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# Design, application and testing of the Work Observation Method by Activity Timing (WOMBAT) to measure clinicians' patterns of work and communication[☆]

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ABSTRACT

*Background:* Evidence regarding how health information technologies influence clinicians' patterns of work and support efficient practices is limited. Traditional paper-based data collection methods are unable to capture clinical work complexity and communication patterns. The use of electronic data collection tools for such studies is emerging yet is rarely assessed for reliability or validity.
*Aim:* Our aim was to design, apply and test an observational method which incorporated the use of an electronic data collection tool for work measurement studies which would allow efficient, accurate and reliable data collection, and capture greater degrees of work complexity than current approaches.
*Methods:* We developed an observational method and software for personal digital assistants (PDAs) which captures multiple dimensions of clinicians' work tasks, namely what task, with whom, and with what; tasks conducted in parallel (multi-tasking); interruptions and task duration. During field-testing over 7 months across four hospital wards, fifty-two nurses were observed for 250 h. Inter-rater reliability was tested and validity was measured by (i) assessing whether observational data reflected known differences in clinical role work tasks and (ii) by comparing observational data with participants' estimates of their task time distribution.
*Results:* Observers took 15–20 h of training to master the method and data collection process. Only 1% of tasks observed did not match the classification developed and were classified as 'other'. Inter-rater reliability scores of observers were maintained at over 85%. The results discriminated between the work patterns of enrolled and registered nurses consistent with differences in their roles. Survey data ($n = 27$) revealed consistent ratings of tasks by nurses, and their rankings of most to least time-consuming tasks were significantly correlated with those derived from the observational data. Over 40% of nurses' time was spent in direct care or professional communication, with 11.8% of time spent multi-tasking. Nurses were

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interrupted approximately every 49 min. One quarter of interruptions occurred while nurses were preparing or administering medications. This method efficiently produces reliable and valid data. The multi-dimensional nature of the data collected provides greater insights into patterns of clinicians' work and communication than has previously been possible using other methods.



## 1. Introduction

Evidence regarding how health information technologies influence patterns of clinical work and support efficient work practices is limited. A systematic review [1] published in 2005 uncovered 23 studies since 1984 which examined the impact of system use on clinicians' (doctors' and nurses') time. These studies in general adopted either work sampling or time and motion methods. Only six (26%) examined work on general wards, all in US hospitals, while the remainder focused on specialized settings (e.g. ICU and general practice). Overall, studies which compared electronic with paper systems and calculated task time per patient or consultation, reported that computer use increased time required to complete tasks. Studies which examined task time across multiple patients or working shifts found computer use was more time efficient than paper-based systems [1]. Lo et al. [2] more recently observed specialists using either paper or computer systems within outpatient clinics and reported no significant difference in time spent per patient visit. A similar but smaller study [3] measuring time taken for hand-written and computer prescriptions in an ambulatory setting in the US also found no significant difference in average time per task for physicians.

Studies of changes in work distribution and communication patterns following system use are less prevalent, but do include evidence of changes. For example in the US, where nurses usually transcribe hand-written medication orders, CPOE eliminates this task [4,5]. Following the introduction of a CPOE system clinicians may sequence work differently. As Callen [6] found, clinicians reported "if you are waiting for something on the computer you go and do something else". This may result in, for example, batching the ordering of patients' tests to one time of the day. Shu et al. [7] found interns in a US hospital spent more time alone and less time with other doctors after system introduction. A French hospital study [8] of doctor–nurse communication around medications showed that a CPOE system, in comparison with paper-based medication records, resulted in a move from synchronous communication to asynchronous. This introduced opportunities for misunderstandings and increased the extent to which nurses had to make assumptions about orders. Carpenter and Gorman [9] also reported a tendency for doctors in a US hospital to talk with nurses less about medication orders following system implementation.

Understanding these shifts in patterns of communication between clinicians are important as poor communication wastes time, threatens patient care and may be one of the major causes of preventable adverse events in clinical practice [10]. Any potential negative consequences of changes in communication patterns may be more than offset by the improvements in information exchange provided by having legible, easily accessible information which computerized systems afford clinicians. However until we have better quality data about how systems enhance or disrupt existing patterns of clinical work and communication we cannot move to redesign work practices or systems in ways which avoid any possible negative outcomes.

