VISUALIZING TIME USE

Amy Rae Fox

International Cognitive Visualization — June 6, 2014
Université Pierre Mendès France — Presentation June 10, 2014

Introduction

This work constitutes the outcome of my semester project exploring time use from psychological and visualization perspectives. This deliverable is divided into three parts, intended to serve as independent papers.

Part 1: Conceptual **3**
Life In Space And Time: Psychological Study of Time Use In Everyday Life
This paper proposes a conceptual framework for psychological approach to time use studies, using the time-geographic framework and sociological time use methods.

Part 2: Applied **32**
Visualization Techniques for Time Use
This paper presents a survey of visualization methods used to depict time use data, based on a review of time use studies and computer graphics literature.

Part 3: Empirical **47**
Spontaneous Productions of Student Time Use
This paper presents an exploratory study evaluating the graphic productions of time use in a student sample evaluated via qualitative content analysis.

Acknowledgements

I would like to offer my thanks to several individuals who supported my work this semester. Thank you to Dr. Alain Fernex and Dr. Laurent Lima for their ongoing guidance, orientation to the methods of time use research, and for and inviting me into their undergraduate classroom to collect data for the empirical study. Thank you to Neil Jacobsen and Jennifer Braun, ICV students who devoted many hours and careful attention to coding data for the empirical study. Thank you to Neil Jacobsen and Ulrich Ludwig for providing feedback on drafts of the conceptual framework and for supporting the development of my ideas. Thanks finally to Dr. Erica de Vries for support in the production of this work, the invitation to participate in a time use research seminar, and encouragement to take on this topic of study.

1

LIFE IN SPACE AND TIME: PSYCHOLOGICAL STUDY OF TIME USE IN EVERYDAY LIFE

TABLE OF CONTENTS

Introduction 5

Psychological Investigations of Time 6

The Study of Daily Life 9

Activity 10

Duration: How much time? 10

Timing: At what time? 10

Sequence: In what order? 11

Frequency: How often? 11

Time-Geography: The Human Grounded in Space 12

Constructs 12

Notation 14

A Time-Geographic Approach: Contexts in Daily Life 17

Activity: What do we do? 18

Location: Where do we do it? 18

Social: With whom do we do it? 18

A Research Model for Psychological Time Use 20

Conceptual Validity 20

Constructs 22

Goals 23

Resources 24

Constraints 24

Contexts 24

Time (use) In Prospect 26

Educational Psychology: Student Use of Time 26

Conclusion 28

References 29

INTRODUCTION

It is by the nature of existence that human activity exists in both space and time. While it is possible for the researcher to examine activity in isolation, and similarly to consider human movement through space without regard to time, in doing so, the researcher risks overlooking puissant relations between these elemental constructs. By accounting for each dimension, time-geography provides an effective approach for examining the use of time in everyday life. In this paper we present a research model for psychological inquiries based on time use data and the time-geographic perspective. We start by reviewing the history of psychological research on the construct of time, as summarized by Hancock & Block in 2012. We differentiate between time perception and experience of time, and argue for a pragmatic but explicit consideration of time by investigators of human behavior. We then present an overview of time use research in the sociological and economic traditions and provide examples for how the study of time allocation may be used to explore psychological phenomena. Finally, the time-geographic perspective (Hägerstrand, 1989) is presented as a conceptual framework for psychological exploration of time use, and two possible lines of research are discussed to exemplify its application.

PSYCHOLOGICAL INVESTIGATIONS OF TIME

> *How people understand the nature of time in passing, and its relationship to time in prospect and to time in memory, is at the heart of the human experience. (Hancock & Block, 2012, p. 267).*

The construct of time has had a tumultuous history in psychological research. In their 2012 retrospective in the American Journal of Psychology, Hancock & Block describe the emergence, decline, and subsequent resurgence of interest in the topic, starting with the Father of American Psychology's seminal work, The Principles of Psychology. In it, William James (as cited in Hancock & Block, 2012) describes the functions of the human mind in relation to three temporal constructs: time past, time present and time in prospect. Memory and attention are the stuff of time past, perception the stuff of time present, while planning and decision-making the stuff of the future: time in prospect. These delineations are equally useful today, and over the intervening years, investigations of memory, perception and decision-making have featured according orientations toward time.

Arguably the earliest treatment of time in psychology was in the area of perception (Block, 1990). Numerous investigators have explored the smallest perceivable duration and what sensory modalities are involved in its detection. But as Hancock & Block (2012, p. 268) argue, "unlike all other forms of sensory psycho-physics, time refers to an evidently intangible quality." It is thus that the decline of interest in time research was concurrent with the rise of a strictly empiricist behaviorism in the United States, though a few insistent Europeans continued their less tangible enterprises. Eventually, the cognitive revolution in the mid twentieth century brought a resurgence of interest. Contemporary investigations of time are now plentiful, predominantly characterized by neuroscience methods.

In addition to fundamental questions of perception, psychological time research has addressed a wide range of topics. Cognitive approaches have considered the temporal sequence of narrative, autobiographical memory, perception of rhythmic patterns, as well as planning and decision-making. Bio-psychological and brain science orientations have explored the relationship between brain function and temporal experience. Clinicians have considered the temporal perspectives of acutely ill psychiatric patients, and compared the cultural tempos of individuals in relation of their subjective well-being (Block, 1990). Despite this long lineage, there exists no single theory that describes the psychological foundation of time. As Block (1990) suggests, there are no simple answers, and no innocent questions.

In calling for a renewed commitment to this line of research, Hancock & Block (2012) describe a puzzle in search of solution: How does the content of an interval influence the perception of that interval?[1] In "content", we might consider an individual's activity, location, attention, emotional and physiological states. This question nags beyond the issue of perception, to any investigation that relies on subjective judgment of duration: a tricky predicament indeed!

In an optimistic conclusion to their retrospective, Hancock & Block suggest (pun intended), "the future of time looks especially bright at present," (2012, p. 272). Developments in the brain sciences promise to shed light on the neurological basis of timing in the brain, and the number of researchers working on time perception seems greater than ever. While it may be tempting to wait for widespread consensus on how this neural functioning relates to behavior, we do not have the luxury of time to wait. If we wish for our investigations of behavior to be grounded in four-dimensional reality, we must remain aware of the open questions in time perception, address their impact on experimental methods, and explicitly consider the treatment of time in our respective research areas. This is particularly important for researchers in fields of applied psychology, where developments in perceptual research may be less conspicuous.

Assume that we leave the direct treatment of time to experimental psychologists in cognitive, biological, and developmental traditions. There remains a wealth of knowledge to be discovered in applied disciplines, where behavior in clinical, educational, organizational (to no name only a few) conditions is necessarily constrained by the individual's temporal experience. It is in this light I take up Block's charge, "psychological time can no longer continue to be ignored by psychologists who propose models of nontemporal behavior, because nontemporal behavior does not exist," (1990, p. xviii). Just as physicists must account for the forces at work on a body in motion, psychologists must account for all forces at work on a mind: we cannot escape the march of time.

---

[1] See Hancock & Block, 2012, for a thorough treatment of "content" as it pertains to the lack of consistency in selection of experimental tasks, and role of attention in individual differences.

One promising line of inquiry is the *experience* of time, and how this affects human behavior. This is directly considered by some phenomenologists, and indirectly in any investigation of (necessarily temporal) behavior. In his oft-cited volume, Ernst Pöppel (1978) puts forth a taxonomy of temporal experiences. According to this viewpoint, the fundamental aspects of our experience of time include: duration, non-simultaneity, order, past and present, and change (Le Poidevin, 2000). Even if one does not accept his subsequent model of perception (Pöppel, 1997), the taxonomy remains a useful tool for organizing questions about behavior in a temporal context.

While some pragmatic understanding of the mechanics of time is required to ensure the reliability of experimental tools (e.g. reaction time), for the most part, psychologists in applied fields can avoid the tricky paradoxical dilemmas a direct examination of time yields. We will leave these pickles to philosophers, who will feast upon them eagerly. Instead, we take our sharpened awareness of these unanswered questions and direct our attention to the impact of time on human experience, and in particular, how we utilize time to construct the fabric of daily life.

THE STUDY OF DAILY LIFE

> *Time can be viewed as the ultimate constraint on human activity. Unlike other resources, it is shared equally by everyone. Each of us has 24 hours per day. (UN, 2013, p. 5)*

Assume for a moment that time is a resource. What does one "do" with time?

In the English language, we most often speak of "using" time. In this sense, time is a non-renewable resource utilized to perform "activities". Activities are the *things*: tasks, actions, or ways of being, with which we fill an interval of time. While all people share the same quantity of time, like monetary resources, we spend our temporal resources in vastly different ways. People perform different activities, at various times, for varying lengths, in distinct orders, in myriad locations, with a diversity of people and tools. The way we use our time is thus a powerful measure to describe and compare daily life.

The earliest academic study of time use was published in 1924, examining the daily life of workers in Russia (Szalai, 1966). In the first half of the 20th century, researchers investigating household budgets and living conditions conducted similar studies across Europe and North America. In the 1960s, the value of time use data to compare populations became apparent, and a renaissance of interest in nationally representative samples ensued, providing a rich source of data for economic and social policy makers. Since this time, the tradition of large-scale data collection by national census bureaus, and subsequent efforts to harmonize data sets has produced a large, heterogeneous literature and well-defined methodology (Juster & Stafford, 1991).

There are five methods commonly used to collect time use data: direct observation, experience sampling, surveys, time-stamped electronic databases and time use diaries. Each method features strengths and weaknesses with respect to different research agendas, but diaries are predominantly favored for national data collection efforts (UN, 2013). In a time use diary, respondents detail their activities over a specified interval of time. One common approach is to complete a logbook, where respondents record the start and end time for each activity they perform[2], in temporal order, along with contextual questions (such as *where* the activity occurred or with *whom* the respondent

[2] An alternative approach requires respondents to fill in activities at predetermined intervals, thus capturing what they were doing at each interval, but not necessarily the start and end time of the activity. For a detailed description of data collection methods, see Eurostat, 2008; UN, 2013.

was present). From this information, the researcher can evaluate the activities the respondents have performed in relation to at least four temporal characteristics: duration, timing, sequence and frequency.

Activity

The fundamental component in the time use diary is the *activity.* With chronological time as the unit of measure, participants record the activities they perform over a chosen interval. If this interval includes at least 24 consecutive hours, the result is a representation of one day in the individual's life. In some cases, respondents may be asked to describe their activities in their own words. Alternatively, they may be asked to select from a standardized list of activities. In the former case, human analysts must translate from the respondent's words to the appropriate value in the activity list in order to perform comparison between diaries. Comparison between data sets is then limited to the extent that the activity list for one study can be equated to the activity list for another. While there is no single standard categorization scheme for time use research, there are multiple international harmonization efforts which offer proposed schemes, advice on categorization, how to compare data sets and other methodological guidelines. The schemes offered by the United Nations (2013) and Statistical Office of the European Union (2008) are particularly robust; though researchers may need to extend the activity categorizations to provide more granularity for activities of particular interest.

Duration: How much time?

Duration refers to the *quantity* of time spent on a given activity. This construct can be equated to Pöpper's (1978) conception of duration. This is the most commonly investigated component of time use in sociology and economics. When activity-duration is collected for representative samples, comparisons can be made between populations, or within populations over intervals of time. Such data has been used to address questions such as (Juster & Stafford, 1991): *How much time do Americans spend commuting? (p. 475) How does the use of leisure time differ between Japan and Sweden? (p.475) Is there a difference in allocation of time to housework between American men and women? (p. 475) Has the amount of time Americans spend sleeping changed between 1965 and 1981? (p. 477)*

Timing: At what time?

Timing refers to the chronological marker in standard time at which an activity is located. By standard time, we refer to the conventional use of calendar and clock utilized by the respondent's societal group. Timing does not have a corresponding construct in Pöpper's (1978) typology, as it does not represent an experience in and of itself, but rather, positions the experience of an activity to the societal conventions of clock and calendar. Timing is related to duration in that it situates a duration in the context of a clock; in mathematical terms: $time_{finish} - time_{start} = time_{duration}$.

Sequence: In what order?

Sequence refers to the order in which activities occur. Sequencing does not explicitly require a relationship to chronological time, but rather, only an ordered relationship to other activities. Sequence corresponds to Pöpper's (1978) construct of temporal order. In considering sequence, we must also respect the concept of temporal continuity: time does not stop. For example, I eat breakfast after I wake and before I brush my teeth. The sequence described is: (first) wake up → (next) eat breakfast → (last) brush teeth. As described in the diary, I transition from the first activity to the second and then to the third, in sequential order.

Frequency: How often?

Frequency refers to the number of times a given activity is performed within a specified interval. For example, if I were to complete a time diary for an interval of seven days, analysis would reveal a frequency of (14) for the activity "brushing teeth."
Along with sequence analysis techniques, frequency data may prove useful in identifying habitual behaviors.

TIME-GEOGRAPHY: THE HUMAN GROUNDED IN SPACE

> *The physical environment we inhabit does not only consist of the readily observable spatial backcloth. Associated with it, indeed inseparable from it, is a temporal component which is just as important. It may not display itself in the same graphic manner but it is an essential ingredient of life. (Thrift, 1977, p. 4)*

In developing the principles of *time-geography*, Swedish researcher Torsten Hägerstrand did not seek to found a discipline or specify a theory. Rather, he proposed a structure of thought: a framework for integrating the temporal and spatial perspectives of multiple disciplines (Lenntorp, 1999). Fundamental to this perspective is the relationship of an individual to their surroundings. It is by the very nature of existence that human activity exists equally in time and space. While it is possible for the researcher to examine duration, sequence, timing and frequency in isolation, and similarly to consider human movement through space without regard to time, in doing so, the researcher risks overlooking puissant relationships between the use of time and space. By accounting for these dimensions, time-geography provides an effective approach for examining constraints on human activities.

The roots of time-geography lie in the early 1960's, in the study of migration patterns of a small population in Sweden. Having collected the life histories of 10,000 individuals, Hägerstrand struggled to generalize his data using existing geographic instruments, which failed to account for an individual's location in space and time (Lenntorp, 1999). Charged with evaluating living conditions with the goal of equalizing access to health, education, and economic opportunities, Hägerstrand perceived a bias in his field (geography), which too often considered, "a purely economic landscape, neglecting other items which make up a livable world," (Hägerstrand, 1989, p. 1). From this experience he constructed the building blocks for a formal notation: simultaneous representation of spatial and temporal dimensions.

CONSTRUCTS

Lenntorp (1999) discerns as many as 52 concepts that constitute the vocabulary of time-geography. Many were present in Hägerstrand's 1970 work, while others were only fully elaborated in his final book in 2009 (Ellegård & Svedin, 2012), demonstrating the wealth of progress on this substantial body of work . The concepts required for a basic understanding include: *resources, goals, activities, projects, constraints, paths, stations, bundles, and prisms.*

Time and space are *resources* used by humans in daily life (Thrift, 1977). Both are limited, can be budgeted and thus allocated by the individual. The individual has *goals,* which are pursued through a series of *activities,* which, taken together, are called *projects.* Everything a human does is considered an *activity,* and all activities take place in space and time. In pursuit of their goals, individuals expend their resources: time, space, as well as materials. *Constraints* serve as obstacles to progress toward goals, and are the primary determinants of human experience in the physical environment. Thrift (1977) takes care to contrast this “negative determinant” approach with that of the space-time budget approach (another geographic construction) which instead considers the choices of individuals reflecting their values as the primary determinants of behavior. The latter is clearly a more psychological perspective, and we will return to this distinction in our discussion of applications.

Human populations form a “web of *paths*” (Thrift, 1977, pg. 7) which flow through locations in space and time called *stations*. The *lifespan* of a *path* refers to its length in time from creation to destruction (accounting for organic and inorganic entities). To allow for analysis at differing granularity, *stations* can be defined by discrete positions in space/time, or as *bundles* of similar positions. The potential volume of space and time within reach of the individual constitutes their *prism,* which graphically expresses their movement limitations in each dimension.

