An Entropy Index for Multitasking Behavior

Completed Research Paper

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Abstract

This study conceptualizes multitasking in a tri-dimensional framework consisting of task, time and technology, and proposes an entropy measure called the Multitasking Entropy Index (MEI) to study multitasking behavior. Entropy indicates the level of disorder or heterogeneity in a system. In natural and social sciences, entropy measures have been used to study the dispersion of objects of interest. However, to date, these measures have not been applied to study human multitasking behavior. Multitasking is defined in terms of the focus shifts that occur when a person changes attention between ongoing tasks. MEI calculates the diversity of focus shifts that take place in a period of time. The index can also be applied to measure focus shifts across different technology devices. The results of an empirical test show the potential of the proposed index. The framework and index presented in this paper are poised to seed a new stream of research.

Keywords: Multitasking, entropy, metrics, focus shifts, user behavior

Introduction

In this technologically-complex and fast-paced world, focusing on more than one task at a time has become the norm (Manhart 2004). Contemporary workers participate in multiple temporally overlapping activities and alternate between them over the course of the workday (González and Mark 2004). Due to this constant shifting, individuals are enmeshed in a complex web of intertwined activities, stopping some tasks to dedicate time to others. Suspended tasks are then periodically reactivated to become the new focus of attention. This shifting creates a dynamic context with multiple ongoing "stacked up" tasks. From this task pile, an individual chooses which one to perform next in order to accomplish his or her work (Reder and Schwab 1990).

Occasionally, tasks need to be suspended while waiting for inputs or events necessary for its completion. To deal with fragmentary non-linear inputs (Appelbaum et al. 2008) or with polychronic tasks, whose events occur at different points in time (Lee 1999), workers avoid idleness by bouncing from task to task. To increase productivity, people must be ready to shift between tasks as needed and complete fractions of tasks in small periods of time whenever they can (González and Mark 2004). As a result, segments from different tasks are reorganized to take into account and leverage time lags (Reder and Schwab 1990), and multiple task segments from different activities co-exist in the same period of time. Multitasking has therefore become the norm in the modern workplace.

Multitasking occurs when workers perform multiple tasks in the same time period and shift attention among ongoing tasks as needed. Prior research has characterized multitasking in terms of task switching (Bell et al. 2005). Consistent with previous definitions, albeit adopting the perspective of the individual worker, this study defines multitasking as shifting the focus of attention among different tasks within a specific timeframe. As defined by Bødker (1989), f*ocus shifts* occur when there is a change in the center of attention or object of the actions. A specific type of focus shift takes place when the center of attention is associated with a different task because, in this case, such shifts are indicative of multitasking behavior.

Multitasking is an important topic of research for which Information Systems (IS) researchers are uniquely qualified. Given the centrality of the Information Technology (IT) artifact in the IS field (Orlikowski and Iacono 2001), it is surprising that the mainstream IS literature has not yet devoted enough attention to this topic. This void is even more noticeable because nowadays users' predominant pattern of engagement with IT devices is characterized by multitasking (Carrier et al. 2009). By incorporating a deep understanding of the capabilities of IT artifacts and modern user behavior, IS researchers are positioned to make unique and substantial contributions to the development of this field of inquiry.

Investigating multitasking is the next grand research challenge for the Information Systems discipline, not only because this behavior is prevalent in modern society but also because it is characteristic of contemporary IT usage. New research on multitasking would shed light on how people simultaneously use a multiplicity of technological devices (like smart phones and laptops) to perform multiple tasks at once. Because of today's developments in connectivity and mobility, new theoretical lenses and novel methodological tools are needed to advance our understanding of multitasking behavior. These are potentially fruitful areas for new IS research endeavors.

In this context, the novelty and expected contribution of this study is twofold. First, it offers a new theoretical perspective to understand multitasking by conceptualizing it in a tri-dimensional framework consisting of task, time, and technology. Second, it proposes a novel methodological tool in the form of an index to measure multitasking behavior. The proposed index takes into account changes of attention between ongoing tasks and calculates the *diversity of focus shifts* experienced by an individual in a particular a period of time. The formula is based on the notion of *entropy*, a concept used in natural and social sciences to capture the amount of chaos, disorder, or heterogeneity in a system. Although entropy measures have been used to examine human behavior, behavioral entropy has not been yet applied to the study of multitasking.