This research agenda needs to continue to progress beyond answering the question, does use of a computer save a clinician time, to questions about how patterns of work are re-arranged in response to the introduction of health technologies. Where time is released, or additional time consumed, how do clinicians re-distribute their time among work tasks? What amount of variation exists among different clinical sub-groups and do work tasks get re-distributed across groups? For example, if senior clinicians are found to spend less time in patient ordering following computerization is this because the system is efficient or because they have re-allocated this task, either explicitly or implicitly, to their junior colleagues? We need to examine how system use interferes with communication processes and as Gorman et al. [11] suggest, ensure that such systems "... *facilitate care without interfering with or eliminating aspects of the process that are essential to high reliability performance in the face of urgency, uncertainty and interruptions*" (p. 383).

We require studies which investigate whether changes in patterns of clinical work result in improved care delivery, patient outcomes and the work experiences of health professionals. These questions require a multi-method approach [12], and work measurement studies form an important component of such investigation. Researchers should be able to build upon previous work undertaken in different settings and countries. This requires standardization of measurement approaches and the adoption of valid and reliable measurement tools. Major factors identified for the paucity of evidence in this area are the limitations and varieties of methods used [1,13,14], the difficulties of capturing the non-linear and interruptive nature of clinical work [15,16], and the lack of consistency in the application of rigorous research methods.

Our objective was to design, apply and test an observational method for capturing clinician work and communication patterns which incorporated an electronic data collection tool. The purpose of the tool was to allow efficient, accurate and reliable data collection, while also capturing a greater level of work complexity than previous paper-based methods have allowed. Results from a small number of previous studies [2,17–19] suggest that the use of handheld computers (including personal digital assistants—PDAs) may be useful for this task, but researchers have presented minimal information about application and reliability issues relating to these tools. Building upon our previous work designing a paper-based, multi-dimensional work classification tool for nurses [14], we sought to investigate how much additional detail and task complexity data we could add using a PDA without reducing data accuracy or reliability. In this paper we detail: the development of these methods and tool; the application of the method in a study of 52 nurses in an academic hospital and a summary of key findings; and tests of the reliability and validity of data produced. This research comprised the first stage in a study to measure the impact of a commercial electronic medication management system (e-MMS) on doctors' and nurses' work and communication patterns.

## 2. Materials and methods

### 2.1. *Design of a multi-dimensional work task classification*

Our first objective was to develop a work task classification system which would be incorporated in the PDA data collection tool. As a basis for this we used a multi-dimensional work measurement classification which we had applied in a paper-based work-sampling study of nurses that showed high levels of inter-rater reliability and face validity [14]. We extended the classification to contain greater detail about work tasks which previous literature indicated may be most susceptible to change following system introduction, and thus would address our long-term aim to use the PDA in a study to examine the impact of an e-MMS on clinicians' patterns of work and communication.

The classification captures the complexity of work tasks in terms of: (i) the activity being undertaken, (ii) other people involved in the task, and (iii) the method of task performance. The ten broad categories of work tasks and definitions are listed in Table 1. Using a PDA allowed us to add further detail to some work tasks by using drop down submenus. Fig. 1 shows the 10 broad work task categories and Fig. 2 one of the submenus for medication-related tasks. Further we wished to capture instances of multi-tasking (undertaking two tasks at the same time) and interruptions. This had not been feasible with a paper version. Interruptions were defined as the ceasing of one task in order to attend to another task. For example, a nurse who stops administering a drug in order to answer a question from a colleague. If the nurse continues to administer the medication while answering her/his colleague the activity would be recorded as multi-tasking.

### 2.2. *Data collection tool*

We designed a work measurement data collection tool using an HP iPAQ rx3000 Pocket PC running Windows Mobile 2003 with a SD card expansion slot. The PDA program was developed in Visual C# using the .NET Compact Framework v1.0. Using ActiveSync enabled the use of SQL and the synchronization of multiple PDA databases with one central database on a PC. Fig. 1 shows the interface design with the 10 broad mutually exclusive work task categories listed on the left. Each task is automatically time-stamped. On the top right hand side the data collector records who else is involved in the task, and in the bottom right of the screen any tool/equipment that is used. Selection from any one of the three sections will immediately start a new time stamp – thus if the data collector is aware

