# Visualizing Student Time Use

Abstract

How do students visually represent the use of time, when it is a non-visual experience? We asked 25 undergraduates at a public university to generate representations of their time-use along four components: sequence, duration, timing, and frequency. The resulting use of space and form was analyzed by way of an iteratively developed coding scheme. We discuss the implications of our findings for the nature of mental representations of time, and how this can be applied to improve student productivity.

*Keywords:* external representation; diagrams; visualization; time-use; coding scheme; qualitative content analysis

How students utilize time has important implications for their academic and professional success (Fernex, Lima, & de Vries, 2014). Students need to effectively allocate their time between competing priorities such as homework, sleep, and extracurricular activities. The *visualization* of time-use offers practical applications from resource allocation, to detecting patterns in behavior. In education, such applications are particularly compelling, as pedagogical activities challenging students to think critically about time-use are a first step toward strategic planning and evaluation of temporal resources.

This visual activity presents a substantial challenge as temporal phenomena are not strictly visual. When speaking about time, we routinely employ metaphors, such as: "The deadline is sneaking up on me, but my manuscript is ahead of schedule." (Lakoff & Johnson, 1980). We use metaphor to create correspondence between unfamiliar (abstract) and familiar (concrete) concepts. Similarly, these mappings can be applied in visual forms: *graphical metaphors*. In this work, we explore students' use of graphical metaphors when representing time.

**Space and Time as Representational Media**

Space and time structure our everyday experience, yet we think of these as entities to be represented (i.e. domains) more than entities that may represent (i.e. media). The advantages of space for representation have been extensively documented (Bertin, 1983/1967; Tufte, 2001), and the observation that space is best represented in a spatial medium is common place (Larkin & Simon, 1987). Conversely, *time* is less frequently considered a representational medium, although Bertin (1983/1967) noted that time does serve as a medium in language, where sequences of letters and words must be preserved, otherwise meaning may be lost. A variety of cultural artifacts, such as calendars and clocks, represent time in the medium of space. These are extrinsic representations, where the properties of the domain must be enforced on the medium in an arbitrary manner (de Vries, 2012; Palmer, 1978). To represent sequence in a two-dimensional plane, some artificial device is required to enforce the property of linearity. This can be accomplished by a graphical form (e.g. an arrow) by a domain-specific representational format (e.g. a calendar), or by relying on reading direction as a convention for imposing linearity. A fundamental asymmetry is evident when using space to represent anything other than space and *a fortiori* time. This asymmetry is consistent with research in cognitive linguistics (Boroditsky, 2000; Casasanto & Boroditsky, 2008), which suggests that individuals use spatial information when thinking about time, but rarely use temporal information when thinking about space.

**Form and Space in Diagrams**

Tversky (2011) examines how space and form are used to convey meaning in diagrams. She first identifies the use of space for depicting order, positioning forms (marks on the page) along horizontal, vertical and central-peripheral planes. She suggests that the "salient dimensions of the world" reinforce these orientations, while certain properties of human vision (the acuity of the center of the visual field) ground the latter (Tversky, 2011, p. 509). Tversky identifies a number of spatial conventions evident in empirical studies of graphic representation. An examination of productions by children revealed a strong relationship between writing direction and depiction of temporal sequence for both Arabic (right-to-left) and English (left-to-right) (Tversky, Kugelmass, & Winter, 1991). While use of the horizontal dimension is flexible, Tversky suggests the vertical dimension is often used to express concepts with asymmetric values (e.g. quantity, quality). These observations are consistent with our bodily experience of the world, in which we find horizontal symmetry in the environment, but must literally overcome the force of gravity to move in the vertical direction.