The conceptual depth and range of applications cannot be gleaned from this cursory description of time-geographic concepts. For a more thorough treatment, see: Ellegård & Svedin, 2012; Hägerstrand, 1970; Shaw, 2012; Thrift, 1977. In these constructs, Hägerstrand planted the seeds of an elegant visualization scheme that depicts the path of an individual as a continuous line through time and space.

Notation

The vocabulary of time-geography is best exemplified through its graphical conventions. Most often, two or three axes are used, with the horizontal depicting space and the vertical representing time.

Figure 1 depicts an individual's *path* through time-space over the course of one day. (1) At home, (2) drive to school, (3) at school, (4) drive home, (5) dinner and bedtime. While the individual is stationary the path is perpendicular to the space axis. In this 2D representation, an arbitrary distance differentiates the locations home (1, 5) and school (3). The slope of segments (2) and (4) indicate the individual's speed as they travel. The length of segment (4) over (2) suggests the individual may have encountered traffic on their drive home.

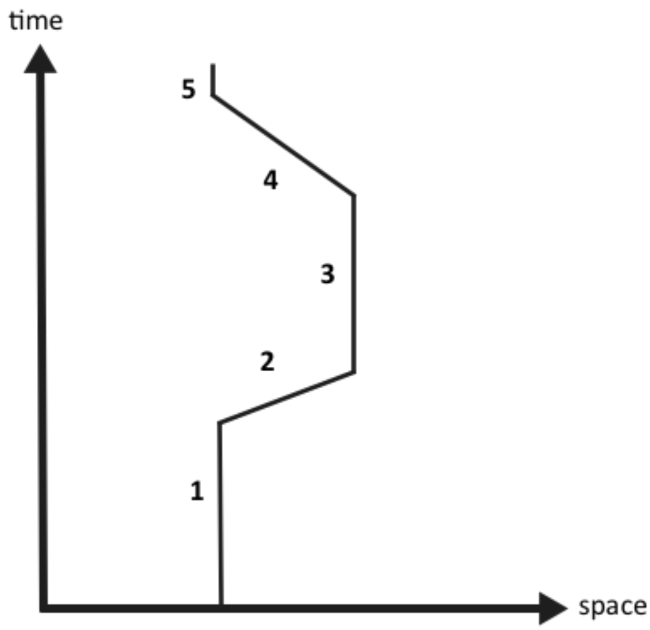


Figure 1 A simple path
source: own illustration

Figure 2 depicts the same individual's path in 2 dimensional space plus time, with cylinders representing the *stations* of home and school. The individual moves between stations over the course of the day.

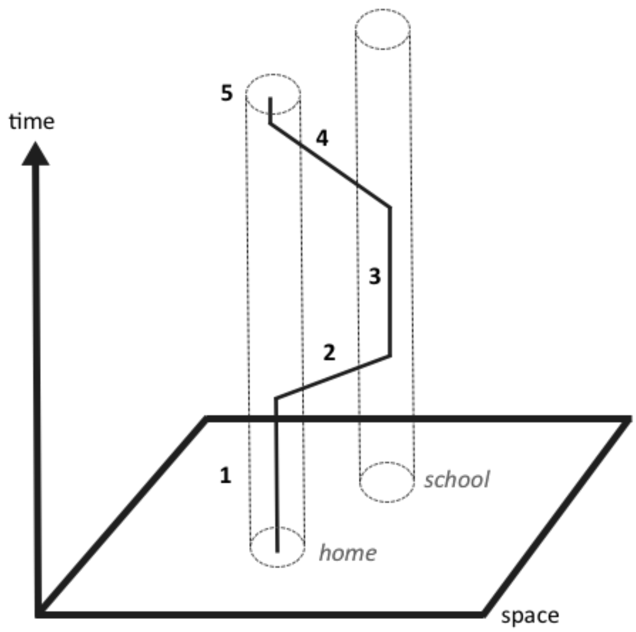
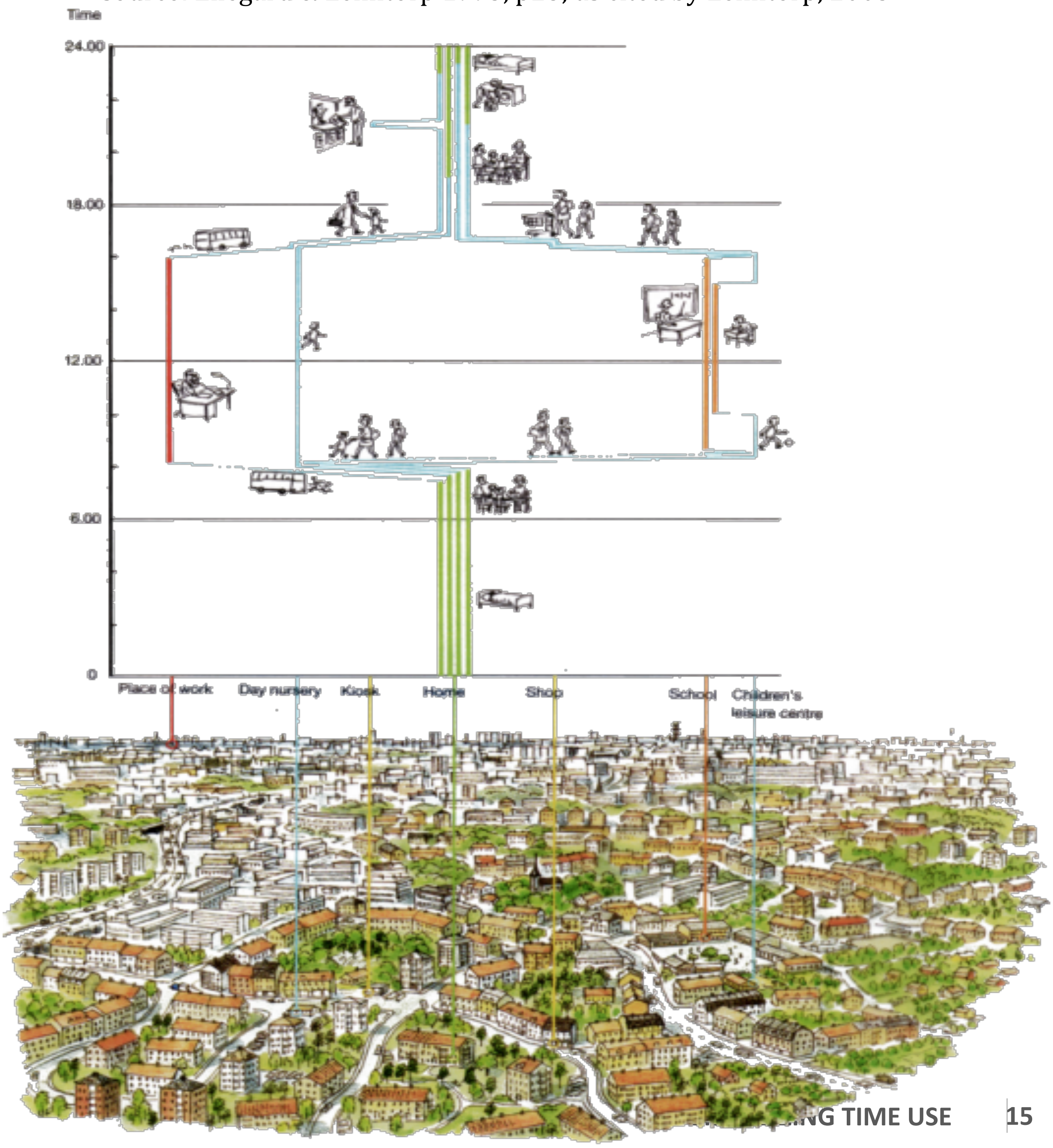


Figure 2 A 3D path with stations

While the individual serves as the single unit of analysis in time-geography, it is possible (and in fact advantageous) to examine the paths of multiple people for the same interval of time. The approach does not require any particular scale for time and space dimensions. Using this method, one can visualize a day, a year, or an entire life over a household, community, or the entire planet, limited only by our graphical and analytic capabilities.

Figure 3 depicts a day in the life of a Swedish family with two adults and two children. Spatial locations are divided into seven stations, and a continuous line represents the path of each individual.

Figure 3 A hybrid representation of a weekday for one Swedish family
source: Ellegård & Lenntorp 1993, p25; as cited by Lenntorp, 2003



Forty years after its emergence in regional planning, time-geography is a widely accepted approach to understanding human activity in the environment (Lenntorp, 1999). In the past decade it has been applied beyond the boundaries of human geography, as a tool for inquiry in public health (Rainham, McDowell, Krewski, & Sawada, 2010; Takahashi, Wiebe, & Rodriguez, 2001), information systems (e.g. Nandhakumar, 2002), transportation planning (e.g. Kwan, 2000) and even psychiatry (e.g. Sunnqvist, Persson, Lenntorp, & Tråskman-Bendz, 2007). Hägerstrand's legacy is a notational format, a vocabulary, and a worldview: a commitment to consolidating knowledge from distinct scientific areas.

Now we turn to the application of the time-geographic structure of thought to time use research.

A TIME-GEOGRAPHIC APPROACH: CONTEXTS IN DAILY LIFE

> *"We live our lives in close proximity both to other human and non-human beings... These settings (or habitats, situations, pockets in time-space) can't unequivocally … be broken up into pieces, classified and studied in isolation. It is, if not dangerous, then far from unproblematic to ignore the contexts in which phenomena locally develop, locally connect, and locally survive. Everywhere and always we live in local contexts, even if our heads are filled with global ideas." (Lenntorp, 2003, p.5)*

While time-geography was not developed for the express purpose of investigating time use, the utility of its application is clearly demonstrable. There is a huge quantity of data generated in time use studies, and the time-geographic approach offers the researcher a comprehensive, flexible framework for organizing this information. Swedish social scientist Kajsa Ellegård (as student of Hägerstrand) proposed such an approach (Ellegård, 1999). In this section, we will describe Ellegård's contribution and advance a number of extensions, culminating in a research model appropriate for psychological investigations of time use.

In addition to its powerful notation, time-geography offers two significant benefits to conventional time use methods. First, its structuring of data supports both micro (individual) and macro (population) analysis. The time geography unit of analysis is always the individual, but in most empirical time use studies, mean values of duration are the primary interest. Ellegård suggests, "a first step is to determine how the activities constitute meaningful parts of the individual's life contexts, while representative mean values characterizing everyday life on a macro level [can] be generated in a second step," (1999, p. 168). While one can generate a macro view by aggregating individual data, one cannot necessarily generate micro values from the macro view. Hägerstrand himself articulated this requirement, "it must be possible to alternate between different levels, to switch between the individual and group without losing important information," (Hägerstrand, 1974 (in original Swedish) as translated by Ellegård, 1999, p. 168). This provision is especially important for psychology, where the ability to evaluate within-individuals, between-individuals and between-groups is essential.

Secondly, Ellegård suggests that time-geography offers a framework for revealing the relationships between activities in daily life that are "mostly taken for granted and… left out of many studies in social science," (Ellegård, 1999, p. 174); referring to the focus in much time use research on aggregate durations. While more recent research is beginning to explore the oft-neglected components of timing, sequence, and frequency (Fisher & Trucker, 2013), Ellegård explicitly links their attention to the time-geographic approach[3]. "The object of study is not [activities] mere existence, but their arrangement into projects, their sequential order, their duration and the social and geographical settings in which they appear. An assumption is that the individual's habits may be revealed by the contexts in which activities are actually performed," (Ellegård, 1999, p. 174). In support of this pursuit, Ellegård proposes a number of *contexts* in which time use data be organized.

ACTIVITY: WHAT DO WE DO?

The activities of living one's life are reflected in the hierarchical scheme or "activity code" in time use studies. Ellegård (1999) distinguishes two contexts for direct examination of activities. The *everyday context* is the one with which we are most familiar, and the one considered in most national time use studies. It constitutes all the activities an individual reports in a period of time, regardless of their purpose. Alternatively, the *project context* allows the researcher to relate activities to an individual's goals, which may be useful for analysis at both the individual and macro levels, where multiple people may collaborate in pursuit of a goal (i.e. keeping a clean house). The granularity of goals, and how they might be assigned to activities is not stipulated in the approach, allowing researchers to adopt a scheme appropriate to their conceptual framework.

LOCATION: WHERE DO WE DO IT?

The *location* context refers to the geographic location at which an activity occurs (Ellegård, 1999). In paper diary methods, location is most often gathered in a free-entry column, where respondents record the relative location of each activity (i.e. home, work, daycare, school, etc.)

SOCIAL: WITH WHOM DO WE DO IT?

The *social* context refers to the social state of the individual when performing an activity. Are they alone, or are they with others? When designing the data collection instrument, it is up to the researcher to decide at what granularity they wish to

---

[3] A cursory review of papers published between 2008 and 2013 in the electronic International Journal of Time use Research discussing timing, sequence or frequency does not reveal citations to Hägerstrand or Ellegård's work. Thus any suggestion that consideration of all four components of time use data is unique to the time-geographic approach requires further review of the literature.

understand the individual's social context. In many time diary formats, respondents are presented a series of checkboxes to indicate if they were: alone, with family, with a partner, or with others.

Figure 4 demonstrates how Ellegård's contexts are represented in a diary instrument. In this example, we pull from the 2008 HETUS guidelines established by the statistics office of the European Union (Eurostat, 2008, p. 118).

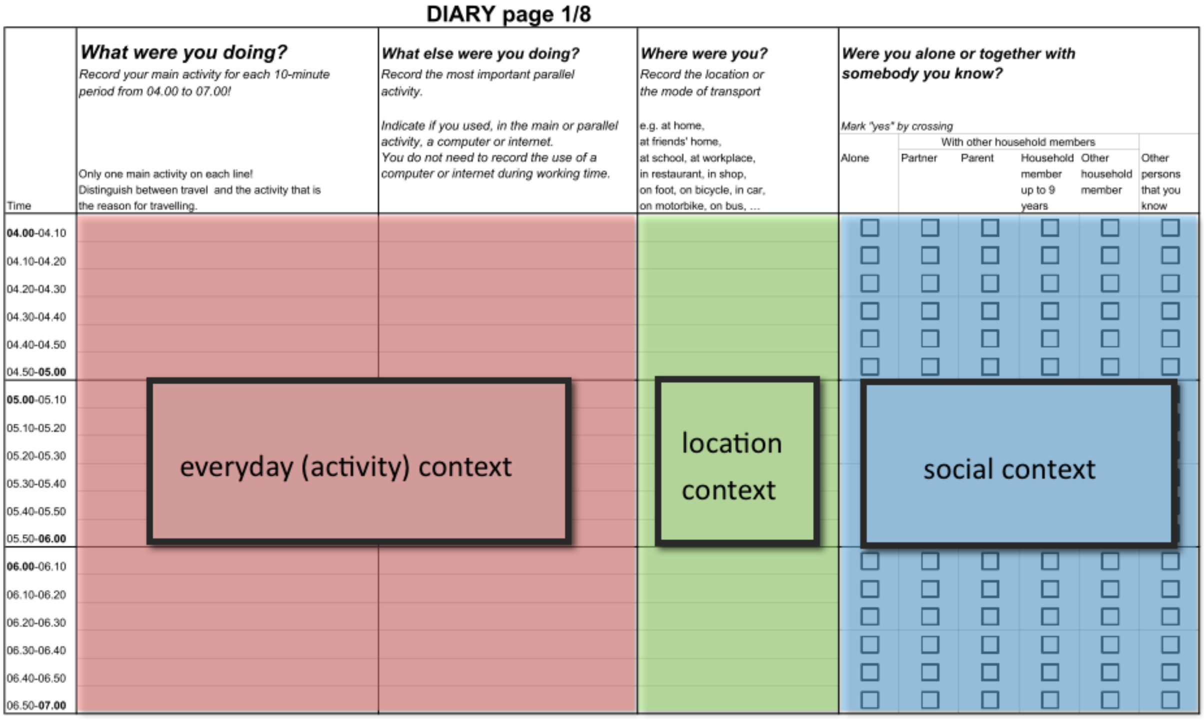


Figure 4 Page 1 of a HETUS diary mapped to time-geographic contexts

In her time-geographic approach, Kajsa Ellegård applied Hägerstrand's worldview to develop a tool for the systematic investigation of activities. The method as presently described represents a substantial contribution, but is lacking an outlet for psychological constructs. In the next section, we will builds on Ellegård's approach to propose a research model for psychological investigations of time use.