**Table 1 – Broad work task categories.**

| Work task | Definition |
|---|---|
| Direct care | Tasks directly involved with patient care, e.g. direct communication with patient and/or family, bathing, applying dressings, etc. |
| Indirect care | All tasks indirectly related to patient care (e.g. reviewing results, planning care) |
| Medication tasks | All tasks associated with medication, includes preparation, administration, documentation, discussion and clarification |
| Documentation | Documentation (paper and electronic), excludes medication documentation |
| Professional communication | All non-medication-related communication with another health professional, includes ward and patient hand overs |
| Ward-related activities | Ward activities, includes coordinating beds and staffing |
| In transit | Time between tasks and between patients |
| Supervision | Supervising others, including students |
| Social | All non-work communication, meal breaks |
| Other | Any other task not included above |


**Fig. 1 – WOMBAT PDA data collection tool.**

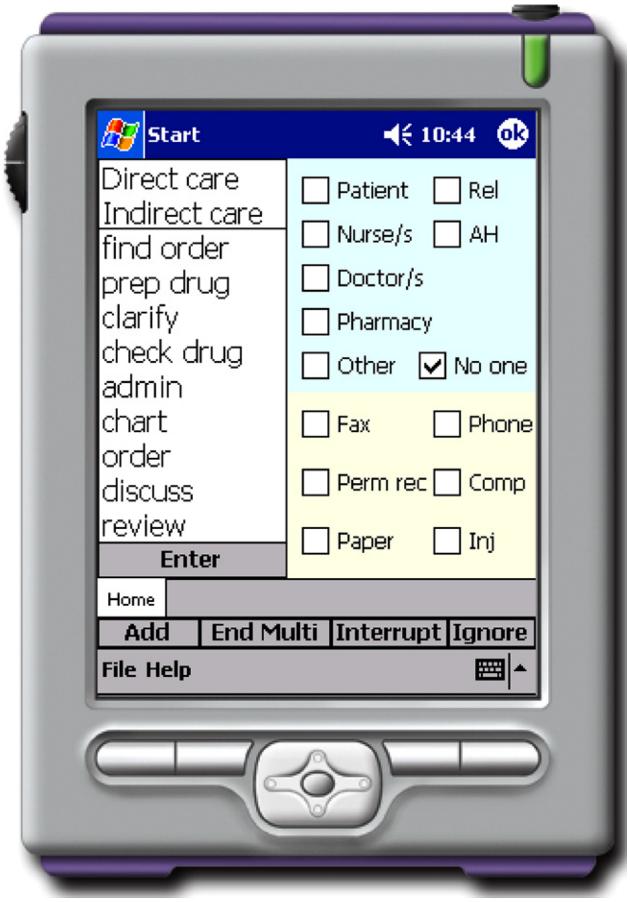


**Fig. 2 – WOMBAT PDA drop down medication task submenu displayed.**

a new activity has started as the nurse is now with another professional, but is unsure what the activity is on initial observation, she/he can select another entry point, such as who the nurse is with which might be easier to distinguish.

If the observed subject is interrupted or is multi-tasking, the observer hits the “Add” button. If the subject is multi-tasking then the observer will continue to record all work tasks until the multi-tasking ends (End Multi). If the subject is interrupted then the interruption button is selected and the interrupted task appears as a tab on the bottom of the screen. When the subject returns to the task the observer is able to pick up this pending task. This allows, for example, calculation of the time from interruption until final completion of the task. The ‘Ignore’ button is used as a quick way for the observer to delete data recorded in error.

All recorded observational data are placed in a database which is stored on the SD card. At the end of an observation session the PDA is synchronized with a computer running Microsoft SQL Server using merge replication. SQL Server replication is commonly described by using the publisher/subscriber metaphor. A database server that makes data available for replication (source server) is referred to as the publisher; a collection of one or more database objects that are enabled for replication is called a publication. One or more servers that receive data and/or transactions from the publisher are called subscribers (the PDAs, in this case). Replication is managed by the system database, which by default is called distribution. A distribution database—which can reside on the publisher, subscriber, or on a separate server or computer—is created when replication is configured.

The server that hosts the distribution database is referred to as the distribution server or distributor. Merge replication combines data from multiple sources into a single central database. This allows multiple observers to use different PDAs for data collection. On synchronization, data from each PDA is then transferred to the central database.

An extraction program was created to extract the data from the distributor. This was written in Visual C# using the .NET Framework v1.1. This allowed data to be imported into a statistical package such as SPSS for analysis. The data collection tool, synchronization and extraction programs underwent considerable field trials. Once these were completed we undertook a full-scale study to examine nurses’ patterns of work and communication tasks. This constituted the first stage in a study to investigate changes in nurses’ work patterns following the implementation of a commercial electronic medication management system.