**Flexibility in Representation**

In response to a representational task, individuals can do a number of things depending on the affordances of the medium and their “catalogue” of available responses. Reuchlin (as cited in Lautrey, 2003) coined the term *vicariance* to describe how individuals rely on a number of redundant mechanisms for performing cognitive tasks. We view representation as a vicariant process, where the range of potential representations is determined by an individual’s repertoire of learned behaviors. In the case of students (with paper and pencils) we might expect to see:

− Letters and numbers

− Figurative drawings

− Standard representations: histograms, pie charts, maps, etc.

− Domain-specific representations: particular to the domain in which they have evolved (diSessa, 2004) (e.g. Gantt Chart)

− Ad-hoc representations: inventing new formats

If like Tversky (2011), we consider representations as indicators of thought, then examining graphic productions of time-use may help us understand how students conceptualize this important factor in their academic success. Do students think of time-use as linear, or cyclical? Do they emphasize order or timing of activities? As a first step, we explore variability of representational behavior in a student population. Our analysis is guided by two questions:

(1) How do students use space and form to represent time-use?

(2) Which mechanisms are used to represent each component: sequence, timing, duration and frequency?

# Method

## Participants

Twenty-five (22 female, 3 male) undergraduate Education majors (median age = 23) at a public university participated as a course requirement.

## Materials & Procedure

Students were given one sheet of paper containing instructions, with one hour to complete the exercise. Instructions prompted students to produce representations of time-use for a typical week during the academic year. They were explicitly directed to represent activity (what), sequence (order), duration (quantity), timing (chronology), and frequency (number of occurrences), in as many representations as necessary, using any graphic conventions. Only the term “representation” was used, avoiding biasing formats with words such as: chart, graph, sketch, text, etc.

A coding scheme was developed using a directed approach (Hsieh & Shannon, 2005). Rubrics were developed for space (Table 1), form (Table 2), and primary mechanisms (Table 3) in alignment with the discussion of space and form in Tversky (2011). The resulting scheme was applied by three graduate students. Results were evaluated for inter-rater reliability, with positive outcomes (space (S1-S6) $\alpha = 0.87$, form (F1-F5) $\alpha = 1.00$, primary mechanisms (M1-M5) $\alpha = 0.97$).

# Results

## Use of Space

The use of space in the diagrams ($n=25$) was consistent with our expectations based on reading direction. Twenty-one diagrams were characterized as linear and four circular. Nearly all students (22) started the day in the upper left corner. Of the remainder, two were circular representations (day start at 12:00 of a clock face), and one was linear (starting in lower left corner).

**Linear Representations** Nineteen of the 21 linear diagrams utilized both horizontal and vertical axes, while the remaining utilized only the horizontal. Sixteen diagrams adopted a left-to-right orientation, while four alternated directions in a snake-like pattern. Figure 1 is a prototypical example of linear representation. Here, the reader scans from left-to-right, jumping at the end of horizontal space, consistent with reading/writing behavior.

**Snake Representations** Four diagrams avoided the end of line scanning effect by alternating direction at the end of each line (Figure 2). We dubbed these “snakes”, as the information appeared to slither across the page. These started in the upper-left and depicted first left-to-right and then right-to-left. In each case a form, either line or arrow, indicated the change in direction. We contrast this with Figure 1 in which the student assumes the viewer will skip to the next line without the need for an indicator.

**Circular Representations** Of the four circular diagrams, three presented information in the clockwise direction (Figure 3). There was minimal use of the radial orientation, with only two diagrams depicting flow from the periphery of the circles toward the center in a spiral fashion.

**Use of Form**

The use of form in the sample varied greatly, suggesting the instructions were effective in motivating students without biasing their use of visual forms. Arrows were found in 21 diagrams, orienting the viewer from “earlier” to “later”.  Number was the most prevalent form, found in 23 diagrams, followed by text with 21. Nineteen students included depictive drawings, while only

13 utilized more than one color. Figures 4 - 6 exemplify the range of forms in the drawings from highly depictive to highly descriptive. As evident in these examples, the use of text vs. depictive drawings to describe activities fell on a continuum.