Taken together, the conceptual framework and the methodological tool (the Multitasking Entropy Index) proposed in this paper will enable researchers to examine a current and relevant topic with a new perspective, and will inspire new upstream and downstream research. Upstream research would consist of developing the theoretical antecedents of multitasking behavior. Downstream research would entail applying the proposed multitasking index in future empirical investigations. To present this innovative work, the remainder of this paper proceeds as follows. The next section presents a new conceptualization of multitasking in terms of task, time, and technology. Then, it lays the foundation for using focus shift as indicators of multitasking and proceeds with the development of the index. The subsequent section reports the results of an empirical study that evaluates the validity and the merits of the new index. The paper concludes with discussion, implications and suggestions for future research.

Conceptualization of Multitasking

Multitasking – with and without technological devices – is a prevalent form of contemporary human behavior (Carrier et al. 2009). McGrath and Kelly (1992) propose that any form of human behavior "*involves some social unit carrying out some patterned set of activities in some physical, temporal and social context.*" (p. 413). This characterization defines three axes of context: scope of activity, time-scale and system level of the social unit. These three axes are useful to conceptualize human behavior in general, and multitasking in particular. Accordingly, to analyze multitasking, it is necessary to articulate the *task-goal* dimension to delimit the scope of the activity, the *temporal* dimension to define the time-scale, and the *technological* dimension to obtain the system-level view. Each dimension is explained next.

Task-Goal Dimension

Tasks are defined as "the actions carried out by individuals to transform inputs into outputs" (Goodhue and Thompson 1995, p. 216). Broader task definitions include not only the processes but also the ultimate objective of a task and its origin. A task is a self-imposed or externally assigned activity consisting of a goal and set of processes necessary to achieve that goal. In this general conceptualization, the defining characteristics of a task are the pursuit of a specific goal and the structure of the task in terms of nested actions or processes such as sub-tasks and steps. This definition synthesizes the two main approaches used in the literature to define tasks, namely *task qua task* and *task as behavior requirement* (Hackman 1969, Zigurs and Buckland 1998). Task qua task properties are the objective characteristics of a task including the nature of the task, the subject matter and the stimulus involved (Hackman 1969). Task as behavior requirement includes the processes by which the task should be carried out, i.e. how the goal should be accomplished (Zigurs and Buckland 1998).

From a goal-oriented perspective, a task is a logically organized system of mental and behavioral actions directed to the achievement of a goal (Bedny et al. 2000). However, goals can also be decomposed into a set of subordinated partial goals to which sub-tasks or actions are directed. This nested decomposition presents a recursivity problem in which a sub-goal can also be considered a goal. Likewise, a sub-task can be considered a task. To address the recursivity issue, it is necessary to distinguish the *overall goal* by answering the question of "what must be done" from intermediate nested sub-goals that respond to the question of "how it can be done." For a high level task-goal characterization, Lee (1999) suggests to define tasks at a conceptual level, as opposed to the physical or procedural level.

Depending on the nature of the goal and the required processes, tasks vary in their complexity (Wood 1986, Zigurs and Buckland 1998). Simple tasks encompass a linear string of consecutive steps, while complex tasks consist of an intricate web of interdependent processes. In terms of an input-process-output model, more complex tasks require more acts and more information cues to be processed than simple tasks. Also, more complex tasks involve more intricate relations between inputs and outputs, and require more sub-tasks (Wood 1986). According to the level of interdependence, some task processes or "bundles of activities" are more flexible than others in the extent to which they can be disaggregated and arranged in time for their performance (McGrath and Kelly 1992).

Temporal Dimension

Multitasking is particularly related to the temporal patterning in which components from different tasks are intertwined and co-located in the same time period for their performance. To understand how "activity bundles" fit into time containers, it is necessary to develop a conceptualization of time. Such conceptualization could be objective, in terms of conventional units (i.e. minutes, hours, days, etc.) or subjective according to each individual's experience (McGrath and Kelly 1992).

The distinction between objective and subjective time is akin to the two words that ancient Greeks used to describe time, namely *chronos* and *kairos*. Chronos refers to chronological time, while kairos refers to a period of time in which something happens (Reinsch et al. 2008). Despite the advantages of convention and standardization associated with chronos, it is preferable to use a more subjective or qualitative measure of time – kairos – to study complex phenomena involving human behavior. While standard time units might conform to social conventions, subjective time units, such as a work session, might be more appropriate to gain an in-depth understanding of temporal patterning of activities.

Further insights into temporal patterning of activities can be obtained by understanding personal preferences regarding time use behavior. Based on Hall's (1983) concepts, time use behavior preferences can be characterized as *monochronic* (doing one thing at a time) or *polychronic* (doing many things at once). Studies in psychology have explored polychronicity as a predictor of multitasking behavior (König et al. 2005). In addition, the management literature has investigated the congruence between chronicity preferences and job demands or organizational characteristics (Slocombe and Bluedorn 1999; Kaufman et al. 1991).