The work measurement study was conducted over 7 months (July 2005–February 2006) in four wards (respiratory, renal/vascular and two geriatric), at a major academic teaching hospital in Sydney, Australia. Data were collected between the hours of 7 am–7 pm, Monday to Fridays.

### 2.3. *Procedures and participants*

Nurses on the four wards were invited to participate at ward information sessions. Following signed consent nurses were assigned a study identification number, and demographic information regarding their age, nurse classification (e.g. enrolled nurse, registered nurse-new graduate, registered nurse, clinical nurses specialist, etc.), and length of experience was collected. The observer shadowed nurse participants for an average of 1 h blocks, noting all work tasks performed using the PDA to record data. When the participant nurse engaged with patients, visitors, or other health professionals, the nurse was asked to introduce the observer and seek permission to continue. Alternatively the observer would identify themselves. The study was approved by the ethics committees of the hospital and the University of New South Wales.

Sample size calculations, based upon our previous work-sampling studies [14], were made which determined the number and times of hours of observation per nurse category required. Our intention was to be able to detect differences in the broad work categories pre and post system implementation. As each category had its own mean and standard deviation, it was decided to use medication-related tasks to determine the sample size – this category had the largest standard deviation and is the most directly related to the proposed system change. We determined that at alpha = 0.05 and with power of 80%, 226 h of observation were required to detect a 3 min difference in the proportion of time spent in medication-related tasks pre and post system introduction using a two-tailed *t*-test. We achieved 250 h of data collection during the pre-implementation phase.

### 2.4. *Data collector training*

All observers were clinically experienced registered nurses. The initial training was delivered by one of the authors (AA), who had experience with previous work measurement studies [9]. Areas covered included outline of study purpose and methodology, instruction in PDA use with explanation of definitions and practice scenarios, introduction to study wards, practice sessions on the wards followed by inter-rater reliability testing. Once the second data collector was trained, she then delivered all subsequent training to three more data collectors. Approximately 15–20 h was required for each data collector to be trained.

Observers are requested to document field notes after each observation session. The purpose was to capture significant events on the wards which may assist in interpreting results. These included, for example, notes regarding the ward nurses' workloads, staff shortages, or the presence of students on the ward. Also any technical difficulties with the PDA which the observer encountered during the session were recorded. These data were discussed at regular meetings of the research teams.

Most observers reported challenges in their early training sessions regarding the speed needed to capture all events as they occurred and also learning to use the PDA. After several training sessions on the ward, and meeting the inter-rater reliability targets, observers reported confidence and ease in using the tool and method.

### 2.5. *Survey tool*

A survey tool was designed and pilot tested. This survey listed the ten broad work task categories as used to categorize tasks during the observations (Fig. 1) with definitions for each task as listed in Table 1. Participants were asked to rank tasks according to time they spent on these tasks in an average day, from most (1) to those that they spent the least (10) time on. A convenience sample of 27 nurses (both those who had and had not participated in the observational study) working in the four study wards was obtained several months after the observational study had been completed. The nurses were not aware of any of the findings from the observational study at this time to prevent the results from influencing their ratings.

### 2.6. *Inter-rater reliability and data analysis*

Following training of each new data collector, inter-rater reliability tests were conducted, as well as at other random times. Two data collectors simultaneously but independently observed a nurse and recorded work tasks on their own PDAs for approximately 45 min during each inter-rater testing session. Data were then analysed and compared. New collectors did not start collecting data until overall percentage time in tasks was in agreement with a more experienced collector over 85% of the time. On average each data collector participated in four inter-rater testing sessions. These were conducted in different wards and involved observing different subjects.

Observational data derived from the PDA tool were analysed using descriptive statistics with 95% confidence intervals and comparisons differences in task time distribution by wards and nurse classification were examined using SPSS. We ranked the observational data according to time spent in each of the ten broad work categories to allow comparison with the survey data. To analyse the survey data we first applied the Kendall's coefficient of concordance to determine the extent to which nurses were consistent in their rankings. Spearman's rank order correlation was performed to compare level of agreement between task rankings based upon the observational data with those derived from the survey data.