**Primary Mechanisms**

Table 4 describes the percentage of diagrams that represented each component of time-use, as well as the number of diagrams utilizing each mechanism. Only four students represented all components of time-use. Frequency was most commonly neglected, followed by duration, then timing. Sequence was always indicated by position, in many cases with the addition of arrows, while timing was almost exclusively represented by number. Two imaginative illustrations also utilized position to indicate timing by placing drawings around the corresponding positions of a clock face to indicate the time of day they began. Duration was often absent from the drawings, but when it was present, it was indicated by number. Two novel illustrations also utilized color to differentiate categories of activities, such as school work, extracurricular activities, and leisure.

## Discussion

We found that students produced a wide range of representations using a variety of spatial principles and visual forms. Students utilized multiple methods for extrinsically representing time in a two-dimensional visual medium: arrows, evoking domain-specific representations (diaries & calendars) and reliance on reading direction.

Regarding space, we observed a preference for linear patterns in accordance with reading direction. Few students used circular patterns to indicate cyclical phenomena. Tversky (2011) made a similar observation, noting that students were reluctant to produce circular diagrams even when asked to model cyclical processes. She suggests that linear thinking is easier than cyclical, and that students may prefer to consider a simple forward progression of time. Another explanation is the influence of cultural artifacts on the choice of format. The linear flow of information in the diagrams was evocative of calendars and agendas, suggesting that the artifacts utilized for planning may influence students' choice of representational format.

Regarding form, text and figurative drawings were employed to represent activities, while number was used to describe timing, frequency and duration. Arrows were used exclusively to enforce linearity, directing the viewer's attention to the forward flow of time.

Of greatest interest were representational choices for the components of time-use. Although the instructions allowed for multiple representations, students attempted to create a single integrated diagram. Standard formats such as charts and graphs were not exploited, despite their efficiency in communicating quantities (such as duration). For the homogeneous sample of education majors, it is possible that these formats were either not familiar, or deemed not suitable for the task goal. Future work should include students in science and engineering to explore variance in formats as a function of prior knowledge. While no student constructed a complete domain-specific representation (e.g. diary, calendar), several utilized space in a fashion consistent with those representations. The remaining productions demonstrate a preference for complex, integrated diagrams, reflecting an attempt at simultaneously inventing a representational format and expressing new content (ad-hoc context-specific representation). Alternatively, students might place a high value on informational efficiency. To examine this further, we suggest refining the stated goal from one of "informing" to differentiated tasks for planning, problem solving and exposition. While revealing sources of variation, a more strictly defined purpose might allow for more robust inferences about the underlying conceptual structure suggested by students' graphic productions.

Overall, our analysis demonstrates noticeable trends in student representations of time-use, which can be applied to the production of organizational aids for students, and the design of subsequent activities. The exercise also prompted student reflection and discussion on time allocation as it pertains to prioritization and goal-setting. Preliminary analysis of the content of the productions revealed diversity in the categorization of activities, which presents an interesting question for further research. We suggest that future work evaluate the content of productions by activity categories (school, homework, leisure, sleep, etc.) alongside pedagogical activities on time-use planning and evaluation. In addition to improving students' meta-representational competency (diSessa, 2004) we propose that constructing and analyzing representations of time-use may help students better understand how they allocate their time, and thus empower them to take control of this important factor of their academic success.

References

Bertin, J. (1983). *Semiology of Graphics: Diagrams, Networks, Maps*. Madison, WI: University of Wisconsin Press. Original published in 1967.

Boroditsky, L. (2000). Metaphoric structuring: understanding time through spatial metaphors. *Cognition*, *75*, 1-28.

Casasanto, D. & Boroditsky, L. (2008). Time in the mind: using space to think about time. *Cognition*, *106*, 579-593.

De Vries, E. (2012). Learning with External Representations. *Encyclopedia of the Sciences of Learning*, 2016-2019.

diSessa, A. (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction*, *22*, 37-41.