The temporal congruence between task characteristics and individual preferences is an important consideration for multitasking behavior. To analyze the possibilities, Lee (1999) distinguishes two temporal domains. The first dimension is how tasks and events occur and the second is how workers organize their time to deal with tasks. The result is a matrix with four temporal fit profiles, in which the most challenging situation occurs when a worker with monochronic time use preferences, undertakes polychronically driven work. From the worker's perspective, multitasking is concerned with a person's decision to organize task polychronically, when task-related events take place at one time (monochronic) or at various points in time (polychronic).

Due to the continuous connectivity afforded by current technology devices, it is important to consider a new temporal structure that Reinsch et al. (2008) call *connected time*. This new structure can be juxtaposed to the typical notion of time, in a chrono-logical or kairo-logical sense. During connected time, task-related events of multiple ongoing tasks co-exist and the individuals are notified of them as they occur. The result of connected time is the layering of ongoing tasks and their reactivation, as events or status changes are received via electronic notifications.

Technological Dimension

Technology artifacts not only enable task performance but also allow individuals to join larger social units, such as groups or communities, with whom they communicate in order to perform their tasks. Hence, the technological dimension offers a useful domain to articulate the system-level view of human behavior. From a utilitarian perspective, technology can be conceived as a tool that enables individuals to carry out their tasks (Orlikowski and Iacono 2001). However, given the complexity of modern technology, a more appropriate view is that of a collection of tools or toolkit. Due to the multiplicity of technological devices that individuals have at their disposal and the simultaneous use of multiple media (Massey and Montoya-Weiss 2006), the notion of *technology portfolio* is more appropriate (Carroll 2008).

The view of a technology portfolio highlights the dual role of technology in human multitasking. On the one hand, technology devices, or applications within the portfolio, act as an amplifier of multitasking by sending notifications linked to new tasks (tech-interruptions). On the other, individuals are able to engage in multiple tasks at will (self-interruptions) and shift their attention between them. The technology portfolio allows these movements of attention. Thus, the dynamic interplay between users and technology in multitasking situations is punctuated by both types of interruptions (self-interruptions and tech-interruptions). In self-interruptions, the directionality of the multitasking trigger is from the user to the technology, and in this case, the technology is an enabler of multitasking. Conversely, in tech-interruptions, the directionality is from the technology to the user and the technology is thus an amplifier of multitasking.

To sum up, task, time, and technology are the three axes of context that define multitasking behavior. An individual who is multitasking pursues multiple goals by integrating components of different tasks in the same timeframe. Elements of his/her technology portfolio are used to initiate, suspend, or continue the performance of these multiple tasks.

Multitasking Entropy Index (MEI)

Multitasking is characterized by attention shifts that place the person's focus on a different task. By quantifying the diversity of such shifts, a measure of multitasking can be obtained. Diversity has been conceptualized as variety, separation or disparity, and several measures have been applied depending on the case (Biemann and Kearney 2010). Researchers in various fields have developed entropy indexes to study the dispersion of objects of interests. For example, in ecology such indexes are used to estimate the number of species. In social sciences, entropy measures are used to calculate the distribution of group members along racial, gender or other categories (Choi et al. 2003; Jehn et al. 1999). The diversity of behavioral patterns has also been studied with entropy metrics in topics such as drivers' workload (Boer 2000), human-robot interaction (Goodrich et al. 2004) and intrusion detection (Balajinath and Raghavan 2001). Drawing from the field of behavioral entropy and the concept of focus shifts, this study develops a multitasking index. For this purpose, diversity is conceptualized as *focus shift variety*.

Focus Shifts Distribution

The notion of *focus shifts* can be situated in the axes of context used to conceptualize multitasking. As defined by Bødker (1989), a focus shift indicates a change in the center of attention of the actions. Using a bi-dimensional space determined by task-goals and time, focus shifts can be mapped out. This representation consists of marking the reallocation of attention from one task to another during a period of kairos time defined by a work session.

For example, the work pattern represented in Figure 1 corresponds to a person who worked on five different Tasks (TG_1-TG_5) during the period (t_1-t_{15}). During this time, the person experienced a total of fifteen focus shifts. For notation purposes, these shifts can be represented by indicating the sequence of tasks that become the focus of attention (e.g. TG_1 – TG_2 – TG_3 – TG_2 – TG_4 – TG_1 – TG_5... and so on). Alternatively, the shifts can be counted and organized in task categories (TG_1 to TG_5) using the number of total shifts per category for a more concise numeric description (e.g. 5-3-1-4-2).