A Research Model for Psychological Time Use

> *"The use of an absolute space and time framework enables the relation of all kinds of substantively different phenomena. It acts as a common language." (Thrift, 1977, pg. 6)*

Conceptual Validity

The discipline of psychology and its myriad specialties suffers from no shortage of conceptual models. This begs the question, "What can psychological investigations of time use gain from an approach developed by geographers?"

We propose the answer lies in the philosophical foundation of time-geography and the worldview of its human-geographer founder, Torsten Hägerstrand. To this end, we offer three propositions, supported in his own words and those of his students.

1. **The philosophy of time geography is based on the desire to integrate scientific knowledge.**

A main objective of time-geography is to work against disciplinary fragmentation of knowledge and to promote both a more synthesising knowledge and the building of platforms for more concerted interdisciplinary interaction. (Lenntorp, 2003, p. 5)

The breadth and depth of Hägerstrand's work is impressive and points to a normative mission for scientists from natural, social, and technical sciences to learn from each other, to cooperate, and to develop integrated approaches in order to create opportunities for a sustainable use of our common world. (Ellegård & Svedin, 2012, p. 18)

Hägerstrand's commitment to interdisciplinary knowledge is evident in his writing and in the constructs of his approach. While he does not explicitly detail the role of cognitive or affective factors, his framework was intentionally designed as an extensible structure for thinking about human behavior, and thus may prove useful for psychological investigations.

2. **The framework of time geography values ecological validity in scientific investigation.**

Time-geography is an attempt to construct a broad structure of thought which may form a framework capable of fulfilling two tasks. The first is to receive and bring into contact knowledge from highly distinct scientific areas and from everyday praxis. The second is to reveal relations, the nature of which escape researchers as soon as the object of research is separated from its given milieu in order to study it in isolation. (Lenntorp, 1999, pg. 155)

Research in psychology is a constant struggle between construct and external validity. The time-geographic approach explicitly seeks to examine human use of time and space in the most ecologically valid method. While psychologists carefully balance construct and external validity in their designs, we can agree that when examining human time use, both types of validity converge on the individual in their natural environment.

3. The constructs of time geography feature the human (and their activity) as grounded in space and time.

As soon as we have come into being we cannot take time off from our bodily existence. We have to leave a space-time trace in the world. And we share this condition with all other living and nonliving entities. As long as something exists it must be somewhere. (Hägerstrand, 1989, p. 4)

I would like to offer the suggestion that we cannot hope to improve our understanding of historical and future processes unless we begin to deviate from humanistic and social science custom and bring both the worlds of human meaning and the world of matter fully into our picture simultaneously. Intentions are free to move in imagined space and time. But real events are bound to the overlapping neighbourhoods of "thing beyond thing," (Hägerstrand, 1989, p. 6)

Since the beginning of the cognitive revolution, psychologists have proposed a number of competing theories to explain human cognition. The traditional view has been that humans use perceptual systems acting on environmental stimuli to generate knowledge, which is then stored in amodal memory systems in the brain, where it is available to the wide range of cognitive activities. More contemporary theories however, including situated action, embodied cognition and grounded cognition, emphasize the role of mental simulation by the human situated in their environment. These theories reject the concept of amodal representations of knowledge, and stress the relationship between the body, the mind and the environment (Barsalou, 2008). It seems then, most appropriate that investigations of behavior would consider an accordingly grounded perspective with the goal of mapping cognitive activities to behavioral outcomes.

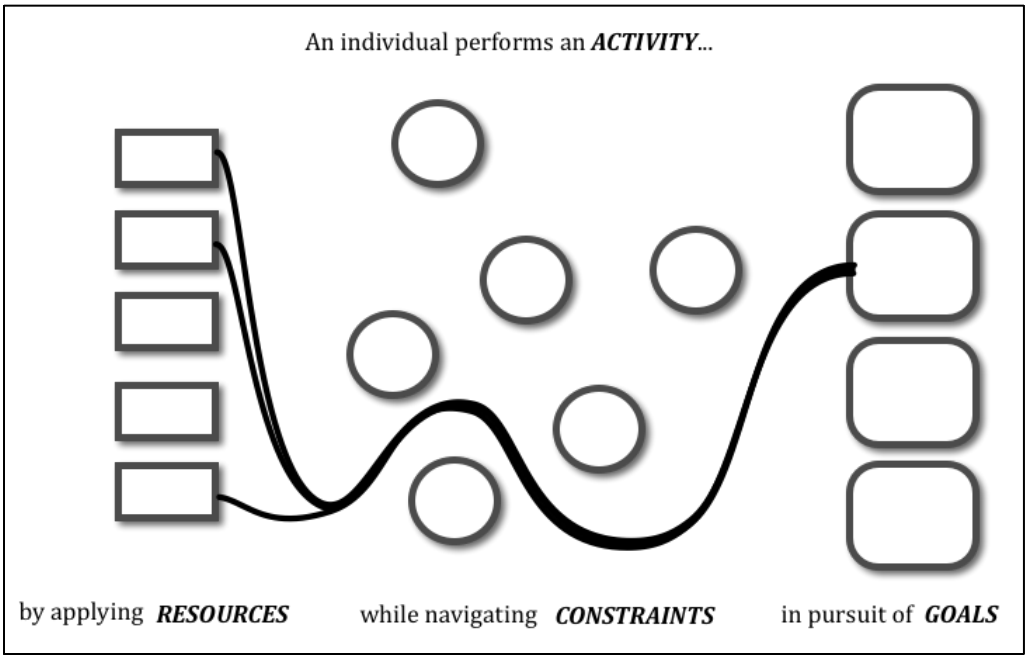
CONSTRUCTS

While Hägerstrand makes reference to intangible, psychological factors (Lenntorp, 2003) they lack systematic treatment in his writing. This is entirely appropriate for human geography to acknowledge but not seek to elucidate the psychological drivers of behavior. Fortunately, their framework offers the flexibility to add this perspective, consistent with Hägerstrand's desire to integrate knowledge between disciplines. Time geography was never intended to explain behavior, but rather to encourage integration of knowledge between disciplines seeking to explain it (Lenntorp, 1999). Here we offer a number of extensions to the time-geographic perspective to facilitate psychological investigation of time use data.

Consider the following premise, illustrated in *Figure 5*:

An individual's use of time is determined by how they elect to utilize their *resources* in pursuit of their *goals* in response to their *constraints*.

Figure 5 A time-geographic model of time use behavior



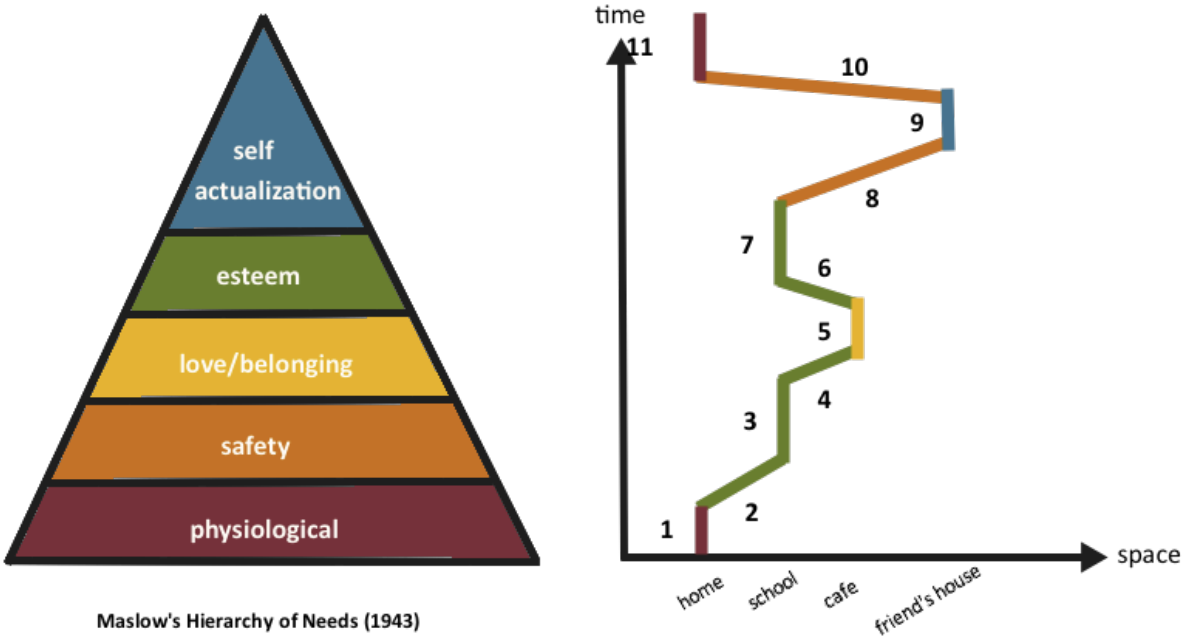
Time geographers have offered definitions or typologies for resources, goals and constraints. We will expand upon these to better incorporate the psychological perspective.

GOALS

The pursuit of goals serves as an organizing concept in time-geography, but no typology of granularity for goals is provided. It is important to recognize that a goal need not be defined *a priori*, in fact, an individual may not be consciously aware of the goal at all. This is the case for the *everyday context* as proposed by Ellegård, where all activities in a day contribute to the goal, “living one’s everyday life”. This allows the researcher to adopt an organizing scheme consistent with their conceptual framework for the individual’s behavior.

Take for example, the (well known) “Hierarchy of Needs” (Maslow, 1943). *Figure 6* depicts a day in the life of the author, displayed in a time-geographic notation, with the author’s goal for each activity color-coded in correspondence with Maslow’s hierarchy (at left). In this day, the author: (1) wakes up, eats breakfast, (2) rides bike to school, (3) attends lecture, (4) rides bike to café, (5) meets classmate for lunch, (6) rides bike to school, (7) studies in library, (8) rides bike to friend’s house, (9) designs game with classmate, (10) rides bike home, (11) eats dinner, sleeps.

Figure 6 A day in the life of the author, related to the goal of each



This example demonstrates how researchers might define an appropriate schema of goals for a hypothesis, and relate daily activities to the schema to test the hypothesis. It offers a powerful approach for investigating motivation in time use.

Resources

Hägerstrand's work was at times criticized for being too physical, or materialistic (Lenntorp, 1999). Discussions of resources were limited to that of time, space, and of course the materials available in the man-made and natural environment. This seems appropriate for a geographic approach, and in fact, a practical footing for psychologists as well; those who desire their work be accordant with modern theories of embodied, situated or grounded cognition.

Rephrasing the question, "what do we *use* to perform activities?" a psychologist might answer: time, money, space, social capital, attention, cognitive effort, perceptual ability, to name only a few. Much like a typology for goals, researchers may enumerate an individual's resources in a fashion consistent with their research agenda, then utilize time use data to explore how the resources are used to perform activities. While a learning scientist might be interested in the attention, motivation and cognitive effort an student expends on daily activities, an industrial psychologist might be more interested in the social capital, scope of influence, and credibility an employee expends. This model affords a flexible typology to support numerous research agendas.

Constraints

Hägerstrand describes three types of constraints that limit an individual's activities. *Capability* constraints encompass the individual's biological needs, and their capacity for performing activities and using tools. *Coupling* constraints refer to the inherent social nature of some activities. *Authority* constraints refer to the limitations imposed by societal, governmental or personal legal, ethical or moral systems (Thrift, 1977). This classification scheme seems consistent with the interest of the originating discipline (human geography): the ability to overcome constraints in pursuit of goals while sharing resources within society. A typology of constraints for psychological inquiry would necessarily benefit from additional perspectives.

Contexts

The contexts serve as the lens through which a researcher can view the interaction between an individual's constraints, resources and subsequent use of time. Practically speaking, contexts are reflected in the questions a respondent completes in their time diary in addition to the time and activity for each interval. In the previous section we discussed the *activity, location, and social* contexts. These are reflective of the most common diary instruments used in national census efforts. But there are many more contexts that make compelling objects of study. An examination of *tools* for example, could shed light on human interaction with the physical world. A context question for computing devices in particular could yield substantive information on an individual's computer mediated life. Similarly, *concurrent activities* questions afford the opportunity to examine multitasking, and therefore attention. And we would be remiss without mentioning the ability to track subjective wellbeing. It seems the only limit on the contexts that can be studied is on the length of the diary instrument the researcher wishes to design, and construct validity of the contextual questions they choose.

It is important to note that the flexibility of this approach allows for resources, goals and constraints to be defined a priori, with contextual data gathered to validate a hypothesis. Alternatively, empirical data might be analyzed to distinguish the goals, constraints and resources for a pre-defined context. In addition to extensions to the constructs of *stations* and *paths* to support investigation of virtual space so common in modern society, the aforementioned constructs constitute a powerful tool and compelling opportunity for psychologists to benefit from the rich source of data present in time use research.

TIME (USE) IN PROSPECT

EDUCATIONAL PSYCHOLOGY: STUDENT USE OF TIME

What does empirical psychology research look like, within a time-geographic approach?

Consider, for example, two research teams. The first, situated in a department of educational science, is interested in how university students allocate their time to schoolwork and extra-curricular activities. They wish to compare the mean activity duration, and identify factors of variability between and within academic majors. At the same university, a team of psychologists is examining the relationship of electronic devices, social engagement and subjective wellbeing. They wish to determine what if any affect, increased use of computing devices has on an individual's mood and self-rated performance. The goal of both teams is to gather empirical data. While the hypotheses and potential applications of these research agendas differ, they can save considerable resources by utilizing the same empirical data to further their work.

The teams agree to gather time use data for a large sample of students at their university. They decide upon diaries as the collection method in order to obtain both activity duration (for team 1) and timing (for team 2). Rather than construct a new diary instrument, they apply the methodological learning from research in sociology and economics and agree examine the HETUS, ICATUS and ATUS[4] diary forms, selecting the standardized format with an activity list most appropriate for their research questions. They then extend this activity list with sub-categories to cover the full range of student-specific activities they wish to investigate.

Having selected a standard diary form and developed an extension to its activity list, their next step is developing the contextual questions relevant to their hypotheses. Here, the time-geographic approach provides a constructive framework for organization. Each team defines their interests; in the language of what data they wish to gather. The education team wants to know what activities the students perform, where they are located, who is present, and whether the activity is required for their course of study. The psychologists wish to gather: the start/end time of each activity, who they were with, if they were using a computing device, and their mood at the time. Based on these requirements, the teams organize their questions into six contexts:

[4] HETUS: Harmonized European Time Use Survey (Eurostat); ICATUS: International Classification Of Activities For Time-Use Statistics (UN); ATUS: American Time Use Survey

1. Everyday life: all the activities the subject performs
2. Location: the relative geographic location of the subject during the activity
3. Social: who the subject was with during the activity
4. Motivation: the nature of the subject's obligation to perform the activity
5. Technology: what (modern digital) technologies the subject utilized while performing the activity
6. Affective: the subject's mood while performing the activity

The everyday life, location and social contexts are present in the standard diary form, and they need only develop questions for the motivation, technology and affective contexts. As the burden of data collection is high on diary subjects (they must answer questions in each context for each activity during the collection interval), they elect to utilize a web-based form. They identify survey software that allows them to customize which contextual questions are applicable for each activity so the subject is only presented with relevant questions at each interaction. Finally, they develop independent surveys to gather the demographic and performance history data relevant to each team. After agreeing on a sampling procedure, the number of diary days and period of distribution, the researchers can begin recruitment and data collection.

After the data is collected, each team will find different methods and objects of analysis. Duration data may be analyzed by generating summary statistics for individual activities, or activity groups. These summary values may be then be analyzed for correlation with the demographic data. The educational research team would look to see the difference in time use on school vs. non-school activities for different academic majors. They could then search for factors to explain within-discipline variation, potentially including: gender, parent's educational background, type of secondary school, and socio-economic status. This duration data would also be of interest to the psychology team, who might compare the total amount of digitally mediated vs. unmediated time. Within the mediated time, they might examine the nature of social interaction recorded by the respondents, and the according affect assessments, to see if there are similar affective patterns in virtual or in-person social time. Examinations of timing and sequence data would be of primary interest to the psychology team, who might look for patterns in the sequencing of technology use. While sequence data in previous research has thus far been limited by the dearth of efficient methods for sequence analysis, lessons from biomedical applications (such as gene sequencing) offer promising new resources to facilitate pattern extraction (cf. Elzinga, 2006).

