

Chapter 11

Computer-Based Tools for Recording Time and Motion Data for Assessing Clinical Workflow



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11.1 Introduction

This chapter focuses on computer-based tools designed to facilitate field data collection for time and motion studies (TMS) conducted in healthcare settings. As a commonly used research method, TMS originated from industrial engineering with a goal to assess workers' time expenditure and physical movements when completing a task, a series of tasks, or distinct steps that constitute a task. In recent years, TMS have been widely adopted and frequently used to study clinical workflow, especially in the context of introduction of health information technology (IT) systems (Lopetegui et al. 2014). As of April 2018, a cursory search in PubMed¹ with the keywords (“*time and motion study*” OR “*time motion study*”) yielded a total of 337 papers. More than 75% of them were published after year 2000. For more details of TMS, please see Chap. 4 in this book, “A Review of Clinical Workflow Studies and Methods.”

TMS usually require a person (i.e., “external observer”) to shadow clinicians' work in order to continuously record when, where, and what clinical tasks are performed. Since early 2000s, Several computer-based tools have been developed to facilitate time and motion data collection with features specifically designed to accommodate capture of complex workflow behaviors, such as multi-tier clinical task classifications and the ability to record multitasking and interruptions. In this chapter, we describe three such tools that have been used in multiple TMS-based research studies with established validity and generalizability. Our choice of these three tools, however, does not suggest they perform better than other competing tools available, or are more generalizable.

¹<https://www.ncbi.nlm.nih.gov/pubmed>

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11.2 Time Capture Tool (TimeCat)

The Time Capture Tool, or TimeCaT, was developed in 2012 with a focus on standardization, scalability, and dissemination. Its development began with a systematic review of the features and limitations of existing TMS tools at the time. Then, a pilot version of TimeCaT was created and tested through an empirical study conducted in an emergency medicine setting. User feedback was collected to inform refinement of the tool, leading toward a significantly modified version with improved usability and functionality. Lopetegui et al. (2012) provides more details on the history, design, and development process of TimeCaT (Lopetegui et al. 2012).

TimeCaT has a user-facing website available at <http://www.timecat.org/>. Its current version (v3.9) is capable of capturing multitasking and interruption events; and allows observers to correct data during the observation (Fig. 11.1). TimeCat uses UNIX-based timestamps to calculate task duration to avoid discrepancies due to time zone difference. It also provides several dashboards for administrative and real-time data reporting purposes (Fig. 11.2). It is worth noting that TimeCaT uses visualization techniques to compare between observations to help researchers assess inter-rater reliability and discover patterns of differences (Fig. 11.3). One exemplar study that used TimeCaT to quantify and visualize nursing clinical workflow was conducted by Yen et al. (2016).

The screenshot displays the TimeCat web interface during an observation. At the top, it shows the current time (9:26:06), total duration (00h 02m 04s), and a 'Notes' tab. A red 'End observation' button is in the top right corner. The interface is divided into three main sections: Communication, Task, and Location. Each section has a list of items on the left and a detailed view on the right. The 'Communication' section shows 'communication 2' selected, with a duration of 00h 00m 54s. The 'Task' section shows 'task 2' selected, with a duration of 00h 00m 57s. The 'Location' section shows 'location 3' selected, with a duration of 00h 00m 57s. Each item in the detailed view includes an 'Edit name' field, a 'Fix time' field, a 'Link to' field, and an 'Add note' field. There are also 'Stop' and 'Delete' buttons for each item. The footer of the interface reads 'TimeCaT 3.9 © 2011-2013 info@timecat.org'.