## 3. Results

### 3.1. *Reliability and validity of data*

Inter-rated reliability testing showed all data collectors maintained 85% or higher (range 85–98%) in the field. The work task classification allowed 99% of all tasks to be classified with only 1% of tasks allocated to the 'other' category. The patterns of work task time distribution for enrolled nurses and registered nurses were compared to determine whether expected differences were reflected in the observational data. As Fig. 3 shows enrolled nurses spent a greater proportion of their time in direct care activities while registered nurses spent comparatively more time in medication tasks and professional communication, consistent with their relative clinical roles and responsibilities.

Validity of findings was also examined by comparing the survey and observational data. Nurses' rankings of the ten tasks were significantly consistent (Kendall's coefficient of concordance $w = .601$, Chi Sq = 64.937, d.f. = 9, $p < 0.001$). Comparison of the nurses' rankings with those derived from the observational data was also significantly correlated (rho = 0.6939, $n = 10$, $p < 0.031$). The greatest discrepancy between observed versus reported rankings was for the social activities task. The observational data identified this as the 4th most time-consuming task whereas nurses reported an average ranking of 10. Removing this task from the analysis produced a correlation rho = 0.9375 ($n = 9$, $p < 0.000$), demonstrating a very high level of agreement between ranks of observed time distribution and nurses' relative estimates of their task time distribution.

### 3.2. *Nurses' work task time distribution*

Fifty-two nurses over four wards were observed for a total of 250 h and 20 min. During this time 15,533 tasks were recorded. Fig. 4 shows the distribution of observed time spent in different work tasks. Direct care and professional communication accounted for 41% of total task time. Overall nurses spent 20% of observed time in professional communication which equates to approximately 12 min/h. We examined task time distribution by wards and found considerable similarity in the pattern of time distribution despite differences in the ward specialties. As Fig. 5 shows, for most task categories the 95% confidence intervals overlapped.

### 3.3. *Multi-tasking and interruptions*

The total task time recorded was 279 h 51 min, compared to 250 h 21 min of observed time, which revealed that nurses

