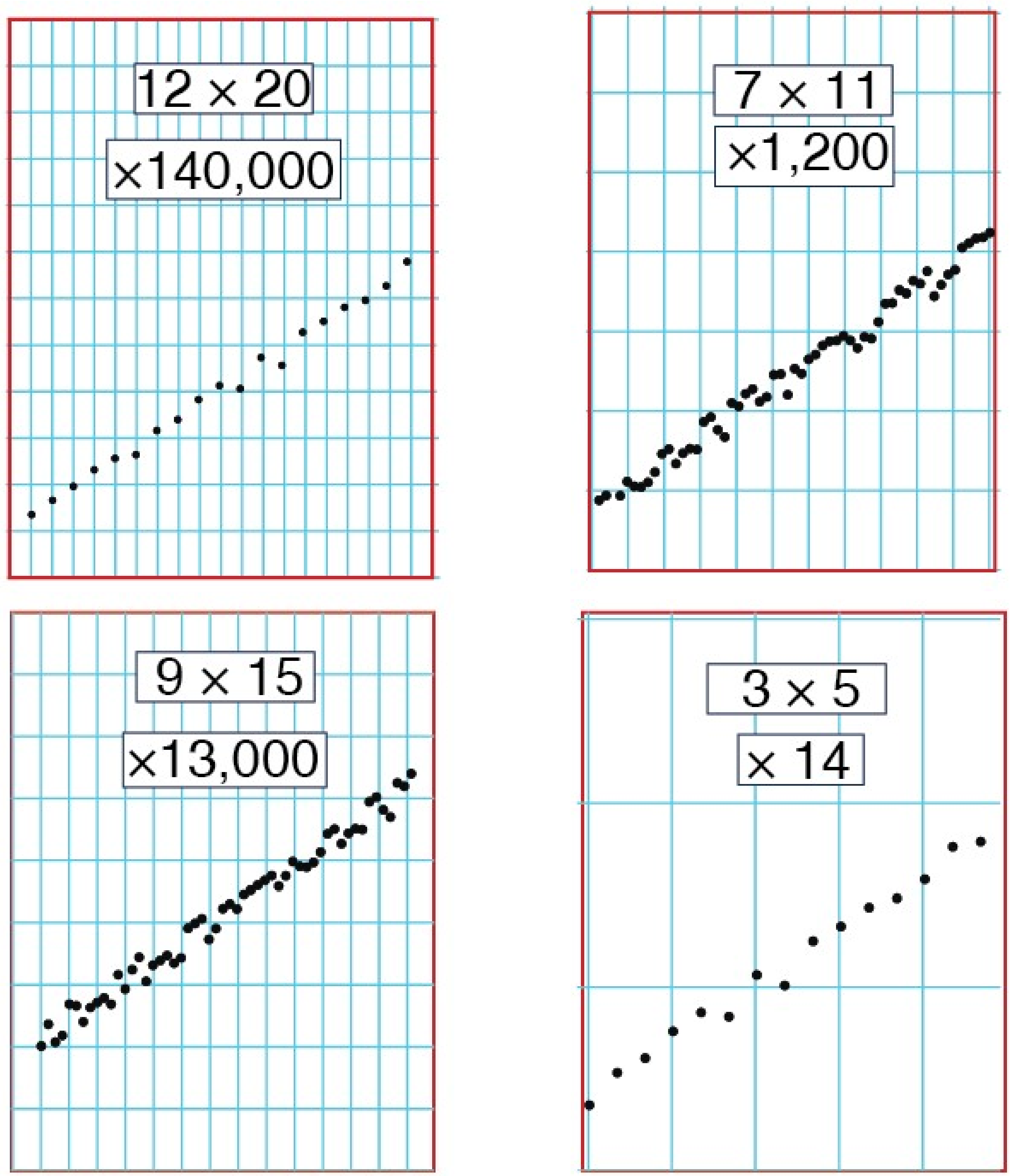
Although all four examples demonstrate the "times-two" angle of a SCC, the variability of the axes means that the angle alone does not communicate the magnitude of change in a standard way.

Figure 10a: Four charts featuring ×2 celerations on variable axes



In the previous examples, four sets of data, multiplying by two each celeration period, show radically different magnitudes of change and are impossible to compare visually. Nevertheless, they all look virtually the same.

Figure 10b: Four charts featuring ×2 celerations on variable axes



By reintroducing the familiar 6 × 20 grid, it becomes clear that those four sets of data are radically different in scope and magnitude. This difference would be clear even without the gridlines' contributions. For example, the span from the lowest number to the highest number of each series varies from a multiple of 140,000 to a multiple of 14.

Figure 10c: The same four ×2 celerations on a 6 × 20 Standard Celeration Chart