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Raquel Benbunan-Fich
City University of New York, rbfich@baruch.cuny.edu

Rachel F. Adler
City University of New York, rachelfadler@gmail.com

Tamilla Mavlanova
City University of New York, tamilla.mavlanova@baruch.cuny.edu

DEVELOPING NEW METRICS FOR COMPUTER-BASED MULTITASKING BEHAVIOR

Completed Research Paper

Raquel Benbunan-Fich
Baruch College
City University of New York
rbfich@baruch.cuny.edu

Rachel F. Adler
CUNY Graduate Center
City University of New York
RachelFAdler@gmail.com

Tamilla Mavlanova
Baruch College and CUNY Graduate Center
City University of New York
Tamilla.Mavlanova@baruch.cuny.edu

Abstract

In response to calls in the Information Systems literature to contextualize usage, we propose that measuring computer-based multitasking is essential to accurately describe and properly assess the manner in which people use Information Technology. To this end, we develop several multitasking metrics ranging from a very lean dichotomous variable to a very rich measure that combines user, task and technology considerations. Our metrics lay the foundation to conduct larger scale studies focused on computer-based multitasking behavior and to use multitasking as a contextual or intervening variable in other research endeavors on IT usage.

Keywords: Activity theory, IT usage, metrics, multitasking, task, switching behavior, user behavior

Introduction

Studying how people use Information Technology in general, and specific systems or applications, is a central concern of IS research. Much of the extant empirical literature is based on adoption models to predict intentions to use a particular type of system or technology. As a result, most of these adoption studies examine the focal system separated from the general context where its use would normally occur (Benbasat and Barki 2007). While adoption models may work well when researchers are exclusively concerned with the possible acceptance of a specific system, focusing on a single system may be too restrictive –and potentially misleading– for investigating its actual use. We argue that in order to conduct "IT research that matters" and provide meaningful insights, modern research endeavors on IT usage can no longer ignore actual usage contexts. In fact, several contemporary articles echo these concerns and call attention to the need to contextualize user behavior and articulate better metrics for IT usage (Barki, Titah and Boffo 2007; Benbasat and Barki 2007; Burton-Jones and Straub 2006).

A key variable to consider in a more realistic usage context is whether an information system or technology is used in isolation or concurrently with other systems. Put differently, whether the user's attention is completely focused on the system at the center of the investigation, or whether the technology usage environment consists of multiple unrelated computer-based activities and is characterized by constant switches among them. Switching windows to perform different tasks is commonplace when users are engaged with personal computing technology. As some recent academic studies report, there is a prevalence of computer-based multitasking while at work or in meetings (Benbunan-Fich and Truman 2009; Chudoba et al. 2005; Hembrooke and Gay 2003; Wasson 2004). Given this evidence, we believe that it is necessary to consider whether a user is engaged in computer-based multitasking to fully understand and thoroughly investigate actual contexts of usage and user behavior.

Surprisingly, the IS literature has been mostly silent on the topic of multitasking. This void may be due in part to the difficulty to conceptualize multitasking and subsequently measure it. To fill this gap, we systematically develop a set of metrics for *computer-based multitasking behavior*. Three qualifications about these metrics are in order before we proceed. First, rather than items or scales to capture users' perceptions of their own multitasking habits, our metrics are objective and based on actual usage patterns. Second, we concentrate on computer-based tasks and exclude all other non-computer-based tasks performed by users. Third, we only consider a single device (personal computer) as opposed to multiple devices such as smart phones and handheld gadgets that might be used concurrently with a laptop or desktop computer. Despite these caveats, it is our hope that our proposed multitasking metrics will shed light on multitasking behavior patterns and seed future research on this topic.

The rest of the paper proceeds as follows. We start with a precise conceptualization of computer-based multitasking behavior, and use Activity Theory as the foundation to address this topic from the perspective of the user, the task and the technology. Based on this tripartite structure (user-task-technology), we proceed to the systematic development of seven multitasking metrics. After presenting and discussing our proposed metrics, we report the results of an empirical study where these metrics were assessed. We end by outlining potential areas for future research. Our aim is to pave the way to incorporate multitasking as a dependent variable in multitasking focused studies, or as an independent or intervening variable in more general studies of user behavior and IT usage.

Defining Multitasking

Although multitasking is prevalent in everyday life, multitasking behavior has been difficult to conceptualize and measure. At present, we lack well established measures of multitasking, perhaps because the very definition of multitasking as "multiple tasks performed at the same time," is open to numerous interpretations depending upon how tasks and time are defined (Rubinstein et al. 2001; Wild et al. 2004). Thus, a precise definition of multitasking requires the articulation of two key dimensions: tasks and time. As Wild et al. (2004: 18) put it "When understanding multitasking it is useful to scope the multiple 'what' and the overall duration of the 'when'." To scope tasks, we define them as self-contained units that incorporate all the components necessary for their performance. Tasks are defined at a conceptual level, as opposed to the physical level. With this approach, tasks are complete and independent from each other. To scope time, we use the notion of a computer session with beginning and end, instead of a standard unit of time, such as an hour. The scoping of a timeframe in terms of a usage session allows for a more comprehensive examination of user-computer interaction patterns.