Fernex, A., Lima, L. & de Vries, E. (2014). Exploring time allocation for academic activities by university students in France. *Higher Education*, 1-22.

Hsieh, H.-F. & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*, 1277-1288.

Lakoff, G. & Johnson, M. (1980). *Metaphors We Live By*. Chigaco: University of Chicago Press.

Larkin, J. & Simon, H. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, *99*, 65-99.

Lautrey, J. (2003). A pluralistic approach to cognitive differentiation and development. In R. J. Sternberg, J. Lautrey, & T. I. Lubard (Eds.), *Models of intelligence: International perspectives* (pp. 117-131). Washington, DC: APA Press.

Marsh, E., & White, M. (2006). Content analysis: A flexible methodology. *Library Trends*, *55*, 22-45.

Palmer, S. E. (1978). Fundamental Aspects of Cognitive Representation. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and Categorization* (pp. 259-302). Hillsdale, NJ: Erlbaum.

Tufte, E. (2001). *Visual Display of Quantitative Information* Cheshire, CT: Graphics Paper Press LLC.

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, *3*, 499-535.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515-557

# Tables

*Table 1*: Coding Scheme for Use of Space.

| # | Variable | Values (select one) |
|---|---|---|
| S1 | Gestalt Use of Space | 1 = Linear<br>2 = Circular |
| S2 | (Linear) Horizontal | 0 = None<br>1 = Left → Right<br>2 = Both<br>3 = Right → Left |
| S3 | (Linear) Vertical | 0 = None<br>1 = Top → Bottom<br>2 = Both<br>3 = Bottom → Top |
| S4 | (Circular) Circumferential | 0 = None<br>1 = Clockwise<br>2 = Both<br>3 = Counterclockwise |
| S5 | (Circular) Radial | 0 = None<br>1 = Periphery → Center<br>2 = Both<br>3 = Center → Periphery |
| S6 | Location of Origin | 0 = Top Left<br>1 = Bottom Left<br>2 = Bottom Right<br>3 = Top Right<br>5 = Center |

*Table 2*: Coding Scheme for Use of Form.

| # | Variable | Definition |
|---|---|---|
| F1 | Text | Alphabetic symbols in French/English |
| F2 | Number | Digits and text units of measure |
| F3 | Drawing | Depictive graphical representations |
| F4 | Arrow | Line with a directional end |
| F5 | Color | More than one color present |

*Table 3*: Coding Scheme for Primary Mechanisms.

| # | Variable | Values (all that apply) |
|---|---|---|
| M1 | Activity | |
| M2 | Duration | Size, Position |
| M3 | Timing | Text, Number, Drawing, |
| M4 | Sequence | Arrow, Color, Other |
| M5 | Frequency | |

*Table 4*: Frequency (# of diagrams) of Time-Use Components

| Mechanism | Sequence | Timing | Duration | Frequency |
|---|---|---|---|---|
| % Inclusion | 100 % | 96% | 54% | 46% |
| Position | 25 | 2 | 1 | 2 |
| Size | | | 4 | |
| Text | | | | |
| Number | 2 | 21 | 9 | 6 |
| Drawing | | 2 | 1 | 1 |
| Arrow | 15 | | | |
| Color | | 2 | | 2 |

* Note that any component of time-use (such as sequence) could be represented by multiple mechanisms, thus each cell has a maximum value of (n=25).

Figures

*Figure 1*: A prototypical linear representation.

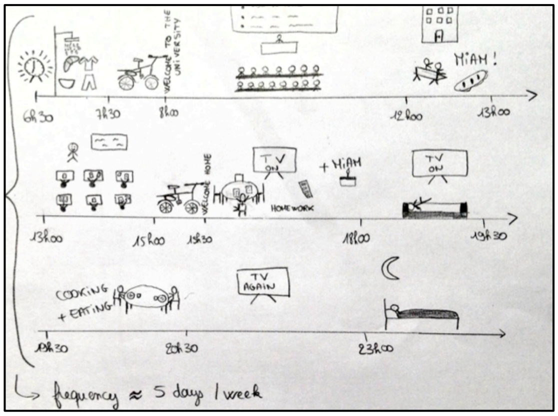


*Figure 2*: A snake representation.