Task																*Total*
TG_1	1					1		1			1				1	*5*
TG_2		1		1						1						*3*
TG_3			1													*1*
TG_4					1				1			1		1		*4*
TG_5							1						1			*2*
Time	**t_1**	**t_2**	**t_3**	**t_4**	**t_5**	**t_6**	**t_7**	**t_8**	**t_9**	**t_{10}**	**t_{11}**	**t_{12}**	**t_{13}**	**t_{14}**	**t_{15}**	*15*

Figure 1. Distribution of Focus Shifts

With this notation, a work session (or episode) is represented by an array of tasks and the number of times each receives attention. The diversity of focus shifts across task categories provides an indication of the variety of the work session.

Calculation of MEI

The proposed Multitasking Entropy Index (MEI) comes from an adaptation of Teachman's (1980) index to measure population diversity, which in turn is an adaptation of the measure of information entropy developed by Shannon (1948). Studying population diversity with Teachman's index does not require any assumptions about the distribution of the data. Instead, the index captures the variety of elements found in the population according to categories determined by researchers.

To calculate the index, a group of population elements or events of interests is divided into *C* arbitrary categories. In this case, the elements or events are focus shifts with a distribution (n_1, n_2, n_3 ..., n_c), where $\sum n_i$ = N and N is the total number of focus shifts. Using the proportion of events falling into the i^{th} category (p_i), an entropy-based diversity index is obtained with the following formula:

$$MEI = -\sum_{i=1}^{c} pi(\ln pi)$$

Where:

i is a particular category

c is the total number of categories.

p_i is the proportion of focus shifts in each category *i*, calculated as: $p_i = n_i / N$, with $\sum p_i = 1$.

By convention, 0*ln(0) is defined as zero.

If all the events (focus shifts) fall into one category, the measure takes the value of zero indicating no variation. Thus, MEI is zero in mono-tasking situations. If additional categories are included but no population elements –focus shifts– belong to those categories, the measure is unaffected. Given two populations –focus shifts from two individuals or from two sessions, in this case– the population with the greater number of categories has higher a MEI. For two populations with the same number of categories, the index displays larger values when the population elements are more heterogeneous. These properties, adapted from Teachman (1980), make the index suitable to measure multitasking behavior.

Standardization of MEI

To control for the number of categories (C) and set its maximum value equal to one, a standardized MEI, hereafter called MEI*, is obtained by dividing MEI by its theoretical maximum (ln(c)) as follows:

$$MEI^* = -\sum_{i=1}^{c} pi(\ln pi)/\ln(c)$$

MEI* ranges from 0 to 1 and can be used to compare two populations with different number of categories. For better calibration and comparability, it is always preferable to use the index in its standardized form (i.e. MEI*).

The measure MEI* is standardized to reach a maximum of 1 when focus shifts are equally distributed across task categories. In the example of Figure 1, where 15 focus shifts are unevenly distributed in five tasks (5-3-1-4-2), MEI is 1.49 and MEI* is 0.93. If most of the focus shifts are concentrated in one task and the others are seldom attended to (11-1-1-1-1) then MEI* is 0.59. A special case occurs when focus shifts are equally distributed in categories (3-3-3-3-3). In this case, MEI is equal to its maximum (ln(c)) and MEI* is equal to 1, indicating maximum multitasking.

In some circumstances, it may be problematic to define maximum multitasking as equal distribution of focus shifts (i.e. maximum evenness). To correct for unwanted maximization of the index, the adjustment term (C-1)/2N can be subtracted from the index. This correction should be used with caution when individuals (or sessions) with unequal task categories are compared because the values of the index might be distorted. For this reason, the calculations shown in the methods section are based on MEI* without the correction term.

Figure 2 offers a more complete illustration of MEI* for 15 focus shifts distributed in three task categories in different patterns. The index values range from 0 to 1, where 0 is complete homogeneity (i.e., focus shifts are exclusively concentrated in one task category [15-0-0]), and 1 is when all task categories have an equal number of focus shifts [5-5-5]. In short, the higher the value of the index, the more equal the representation of all of the tasks, and the lower the value, the more one task category dominates. A low index value thus means that the proportional distribution in task categories is diverse, and that a few tasks concentrate most of the focus shifts.