A complete conceptualization of multitasking also requires an understanding of how users structure and combine several independent tasks within a timeframe, and should reflect "how" tasks are performed. There are different approaches for the temporal organization of multiple independent tasks in a segment of time. At one extreme, multiple tasks can be executed in sequence by starting each task after the completion of another. In a sequential mode, only one task is attended to at a time from beginning to end. Even though multiple tasks might be performed in a unit of time, there is no concurrency. At the other extreme, multiple tasks can be executed in parallel, if all of them are ongoing at the same time. In this case, there is maximum concurrency among tasks. In practice, however, absolute parallel performance might not be possible as humans are unable to simultaneously divide their attention among ongoing tasks (Bluedorn et al. 1992). The middle ground between these two extremes is interleaving tasks by diverting attention or switching from one task to another and eventually resuming previously abandoned tasks (Payne et al. 2007). This interspersing strategy is common in computer-based multitasking, where tasks underway are voluntarily or involuntarily suspended to perform other tasks. Multitasking implies at least a partial degree of concurrency among tasks performed in a segment of time.

We propose that the principles of *task independence* and *performance concurrency* are central to achieve a precise conceptualization of multitasking and adopt the following definition: A user engages in computer-based multitasking behavior when s/he performs more than one *unrelated* computer-based task *concurrently*. Computer-based multitasking is thus a function of how users combine multiple *independent* tasks in a segment of time and the degree of *concurrency* with which these tasks are performed in that period of time. According to this definition, a comprehensive view of multitasking encompasses the components of the "tripartite structure" identified by Burton-Jones and Straub (2006) to measure IT usage: user-task-technology. Our metrics development effort is grounded on the analysis of these elements from the perspective of Activity Theory.

Theoretical Background

Activity Theory provides a framework with a set of principles that describe the hierarchical nature of human activities and the role of tools in human thought and behavior (Nardi 1996). Activity Theory emphasizes motivation and purposefulness of human endeavors but acknowledges that the components of an activity can dynamically change as conditions change. The combination of goal-orientation with dynamic adaptation in human activities accounts for predictable and routine events, as well as emergent and contingent actions.

A key premise in activity theory is the notion of *mediation* by artifacts or tools that enable humans to carry out specific activities (Kuutti 1991). A tool mediates an activity that connects a person not only with the world of objects, but also with other people. Tool mediation allows the formation of "functional organs," through which humans can extend their capabilities and perform new functions, or perform existing functions more efficiently (Kaptelinin 1996). For instance, people use computers to extend their information processing or their communication capabilities. In so doing, they seek to achieve objectives that are meaningful beyond the actual use of the computer (Kaptelinin 1996).

The unit of analysis in this theory is an activity, which is defined at a high level and consists of actions and operations. By adopting the perspective of an activity, this theory views humans as goal-oriented and able to undertake purposeful activities whose performance is mediated by tools. With an explicit articulation of humans, activities and tools, this framework is suitable to analyze each of the components of the tripartite structure (user-task-technology). Although this theory does not directly address multitasking, we extend it for this purpose as we lay the foundation for a systematic development of multitasking metrics.

Task Perspective

A task is an assigned or voluntary chore that requires time and other resources to produce an outcome. A task can be thought of in terms of input-process-output. As such, tasks include the required steps and information cues necessary to create a product or achieve a goal (McGrath 1991; Wood 1986). We draw a parallel between traditional task definitions and the concept of an activity in Activity Theory. Analogous to the concept of tasks and underlying steps, Activity Theory proposes a hierarchical conceptualization of activities. Each activity consists of several actions, which in turn involve several operations (Nardi 1996). Activities reflect the motives that satisfy a need, while actions are functionally subordinated processes directed at specific conscious goals. Actions are made up of operations, which do not require conscious effort to execute. Operations are automatic responses to perceived conditions that allow humans to adjust their actions to the current situation (Nardi 1996; Kaptelinin 1996). Activities are defined in a broad conceptual sense, actions bridge the gap between cognition and execution and operations represent physical movements or keystrokes.