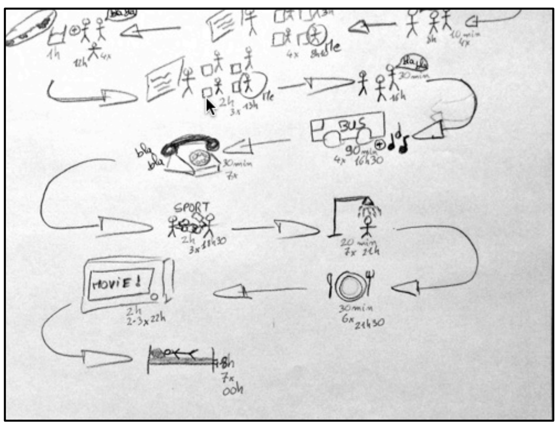


*Figure 3*: A circular representation.

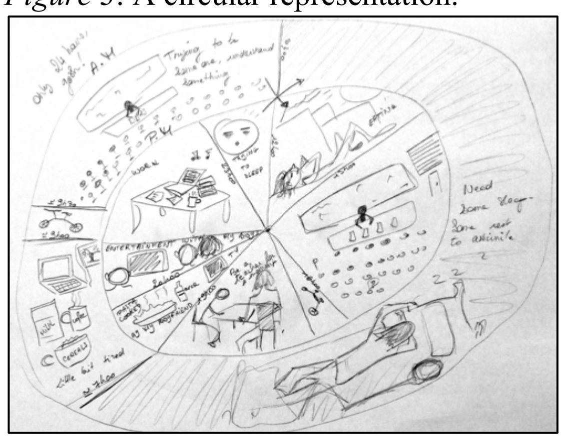

*Figure 4*: A depictive representation.

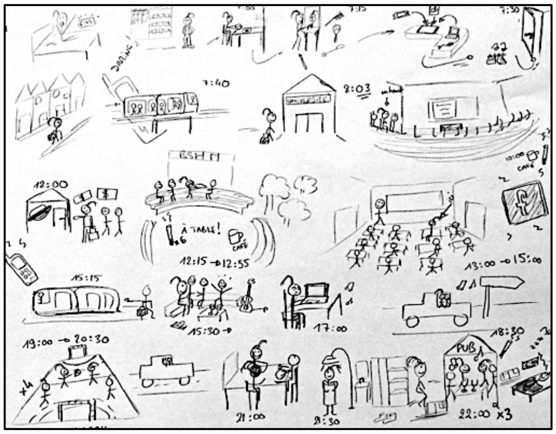


*Figure 5:* A balanced representation

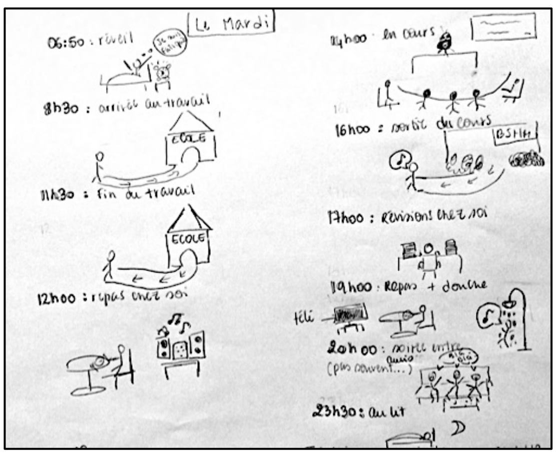


*Figure 6:* A descriptive representation.