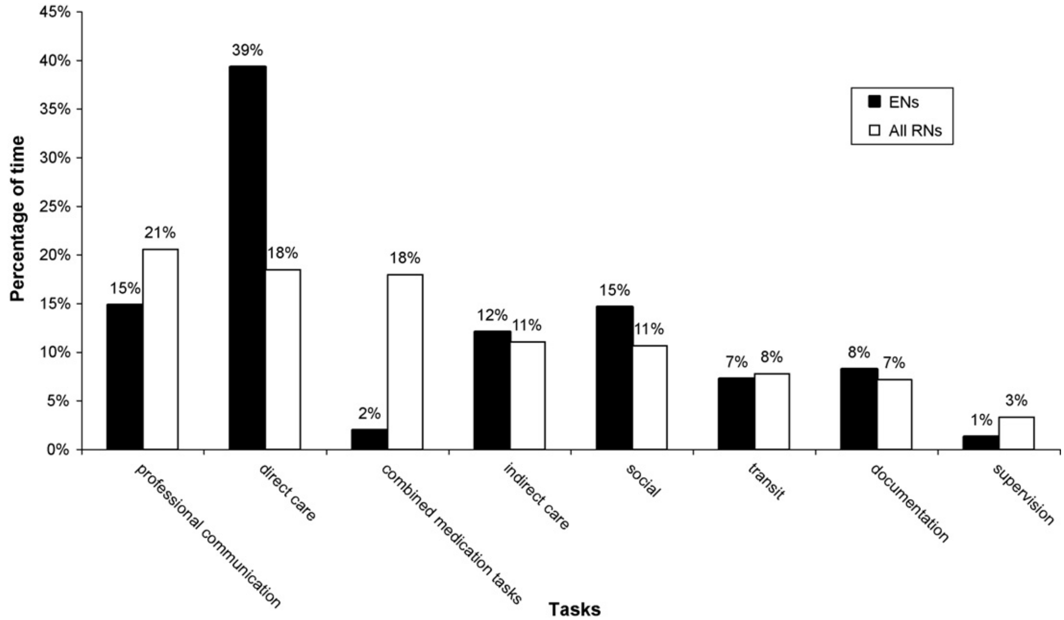


**Fig. 3 – Task time distribution by enrolled and registered nurses.**

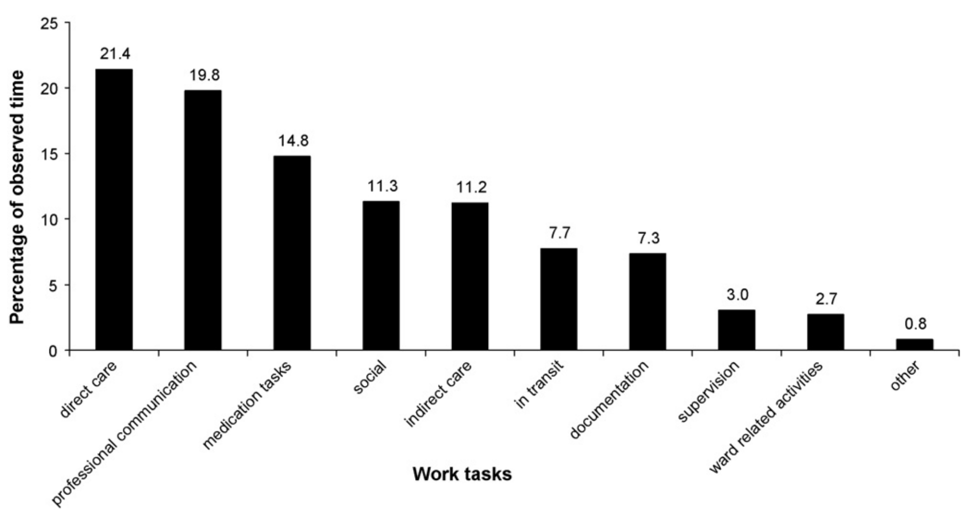


**Fig. 4 – Percentage of time spent in different work tasks (N = 250 h of observation).**

spent 11.8% (29 h 30 min) of observed time multi-tasking in which two or more tasks were performed in parallel. On average nurses were found to multi-task for approximately 1 h and 2 min every shift. In addition, on average, nurses were interrupted every 49 min. One quarter of all interruptions occurred while nurses were undertaking medication-related tasks and a further 23% of interruptions occurred while nurses were documenting.

## 4. Discussion

Our aim was to design research methods and a tool to allow efficient, reliable and accurate data collection about clinicians' patterns of work and communication, which could potentially be used across specialties, professional groups, settings and countries. The Work Observational Method by Activity Timing (WOMBAT) proved to be a reliable means for collecting valid, complex, multi-dimensional data about nurses' work and communication patterns, based on the indicators we measured. High levels of inter-rater reliability were achieved with an average of 15–20 h of training. Training, recruitment and 250 h of data collection were undertaken by the 1.5 full-time equivalent staff over approximately 7 months. Thus, we found it to be a relatively time-efficient method, particularly as data are entered electronically in real-time reducing transcription errors. The work task classification and accompanying definitions dealt well with the array of nurses' observed work tasks with less than 1% of all tasks being categorized in the other category. Application of this approach to hospital ward-based doctors has further demonstrated its robustness for different clinical groups [20].