Based on this hierarchy, we define tasks as activities that encompass actions or sub-tasks carried out through specific operations. This definition is consistent with the two parameters we used to scope tasks. First, it includes within each task all the components necessary for their performance (i.e. tasks are complete and self-contained). Second, it operates at a high-level of abstraction, which is consistent with our scoping of tasks at a conceptual level. Furthermore, by equating tasks to activities, we incorporate the hierarchical view of activities, which is at the center of Activity Theory. An extension of Activity Theory to the context of multitasking involves the joint analysis of multiple goal-independent activities and an understanding of how the user sequences or intersperses the actions (sub-tasks) of these activities in a time interval.

User Perspective

Each individual's interpretation and performance of a task is, to some extent, unique as different people may interpret the same task differently or may develop different strategies to complete a task (Hackman 1969; McGrath 1991). Activity Theory considers humans as goal-oriented in the performance of activities. Hence a natural extension of this theory supports the view of individuals undertaking different tasks to fulfill multiple goals, with freedom to choose how many tasks will be performed and how they will be combined. Literature in the fields of psychology and management offers different accounts of the drivers of voluntary multitasking behavior, which can be grouped into task related factors and individual characteristics.

A large body of research in psychology has demonstrated that the decision to carry out multiple tasks at once has implications for attention and performance. Findings from this body of literature indicate that people have a limited capacity to multitask, and when attention is divided between two or more tasks, performance suffers (Meyer and Kieras 1997). There is also evidence of cognitive costs associated with switching between unrelated tasks, as some time is spent resuming a previously suspended task (Payne et al. 2007). Some of these cognitive switching costs account for the negative effects of multitasking on performance. While early psychology studies tend to be prescriptive by telling subjects *when* to multitask, more recent studies in this field have allowed subjects to switch between multiple tasks voluntarily in order to understand *why* people multitask. Findings in Payne et al. (2007) indicate that discretionary task interleaving (i.e. the decision to voluntary switch between unrelated tasks) is motivated by a combination of two task-related factors: (1) diminished rate of return of an activity: propensity to temporarily abandon a task that is no longer rewarding; (2) sub-goal completion: tendency to switch to an unrelated task when a sub-task is completed.

Studies in other fields suggest that voluntary task switching is also the result of factors *internal* to the user, such as individual characteristics or personality traits that motivate people to undertake unrelated activities concurrently and switch between them. One way to capture people's propensity to multitask is to measure their time use preferences and behavior. Based on Hall's (1983) concepts of *monochronic* and *polychronic* time use, an individual with monochronic time preferences tends to do one thing at a time, while an individual with polychronic tendencies will simultaneously undertake two or more activities (Lee 1999). Instead of a dichotomy, Bluedorn et al. (1992) argue that there are degrees of polychronicity, ranging from people who tend to be very monochronic to those who are very polychronic. Because of time use preferences, polychronic individuals will tend to engage in multiple computer-based tasks, while monochronic individuals will tend to perform one task at a time.

The foundation of Activity Theory, and our extension to the context of multitasking, offers an additional explanation to account for switching among multiple tasks. In Activity Theory, goal-oriented individuals are able to adapt to dynamic changes in their environment and respond accordingly. As users remain contextually sensitive, environmental signals might prompt them to switch to a different activity. In particular, users pay attention to and decide whether to respond to electronic alerts and notifications. Therefore, computer-based multitasking is also influenced by the dynamic adaptation of users to the technology.

Technology Perspective

Activity Theory supports the view of technology as a mediating tool that allows individuals to carry out tasks. Technology mediation plays a dual role in the performance of multiple concurrent tasks. On the one hand, contemporary computing platforms have been explicitly designed to support multitasking. From the design of the taskbar that allows users to keep open different programs and alternate among them, to the availability of browser tabs that let users conduct multiple activities within a web browser window, modern personal computing facilitates multitasking. On the other hand, the very same technology that enables multitasking tends to intensify it, as users are interrupted by programs or electronic notifications[1] that may lead (or force) them to switch tasks unexpectedly. Notifications are a specific technology feature designed to keep users contextually aware of changes in their computer-based environment (McCrickard et al. 2003). Thus, personal computing technology acts as an *enabler* of multiple task performance and as a potential multitasking *inducer* as well.

As an enabler, the technology allows users to work concurrently on multiple outstanding tasks as they await responses from others concerning these tasks (Whittaker 2005). The need to constantly wait for responses, or perhaps the need to be constantly available for others, explains why people tend to keep email running in the background. Renaud et al. (2006) found that 84% of the people kept email running in the background at work, while 55% of them had email running in the background at home. Although about 49% always used alerts to get notified of new incoming email messages, usage tracking showed that most people voluntarily switched to check email about every five minutes (Renaud et al. 2006). Consistent with these findings, González and Mark (2004) report that office workers tend to switch between different *working spheres* due to either self-interruptions or external interruptions.