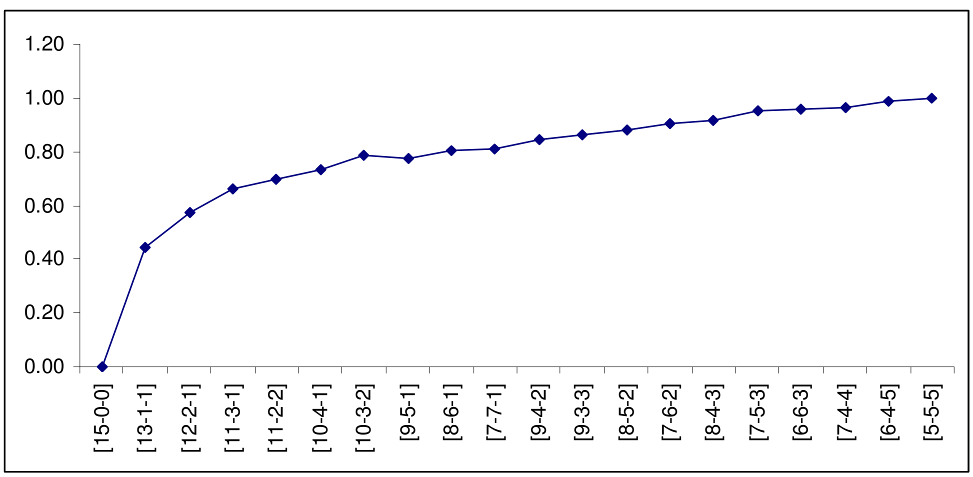

Figure 2. Values of Standardized MEI for Different Distributions of Focus Shifts

Research Methods

The performance of the MEI index was initially tested with a sample of users who kept a diary of their activities during a work session of one to two hours. Diaries are a method of data collection used for obtaining information about episodic or recurrent behaviors and are particularly suitable to collect information about time-use. Diary methods have been widely used in various fields, including psychology (Bolger et al. 2003), economics (Juster and Stafford 1991), and human-computer interaction (Rieman 1993). Data obtained from diary-reporting methods is more reliable than questionnaires because measuring time-use results in complex surveys (Juster and Stafford 1991). Using data collection instruments that impose a high burden on participants increases the risk of biases and non-response (Kenyon 2008). In addition, since the method is self-administered, it is free from interviewer and/or researcher effects. However, the insertion of diary reporting into normal activities may cause interference.

Depending on the format and reporting requirements, diaries vary in their degree of structure. This research used a semi-structured diary. The respondents were given a form to record their behaviors but they were encouraged to explain their activities in their own words. Neither the time units nor the activities to be recorded were fixed. To minimize the problem of retrospective recall, participants filled out their diary as their work session took place. This ensures more accurate reporting of time-use activities. Because of the burden imposed by the data collection method, the requirements of diary reporting were limited to one to two hours. Producing concurrent documentation of longer sessions increases the risk of underreporting activities.

Sample

To recruit users for this research study, a convenience sampling approach consisting of non-probabilistic case selection was used. Although this sampling technique does not allow for generalizability, it is appropriate for gathering initial user behavior information and conduct a preliminary testing of the Multitasking Entropy Index (MEI). To provide a broad view of contemporary workers and their activities, subjects were selected from different companies and positions.

The sample consists of five subjects who agree to keep a semi-structured written diary of their activities at work. Due to workplace restrictions and privacy and confidentiality concerns, work sessions could not be video-taped. The diaries were manually filled out and later transcribed for further analysis. Participants recorded their activities in a specially designed form where they described their time use with shifts of attention, the objects of their attention, and the task they were performing.

Table 1 shows the subjects' characteristics. The names of participants have been changed to preserve anonymity.

Table 1. Characteristics of the Sample

Pseudonym	Position	Organization	Session Duration
Bianca	Front Desk	Gym	119 min
Ellen	Admin. Assistant	Educational Institution	68 min
Jim	Accountant	Accounting Firm	61 min
Anita	Sales Rep.	Jewelry Distributor	86 min
Carol	Concierge	Spa	97 min

Before calculating MEI* to describe the behavior of each user in the sample, a short description of the work session reported in their diaries is provided.

Case 1 – Bianca

Bianca works at the front desk of a local gym. In the work session documented in her diary, Bianca checked-in eight arriving gym members. For the check-in process, she used a commercial web application for health clubs. In the lags during her check-in duties, she created an "employee wanted sign" in Word, and conducted web research for a speech she was planning to give at a volunteer organization. Upon printing the sign, she continued searching for articles for her speech. Later on in her work session, Bianca checked her personal email and her Facebook account. All of these, while processing incoming members to the gym.

Case 2 – Ellen

Ellen works as an administrative assistant at a higher education institution. One of her main duties is to schedule events for requests she receives via email. In the work session she logged, she started by opening her email and immediately going to iTunes to play music ("*Cannot work without music!*"). For the most part, during the session, Ellen was taking information from her email and creating events in a specialized scheduling software. Periodically, she switched to iTunes to change her song selection. Some of the emails she handled were grade requests from students. At one point, she was interrupted by an instant message from a colleague ("*IM from my co-worker re: lunch!*"), which she promptly answered. Later on, while still working through her email inbox to continue scheduling events, she received an IM from her sister, which she also answered. She also received a phone call and continued working. Her session ended when she left for lunch upon getting another instant message from her colleague.