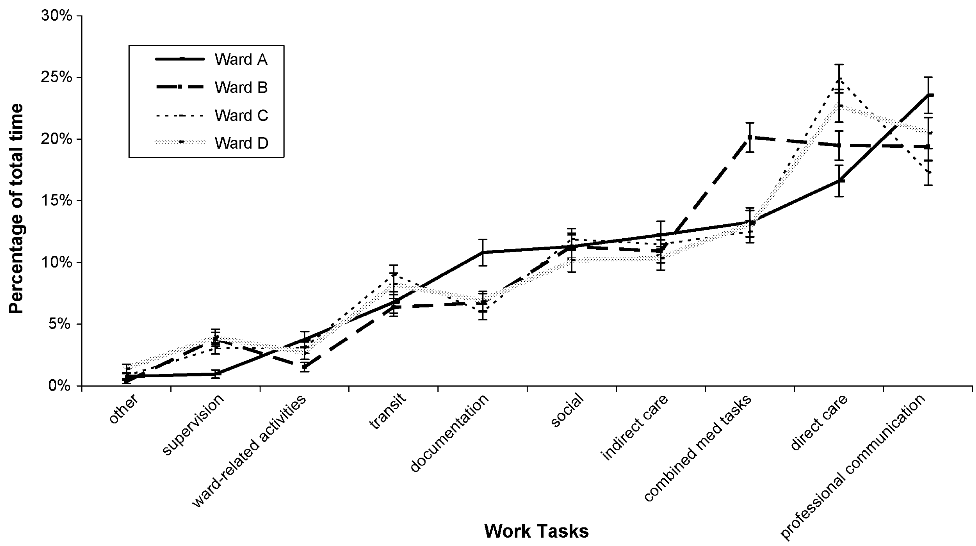


**Fig. 5 – Distribution of task time by ward for all enrolled and registered nurses with 95% confidence intervals.**

The high level of agreement between nurses' ranking of the most time-consuming tasks, and between these ranks and the observational data, provides us with confidence in the validity of data produced using this method. The lower level of agreement in the ranking of time spent on social activities by nurses in the survey with that produced from the observational data is not unexpected. Both direct close observation and survey responses lend themselves to potential "Hawthorne effects" whereby participants 'improve' their performance while being observed or provide socially acceptable responses. In this study the effect might be expected to be most apparent for time spent in social activities. We took several steps to reduce the potential for the Hawthorne effect in the observational studies by, for example, undertaking many hours of training on the study wards which allowed nurses to become familiar with the researchers and the methods. Data collection occurred over 7 months which reduced the chance of sustained changes in participants' behaviour, and the nature of clinical work on busy hospital wards also reduces the ability to sustain significant work practice changes during observation. Thus we believe that the observed data are likely to accurately or slightly under-estimate time in this category. In completing the survey nurses are likely to have viewed time spent in social activities as potentially being interpreted as 'wasted' or 'inappropriate' time and thus under-estimated this category. In reality of course time in social activities (which included breaks and toilet visits) are an integral part of a safe and healthy work environment.

Our analysis comparing ENs and RNs provides some validation of the data collected. For example, ENs are legally restricted in their performance of many medication-related tasks and this was demonstrated in the data with ENs spending very little time in this task category. Further ENs are required to undertake a greater proportion of less technical direct patient care tasks, such as bathing, which was also reflected in the results. Work task time distribution by ward was similar. Where differences existed these could be explained by the nurse classification mix on the wards. For example, ward B had a low number of ENs and thus the average proportion of time spent in tasks in this ward would more closely reflect the work of the RNs. Ward A had few new graduate nurses and thus staff spent less time in supervision.

The results demonstrate the greater detail of data about work and communication patterns which can be obtained using the PDA tool compared to traditional paper-based methods. The PDA allowed us to capture more data items than paper data collection methods as there is no requirement for the observer to record times as when using the PDA. A good example was new data about multi-tasking and interruptions. Most previous studies of interruptions to clinical work have not distinguished between interruptions and multi-tasking. This tool provides a useful way of doing this. For example, Lo et al. [2] reported the use of a Microsoft Access form on a laptop computer to undertake a time and motion study of specialists in outpatient clinics. When Lo's observers identified two tasks being undertaken in parallel, they were required to decide upon and record the 'primary' activity. Using such an approach in our study would have missed over 10% of nurses' task time.

Importantly, we found that the greatest proportion of interruptions occurred while nurses were undertaking medication tasks. Such a finding raises the question of the role of interruptions in contributing to medication errors. We are currently investigating this issue further. The data cannot reveal whether interruptions had negative or positive effects. For example, the outcome of an interruption to stop administering a drug in error versus an interruption which occurs in the middle of a drug dose calculation will be quite different. The use of interventions such as 'interruption vests' at some sites in order to reduce interruptions during medication rounds suggests a belief that such events are potentially hazardous to this care process, though we have identified no empirical evidence of the effectiveness of such interventions to reduce medication errors.

The WOMBAT method has many advantages in providing detailed data not previously possible from paper-based

**Summary points**

What was known on this topic:

- Introduction of information systems change health professionals' patterns of communication
- Baseline data regarding current work and communication patterns of clinicians are rarely available against which to compare work changes following system implementation
- Traditional paper-based methods for data collection in observational studies of clinicians' patterns of work and communication are limited in the amount of information able to be collected
- Electronic data collection tools are emerging yet have rarely been assessed for reliability and validity

What this study added to our knowledge:

- The work observational method by activity timing (WOMBAT) provides a valid and reliable method for measuring the work and communication patterns of clinicians
- The use of a PDA data collection tool allows for a greater amount and complexity of data to be efficiently collected than possible using paper-based methods.
- Application of this method in a study of nurses identified how nurses distributed their time, their rates of interruptions and multi-tasking
- Nurses are most frequently interrupted during medication preparation and administration tasks

methods, and the tool has extended current work measurement computer applications which have generally failed to capture interruptions and multi-tasking events. In seeking to devise a standardized quantitative data collection method we are unable to also capture the rich contextual data that are possible with earlier observational methods which, for example, have combined audio recordings of clinicians in conjunction with observational field notes [15,16,21]. The use of video recordings could also be proposed for the collection of these data. However while these latter methods provide important data for understanding and interpreting clinical work and communication patterns the data transcription and coding procedures are laborious, inter-rater reliability is difficult to measure and sample sizes are usually modest.