As an inducer, the technology prompts users to switch tasks when they receive notifications from computer-mediated communication systems, such as email and instant messaging software, or alerts from their computers (i.e. schedule reminders). Regardless of the origin of the interruption, there are performance implications when tasks are stopped and then resumed and a substantial body of literature on the effects of interruptions on performance presents some conflicting results. For example, while Gillie and Broadbent (1989) suggest that interruptions have a deleterious effect on performance, Speier et al. (2003) suggest that interruptions may have positive effects by allowing people to break from a difficult task and approach it later with a different mindset. It appears that the nature of the interruption (related vs. unrelated to the task at hand) and the type of interruption (self-initiated vs. external) are useful to explain these conflicting findings. Accordingly, Cutrell et al. (2000) found that interruptions that are pertinent to current tasks are less disturbing than those that are irrelevant. In addition to nature and type, the timing of the interruption and the way it is handled is germane (McFarlane 2002). With respect to timing, the effects on performance are less severe when the interruption occurs at sub-task boundaries (Hodgetts and Jones 2006; McFarlane and Latorella 2002; McFarlane 2002; Payne et al. 2007).

This dual view of technology that not only supports but also generates multitasking is consistent with Activity Theory. According to the tool mediation principle, personal computing technology makes possible the performance of multiple tasks concurrently. Additionally, electronic notifications emerging from the technology itself encourage users to exhibit dynamic adaptation capabilities by receiving and responding to these contextual signals.

Development of Multitasking Metrics

To date, no consensus has been reached about precise operationalizations of multitasking. Several studies rely on different metrics. Some studies measure multitasking mostly from the perspective of the task, as rapid task switching (Bell et al. 2005), as parallel and interleaved tasks that are carried out over a period of time (Wild et al. 2004), or using temporal dimensions as well as number of tasks performed (Lee 1999). Other studies measure multitasking from the perspective of the user by indirectly examining the effects of interruptions (Speier et al. 2003; McFarlane 2002), or from the perspective of the technology by counting the number of application switches (Crook and Barrowcliff 2003). More comprehensive studies in work settings measure multitasking with the number of working spheres and average time per segment (González and Mark 2004) as well as with a count of task switches (Czerwinski et al. 2004).

We organize existing metrics for computer-based multitasking behavior and propose new ones in a systematic way, using the tripartite structure identified by Burton-Jones and Straub (2006). These metrics are developed and discussed with respect to the user, task or computer technology perspective, and the progression from leanest to

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[1] Although interruptions may come from other devices (such as smart phones, cell phones, pagers, etc.), or from other people, our interest here is focused on interruptions that occur within the same personal computing platform where the user is carrying out his/her work (i.e. laptop or desktop).

richest depending on how many elements of the structure are considered in each measure. Heretofore, we identify each measure of multitasking (MT) with subscripts to indicate its relation to the user (U), task (T) or computer technology (C).

Figure 1 introduces our proposed multitasking measures and their relation to the tripartite structure. We formally define each metric below the figure.

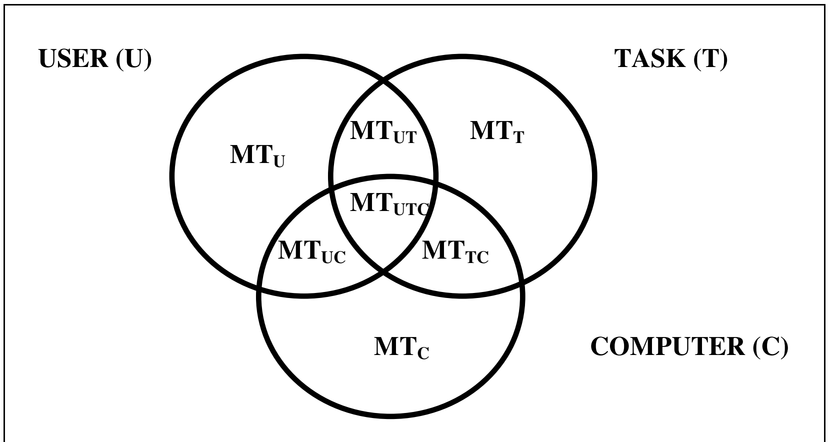

Figure 1. Multitasking Metrics

- From the perspective of the **user**, a very lean measure of multitasking (**MT_U**) would indicate with a *dichotomous variable* whether or not an individual is performing multiple goal-independent tasks concurrently in a specific period of time (or in a computer session).
- When the focus is on the **task**, a more informative but still lean measure (**MT_T**) would indicate the extent to which multitasking is occurring by measuring the *number of unrelated tasks per session time*.
- From the perspective of the **computer** technology, multitasking (**MT_C**) can be measured by the *number of applications or software programs*[2] used during a computer session.

Richer measures of multitasking combine at least two elements of the tripartite structure. There are three alternatives, one for each pair of elements.