Case 3 – Jim

In his position as an accountant at a medium-sized firm, Jim processes vendor invoices by entering data in an Access database and verifying billing information so that specific clients can be billed. Throughout most of the documented work session, Jim shifted his attention between the company's accounting software and specific databases for the reconciliation task. He also replied to email messages requesting specific customer information. Twice during the session, he was interrupted by work-related instant messages requesting verification of customer information, which he also answered promptly.

Case 4 – Anita

Anita works as a sales representative at a jewelry distributor. Her main duties include making invoices using the company's software as well as information from Excel spreadsheets. During the work session reported in her diary, she created/ updated customer invoices and generated complementary FedEx labels for the customers whose invoices she prepared. She also accessed her e-mail for information needed to issue the invoices.

Case 5 – Carol

As a spa concierge, Carol handles appointments and basic office duties. In the session she documented, she processed appointment requests, answered the spa's email, printed the spa menu of services with appointments, and checked out customers. For new clients requesting appointments, she had to create a new customer record in the database. The checkout process included issuing sales receipts with Quickbooks and adding the transaction to the Spa's daily report log. At one point, she looked up prescription information on the web. At another point, she checked the Spa's bank account online.

Data Analysis

The original diaries were transcribed and used for data analysis. Two coders, blind to the purposes of this research, were instructed to determine the number of tasks performed by each subject. The inter-rater reliability calculated with Ebel's (1951) formula for two raters was 0.86. Discrepancies were solved with discussion. Upon reaching agreement on the number of tasks per participant, the coders counted the number of times each task was the focus of attention for every user. The inter-rater reliability was calculated in stages, first for the total number of focus shifts per participant and then for the number of focus shifts in each participant's task. The disagreements were solved by reaching consensus. Table 2 shows the inter-rater reliabilities for each variable. All coefficients are higher than .80 indicating high agreement between the coders.

Table 2. Inter-Rater Reliability Results

Focus Shifts Distribution (FDS) Coding	Inter-Rater Reliability
Total Number	0.94
Bianca's FDS	0.99
Ellen's FDS	0.93
Jim's FDS	0.87
Anita's FDS	0.89
Carol's FDS	0.94

Table 3 shows the final consensus coding of the number and type of tasks per participant and their corresponding number of focus shifts.

Table 3. Participants' Tasks

Participant	Tasks*
Bianca	Member check-in [8]; Research speech topic [4]; Employee wanted sign [2]; Personal email [2]; Facebook [2]
Ellen	Schedule Sessions [11]; Play/Change song [6]; Answer Email Grade Inquiries [2] Instant Messages [4]; Phone Call [1]
Jim	Reconciliation [5]; IM information verification [2]; Email info requests [1]
Anita	Preparing Invoices [2]
Carol	Check out clients [2]; Appointment scheduling [6]; Respond email [2]; Print Spa Menu [4]; Look up prescription [1]; Enter New Client information [2]; Online Banking [1]

* The count of focus shifts is shown in square brackets next to each task.

Several issues are noteworthy in the identification of participants' tasks. Bianca checked her personal email and Facebook page while at work. Although these are non-work activities, the decision was made to list them as tasks, so their focus shifts could be counted. Alternatively, they could have been combined into one and labeled as "personal" or ignored and considered as interruptions in the flow of work. This shows that focus shift analysis is a flexible approach that allows different ways of defining tasks. Another participant, Ellen received a phone call during her work session. This was characterized as a separate task. Therefore, focus shifts are also flexible for capturing computer and non-computer based activities.

Some computer-based activities are seemingly similar but in fact they are representative of different tasks. For example, Ellen's session was driven by her processing of emails. While most of the messages she handled contained requests to schedule sessions, a few other emails were from students inquiring about their grades. Accordingly, two tasks were defined depending on the type of request. Similarly, Jim processed two types of requests while he was performing his reconciliation task: email inquiries and quick information verification via instant message. Here as well, the decision was made to consider them as separate tasks because of the different nature of the information requested.

Occasionally, workers carry out multiple tasks but they are all subordinate to the same overall task-goal. For instance, Anita's session consisted of a single task – preparing customer invoices – which included handling several software programs (company's software, Email, Excel and FedEx label maker). Her two focus shifts are marked by a break. In contrast, Carol's session was the most diverse both in terms of number of tasks and heterogeneity of focus shifts.