At the conclusion of this considerable effort, they are left with a set of data in a standardized time use format that can be shared with the time use research community, and harmonized for comparison with other datasets. In one effort, their inquiry reveals duration, sequence, and frequency characteristics for activities and allows them to investigate correlations within five contexts: location, social, motivation, technology and affect. They can further correlate this data with the demographic information collected in the independent surveys. In this example, we see how the time geographic approach allows psychologists with differing agendas to apply time use methods in pursuit of their research goals.

CONCLUSION

> *"Elaborating a method that captures activities, both as individual entities and as parts of a whole, is like knitting a complicated pattern." (Ellegård, 1999, p.168)*

With the wealth of detail available in time use data, and the potential afforded by the proliferation of personal data tracking capabilities, there is a compelling opportunity for a flexible, comprehensive research model for investigating human behavior in time use data. In developing time-geography, Torsten Hägerstrand's goal was a deeper understanding of human action, rooted in an ecologically valid worldview. His resulting approach does not seek to explain the motivation of behavior, but rather, serve as a structure for thought. This paper has described potential extensions to Hägerstrand's work that would allow psychologists to explore time use data using diary methods honed in the broader social sciences, in a way that is grounded in modern theories of cognitive psychology.

References

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617–45. doi:10.1146/annurev.psych.59.103006.093639

Block, R. A. (1990). Models of Psychological Time. In R. A. Block (Ed.), *Cognitive models of psychological time* (pp. 1–35). Hillsdale , NJ: Lawrence Erlbaum Associates.

Ellegård, K. (1999). A time-geographical approach to the study of everyday life of individuals–a challenge of complexity. *GeoJournal*, *48*, 167–175.

Ellegård, K., & Svedin, U. (2012). Torsten Hägerstrand's time-geography as the cradle of the activity approach in transport geography. *Journal of Transport Geography*, *23*, 17–25. doi:10.1016/j.jtrangeo.2012.03.023

Elzinga, C. (2006). Sequence analysis: Metric representations of categorical time series. *Sociological Methods and Research*, 1–39.

Eurostat. (2008). *Harmonised European time use surveys: 2008 Guidelines*. *Eurostat European Commision*.

Fisher, K., & Trucker, J. (2013). Technical Details of Time Use Studies. *Oxford: Center for Time Use Research, University of Oxford*. Retrieved January 06, 2014, from http://www.timeuse.org/information/studies/

Hägerstrand, T. (1970). What About People in Regional Science? *Papers in Regional Science*, *24*(1), 7–24. doi:10.1111/j.1435-5597.1970.tb01464.x

Hägerstrand, T. (1989). Reflections On "What About People in Regional Science?" *Papers of the Regional Science Association*, *66*, 1–6.

Hancock, P. A., & Block, R. A. (2012). 125th Anniversary Articles The Psychology of Time : A View Backward and Forward. *American Journal of Psychology*, *125*(3), 267–274.

Juster, F., & Stafford, F. (1991). The allocation of time: Empirical findings, behavioral models, and problems of measurement. *Journal of Economic Literature*, *29*(2), 471–522.

Kwan, M. P. (2000). Interactive geovisualization of activity-travel patterns using three-dimensional geographical information systems: A methodological exploration with a large data set. *Transportation Research Part C: Emerging Technologies*, *8*, 185–203. doi:10.1016/S0968-090X(00)00017-6

Le Poidevin, R. (2000, August 28). The Experience and Perception of Time. In *The Stanford Encyclopedia of Philosophy (Fall 2011 Edition)*. Retrieved from http://plato.stanford.edu/entries/time-experience/

Lenntorp, B. (1999). Time geography - at the end of its beginning. *GeoJournal*, *48*(3), 155–158.

Lenntorp, B. (2003). The Drama of Real-Life in a time-geographic disguise. *Sixth Theo Quant Meeting, Besancon, France*, 1–10.

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*, 370–396. doi:10.1037/h0054346

Nandhakumar, J. (2002). Managing Time in a Software Factory: Temporal and Spatial Organization of IS Development Activities. *The Information Society*. doi:10.1080/01972240290075101

Poppel, E. (1978). Time Perception. In *Handbook of Sensory Physiology* (pp. 713–729). Springer Berlin Heidelberg. doi:10.1007/978-3-642-46354-9_23

Pöppel, E. (1997). A hierarchical model of temporal perception. *Trends in Cognitive Sciences*, *1*(2), 56–61. doi:10.1016/S1364-6613(97)01008-5

Rainham, D., McDowell, I., Krewski, D., & Sawada, M. (2010). Conceptualizing the healthscape: Contributions of time geography, location technologies and spatial ecology to place and health research. *Social Science and Medicine*, *70*, 668–676. doi:10.1016/j.socscimed.2009.10.035

Shaw, S.-L. (2012). Guest editorial introduction: time geography – its past, present and future. *Journal of Transport Geography*, *23*, 1–4. doi:10.1016/j.jtrangeo.2012.04.007

Sunnqvist, C., Persson, U., Lenntorp, B., & Traskman-Bendz, L. (2007). Time geography: A model for psychiatric life charting? *Journal of Psychiatric and Mental Health Nursing*, *14*, 250–257. doi:10.1111/j.1365-2850.2007.01071.x

Szalai, A. (1966). Trends in Comparative Time-Budget Research. *American Behavioral Scientist*, *9*.

Takahashi, L. M., Wiebe, D., & Rodriguez, R. (2001). Navigating the time-space context of HIV and AIDS: Daily routines and access to care. *Social Science and Medicine*, *53*, 845–863. doi:10.1016/S0277-9536(00)00363-4

Thrift, N. (1977). *An introduction to time-geography*. Geo Abstracts, University of East Anglia.

UN. (2013). *Guidelines for Harmonizing Time-Use Surveys* (p. 129).

2

VISUALIZATION TECHNIQUES FOR TIME USE

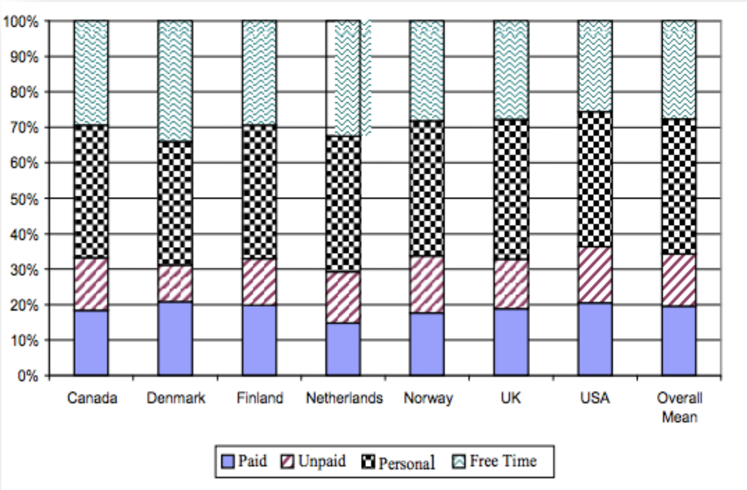
TABLE OF CONTENTS

Introduction **34**
100% Stacked Column Chart *35*
Clustered Column Chart *36*
2D Activity Path *37*
3D Activity Path *38*
Triangle Plot *40*
Tempogram *41*
Spiral Graph *42*
Stream Graph *43*
Conclusion **44**
References **45**

INTRODUCTION

In this brief survey we highlight the wide variety of visual techniques that may be used to describe time series data. We will focus our discussion on statistical graphics in published academic literature, and only those with potential application to time use data. We will briefly describe each visual technique, provide a published example, and discuss how it might be applied to time use data sets.

Figure 1: Average activity duration between countries
Source: (Fisher & Layte, 2004)

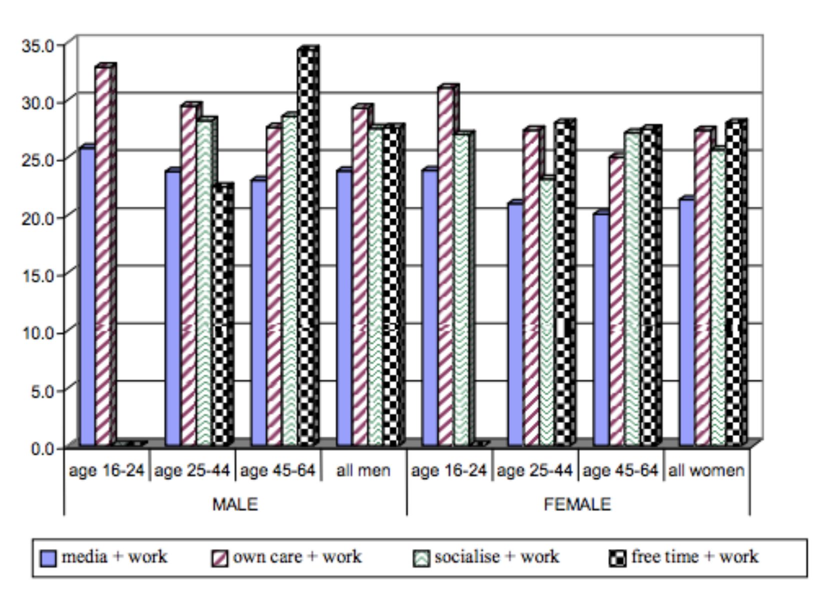


Readers of academic journals and news media alike will be no strangers to stacked bar and column charts; a perennial favorite for depicting a series of categories by ordinal and ratio values. In this variation, we see the added constraint of the height of each bar being equal to what is defined as a "whole" quantity on the Y-axis.

This example of a stacked column chart comes from the time use research community, in a study reporting the distribution of work-life balance between different countries (Fisher & Layte, 2004). In this case, the x-axis is used to represent countries, the y-axis the mean percent of possible duration devoted to an activity category, and the color/shading differentiates the activity categories. In this way, the stacked bar allows easy comparison of duration data across populations or individuals. The stacked bar also suffers from the jiggled baseline effect, whereby it is more difficult to directly compare the size of bar segments that do not originate at the x-axis, though the use of perpendicular lines makes the reading easier than the subtle contours that must be evaluated in the Stream graph.

100% Stacked column charts are most appropriate to communicate large differences or substantial similarity in aggregate duration data. X-axis values may describe individuals or population groups. In order to depict activity categories on the x-axis one must resort to a traditional column chart as the aggregate duration for each activity will not add to 100% over the same interval. We recommend avoiding stacked column charts if you wish the reader to make direct comparisons between segments not originating on the x-axis.

Figure 2: Multitasking activity for different populations in England *Source:* (Fisher & Layte, 2004)

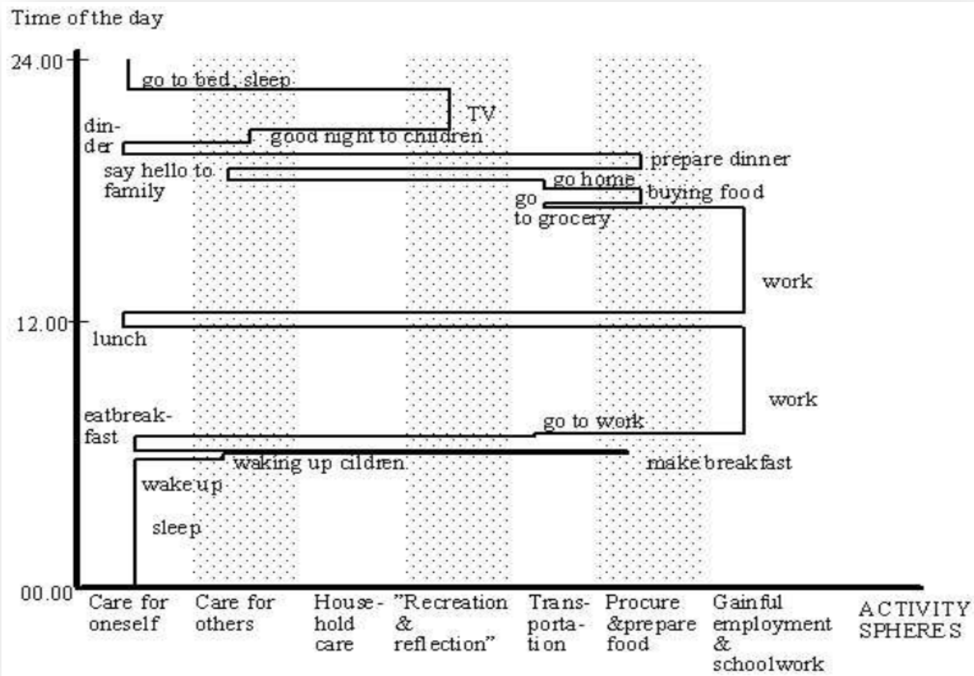


Unlike its Stacked Column cousin, the clustered column chart supports comparison between columns from the same baseline. In order to accommodate multiple categories however, the tradeoff is the visual clutter of categorical clusters.

This example of a clustered column chart comes from the time use research community, and a study reporting the distribution of work-life balance between different countries (Fisher & Layte, 2004). In this case, the x-axis is used to represent population groups, and the y-axis a quantity of time (the number of minutes per day). Again, color/shading differentiates activity categories. In order to compare the same category between population groups, the viewer must read across the columns of colors. A first order comparison between activities for a single group is straightforward, but first order readings across groups, and any second order readings, prove cognitively taxing.

Clustered column charts are most appropriate for demonstrating variability between different categories of data within the clustered group. As in this example, x-axis values may describe individuals or population groups, with activities differentiated by color and shading. Alternatively one might depict activity groups along the x-axis and categorize individuals or population groups by color/shading across the clusters. Either aggregate duration or frequency maybe depicted on the y-axis. As with stacked column charts, first order readings are relatively straightforward, while second-order comparisons across clusters are more challenging.

Figure 3: Activity oriented path of one individual over one day *Source:* (Ellegård & Cooper, 2004)



The 2-D activity path represents a meaningful extension to the time-geographic notation (c.f. Hägerstrand, 1970; Thrift, 1977). In this example from the electronic International Journal of Time-Use Research, the authors describe a day in the life of one individual in the context of the activities they perform at different times (Ellegård & Cooper, 2004). Along the x-axis we see activities grouped into categories and along the y-axis the continuous progression of time. Unlike traditional time-geography notation in which horizontal line segments indicate movement through space, in this variation they indicate a change in activity. Correspondingly, vertical segments indicate a continuation of the same activity. This graphic provides a view of both activity sequence and real-time duration over the course of a day. The position of activity categories through the horizontal plane however, may indicate to the viewer a conceptual distance between the categories. Designers should take care to order the categories along the x-axis accordingly. There are numerous ways in which this technique might be altered to represent different contexts of time use data, and in doing so it is worth exploring transposing the axes of the graph depicting the flow of time along the horizontal axis as is preferred in graphic productions (Boroditsky, 2001; Fuhrman & Boroditsky, 2010; Tversky, 2011).

2-D activity path diagrams offer a flexible notation for depicting multiple components of time use in a single diagram. They seem particularly useful for depicting information for one individual or aggregate group, though color could be introduced to differentiate between groups.