- First, a measure combining **user and computer technology (MT_{UC}**) would indicate how many windows are used (or active) during a computer session. It is necessary to make a distinction between open windows and active windows. Users may open windows that they are not attending to, or neglect to close them after they finish and leave a trail of open windows. In contrast, active windows are those that an individual is using by switching to and from them during his computer session.
- Second, a measure focused on **task and computer technology (MT_{TC}**) would give an indication of the number of different software programs required for each task by dividing the number of applications by the total number of tasks.
- Third, a measure combining **user and tasks** (**MT_{UT}**) would indicate the percentage of overlapping tasks. A task (*t*) is considered an *overlapping task* (θt) when its start time occurs before the end time of a previously started task[3].

[2] The assumption for this metric is that different application programs are used for unrelated tasks, which may not hold in all situations. For example, a user can be taking information from the Internet to write a report. In this case, the browser and the word processor are two different applications used for the same high-level task (i.e. writing a report). Nevertheless, the rationale for building multitasking capabilities in personal computers is to allow people to use different applications concurrently. Hence, this is an appropriate measure from the technology perspective.

These metrics are richer than the previous ones because they combine two out of the three elements of the tripartite structure. While the percentage of overlapping tasks is a promising metric, it can be improved by incorporating the number of times that the user actually shifts attention between overlapping tasks. A change of tasks in a computer-based environment involves changing active windows. However, it is necessary to distinguish between two types of switches: *within-task* switches and *between-task* switches. Wild et al. (2004) make this distinction based on whether the primary task changes when there is a switch. In this study, we define within-task switches (S_w) as changes of windows while performing the same task and between-task switches (S_b) as window changes that indicate a change in the tasks being performed.

- The most comprehensive and richest measure we propose (**MT_{UTC}**) includes **user-task-technology** considerations and consists of calculating the *proportion* of between-task switches (S_b) with respect to all switches ($S_b + S_w$). This ratio gives an indication of the extent to which users perform tasks concurrently, as it considers how the user changes focus from one task to another by changing active windows. To the best of our knowledge, this metric is new and has not been used before in the literature. Furthermore, this measure offers a more precise account of multitasking behavior by incorporating the two principles of performance concurrency and task independence we used to define multitasking.

Table 1 provides the mathematical formulas for each of these metrics.

Table 1. Mathematical Formulation of Multitasking Metrics

Perspective	Formula	Explanation
User	$\mathbf{MT_U} = 0$ or 1	Where 0 is single-tasking and 1 is multitasking
Task	$\mathbf{MT_T} = \Sigma t_i$	Where t is a task carried out during the session
Computer Technology	$\mathbf{MT_C} = \Sigma a_i$	Where a is an application or software program
User and Computer Technology	$\mathbf{MT_{UC}} = \Sigma w_i$	Where w is a window from an application or from a browser
Task and Computer Technology	$\mathbf{MT_{TC}} = (\Sigma a_i) / (\Sigma t_j)$	Where the numerator is the number of applications and the denominator is the total number of tasks.
User and Task	$\mathbf{MT_{UT}} = (\Sigma \theta t_i) / (\Sigma t_j)$	Where the numerator is the total number of overlapping tasks and the denominator is the total number of tasks.
User-Task-Computer Technology	$\mathbf{MT_{UTC}} = (\Sigma S_b) / [(\Sigma S_b) + (\Sigma S_w)]$	Where the numerator is the total number of between-task switches and the denominator is the total number of switches.

The richest metric **MT_{UTC}** is based on an analysis of switching behavior regardless of whether there is a change in the underlying software application being used. A window switch may (or may not) involve an application change. For instance, switching to a checkbook balancing spreadsheet while doing online banking is an example of switching within a task (S_w) with application change, as two different applications (spreadsheet and Web browser) are used for the same task. In contrast, a person who uses two related Word documents, while s/he is writing a report is an illustration of switching within a task (S_w) without application change, as the same application (Word) is used for the purpose of the same task. Similarly, switching between tasks (S_b) could potentially involve an application change but not necessarily so. For example, switching to check online weather information while writing a research report about multitasking exemplifies S_b with application change, while changing between browser tabs to check the weather and to check email is an illustration of S_b without application change. For measuring multitasking, we are only interested in the type of switch (S_b or S_w) with respect to the underlying task, and not in whether the software

[3] The percentage of overlapping tasks depends on the general strategy employed by a user to execute multiple tasks in a period of time. For example, strictly sequential users would have no overlapping tasks while those who work in parallel will have a high percentage of tasks overlapping.

programs change when there is a window switch. We recognize, however, that switching-related metrics can be extended in this direction.