## 5. Conclusions

Capture and analysis of clinicians' work and communication patterns are vital if we are to further understand the full and far-reaching effects of electronic systems. The use of the WOMBAT approach allows us to go further than gathering clinicians' perceptions of their time in various tasks, providing valid and reliable measurements of task time distribution and with whom and how tasks are undertaken. Further it enables us to distinguish between multi-tasking and interruptions and the association of these events with specific tasks.

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## REFERENCES

[1] L. Poissant, et al., The impact of electronic health records on time efficiency of physicians and nurses: a systematic review, J. Am. Med. Inform. Assoc. 12 (5) (2005) 505–516.
[2] H. Lo, et al., Electronic health records in specialty care: a time-motion study, J. Am. Med. Inform. Assoc. 14 (5) (2007) 609–615.
[3] W. Hollingworth, et al., The impact of e-prescribing on prescriber and staff time in ambulatory care clinics: a time-motion study, J. Am. Med. Inform. Assoc. 14 (2007) 722–730.
[4] M.J. Ball, C. Weaver, P.A. Abbott, Enabling technologies promise to revitalize the role of nursing in an era of patient safety, Int. J. Med. Inform. 69 (1) (2003) 29–38.
[5] R. Kaushal, et al., Return on investment for a computerized physician order entry system, J. Am. Med. Inform. Assoc. 13 (3) (2006) 261–266.
[6] J. Callen, The people and organisational issues which impact on the diffusion of IT systems in healthcare facilities, in: School of Public Health and Community Medicine, University of New South Wales, Sydney, 2006.
[7] K. Shu, et al., Comparison of time spent writing orders on paper with computerized physician order entry, in: World Congress on Medical Informatics (MedInfo), IOS Press, London, 2001.
[8] M. Beuscart-Zephir, et al., Impact of CPOE on doctor–nurse cooperation for the medication ordering and administration process, Int. J. Med. Inform. 74 (2005) 629–641.
[9] J. Carpenter, P. Gorman, What's so special about medications: a pharmacist's observations from the POE study, Proc. Am. Med. Inform. Assoc. Symp. (2001) 2001.
[10] J. Gosbee, Communication among health professionals, BMJ 316 (1998) 642.
[11] P. Gorman, M. Lavelle, J. Ash, Order creation and communication in healthcare, Methods Infom. Med. 42 (2003) 376–384.
[12] J. Westbrook, et al., Multi-method evaluation of information and communication technologies in health in the context of wicked problems and socio-technical theory, J. Am. Med. Inform. Assoc. 14 (6) (2007) 746–755.
[13] T. Burke, J. McKee, et al., A comparison of time-and-motion and self-reporting methods of work measurement, J. Nurs. Admin. 30 (3) (2000) 118–125.
[14] A. Ampt, et al., Comparison of self-reported and observational work sampling techniques to measure nurses' work, J. Health Serv. Res. Policy 12 (1) (2007) 18–24.
[15] E. Coiera, et al., Communication loads on clinicians in the emergency department, Med. J. Aus. 176 (2002) 415–418.

[16] R. Spencer, E. Coiera, P. Logan, Variation in communication loads on clinical staff in the emergency department, Ann. Emerg. Med. 44 (2004) 268–273.
[17] P. Asaro, Sychronized time-motion study in the emergency department using a handheld computer application, in: Proceedings of the World Congress on Medical Informatics (MedInfo), IOS Press, San Francisco, 2004.
[18] J. Starren, et al., When seconds are counted: tools for mobile, high resolution time-motion studies, Proc. Am. Med. Inform. Symp. (2000) 833–837.
[19] Z. Tang, et al., Workflow in intensive care unit remote monitoring: a time-and-motion study, Crit. Care Med. 35 (9) (2007) 2057–2063.
[20] J. Westbrook, et al., All in a day's work: an observational study to quantify how and with whom doctors on hospital wards spend their time, Med. J. Aus. 188 (9) (2008) 506–509.
[21] E. Coiera, V. Tombs, Communication behaviours in a hospital setting: an observational study, BMJ 316 (1998) 673–676.