In this analysis, participants' tasks were identified with respect to high-level goals and independent of the object (software application or IT device) being used. For the itemization, non-work tasks were listed, as well as non-computer based tasks. This way of conceptualizing focus shifts is free from the details of any particular IT platform.

The agreed upon distribution of focus shifts produced by the coders, was used to calculate MEI* for each participant. The data generated by the coding process and the results of MEI* are summarized in Table 4.

Table 4. Multitasking Assessment with Standardized MEI (MEI*)

Pseudonym	Number of Tasks	Total Focus Shifts	Distribution of Focus Shifts	MEI*
Bianca	5	18	8-4-2-2-2	0.89
Ellen	5	24	11-6-2-4-1	0.83
Jim	3	8	5-2-1	0.82
Anita	1	2	2	0
Carol	7	18	2-6-2-4-1-2-1	0.90

The final step in the coding process consisted of ranking participants in terms of their multitasking activity. Coders used different approaches such as considering the total number of focus shifts or the total number of tasks in their independent determination of participants' ranks. The coders were not aware of the formula or the values of MEI* when they produced their own ranking of participants. The inter-coder reliability of the participants' ranks was 0.96. All disagreements were solved by discussing discrepancies to converge on a definitive sorting. According to the coders', the final ordering of participants, from higher to lower multitasking was: Carol – Ellen – Bianca – Jim – Anita.

For a validity check, the participant ranking agreed upon by the coders was compared to the order resulting from the values of MEI*. Table 5 shows this comparison. A Spearman rank correlation of rankings is equal to 0.9, indicating that the index has high validity compared to the assessment produced by the coders.

Table 5. Comparison of Ranks

Pseudonym	**Coder Rank**	**MEI* Rank**
Bianca	3	2
Ellen	2	3
Jim	4	4
Anita	5	5
Carol	1	1

The multitasking Entropy Index (MEI) provides a measure of focus shift heterogeneity by quantifying the distribution of focus shifts in different task categories defined by independent task-goals. A different view of focus shift diversity can be obtained by classifying focus shifts with respect to the *technology* object (software application or technology device) on which attention is focused. To distinguish this index from

MEI when both are used, it is advisable to indicate that it refers to technological multitasking, and designate it with an alternative name, such as TEI (Technology Entropy Index).

The best case to illustrate the calculation of TEI is Anita's work session. According to her diary, she used the company's software, Excel, email and a FedEx label maker. With respect to these four technological objects, the distribution of her focus shifts is: 3-1-2-2 and the corresponding standardized Technology Entropy Index (TEI*) is: 0.95. For this calculation, instead of task changes, focus shifts were defined with respect to the technology-objects on which her attention was focused. It is noteworthy that Anita was performing a single task during her work session and her MEI* is zero. In contrast, her TEI* is close to 1 (0.95). Thus, while TEI indicates technology focus shift variety, MEI reflects task shift variety.

Discussion

The mathematical properties of the proposed index (MEI) make it suitable for measuring multitasking behavior of a single user or a sample of users. The index consists of calculating the diversity of focus shifts with respect to the tasks that become the center of attention. It quantifies the distribution of focus shifts along a continuum, ranging from homogeneity to heterogeneity, which is illustrated in Figure 2. At one extreme, the index is zero when all focus shifts are concentrated in one task. As the number of tasks and heterogeneity of focus shifts increases, the index also increases. The index reaches its maximum level when all the focus shifts are equally distributed. In its standardized form, the index can be used to compare multitasking activity across subjects or among different work sessions of the same individual.

The preliminary empirical test with a small convenience sample shows the potential of the proposed measure. The results of this initial proof-of-concept and validation suggest that the index captures well the extent to which users multitask. As such, this study provides a starting point to extend this research to a larger sample. As the findings indicate, the index yields a value of zero in mono-tasking situations (as illustrated by Anita's work session). For all other cases, the index is sensitive to the number of categories (tasks), and the distribution of focus shifts in these categories.

The multitasking entropy index (MEI) proposed in this paper is not without limitations. One caveat is the difficulty to identify task categories. The diary reporting method was helpful to identify tasks. However, in some circumstances, task identification could be unique to each worker or work session. This connects to a second limitation. Although the index is standardized to account for different task categories and values greater than 1, it might not be appropriate to compare individual workers whose sessions differ substantially in the type of tasks performed.

Another issue is that the proposed entropy index can be applied to actual patterns of multitasking behavior when there is a recording method (manual or computerized) that captures attention shifts. In the empirical investigation reported here, the recording method was implemented via a self-reported diary that participants kept during the session. To expand the study to a larger sample, video-tapping and automatic logging methods of computer-based activities are recommended.