Fig. 11.1 TimeCat: Data capture and correction



Fig. 11.2 TimeCat: Real-time data reporting dashboards

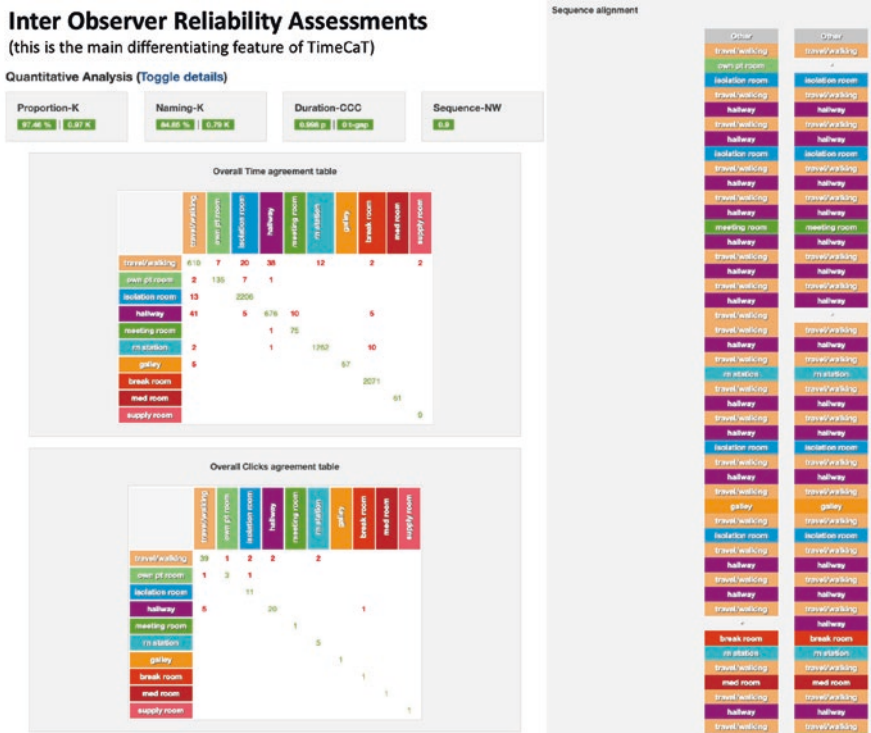


Fig. 11.3 TimeCat: Visual comparison to assist in evaluating inter-rater reliability

11.3 Work Observation Method by Activity Timing (WOMBAT)

WOMBAT was developed in 2008 by Johanna Westbrook and her colleagues at the Macquarie University, Sydney, Australia. Its design objective is to create a digital tool for efficient, accurate, reliable, and detailed TMS data collection to effectively capture health professionals’ work and communication patterns. WOMBAT is capable of recording clinical work activities in four dimensions, namely *What*, *Who*, *How*, and *Where*; in addition to *When* which is automatically captured as computer-recorded timestamps.

WOMBAT was initially developed on the Personal Digital Assistant (PDA) platform and was later migrated to Android. Tablets with larger screen sizes (7" or 8" at the minimum) are recommended for optimal experience when using WOMBAT as a field data collection tool. In addition to the Tablet-based app, WOMBAT provides a web front to manage the app as well as to analyze time and motion data collected. Figure 11.4 shows a screenshot of the app (left) and the web front (right), respectively.

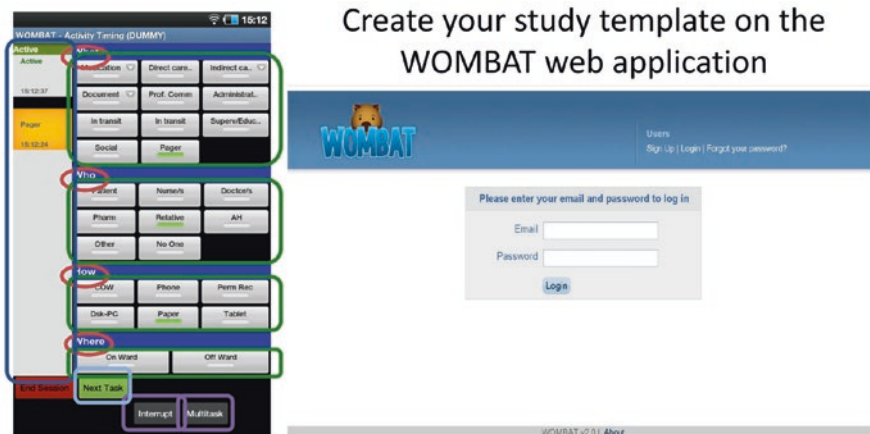


Fig. 11.4 Screenshots of WOMBAT Tablet (left) and web-based application (right) for data capture and tool administration, respectively

The initial version of WOMBAT was designed and evaluated through a nursing workflow study conducted by Westbrook and Ampt (2009) that involved four wards, 52 nurses, and 250 observation hours. The results of the study demonstrated that the nursing workflow data collected by WOMBAT accurately reflected known differences in clinical roles and tasks. WOMBAT was further validated in a study conducted in Canada in 2011 by Ballermann et al. (2011). This study observed clinicians' work in two intensive care units where a computerized clinical system was introduced. The study again demonstrated WOMBAT's utility in collecting high-quality workflow data to compare clinicians' time allocation before and after the system implementation. Since then, WOMBAT has been used in multiple TMS globally conducted by different research groups. A list of use cases of this tool can be found at <http://aihi.mq.edu.au/content/wombat-case-studies>.

The current version of WOMBAT can be accessed through its official website at <https://aihi.mq.edu.au/project/wombat-work-observation-method-activity-timing>. Of note, WOMBAT requires a license agreement for individual users. Once the license is obtained, WOMBAT can be used in any number of projects.