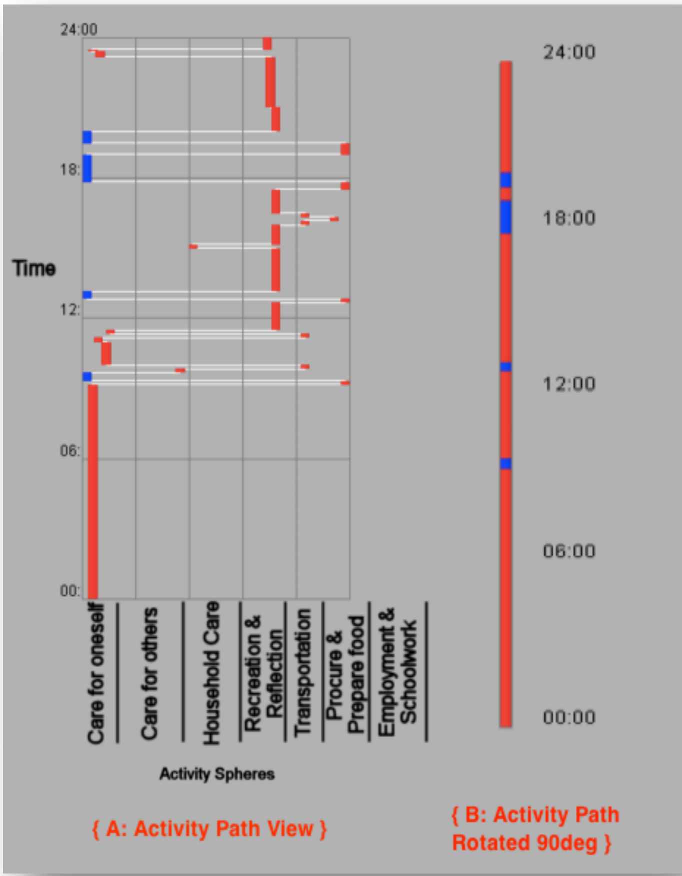


Figure 4: Activity oriented path of one individual during one day + same view rotated 90deg
Source: (Ellegård & Cooper, 2004)

In a significant extension to the 2D path notation first proposed in 1999, in 2004, Ellegård & Cooper published examples of a 3-D implementation generated by a custom-built software application (Ellegård & Cooper, 2004). In *Figure 4* we see the 2-D activity path of an individual. Again the y-axis represents the flow of time and the x-axis the activity categories. In the interactive software package, the author selected a specific activity, "eating food" and colored it blue, designating it for further analysis. The right side of the diagram shows the same data rotated 90°, thus collapsing the activity categories. According to Ellegård, the system always represents time on the y-axis and individuals/groups on the x-axis reserving the z-axis to display other factors or contexts available in the data set (Ellegård & Cooper, 2004). Colors can be utilized to isolate one variable value for analysis (as seen in *Figure 4*).

The system can also be used to compare the timing and sequence and duration of activities for multiple individuals, as shown in *Figure 5.* Here we see a day in the life of three family members with their time spent eating meals highlighted in blue. In *Figure 5* the viewer can easily read the concurrence of timing in eating meals as well as the relative sequence of the activity, the timing, and therefore infer the duration.

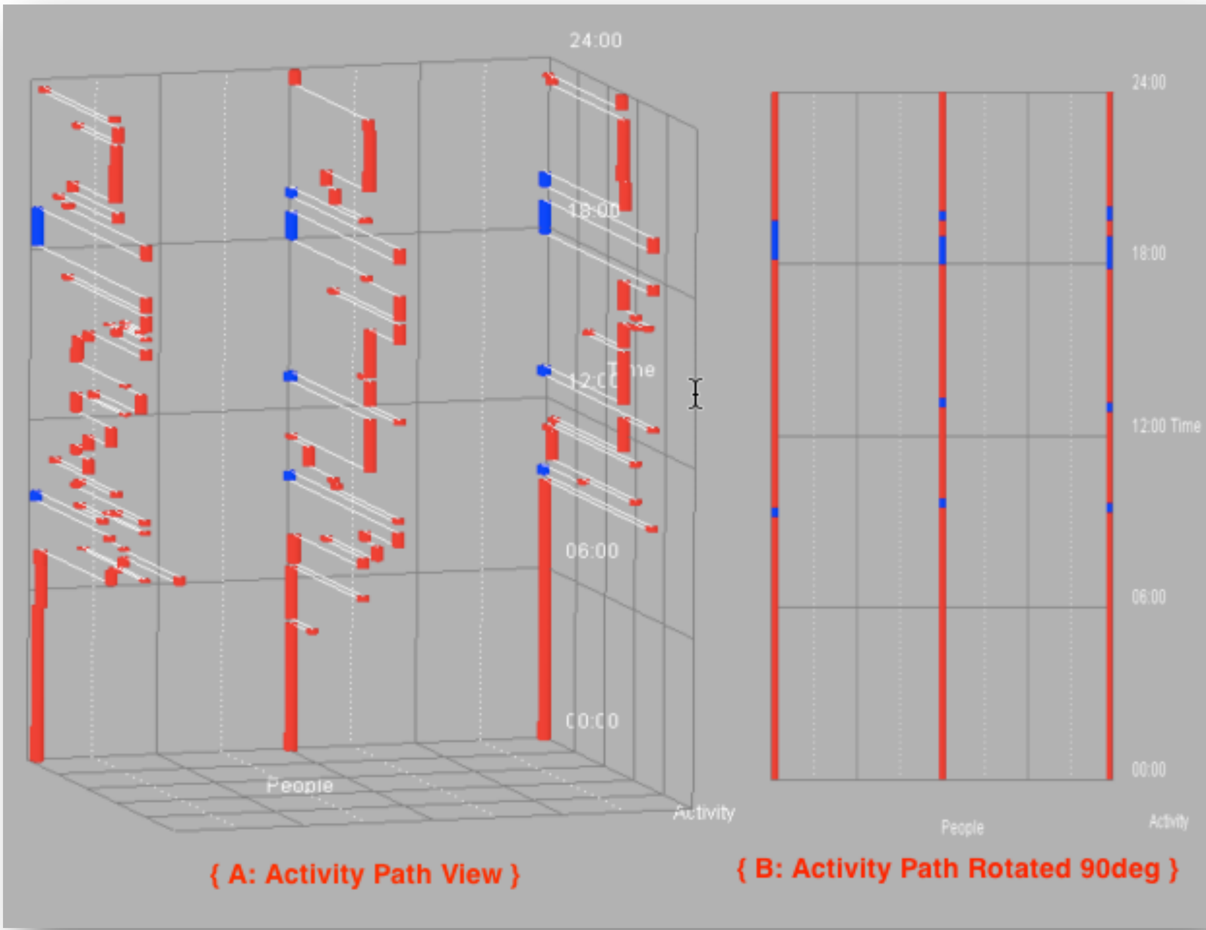
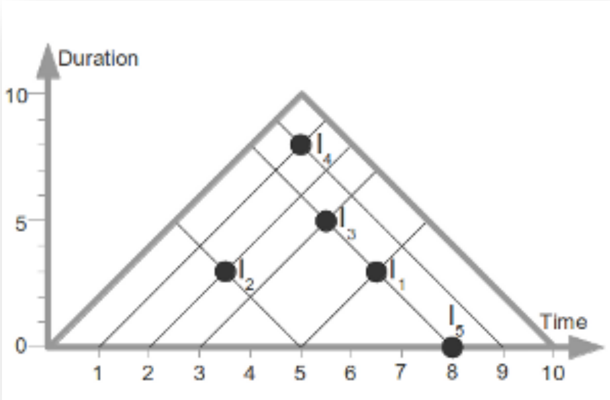


Figure 5: Activity oriented path of three individuals in a family; “eating meals” activity highlighted in blue *Source:* (Ellegård & Cooper, 2004)

The interactive 3-D techniques described by (Ellegård & Cooper, 2004) represent a powerful framework[1] *depicting activity, duration, sequence and timing in a single graphic. They suggest the software supports the depiction of other contexts in the z-axis and aggregate population data can be substituted for the individual views we see here. This visualization technique would be useful for exploratory data analysis as well as generating graphics to depict multiple time use components in a single space.*

[1] More information about the software built to generate these visualizations (VISUAL-Time-PAcTS can be found at http://www.itn.liu.se/mit/research/visual-interactive-data-analysis/interactive-visual-exploration/visual-timepacts?l=en

Figure 6: A triangular representation of timing and duration
Source: (Aigner & Tominski, 2013)



In *Figure 6* we find a mathematically sophisticated description of an interval of time. Along the x-axis we find chronological time, and along the y-axis a quantity of time (duration). When a point is positioned in the plane, line segments extending from the point to the x-axis at a 90° angle will intersect with the horizontal access at the start and end time of the interval described by the point. Take for example the point 1_2 in *Figure 6*. The suggested start time is 2 and end time is 5 resulting in a duration of 3. If we draw a mental line from the point to the y-axis, we find it intersects at 3.

This relatively obscure technique might prove aesthetically pleasing for integrated depictions of multiple time use components. It might also be used to compare timing and duration for different activities for different individuals. It is likely more appropriate for researchers than consumers.

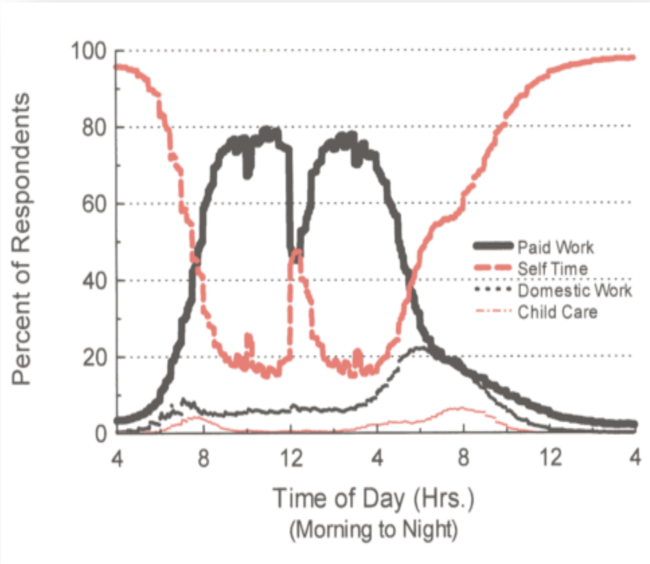


Figure 7: Four functions by time of day: conventional workers

Source: (Michelson & Crouse, 2004)

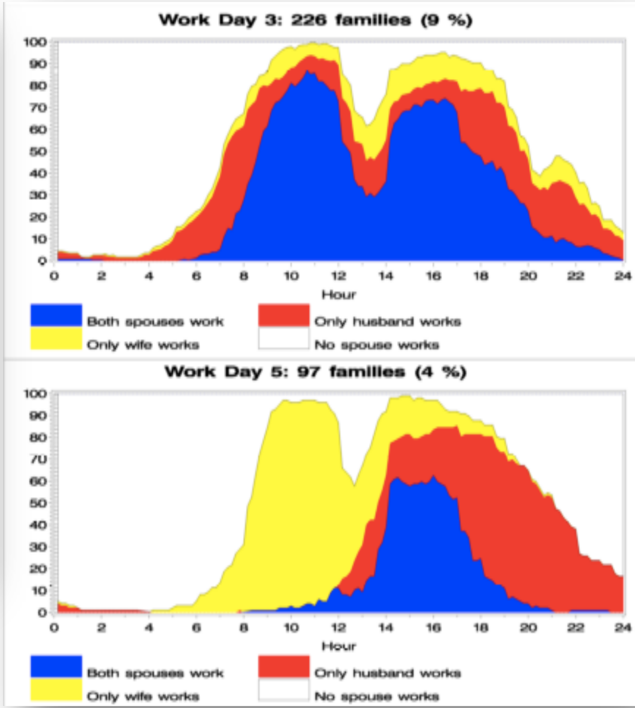


Figure 8: Two work days of French dual earner couples in 1985-86

Source: (Lesnard, 2004)

Tempograms are variations of line graphs where the x-axis describes an interval or point in time and the y-axis describes a percentage of the sample. Colors or variations in line can be used to differentiate categories.

In *Figure 7* we see an example from a time use publication which describes four types of activities represented by different color and weight of line for a sample of workers in Canada (Michelson & Crouse, 2004). The graph clearly displays the reciprocal relationship between paid work and self-time. In *Figure 8* we find two tempograms using an area variation that depicts two separate workdays for French families in 1985. Color is used to differentiate categories, and we can easily see the distinction between hours of the day when one or both of the spouses are working.

Tempograms are among the most commonly used graphics in population level time use research, as they provide an effective mechanism for visualizing the temporal relationship of statistical results in contextual (ie. demographic) data.

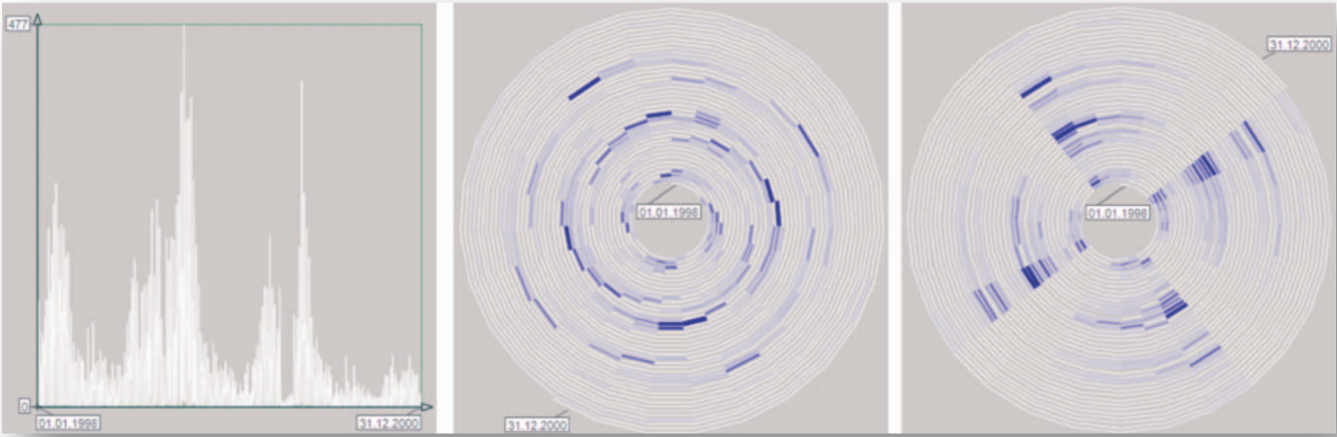


Figure 9: The same data set describing influenza cases over a period of three years. (Left) A time series plot, (b) Spiral graph incorrectly parameterized, (Right) correctly parameterized

Source: (K.P. Hewagamage, M. Hirakawa, and T. Ichikawa, 1999 as cited in Aigner, Miksch, Müller, Schumann, & Tominski, 2008)

One of the more compelling visual techniques surveyed is the spiral graph. This method examines the cyclical characteristics of data along a spiral-shaped axis. It relies on the correct parameterization of the length of a cycle in order to detect a periodic pattern in the data set (Aigner, et. al, 2008). *Figure 9* exemplifies the power of this method as used to describe a periodic cycling of the influenza virus. At left we see a time series plot of influenza data. In the center we find a spiral graph whose cycle parameter is set to 27 days. At that parameterization, no pattern in the data is observed. On the right however with the cycle length set to 28 days, a clear pattern emerges in the visualization.

Spiral graphs are complex constructions well-suited to exploratory data analysis and problem-solving tasks. One possible application to time use data is in the identification of cyclical patterns in contextual data (i.e. Mood, sleep quality, etc.)

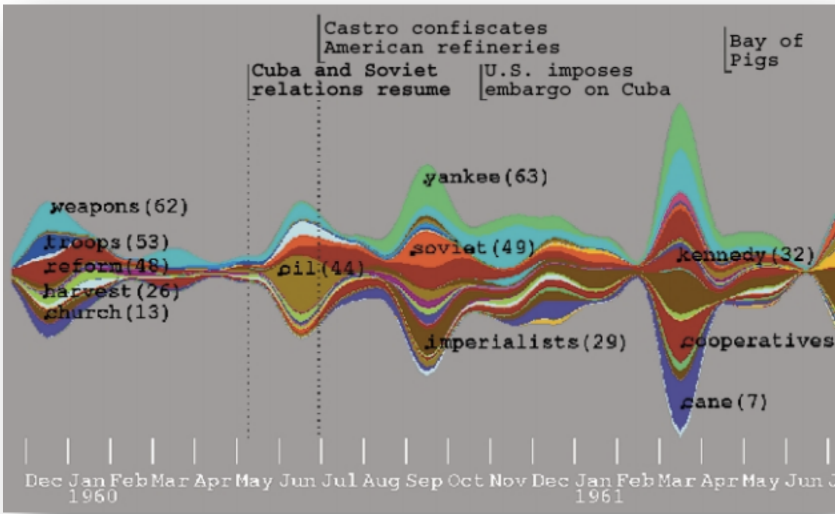


Figure 10: ThemeRiver style Stream Graph visualization of newspaper content during the months surrounding the Bag of Pigs historical event
Source: (Havre et al., 2000)

Stream Graphs and their derivatives depict the frequency or intensity of a variable over a continuous period of time. ThemeRiver (*Figure 10)* is one such an example, a prototype data analysis tool developed in 2000 to aid in the visualization of trending topics in news media (Havre, Hetzler, & Nowell, 2000).