Research Methods

In order to examine these alternative multitasking indicators, we collected a sample of user self-reports of home computer usage. A home setting allows an investigation of discretionary computer usage with more freedom for choosing tasks and switching among them than an office environment. In particular, we chose such a setting to eliminate constraints related to social norms of appropriate computer use, or more explicit access restriction mechanisms, which might be prevalent in the workplace. Participants were asked to self-report in detail their computer-based activities for one session of their computer usage of about one to two hours. This assignment was embedded in an undergraduate introductory course in Information Systems taught at a large urban college in the Northeast of the U.S. Upon submission to their instructor, the students were asked by a researcher not connected to the course to donate their assignments for research. Those who agreed signed a consent form and made their assignments available to the researcher. No incentives were given to encourage students to participate in this project.

Other researchers who have used user-produced reports or diaries of computer activities have evaluated the merits and drawbacks of this data collection method. Self-produced reports of computer usage have high ecological validity but they may disrupt typical computer-based activities. On the upside, diary studies or user-generated logs are produced by the respondents themselves as the events take place and do not suffer from problems of recall. The downside is that the process of recording activities may be tedious for participants and affect their normal flow of work (Czerwinski et al. 2004). In our study, to separate record keeping from their normal computer-based activities, we asked subjects to annotate manually all of their switches on a standard paper form. The form consisted of a table with five columns: time, window (or tab) with file name or web site name (if applicable), action (open/close/return), purpose of using the window, and reason for going to another window. Filling out the log in their computers was not an option because this additional activity may inflate some of the multitasking metrics. In addition, to mitigate potential problems associated with tedium, we asked users to log only one session of computer usage of about one or two hours. We decided to collect self-reports despite the limitations of the method, because self-reports allow users to describe their tasks and goals in their own words and to provide the rationale for changing windows.

Data Analysis and Results

We collected a total of thirty seven self-reports from participants who agreed to participate in this research. Two of the reports did not comply with the requirements of the assignment and were deemed unusable (one reporting a 4 min session and another reporting a 515 min session of computer usage while at work with very little detail). Two other logs were also excluded because the session was under half an hour or more than six hours. After discarding these reports, the final sample consists of 33 logs of continual computer use, with session duration ranging from 29 to 198 minutes (mean of 95.1 minutes and a standard deviation of 49.6 minutes).

Two independent raters coded the logs in three phases. In the first phase, the leanest measure ($\mathbf{MT_U}$) was coded as per our definition of multitasking based on the principles of performance concurrency and task independence. As coders analyzed each log, they counted the number of goal-independent tasks ($\mathbf{MT_T}$) and the number of applications used ($\mathbf{MT_C}$). In the second coding phase, coders estimated the number of windows ($\mathbf{MT_{UC}}$) and the number of overlapping tasks. In the third phase, coders conducted a micro-analysis of the switches in each log, and determined whether the user was changing windows within the same task (S_w) or changing between unrelated tasks (S_b).

Inter-rater reliability results for coded variables, computed with the intra-class coefficient (ICC) range from 0.78 to 0.98. All the disagreements were solved by a third coder. Three of our multitasking metrics result from the division of coded variables. $\mathbf{MT_{TC}}$ is obtained from dividing number of tasks by applications. $\mathbf{MT_{UT}}$ is calculated as the ratio of overlapping tasks to total tasks. $\mathbf{MT_{UTC}}$ is computed as the percentage of between-task switches by dividing between-task switches (S_b) by total number of switches (S_b+S_w). These three variables were computed upon reaching consensus on the number of tasks, number of applications, overlapping tasks and switches in each log.

Table 2 presents the basic statistics for each variable. We provide more detail on the coding of each variable below the table.

Table 2. Descriptive Statistics of Variables				
Sample Size	n= 33			
Dichotomous Multitasking (MT_U)	N=15; Y=18			
	Mean	**St. Dev**	**Min**	**Max**
Session Time (mins)	95.1	49.6	29	198
Number of Tasks (MT_T)	4.36	1.87	1	7
Number of Applications (MT_C)	2.85	1.03	1	5
Number of Applications by Task (MT_{TC})	0.81	0.50	0.14	2
Number of Windows (MT_{UC})	6.48	2.93	3	18
Number of Overlapping tasks	1.76	1.52	0	5
Total Number of Switches	14.64	11.67	4	65
Number of Between-Task Switches	5.15	6.21	0	30
Percentage of Overlapping Tasks (MT_{UT})	0.35	0.28	0	0.80
Percentage of Between-Task Switches (MT_{UTC})	0.29	0.20	0	0.69

MT_U was independently coded with a dichotomous indicator. The percentage of inter-coder agreement was 80%. Most of the discrepancies occurred because several logs did not contain enough detail to determine whether some activities were related or unrelated to each other (i.e. task independence). Additionally, it was not clear in some logs whether some tasks actually overlapped or were concluded without closing the appropriate windows (i.e. performance concurrency). After the discussion and consensus process with the intervention of a third coder, it was agreed that 18 (55%) users were multitasking (MT_U =1) and the remaining 15 users (45%) were not (MT_U =0).