11.4 Time and Motion Data Collector

The Time and Motion Data Collector (the "TM Collector" hereafter) was developed in 2015 as part of a research project funded by the U.S. Agency of Healthcare Research and Quality (see Chap. 17, Examining the Relationship Between Health IT and Ambulatory Care Workflow Redesign) (Zheng et al. 2015). The tool was designed to capture both discrete clinical activities based on customizable task taxonomies, as well as multitasking and interruptions.

Fig. 11.5 Main data capture page of the T&M data collector

The TM Collector incorporates carefully designed features to accommodate recording of multitasking and interruption events (Fig. 11.5). Tasks being performed simultaneously by the observee can be handled with two approaches depending on the use scenario. In the first approach, overlapped task durations as a result of multitasking are grouped into new “composite” activities. In the second approach, overlapped durations are split and attributed proportionally to each of the tasks being performed at the same time. Take two tasks, A and B, as an example. Assume task A lasted 10 s, task B lasted 15 s, and there was a 5-s overlap between them. Using the first approach, a new composite task A/B would be created so that it produces a new event sequence of A (5 s) to A/B (5 s) to B (10 s). When the second approach is applied, the overlapped portion would be split and attributed equally to activity A and B, resulting in a new event sequence of A (7.5 s) to B (12.5 s). This distinguishing is important when certain measures, such as how clinicians distribute their time across different clinical tasks, are computed.

In addition to specifically developed features for accommodating the complex nature of clinical workflow, the TM Collector also has a web-based analytics platform for analyzing workflow data in real time using data mining and visualization techniques. Figure 11.6 shows the landing page of the analytics platform, which displays key descriptive statistics related to the duration of performance for each of the tasks or task groups. Users can then choose to conduct drill-down analyses at different levels. The platform also supports data analyses

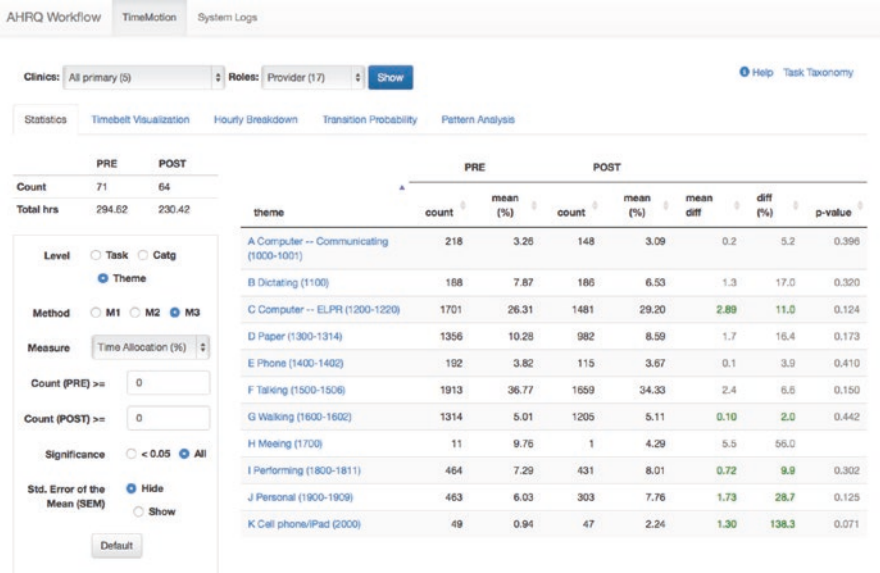


Fig. 11.6 Statistical summary of task allocation and continuous time on the analytics platform

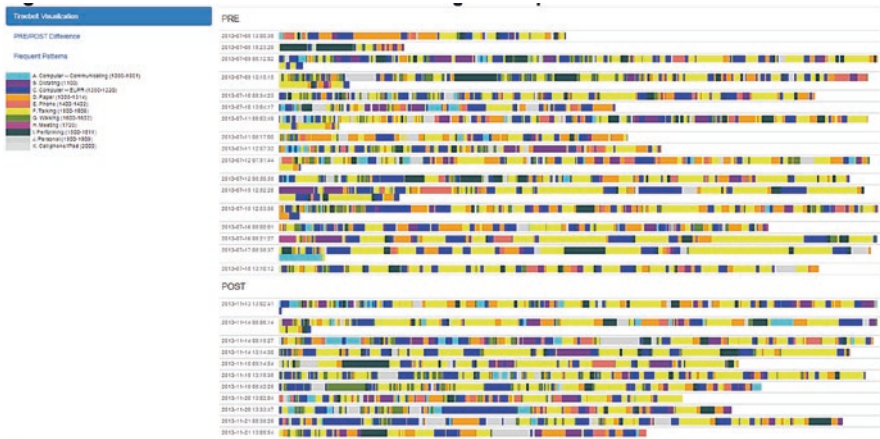


Fig. 11.7 Time-belt visualization on task sequences

for *before-and-after* studies. Pre- and post-data can be separately uploaded, which will be automatically compared using common statistical procedures such as paired or unpaired *t*-test and chi-square test. The analytics platform also provides a variety of visualization options to help researchers discern patterns of potential interest from the visual representations of their data. Figures 11.7 and 11.8 exhibit two examples.