The metaphor of a stream is used to depict the frequency of coded content in the sample data over time. Time is represented on the x-axis, with the y-axis representing the frequency of related content. Color is used to differentiate categories of content. The width of a band of color at any point in time suggests the amount of content in the media on that topic. Lead lines are used at the top of the graph to provide additional context of in the form of current events. The designers elected to use a continuous positioning system to make the bands of color more readily distinguishable, however, this choice may also present a usability obstacle, as viewers may construe the width of the whole river with the width of an individual current. This approach violates the common convention of not "jigling the baseline" in order to directly compare values (Tufte, 2001; Wainer, 1997).

The application of this technique to revealing temporal patterns in text or other media is self-evident, and the technique has been widely applied to analysis of social media and more general web-based content. The inherent difficulty in comparing the width of different colored bands renders this technique inappropriate for representing multiple categories. However, it might be produce an aesthetically pleasing display of correlated data as a sequence in time. For example, one might consider a simultaneity context in a diary study and then plot the number of simultaneous activities for an individual over the sequence of the day. Small multiples could then be employed to compare individuals.

CONCLUSION

The scope of this survey has been limited to statistical graphics published in peer-reviewed academic journals and conference proceedings. These venues comprise but one source of visualization techniques. An Internet search of the keywords: self-data, quantified self, or personal data tracking reveals a wealth of unique visualizations of time use and behavioral correlates. The comparative analysis of techniques in academic literature and those present in personal data applications is a worthy subject of future investigation. Additional differentiation of techniques based on their suitability for different communicative, analytic and problem solving tasks is the logical next step of this discussion. Finally, while this survey focused on techniques for representing the four basic components of time use, the next frontier of novel methods should address the need to represent polychronicity (multitasking) in each of these dimensions.

References

Aigner, W., Miksch, S., Müller, W., Schumann, H., & Tominski, C. (2008). Visual methods for analyzing time-oriented data. *IEEE Transactions on Visualization and Computer Graphics*, *14*(1), 47–60. doi:10.1109/TVCG.2007.70415

Aigner, W., & Tominski, C. (2013). The TimeViz Browser: A Visual Survey of Visualization Techniques for Time-Oriented Data. Retrieved June 06, 2014, from http://timeviz.net/

Boroditsky, L. (2001). Does language shape thought? Mandarin and English speakers' conceptions of time. *Cognitive Psychology*, *43*(1), 1–22. doi:10.1006/cogp.2001.0748

Ellegård, K., & Cooper, M. (2004). Complexity in daily life–a 3D-visualization showing activity patterns in their contexts. *Electronic International Journal of Time Use Research*, *1*(1), 37–59.

Fisher, K., & Layte, R. (2004). Measuring work-life balance using time diary data. *Electronic International Journal of Time Use Research*, *1*(1), 1–36. doi:dx.doi.org/10.13085/eIJTUR.1.1.1-13

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–51. doi:10.1111/j.1551-6709.2010.01105.x

Hägerstrand, T. (1970). What About People in Regional Science? *Papers in Regional Science*, *24*(1), 7–24. doi:10.1111/j.1435-5597.1970.tb01464.x

Havre, S., Hetzler, B., & Nowell, L. (2000). ThemeRiver: Visualizing theme changes over time. *… Visualization, 2000. InfoVis 2000 …*, 115–123. doi:10.1109/INFVIS.2000.885098

Lesnard, L. (2004). Schedules as sequences: a new method to analyze the use of time based on collective rhythm with an application to the work arrangements of French dual-earner couples. *Electronic International Journal of Time Use Research*, *1*(1), 60–84.

Michelson, W., & Crouse, D. (2004). Examining large-scale time-use files through graphic representation. *Electronic International Journal of Time Use Research*, *1*(1), 85–100.

Thrift, N. (1977). *An introduction to time-geography*. Geo Abstracts, University of East Anglia.

Tufte, E. (2001). *Visual Display of Quantitative Information* (Second., p. 197). Cheshire, CT: Graphics Paper Press LLC.

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, *3*(3), 499–535. doi:10.1111/j.1756-8765.2010.01113.x

Wainer, H. (1997). Graphical Forms. In *Visual Revelations. Graphical Tales of Fate and Deception from Napoleon Bonaparte to Ross Perot*. Mahwah, NJ: Lawrence Erlbaum.

3

Spontaneous Representations of Student Time Use

TABLE OF CONTENTS

Abstract **49**

1. Introduction **50**

Form and Space as Indicators of Thought *51*

Hypotheses *52*

2. Development of Coding Scheme **53**

2.1. Use of Space *54*

2.2. Use of Form *56*

2.3. Primary Mechanisms *57*

3. Method **58**

3.1. Participants *58*

3.2. Materials *58*

3.3. Procedure *58*

3.4. Analysis *59*

4. Results **59**

4.1. Use of Space *59*

4.2. Use of Form *62*

4.3. Primary Mechanisms *62*

5. Discussion **64**

6. Conclusion **65**

References **67**

Appendix A – Visualization Scenario **68**

English Instructions *68*

French Instructions *68*

ABSTRACT

How does one depict the use of time, when it cannot be described by sensory perception? We collected drawings from 25 undergraduates at a public French university. Students were asked to generate external representations of their allocation of time to activities along four components: duration, timing, sequence and frequency. The resulting use of form and space was analyzed by way of qualitative content analysis. Our results indicate a high level of correspondence with existing literature on visual representations of time, with one surprising result. We discuss these findings, and the iterative development of a theoretically based coding scheme, and their implications for further study.

Keywords: external representation, visualization, qualitative content analysis, visual content analysis, time use, time allocation, time budget

1. Introduction

Everyday we employ linguistic metaphors to express ideas about time. *The deadline is sneaking **up on** me, but my manuscript is **ahead** of schedule. I need to be **on** time for my appointment, officer. Is it just me, or are these lab meetings getting **longer**? I sure am looking **forward** to the weekend!* In language, we employ metaphor and analogy to create correspondence between familiar and unfamiliar concepts. Similarly, symbolic mappings can be applied in visual forms: *graphical metaphors*, constructed to convey meaning. Evidence of these substitutions is pervasive in everyday life, so much so, we often employ them without conscious awareness.

Time use (also referred to as time allocation, Zeitbudget, or time budget) refers to the way we utilize time to perform activities. Like the construct of time itself, it is a compelling object of study in visualization: amorphous in nature with an enigmatic perceptual basis. In addition to the activities an individual performs, there are four components that can be derived from time use data: duration, timing, sequence and frequency. Duration refers to the amount of time spent on a given activity. Timing locates an activity in the context of the conventional use of clock and calendar. Sequence refers to the relative order of activities; while frequency refers to the number of times an activity occurs within a given interval. Visualization of time use data offers numerous practical applications, from planning events on a calendar, to allocating resources on a project, to detecting patterns in human habits[1].

In her 2011 paper, "Visualizing Thought", Barbara Tversky summarizes more than a decade of empirical research on visual representation, describing how individuals utilize space and form to communicate both concrete and (more interestingly) abstract concepts. Her findings have implications for both internal and external representations; as clues to how we think, and indications of how we should design. In this exploratory study, we will apply Tversky's designations to the domain of time use, to investigate how students represent their own experience of time.

---

[1] Can you spot the spatial metaphors used to describe time use components? It seems one cannot escape using metaphors when writing about time.

Form and Space as Indicators of Thought

The components of visual communication are simple: Typically, a flat surface, prototypically, a page (or something analogous to a page like a computer screen) and marks or forms placed on it.
(Tversky, 2011, pg. 502)

Tversky (2011) examines how space and form are used to convey meaning in diagrams. She first identifies three methods for depicting conceptual order, positioning form 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 (notably the acuity of the center of the visual field) serve to ground the latter (Tversky, 2011, p. 509). These dimensions are not equivalent, however. While both the horizontal and vertical effectively represent explicit order (i.e. first to last, greatest to least) the center-periphery can only indicate relative importance, since the space of the page extends from the center outward in all directions.

The meanings conveyed by direction in the horizontal and vertical planes are more ambiguous, though Tversky identifies several consistencies evident in empirical studies of graphic production. A cross-cultural examination of representation by children revealed a relationship between direction of written language and concepts of time for both Arabic (right to left) and English (left to right) readers. In both cases, the depiction of temporal flow from past to present was concordant with the direction of written language (Tversky, Kugelmass, & Winter, 1991). It seems the horizontal use of space is strongly influenced by linguistic convention in literate individuals.

The horizontal dimension appears to be plastic, as Tversky (2011) suggests, grounded in our experience of left-right symmetry in the environment. Contrast this with our experience of the vertical, which is strongly grounded by the force of gravity. We must literally exhibit strength to go upward, by body or machine. In kind, Tversky finds the vertical dimension is often used to express evaluative concepts with asymmetric values (such as quantity, quality, and strength), with the preferred value positioned in the upward direction.

Space *exists*, in multiple dimensions, while form on the other hand, is constructed. Complex forms are constructed by combining simple forms in purposeful configurations. The simplest forms are points and lines, which can be extended, contoured and combined to generate realistic depictions of worldly objects, or more abstract flights imaginative fancy. The classification of visual forms, however, is far from a straightforward enterprise! What I perceive as a picture of a rose, you might consider an icon for organic, an index for gardening, or a symbol of beauty and love. What type of drawing then, is this rose? Dyadic perspectives in semiotics utilize the notion of convention to simplify this ambiguity, while triadic perspectives maintain that meaning is always constructed in the mind of the viewer (de Vries & Masclet, 2013). As time use bears no physical analog, we will avoid this ambiguity by considering a limited number of easily distinguishable forms: symbols consisting of letters and numbers, and drawings in the general sense. We offer special treatment only to arrows: lines with directional indications, which serve as pervasive signs for movement, flow, process or time.

HYPOTHESES

We decided to conduct an exploratory exercise in conjunction with a pedagogical activity on time management. We expected our participants, third year undergraduates, would be capable of reasoning about, and attempting to represent, their daily activities along the four components of time use. Working with a limited sample of students, we decided on a qualitative approach that would enable us to pilot our materials, validate our conceptual framework and refine our hypotheses. We elected to conduct a qualitative content analysis, as it afforded an iterative deductive-inductive coding process, accommodating novel and unexpected forms of representation (Marsh & White, 2006).

Our analysis would be guided by three questions:

(1) How do students use space to represent time use?
(2) How do students use form to represent time use?
(3) Is there any consistency in which mechanisms are used to represent each component of time use?

Based on the literature reviewed, we formulated three hypotheses predicting what the students would produce.

(1) As *activities* have physical correspondence with objects in the world, we expect they will be primarily represented through realistic drawings and descriptive text.
(2) *Duration* and *frequency* have magnitude, but not order. We expect these constructs will be represented via statistical graphs (such as pie or bar charts), independent of the more depictive activity data. If presented spatially, we expect the vertical dimension will be used, with the upward direction representing greater values.
(3) *Timing* and *sequence* have order, but no shape or physical analog. We expect these constructs will be represented with spatial positioning. As they have no qualitative value, we predict they will likely be shown in the horizontal dimension.

2. Development of Coding Scheme

The coding scheme was developed by the author using a directed approach (Hsieh & Shannon, 2005). First, categories were defined in response to the foreshadowing questions, in alignment with the discussion of form and space in Tversky (2011). The author then reviewed a subset of diagrams (n=5), and applied the coding scheme. Multiple modifications were made during this inductive process, including the addition of two categories the researcher noted as present and variant in the sample, and removal of one category that proved too subjective to evaluate[2]. The researcher then developed operational definitions for each variable and set variable values that were exhaustive and mutually exclusive (Theo & Jewitt, 2004).

The resulting scheme was then applied to the diagrams by two additional raters, who coded the entire sample. After every five diagrams, the raters paused to discuss their evaluations, following the constant comparison method (Glasner & Strauss, 1967 as cited in Marsh & White, 2006). In the case of discrepancies, each rater explained their interpretation of the code, after which raters could revise or maintain their original assessment. In one case, a revision to an operational definition was proposed, and the corresponding components of the previously reviewed diagrams were re-evaluated. The final coding scheme reflects a response to the both the research questions and the evidence present in the sample.

[2] The researcher decided to treat all depictive representations in a single category (drawing), rather than differentiate them as icons, indexes, representative depictions, etc.

2.1. Use of Space

We first sought to categorize the students' use of space. In language we use conflicting spatial metaphors when describing time. We describe history as a series of "timelines" but sleep as a circadian "rhythm". Before dissecting the representations into component dimensions, we first considered the nature of their Gestalt use of space. Raters were asked to categorize an overall pattern as *linear* or *circular*. Linear representations appeared to follow a line whose end did not return to its beginning, while circular representations resembled a curved path with no start or finish. This distinction formed the basis for the first variable in the coding scheme (S1).

Next, we turned to the dimensions of the page, defining them in regard to the student's frame of reference. The horizontal and vertical orientations corresponded (respectively) to the long and short sides of a sheet of A4 paper, and the center-periphery to the middle and boundaries of the page.

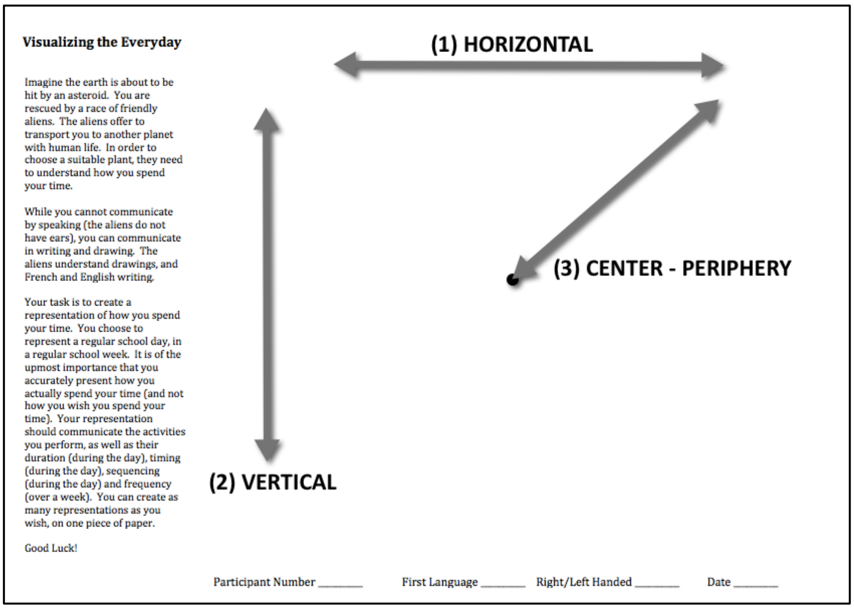


Figure 1: Page Dimensions

Figure 1 depicts the three spatial dimensions we examined, imposed on the experimental materials: (1) horizontal, (2) vertical, and (3) center - periphery

We at first considered these orientations universally, coding the directional flow of information in each dimension, for each representation. During the inductive coding however, it was apparent that the use of each dimension was dependent on the overall pattern of space (S1). The horizontal and vertical were only relevant for linear representations, while the center-periphery distinction was relevant in circular cases. Variables (S2-S5) were assigned to evaluate the direction of flow for: (2) horizontal, (3) vertical, (4) clockwise/counterclockwise and (5) center-periphery. Raters considered the questions: in what direction does the author intend you to follow in the information? In which (if any) direction does the information "flow"? In evaluating this task, it was critical to consider the whole representation as the unit of analysis in order to code the flow of information, rather than the direction of text, which would skew the results in favor of left to right, top to bottom and clockwise values. Finally, we chose to categorize the point of origin in each representation (S6). The raters agreed on the "start" of the day as earliest activity beginning after 12:00 AM.