MT_T was determined by counting the number of independent tasks that the user performed during the session. Consistent with our conceptualization, tasks were defined at a higher level (i.e. checking email, doing homework, playing music, etc.) and we found that the subjects reported their tasks at a similar level. Appendix A provides the list of typical computer-based tasks at home. Most of the subjects performed more than one unrelated task during their sessions, except for two. These participants' task involved using the courseware system, a publisher's website and an excel spreadsheet to complete a homework assignment.

MT_C was determined by counting the different software programs, such as Word processor, Web browser, Spreadsheet, Music Player and others, that were used throughout the session. We find that the correlation between the number of tasks and the number of applications is not significant, as high-level tasks may involve the use of more than one software program and the same program can be used to perform many different tasks. For example, Web browsers can be used to perform mostly unrelated tasks ranging from a Web search to checking email or watching videos. Conversely, a typical homework usually involves the use of more than one application (e.g. Web browser and word for essays or Excel and Word for analysis and report of numeric data).

MT_{UC} was computed by counting the number of windows from software programs and browser tabs, used during the session. This measure indicates the extent to which an individual is engaged with the computer and is using different windows for his/her tasks. We find that this measure is significantly correlated with the number of independent tasks (ρ = 0.65, p<.001), indicating that more tasks tend to require more windows.

MT_{TC} was obtained by dividing the number of applications by the number of tasks. The results of this metric (mean of 0.81 and standard deviation of 0.50) indicate that on average, more than one task is performed with each application. The most illustrative example of this situation is the use of the Web browser for different purposes such as checking email, watching videos, reading web-based news, searching for information, etc.

MT_{UT} is measured with the percentage of overlapping tasks with respect to the total number of tasks. The percentage of overlapping tasks ranges from 0 to 80% with a mean of 35% and a standard deviation of 28%. This allows us to assess the temporal organization of the tasks. At the low end of this metric, we find users who work in a strictly sequential way showing no overlap among independent tasks. In fact, 5 logs showed a pure sequential behavior. At the high end, we find users who carried out most of their tasks with a high degree of concurrency.

$\mathbf{MT_{UTC}}$ was the result of the micro-analysis of switching behavior within a task and across tasks. The percentage of between-task switches ranges from 0 to 69% with a mean of 29% and a standard deviation of 20%. This measure is indicative of the overall strategy employed by participants in combining multiple tasks as they are using the technology. Users who are purely sequential do not have any between-task switches, while those who interleave independent tasks have a high proportion of between task switches.

We compared our continuous metrics with a correlation analysis which included session length. We find that session duration is not significantly correlated to any of our metrics, indicating that neither number of tasks nor multitasking patterns are influenced by the length of the session. Our richest multitasking metric ($\mathbf{MT_{UTC}}$) was significantly correlated with number of tasks $\mathbf{MT_{T}}$ ($\rho = 0.36$, $p<.05$) and with percentage of overlapping tasks $\mathbf{MT_{UT}}$ ($\rho = 0.78$, $p<.0001$). In addition, we compared the richest measure ($\mathbf{MT_{UTC}}$) with dichotomous multitasking ($\mathbf{MT_{U}}$) with a chi-square test and find a significant association. Those who are multitasking according to the leanest dichotomous measure have a significantly higher percentage of between-task switches than those who are not (14% vs. 41%; Chi-Square = 16.62; $p<.001$). Table 3 presents these results.

Table 3. Percentage of between-task switching by Multitasking Category

	Non-Multitaskers	**Multitaskers**	**Chi-Square**
Percentage of between-task switches	0.14 (0.15)	0.41 (0.14)	16.62***

Cells show means and standard deviation in parentheses. Significance Level: *** p<.001.

Discussion

We propose alternative measures for multitasking behavior by extending Activity Theory to encompass multitasking situations. With a focus on activities, the basic tenets of this theory are goal-orientation, dynamic adaptation and technology mediation. Together, these principles lay the foundation to explain *why* users undertake multiple activities concurrently. Our systematic development of metrics is aimed at measuring *how* this concurrent performance takes place from the perspective of the task, the user and the technology, separately and in combination with each other. The metrics we propose were tested with data from a sample of users who self-reported their computer-based activities. The results of our empirical study indicate that the proportion of between-task switches is the best one to capture and reflect the strategy employed by the user to combine multiple tasks while using the technology. For example, if a pure sequential approach is followed (i.e. a task is initiated only upon the completion of the previous one), our $\mathbf{MT_{UTC}}$ multitasking measure is zero. In contrast, if the user interleaves independent tasks by switching among them frequently, multitasking measured with $\mathbf{MT_{UTC}}$ is higher and indicates the extent to which interleaving takes place.