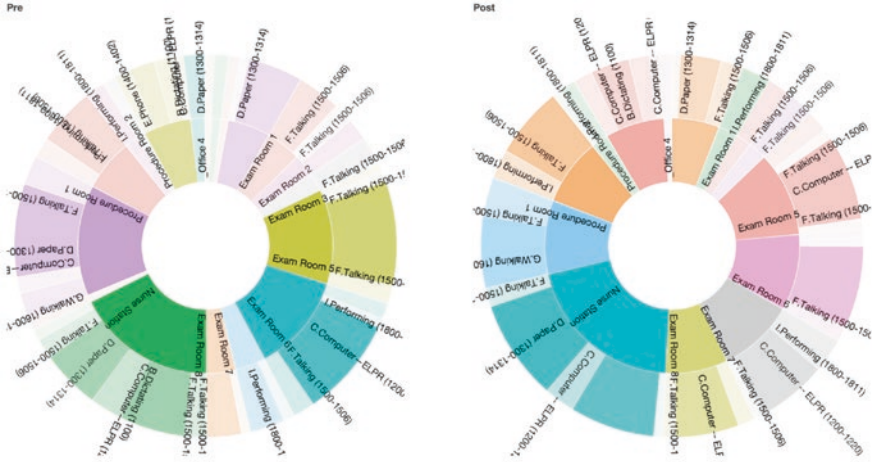


Fig. 11.8 Location-task analysis using a sunburst graph

The TM Collector has been recently adopted by two researcher teams to conduct TMS outside its original development context, demonstrating its generalizability. In the first study, it was used to record workflow data in an emergency medicine setting at an academic medical center in the U.S. to inform the design of a computerized clinical decision-support system (Ozkaynak et al. 2018). In the second study, the tool was used to collect behavioral data on how bedside nurses used a mobile app in Geneva, Switzerland (Ehrler et al. 2018).

11.5 Methodological Challenges and Potential Solutions

While TMS have been considered the “gold standard” approach for quantifying clinical workflow, it has its own limitations. First, collecting time and motion data requires a significant amount of resources, from hiring and training external observers to coordinating observation sessions with busy clinicians. Second, the quality of TMS data collected by human observers can be variable depending each individual’s capabilities and biases. For example, an observer might deem an activity unimportant, or not clinically related, and therefore did not record it; yet the activity might turn out to provide crucial information for answering some research questions down the road. Moreover, the granularity of TM data and proper classification of activities require a thorough understanding of the clinical work being observed. This can be difficult for external observers who do not have relevant background. Further, TMS involving external observers is inherently intrusive. Study participants’ behavior while being observed may deviate considerably from how they usually conduct their work.

Another critical limitation of TMS is that it is very difficult to compare results across different TMS studies due to the inconsistent methodologies they apply (e.g., how external observers are trained, how inter-observer reliability is assessed and calibrated, and whether the same observer is assigned to observe the same study participant across different study stages such as before and after an intervention is introduced). To address this issue, Zheng et al. developed a checklist called Suggested Time And Motion Procedures, or STAMP, based on a review of relevant TMS studies (Zheng et al. 2011). The STAMP list outlines 29 essential elements that need to be carefully considered in designing TMS and in reporting TMS-produced study results and research findings. These 29 elements are organized in eight key areas, including (1) intervention, (2) empirically setting, (3) research design, (4) task category, (5) observer, (6) subject, (7) data recording, and (8) data analysis.

Zheng et al. also provided a new perspective on how to analyze time and motion data. Specifically, they argued that the prevalent method that focuses on the “time expenditures” measure (e.g., how clinicians allocate their time across different tasks) is limited, and can generate conflicting or misleading results. Alternatively, they argued workflow studies should focus on investigating the “flow of work” instead. Through an empirical study, they demonstrated that this could be achieved by introducing using new workflow measures and new analytical approaches, such as workflow fragmentation assessments, pattern recognition, and visualization. These new measures and new analytical methods could collectively contribute to uncovering the “hidden regularities” embedded in clinicians’ work and workflow (Zheng et al. 2010).

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