Table 1 summarizes the six variables evaluating space, along with their range of values and operational definitions.

Table 1: Coding Scheme for Use of Space

#	VARIABLE	VALUES	OPERATIONAL DEFINITION	
S1	PATTERN	1 = LINEAR 2 = CIRCULAR	Overall, the use of space…	follows a line (visible or not) with an end and beginning follows a circular path
S2	(LINEAR) HORIZONTAL	0 = NONE 1 = LEFT → RIGHT 2 = BOTH 3 = RIGHT → LEFT	The linear use of space in the horizontal plane proceeds primarily…	NA: The dimension is not used from left to right In both directions from right to left
S3	(LINEAR) VERTICAL	0 = NONE 1 = TOP → BOTTOM 2 = BOTH 3 = BOTTOM → TOP	The linear use of space in the vertical plane proceeds primarily…	NA: The dimension is not used from top to bottom in both directions from bottom to top
S4	(CIRCULAR) CIRCUMFERENTIAL	0 = NONE 1 = CLOCKWISE 2 = BOTH 3 = COUNTERCLOCKWISE	The circular use of space around the perimeter of the proceeds primarily…	NA: The dimension is not used in a clockwise direction in clockwise and counterclockwise directions In a counterclockwise direction
S5	(CIRCULAR) RADIAL	0 = NONE 1 = PERIPHERY → CENTER 2 = BOTH 3 = CENTRE → PERIPHERY	The circular use of space inside the perimeter of the proceeds primarily…	NA: The dimension is not used starts in periphery, moves to center in both directions starts in center, moves to periphery
S6	LOCATION OF ORIGIN	0 = TOP LEFT 1 = BOTTOM LEFT 2 = BOTTOM RIGHT 3 = TOP RIGHT 5 = CENTER	The location of the origin (start of the individual's day) is located in the …	top left area of the page bottom left area of the page bottom right area of the page top right area of the page center of the page

2.2. Use of Form

In analyzing form, we chose to assume a pragmatic stance, allowing for a wide range of artistic abilities. We read for forms that were used consistently throughout a drawing, reflecting intentional choice by the author. We were particularly interested in evaluating when students chose to use text, versus numbers versus drawings. In support of this goal, we adopted two conventions:

1. *Text vs. Symbol augmenting numbers*

This sentence is text, and "12" is a number. But what about "12h14", or "4pm": text or number? The answer in the strictest sense is *both*. However, we chose to allow a limited number of textual characters to be considered numeric in our coding scheme, when their purpose was clearly to label a numeric quality. These include the conventions: h, m, s, hr, min, sec, x (for number of times), am, pm.

2. *Text vs. Symbol augmenting a drawing*

Similarly, text can be used to *accompany* a diagram, or, text may be *present* in a diagram, as it is present in the physical world. Imagine a photograph of a road sign. Most would consider the words on the sign a part of the image, while the caption of the photograph constitutes a textual description of the image. We chose to make a similar distinction, allowing for a pragmatic treatment of integrated text labeling otherwise realistic depictions.

Figure 2: Symbol augmenting drawing

Figure 3: Text, and symbol augmenting drawing

In the *Figure 2,* the author represented their arrival at school using a combination of numeric symbol [7h55] and realistic drawing. The word "UPMF" (in red: acronym for their university) is used to distinguish the building as a school. As the remaining drawings in the representation do not contain text labels, the coders agreed, in this case the author used the text only to augment their drawing skills. The representation was coded as having included number (7h55) and drawing.

In *Figure 3*, the author represented their departure from school using text description (in green) and drawing (a pathway and building). The word "ECOLE" (in red: English = "school") is used only to identify the building as a school. The representation was coded as number (12h00), text ("repas chez soi") and drawing (the building and path).

Table 2 summarizes the five variables evaluating form, along with their range of values and operational definitions.

Table 2: Coding Scheme for Use of Form

#	VARIABLE	VALUES	OPERATIONAL DEFINITION	
F1	TEXT	0 = NO 1 = YES	Is the following present in the representation?	Symbols: english or french language (not embedded in images, intended only to mitigate poor drawing skills)
F2	NUMBER	0 = NO 1 = YES	Is the following present in the representation?	Symbols: numbers, including linguistic labels: s, m, h, seconds, x, minutes, hours, times
F3	DRAWING	0 = NO 1 = YES	Is the following present in the representation?	depictive representation
F4	ARROW	0 = NO 1 = YES	Is the following present in the representation?	line with a directional end
F5	COLOR	0 = NO 1 = YES	Is the following present in the representation?	more than one color

2.3. Primary Mechanisms

Finally we turned to the essential components of time use, and sought to identify which graphic mechanisms were used in their depiction. Raters were asked to identify each component in the diagram, and indicate which of the previously identified spatial and form elements were employed in their representation.

Table 3 summarizes the five variables evaluating primary mechanisms, along with their range of values and operational definitions.

Table 3: Coding Scheme for Primary Mechanisms

<table>
<tr><th>#</th><th>VARIABLE</th><th>VALUES</th><th colspan="2">OPERATIONAL DEFINITION</th></tr>
<tr><td>M1</td><td>ACTIVITY</td><td rowspan="5">SPATIAL/SIZE
SPATIAL/POSITION
TEXT
NUMBER
DRAWING
ARROW
COLOR
OTHER</td><td rowspan="5">Which mechanisms are used to represent the component?</td><td>Activities: the actions the individual performs (i.e. eating, driving to work)</td></tr>
<tr><td>M2</td><td>DURATION</td><td>Duration: the quantity of time the individual spends performing the activity. (i.e. 2 hours, 1.5 hours)</td></tr>
<tr><td>M3</td><td>TIMING</td><td>Timing: the start and or end time at which the individual performs the activity (i.e. 9:00 am, 8pm)</td></tr>
<tr><td>M4</td><td>SEQUENCE</td><td>Sequence: the order in which the individual performs the activity (i.e. brushing teeth is followed by going to bed)</td></tr>
<tr><td>M5</td><td>FREQUENCY</td><td>Frequency: the number of times the activity is performed in a given time interval (i.e. 4 times per day, 2 times per week)</td></tr>
</table>

3. METHOD

3.1. PARTICIPANTS

Twenty-five (22 female, 3 male) undergraduates at a public French university participated as a requirement of a graduate studies preparation course. The median age was 23, and all were registered Education majors.

3.2. MATERIALS

A text scenario was developed to motivate students to generate accurate representations of their time use. While there are many purposes for external representation (i.e. persuasion, problem solving, exposition, planning) the scenario was constructed to prompt graphic productions in the most general case: informative communication.

Although the students' participation was required for their academic course, we did not feel this obligation was sufficient to motivate cognitive and creative effort. To encourage engagement, a humorous scenario was developed involving an alien attack (see Appendix A). Although the students would be rescued, relocation to a suitable planet would depend on their ability to accurately communicate how they typically use their time.

The scenario explicitly called for representation of five components: activity (*what*), duration (*quantity*), timing (*chronological point in time*), sequence (*order*) and frequency (*number of times*). They were prompted to represent their time use for a typical school day in a typical week, and allowed to define for themselves what to consider as typical.

The students were given one sheet of A4 paper; but instructed to create as many representations as necessary, using any graphic conventions desired. The text was carefully worded to use only the term "representation" when referring to the graphic output, avoiding a bias in visual forms with words such as: chart, graph, picture, sketch, icon, or text. They were free to use any resources available, including pens, pencils, highlighters and colored pencils.

3.3. PROCEDURE

The exercise was administered in conjunction with a pedagogical activity on study time allocation. First, the students listened to a presentation on time use research where they were introduced to the components of time use data. The presentation contained no graphics in order to avoid priming the students with spatial metaphors for temporal characteristics. The students then completed a short demographic survey and were given a sheet of paper containing the visualization scenario. Students were directed to read the scenario and create an appropriate representation. The resulting graphic productions were collected and scanned by the author for archiving.

3.4. ANALYSIS

Three graduate students in Cognitive Visualization (including the author) coded the resulting diagrams following the procedure for directed qualitative content analysis (see Hsieh & Shannon, 2005; Krippendorff, 1989; Patton, 2002, for a thorough description). The raters agreed on the operational definitions for each component in the coding scheme before analyzing two diagrams from the sample as a training exercise. As the sample size (n=25) was small, each rater proceeded to code the entirety of the sample.

Coding results for the whole sample were then evaluated for inter-rater reliability, with positive outcomes. Krippendorff 's alpha was selected as the most appropriate measure of reliability for nominal variables assessed by more than two coders (Hayes & Krippendorff, 2007). For use of space (S1-S6) $\alpha = 0.876$, use of form (F1-F5) $\alpha = 1.000$ and primary mechanisms (M1-M5) $\alpha = 0.972$, all exceeding the recommended threshold of $\alpha \geq 0.800$ (Geertzen, 2012; Lombard, Snyder-Duch, & Bracken, 2004).

Finally, a combined coding result was constructed from the individual results (based on the majority rating) for use in data analysis.

4. RESULTS

4.1. USE OF SPACE

Of the 25 diagrams analyzed, 84% (21) were characterized by a linear flow of information. In this set, 76% (16) adopted a left to right horizontal orientation, while 20% (4) alternated left to right and right to left. 90% adopted a top to bottom vertical orientation and two diagrams utilized only one of the two dimensions. *Figure 4* describes the directional use of space in linear diagrams.

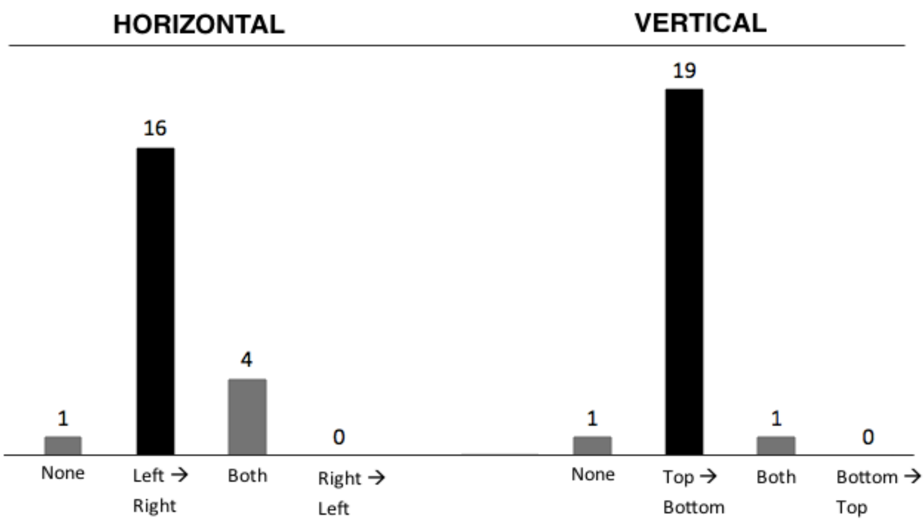


Figure 4: Frequency of directions in linear diagrams (n=21)

Figures 5 and 6 are prototypical examples of linear representations, with origins in the top left corner of the page. In both cases, the reader scans the diagram from left to right, then jumps down at the end of horizontal space, like reading English text.

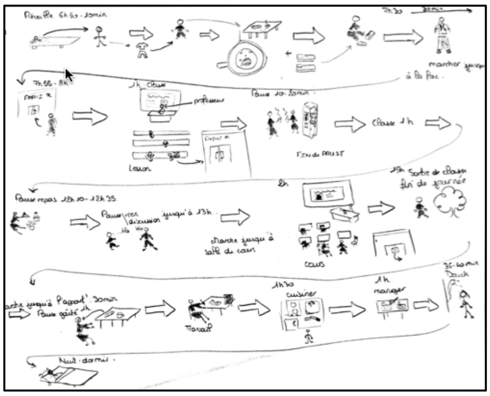


Figure 5: A linear representation

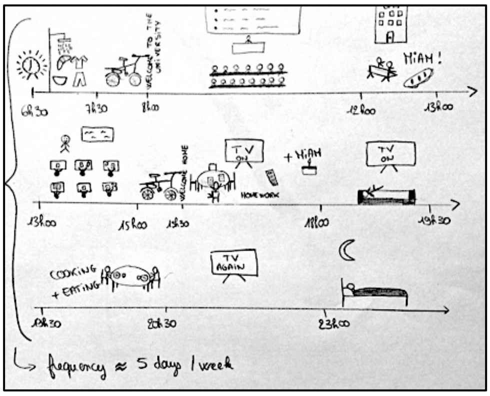


Figure 6: A linear representation

We identified four diagrams *(Figure 7)* that avoided the scanning effect by alternating horizontal direction at the end of each “line”. We dubbed these “snakes”, and they followed a slithering pattern across the page. In all four cases, the students started in the upper left hand corner and depicted first left to right and then right to left, from top to bottom of the page. However, a form (line or arrow) was always used to indicate the change in direction. We contrast this with *Figure 6* in which the author assumes the viewer will skip to the next line and continue reading left to right.

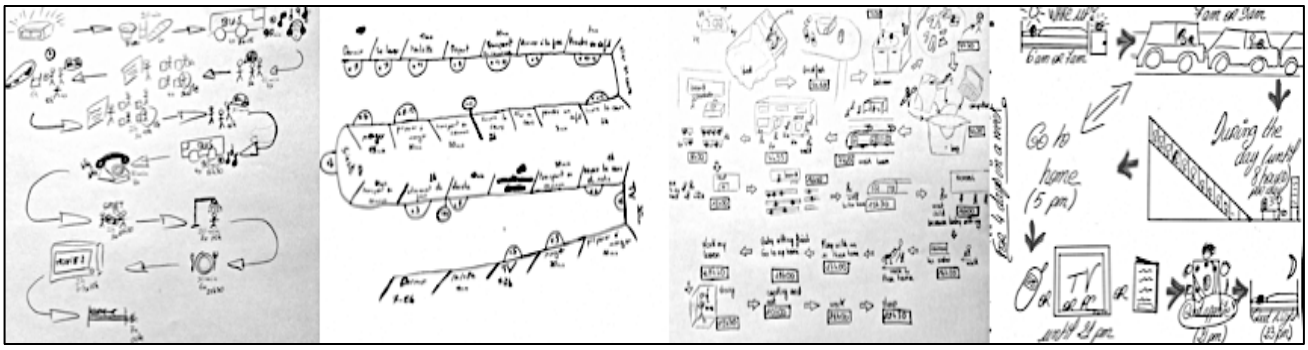


Figure 7: Four “snake” linear representations

Of the 4 circular diagrams, 3 presented information in the clockwise direction. There was minimal use of the radial orientation, with only two diagrams depicting flow from the periphery toward the center. *Figure 8* describes the directional use of space in circular diagrams.

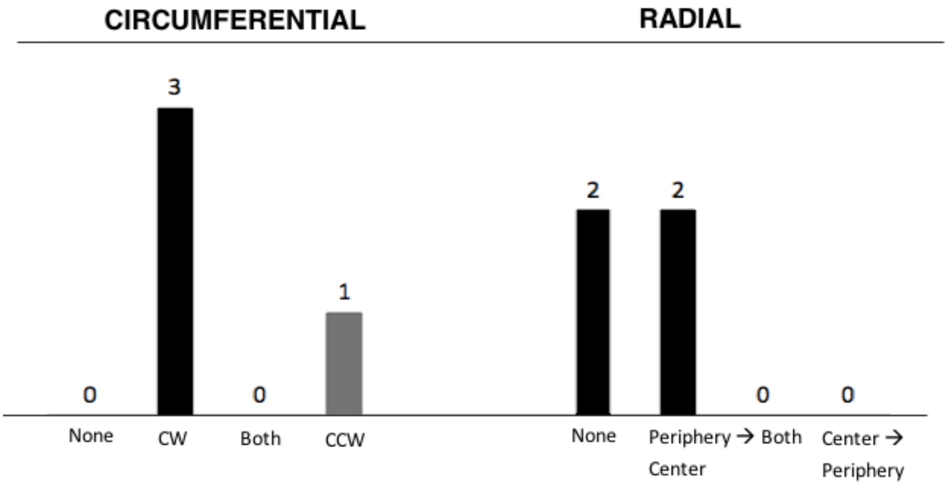


Figure 8: Frequency of directions in circular diagrams (n=4)

Nearly all of the students (88%) depicted the start of their day in the upper left corner of the page. Of the remaining three, two were circular representations and one was linear.