The richest measure we propose ($\mathbf{MT_{UTC}}$) is correlated with the leanest one ($\mathbf{MT_{U}}$). According to our results, about half of the users were truly multitasking, and their average proportion of between-task switches was 41%. The other half, who was not multitasking, shows a significantly lower percentage in $\mathbf{MT_{UTC}}$ (14%). Strictly speaking, when $\mathbf{MT_{U}}$ is zero, $\mathbf{MT_{UTC}}$ should be zero as well. Put differently, a user who is not concurrently performing independent computer-based tasks (i.e. $\mathbf{MT_{U}} = 0$), should not have any between-task switches and his $\mathbf{MT_{UTC}}$ should be zero as well. However, we noticed two patterns of user behavior that produced higher than zero counts of between-task switches in non-multitaskers. First, some users occasionally switched to an unrelated task but their predominant pattern during the session was to stay on task. Although there was some evidence of minor switching among unrelated tasks, most of the switches were within the same task. Second, users occasionally moved to a different task without closing the windows associated with the earlier task. These changes were coded as between-task switches assuming that the earlier task was still ongoing when in fact the first task had concluded. Some users showed a tendency to leave windows open even when they were no longer needed and to close all the windows at the end of the session. These two patterns of user behavior (mixed temporal strategies and window abandonment) explain the 14% average proportion of between-task switches in subjects who were not multitasking.

An important observation associated with this analysis is that these metrics are dependent on the underlying data sources. Our data is based on information reported by the subjects themselves using a standardized paper form. The process of manually logging computer-based activity may have affected the flow of work of some participants, and may have caused under-reporting of some activities. As a result, our calculation of the number of switches may not be entirely accurate. Moreover some aspects in a few logs were ambiguous or unclear, and required some judgment calls. Given these limitations, the use of multiple coders allowed for more reliability.

Our results are based on self-reported data. Although the validity of self-reports has been called into question, researchers have found self-reported estimates relatively accurate and similar in magnitude to log data values (Deane, Podd and Henderson, 1998). More importantly, self-reported logs have the advantage of allowing users to describe their tasks in their own words. Such an understanding is not available with automatic logs produced by monitoring software. We believe that future research applying these metrics will benefit from a combination of user-logs with automatically collected monitoring logs of computer usage.

Because of the small size of the sample of self-reports, we do not attempt to make any inferences regarding the patterns of multitasking behavior observed in the logs. Moreover, due to the type of subjects who participated in the pilot study (college students) and the homebound nature of their computer session, we refrain from making generalizations about multitasking behavior. The objective of this empirical study is to demonstrate how to collect and estimate the different multitasking measures we are proposing.

Future research can expand this study in several theoretical, methodological and empirical directions. First, there is ample opportunity to solidify the theoretical roots of multitasking behavior using Activity Theory or other theories. This work will further enhance our understanding of this prevalent behavior. Second, to improve the methodological foundations in support of multitasking research, additional objective metrics can be developed, tested and compared to the ones presented here. A parallel effort could consist of using our definition of multitasking and the tripartite structure to develop subjective measures or scales to assess the perception of multitasking. Third, our metrics can be applied in a larger sample of users by collecting self-reported logs along with system-generated logs to investigate multitasking behavior patterns. Overall, we believe that the main contribution of this work is to enable researchers to contextualize studies of IT usage and pave the way to investigate multitasking behavior with new metrics.

Conclusion

With this study, we sought to establish a foundation to investigate computer-based multitasking behavior. With the theoretical background of Activity Theory, and the three elements proposed to study IT usage (user, technology and tasks), we developed different multitasking metrics in a progression from leaner to richer metrics. We then conducted a study to evaluate each of the proposed metrics and concluded that a very simple dichotomous variable offers an indication of whether or not the user is multitasking, while a richer measure based on an analysis of switches measures the extent to which a user is multitasking. Depending on the research objectives, either one of these metrics could be suitable. Since the richer metrics we propose are more complex and time consuming to produce, they are recommended for research endeavors focused on multitasking behavior. In contrast, the leaner metrics can be used as control variables in studies of user behavior. The main contribution of this paper is to offer alternative measures to investigate multitasking behavior and incorporate this variable in future empirical studies. These metrics open up multiple avenues of inquiry aimed at achieving a better understanding of the multitasking construct to contextualize IT usage.

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Appendix A. List of Tasks

List of Computer Tasks for Homebound users
Checking courseware system (Blackboard ®)
Checking email
Checking social networking site
Doing homework
Doing job-related activities at home
Online banking
Online shopping
Playing computer games
Playing music with music player program
Reading web-based news
Searching for information for personal use
Trading (or tracking items) on eBay
Using instant messaging (IM) software
Watching movies, TV programs or video clips on the computer