With systematic recording of multitasking behavior, the validity of the index can be investigated in more depth. For example, a recent multitasking study reports that participants used their laptops mostly for activities unrelated to the meeting (Benbunan-Fich and Truman 2009). Multitasking was measured by assessing computer-based task switching using a computer monitoring program supplemented with human coders. This situation highlights a context where the use of MEI can be most useful in terms of participants and recording methods. In that study, participants were somewhat homogeneous and worked in a comparable environment. Their computer-use behavior was captured with a combination of automatic recording and human coding to discern the meaning of switching activity.

The strength of the proposed index (MEI) is its potential to assess any type of multitasking, whether it is technology-related or unrelated. The core of MEI is the definition of focus shifts. When shifts are defined with respect to independent task-goals, the technology component is embedded into the conceptualization of tasks. However, the index is flexible enough to allow the technology to play a more prominent role, if focus shifts are defined in terms of the technology objects (IT applications and/or IT devices) that occupy attention. In this case, the index is called TEI.

At one level, focus shifts can be defined with respect to the *task* that becomes the focus of attention. Alternatively, at another level, focus shifts can be defined with respect to the *technology* object that takes center stage, even when the overall task-goal remains the same. For example, during a session, a worker may toggle between applications (word processor, spreadsheet, web browser) and different data files to write a report. Although s/he will experience a number of technology-related focus shifts, they are all related to the pursuit of the same task-goal (writing the report). Thus, while the count of task-related focus shifts is low (one in this case), the number of technology-related shifts is higher. A similar situation was illustrated in Anita's case.

For IS researchers seeking to investigate the use of technology artifacts more explicitly, TEI can be a potentially useful tool. To directly examine technological-multitasking, the entropy index is calculated by estimating the diversity of focus shifts with respect to the technology object (i.e. application or device) on which the individual's attention is focused. Together, MEI would provide an indication of the range of tasks performed in a time interval, and TEI would indicate the diversity of technology artifacts used. This extension could seed future research on the concurrent use of multiple technology devices.

Implications

To date, there is no consensus on how to measure multitasking perhaps due to the multiple definitions of this type of behavior. Previous metrics range from simple counts of tasks (Lee 1999) to more complex indicators based on technology switches (Benbunan-Fich et al. 2011). Unlike these previous metrics, the multitasking entropy index proposed herein is comprehensive and yet flexible. MEI is comprehensive because it can measure multitasking in different situations – with or without technology devices – depending on how focus shifts are conceptualized. MEI is flexible because it can be adapted to the interests of the researchers depending on how focus shifts and categories are defined. Each categorization would depend upon the objectives of the research project.

Proper measurement is critical to the advancement of any field of inquiry. Although the development of theory is important in any research endeavor, reaching consensus on issues of conceptualization and measurement facilitates progress (Salisbury et al. 2002). For the study of multitasking, a rigorously developed index like MEI provides an invaluable analytical tool that will enable not only to revise existing conceptualizations but also to integrate and reconcile empirical findings from different disciplines.

By virtue of its position in the center of a new research stream, MEI can be a catalyst for the development of the nomological network of multitasking. For example, the conceptualization of multitasking behavior in terms of task, time, and technology suggests that factors in these three areas could be potential antecedents of this behavior. Similarly, different levels of multitasking captured with MEI are likely to have different consequences for performance and perceptions of productivity.

The contribution of this study is to bring a new theoretical and methodological perspective to investigate multitasking behavior. At the theoretical level, the development of a tri-dimensional conceptual framework consisting of task, time and technology, along with the notion of focus shifts, offers a solid foundation to describe and investigate multitasking behavior. With this foundation, the theoretical roots of multitasking behavior can be further developed. At the methodological level, the use of the Multitasking Entropy Index (MEI) allows to measure the extent to which multitasking occurs. This novel perspective has the potential to generate a new stream of empirical studies documenting multitasking patterns in various settings and researching the impact of multitasking on performance, perceptions or other outcomes.

Conclusions

Multitasking occurs when an individual experiences a number of *focus shifts* as his/her attention moves from one ongoing task to another. Using the notion of entropy, this study proposes a tri-dimensional framework to conceptualize multitasking behavior and a new multitasking measure. The proposed index (MEI) is based on the concept of entropy and consists of quantifying the *diversity of focus shifts* experienced by an individual worker in a specific time period. Although the index relies on actual activity data collected during a work session, preliminary testing indicates appropriate validity as a measure of multitasking behavior. More extensive validation is suggested as a fruitful direction for future research. Other suggested directions include the application of the index to quantify the diversity of IT artifacts (software programs or devices) used during a work session.

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