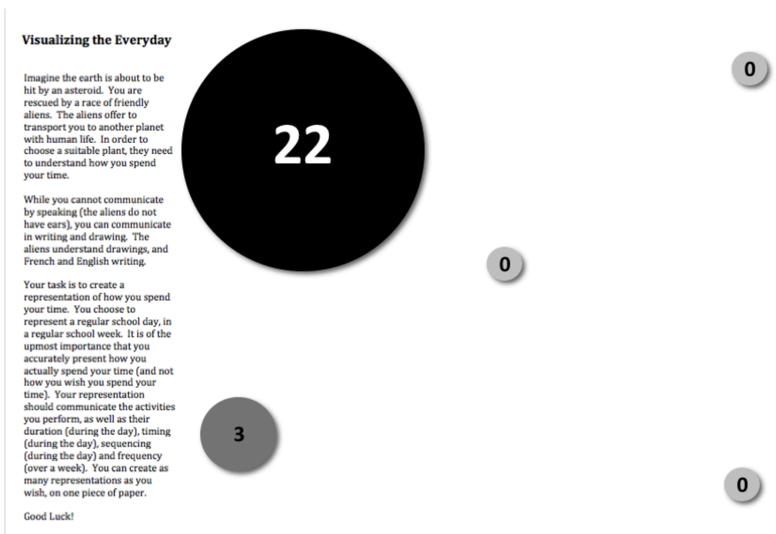


Figure 9: Location of origin in reference to the page (n=25)

4.2. Use of Form

Figure 10 describes the use of form in each diagram, grouped by linear and circular spatial patterns. The most frequently used form was numbers at 92%, with the least frequent being color at 52%. Five diagrams made use of all five types of form evaluated. Visual examination of the frequency distribution suggests a relationship between the use of number and text, and drawing and color, though the sample was too small to evaluate statistical correlation.

PATTERN	LINEAR																					CIRCULAR				
ID	14	4	28	7	16	10	11	26	27	18	24	21	20	1	6	8	5	17	12	13	23	29	2	22	9	TOTAL
NUMBER	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	23
TEXT	1	1		1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	21
ARROW		1	1		1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1	1	21
DRAWING			1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1		1	1	1	19
COLOR										1	1	1	1	1	1	1	1	1	1	1	1				1	13

Figure 10: Frequency of form use in linear and circular representations (n=25)

Figures 11 -13 exemplify the range of form from highly depictive to highly descriptive expressions with drawing and text.

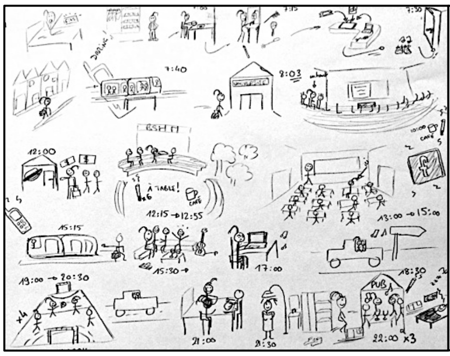


Figure 11: Primarily picture

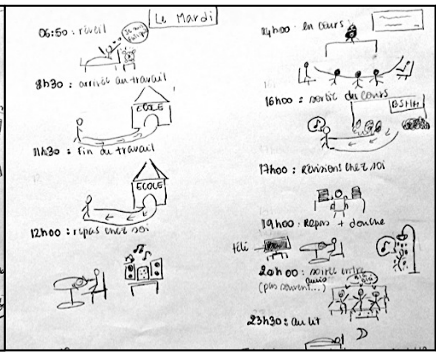


Figure 12: Balanced

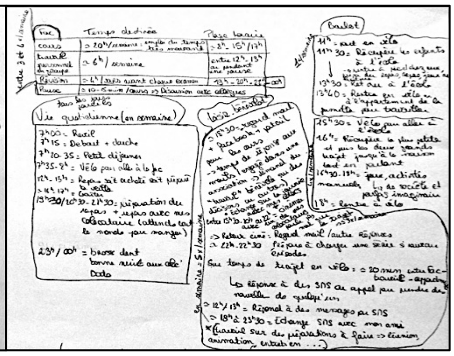


Figure 13: Primarily text

4.3. Primary Mechanisms

Our first prediction was the use of realistic drawings and text to depict activities. Comparison of frequency in the coded data supports this hypothesis, with 80% of the sample using text, and 70% using drawings. Two novel representations differentiated activities through the use of color. 60% of the drawings used both text and drawing, and all three raters noted the use of text to mitigate poorly executed sketches.

Only four individuals manged to represent all four components of time use. Frequency was the most commonly neglected component, followed by duration, then timing. When represented, numbers were consistently used to depict frequency and duration. Our second hypothesis was that duration and frequency would be described using statistical graphs, independent of the more depictive activity data. Surprisingly, none of the results diagrams included statistical graphs.

Our last hypothesis was the use of spatial positioning on the horizontal dimension to represent timing and sequence. 100% of the drawings used spatial position to represent sequence, however only 2 diagrams used it to represent timing. These two novel representations were both circular, positioning activities around the corresponding place in space on the face of a clock to indicate the time they occurred.

.

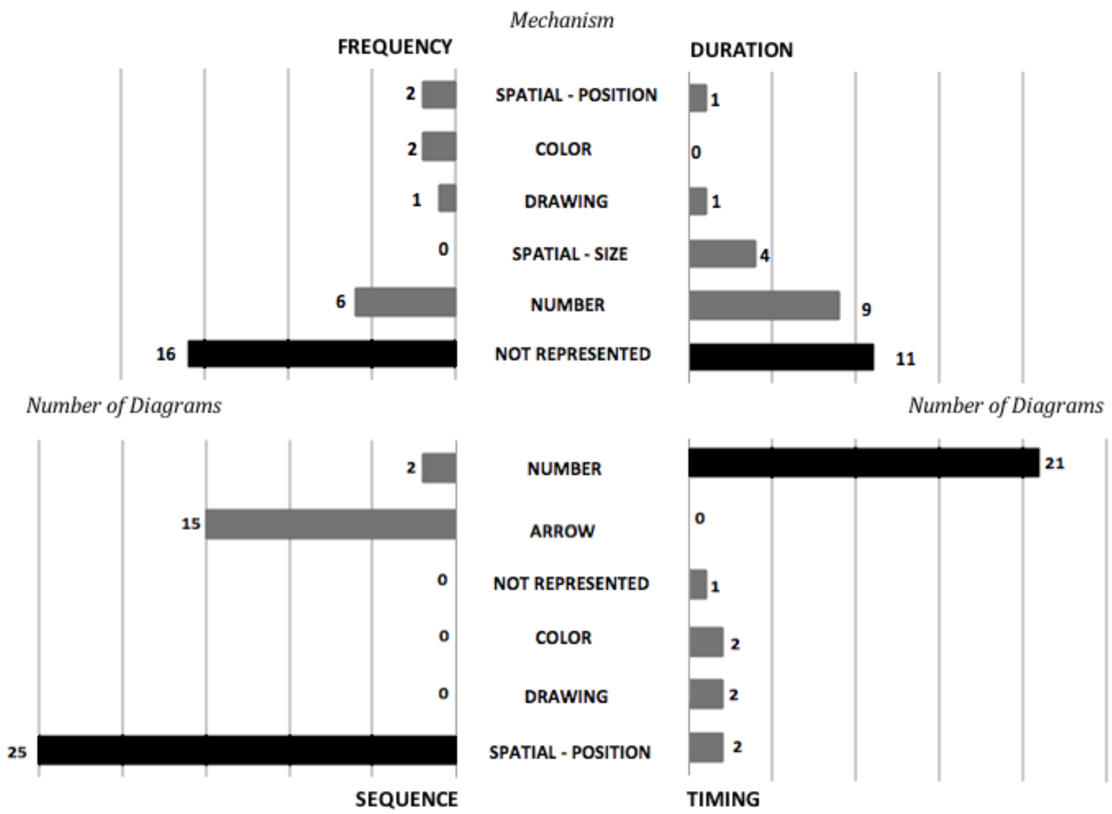


Figure 14: Frequency of mechanisms representing frequency, duration, sequence and timing

5. Discussion

There are a number of limitations in this exploratory study, several of which point to promising directions for future research. First, we found qualitative content analysis to be an appropriate method for developing a conceptually grounded, empirically relevant coding scheme. By testing the coding scheme on a small, non-random sample however, we were unable to make statistical inferences, relying instead on rank order comparisons of frequency. The next stage of research should include quantitative studies with larger, random samples.

Our results did indicate a strong preference for linear patterns when representing time. The predominance of the left to right and top to bottom orientations is consistent with Tversky's (2011) discussion of correspondence between linguistic direction and temporal depiction. Although we made no prediction regarding the relative frequency of linear and circular diagrams, we did expect a greater proportion of students to use circular space to indicate the cyclical nature of days and weeks. Tversky addresses a similar discrepancy in her data, where students were reluctant to produce circular diagrams, even when asked to model cycles and processes (Tversky, 2011). She speculates that linear thinking is *easier* than cyclical, and students prefer to consider the forward progression in time. "Events occur in time, time marches relentlessly forward, and does not bend back on itself," (Tversky, 2011). We also observed the linear flow of information in the diagrams to be evocative of weekly calendars and daily agendas. This suggests that the temporal representations the students are exposed to for planning may influence their choice of representation for communicative tasks. In future work, we recommend including questions about the type and frequency of calendar-agenda planning instruments the individuals use, as well as their general orientation and attitudes about time use.

We found the students' use of form impressive, reflecting varying degrees of artistic ability and a consistently high degree of effort. This suggests our scenario *(Appendix A)* was effective in motivating students to complete the task without biasing their use of visual form. A number of student's used color, most often to distinguish the communicative purpose of text labels for frequency vs. duration vs. timing. Two students used color to represent activity, by "color-coding" activity categories. We suspect that access to materials may have impacted which students chose to use color to what end. Future work should control this by providing all participants with the same drawing implements.

Some diagrams were rich with depictive detail, including advanced artistic devices such as overlap, perspective and motion lines, while others relied entirely on textual description. In the future, we recommend controlling for the individual's artistic ability, possibly through the inclusion of a drawing task.

The biggest surprises came in the student's choices for representing the components of time use. Although the instructions explicitly allowed for the creation of multiple representations, all 25 results reflected attempts to create a single, integrated diagram, to varying degrees of success. This proved to be the most unexpected result, as we predicted students would employ different graphic forms to depict different components of time use. Statistical graphics such as pie or bar charts were noticeably absent, despite their efficiency in communicating relative quantity. Clearly, different graphics are better suited for different purposes, and we find the tendency for students to produce complex integrated diagrams rather than simple distributed diagrams to be worthy of further investigation. We suspect this may be related to the students' educational backgrounds, reflective of their both their interests and technical abilities. One of the clear limitations of this exploratory study was the homogeneous sample of education majors. We suggest that future work include students from a variety of backgrounds, notably engineering, science and the fine arts. An alternative explanation for the observed preference for complexity is that the students might place a high value on informational efficiency. To examine this hypothesis, we suggest refining the communicative task from one of "informing" to differentiated tasks for planning, problem solving and informing. In addition to potentially revealing sources of variation, more strictly defined communicative purpose might allow us to more reliably infer about the underlying conceptual structure suggested by an individual's graphic production. The broad scope of the "informing" task prevents us from making generalizations about the nature of the students' mental representations.

6. Conclusion

This activity was successful in addressing our exploratory questions. We found that students were capable of producing a wide range of graphic representations using a variety of spatial conventions and visual forms. The results serve to validate the usability of our coding scheme, and indicate which correlational hypotheses to explore in future quantitative studies.

As Tversky (2011) notes, the visual forms we produce to communicate with the world have two important implications. First, they serve as clues to the underlying mental representation of the depicted thoughts. While much research in psychology has explored the cognitive processes involving the perception of time, little attention has been paid to the idea of time *use.* As psychologists explore the time use methods honed in sociology and economics, an understanding of the individual's underlying conceptual representation of time allocation will become increasingly important. Secondly, Tversky suggests that the graphics we produce are suggestive of the graphics would might like to use, thus they have clear implications to design. The proliferation of mobile computing technologies had brought with it unprecedented access to personal data, spawning a worldwide movement of personal data analysis; dubbed *the quantified self*. Further studies investigating graphic production of time use may suggest novel designs and interface patterns for self quantifying applications, aimed at empowering the individual to know and therefore take control over their use of time.

References

De Vries, E., & Masclet, C. (2013). A framework for the study of external representations in collaborative design settings. *International Journal of Human-Computer Studies*, *71*(1), 46–58. doi:10.1016/j.ijhcs.2012.07.005

Geertzen, J. (2012). Inter-Rater Agreement with multiple raters and variables. Retrieved June 5, 2014, from https://mlnl.net/jg/software/ira/

Hayes, A. F., & Krippendorff, K. (2007). Answering the Call for a Standard Reliability Measure for Coding Data. *Communication Methods and Measures*, *1*(1), 77–89. doi:10.1080/19312450709336664

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277–88. doi:10.1177/1049732305276687

Krippendorff, K. (1989). Content Analysis. In (E. Barnouw, Ed.)*International Encyclopedia of Communication*. New York, NY: Oxford University Press.

Lombard, M., Snyder-Duch, J., & Bracken, C. (2004). Practical resources for assessing and reporting intercoder reliability in content analysis research projects, (2002), 1–18.

Marsh, E., & White, M. (2006). Content analysis: A flexible methodology. *Library Trends*, *55*(1), 22–45. doi:10.1353/lib.2006.0053

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. *Qualitative Inquiry* (Vol. 3rd, p. 598). doi:10.2307/330063

Theo, C., & Jewitt, V. L. (2004). The Handbook of Visual Analysis. *Social Semiotics*, 134–155. doi:10.4135/9780857020062

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, *3*(3), 499–535. doi:10.1111/j.1756-8765.2010.01113.x

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515–557. doi:10.1016/0010-0285(91)90005-9

Appendix A – Visualization Scenario

English Instructions

Imagine the earth is about to be hit by an asteroid. You are rescued by a race of friendly aliens. The aliens offer to transport you to another planet with human life. In order to choose a suitable plant, they need to understand how you spend your time. While you cannot communicate by speaking (the aliens do not have ears), you can communicate in writing and drawing. The aliens understand drawings, and French and English writing.

Your task is to create a representation of how you spend your time. You choose to represent a regular school day, in a regular school week. It is of the upmost importance that you accurately present how you actually spend your time (and not how you wish you spend your time). Your representation should communicate the activities you perform, as well as their duration (during the day), timing (during the day), sequencing (during the day) and frequency (over a week). You can create as many representations as you wish, on one piece of paper.

Good Luck!

French Instructions

Imaginez que la terre est sur le point d'être frappé par un astéroïde. Vous êtes sauvé par une race d'extra-terrestres amicaux. En effet ces aliens proposent de vous transporter sur une autre planète avec une vie humanoïde. Afin de choisir une planète convenable, ils ont besoin de comprendre comment vous passez votre temps. Cela dit vous ne pouvez pas communiquer par la parole (les aliens n'ont pas d'oreilles), vous pourrez communiquer par écrit et par dessin. En effet ces aliens comprennent les schémas, et le français et l'anglais écrit.

Votre tâche est de créer une représentation de la façon dont vous passez votre temps. Vous devrez choisir de représenter un jour de classe ordinaire, dans une semaine régulière de l'université. Il est de la plus haute importance que vous présentez de manière précise la façon dont vous passez réellement votre temps (et pas la façon dont vous souhaitez avoir passé votre temps). Votre représentation devra comprendre les activités que vous effectuez, ainsi que leur durée (pour la journée), l'heure (pour la journée), l'ordre de vos activités (pour la journée) et la fréquence (pour une semaine). Vous pouvez créer autant de représentations que vous le souhaitez, sur une feuille de papier.

Bonne chance!