Towards A Composite Modelling Approach for Multitasking

Peter J Wild, Peter Johnson and Hilary Johnson
HCI Group, Department of Computer Science
University of Bath, Bath
BA2 7AY, UK. Tel: +44 1225 386811
Email: {pwild, p.johnson, h.johnson}@cs.bath.ac.uk

ABSTRACT

Much information and knowledge work (with and without information technology) can be characterised as multitasking and interrupt driven. A whole host of characterisations and buzzwords imply an increase in the number of roles, tasks/activities, IT artefacts, interruptions and exceptions that people have to deal with. This provides a challenge for Task Analysis approaches as they have historically focussed around single tasks and users.

A preliminary version of a composite modelling approach (the Composite Multitasking Model) is presented that draws from approaches that model task, events, interruptions, exceptions and the temporal aspects of tasks. As well consideration of how information about multiple tasks is elicited, we apply the approach to the modelling of data from our own studies.

Keywords

Tasks, multitasking, exceptions interruptions, events, goals.

INTRODUCTION

Advances in Information Technology (IT) provide greater enabling support for carrying out individual tasks in a parallel or interleaved fashion. Once we would have to wait around for a desktop computer to complete printing a document and its limited memory meant we could only open one application at a time. Now mainstream computing has enough power to provide greater flexibility about how we arrange our work. The convergence of telecommunications and IT has brought separate tasks and artefacts such as document preparation, fax, phone, into one electronic workspace (e.g., desk- / lap-top computer, personal digital assistant or mobile phone). Through the use of automation, tasks that were conceived to be performed separately are integrated into supervisory task allocation schemes. These technological shifts both encourage the performance of traditionally specialist tasks by generalists (e.g., document production). Resulting in the potential for people to undertake a greater amount of, and a wider variety of work, and the possibility of greater interleaving of goals and sub goals [1, 2, 5]. As well as technological shifts, there have been shifts towards economies where services and knowledge work form a larger part of the work carried out. In turn how, when and by whom tasks are carried, out are less constrained by the physical world. Furthermore, as the volume of tasks increases, the management of tasks itself, becomes a recurring and important task. Overall these shifts amount to what some refer to as interrupt-driven [11] multitasking [1], or polychronic behaviour [16].

However, technological and artefactual task support is not generally designed to take account of phenomena such as multiple tasks, multiple instances of the same task, interruptions, exceptions, tasks with multiple participants, and multiple ways of ordering the sequence of subtasks and opportunism in dynamic environments. We cannot assume that because we have designed a task well from a single user - single task perspective, that it will necessarily offer effective support for such phenomena. At best, IT artefacts may be inefficient, at worst inflexible, frustrating, error causing, and ultimately unusable.

As a step towards design to support we need to be able to model people multitasking. When modelling people multitasking, we face the “classical” difficulty of modelling the task and its context, but also the interaction and potential clashes between tasks and contexts. In turn this presents a challenge for relevant modelling approaches - whether of task / activity, domain, tools, event or interruption. Each modelling approach, by being predominantly focussed around one issue, misses other important facets relevant to the performance of multiple tasks. Task modelling tends to model one person, one task; domain modellers only seem to assume that a person works within one domain; work on events, interruptions and temporal modelling is aware of the polychronic nature of work (i.e., lots of things happening at once) but have little representation of tasks. We also need to go beyond yet another set of primitives for modelling to something that attempts to tie together both the needed primitives, the theoretical reasoning behind the approaches and cross referencing between the approaches.

Starting To Unpack Multiple Tasks

Multitasking, in common parlance has come to mean doing many things at once. When understanding the multitasking it is useful to scope the multiple "what" and the overall duration of the "when." Traditionally in cognitive psychology multitasking along with task switching has relied on "tasks" that are easily specified, learnt and performed in laboratory contexts and undertaken in a few seconds [e.g., 12]. We refer to this type of multitasking as micro-multitasking. Whilst a powerful paradigm for understanding the constraints on cognitive processing, in HCI contexts tasks have attendant ambiguities about their outcome, multiple participants and roles, mixed resources, as well as being broader in scope and longer in duration. Accepting the strong suggestion in the literature that performing even a single simple task involves parallel and interleaved cognitive processes (i.e., micro-multitasking); we shift our attention to the forms of multitasking discussed in the paper's introduction. With regards to the "once" element we refer to forms of parallel and interleaved tasks that are undertaken over longer time scales: minutes, hours, days and months. These involve tasks that are open ended, that converge or diverge in relation to the dynamics of the environment. Or require collaboration and cooperation between multiple agents. This is the form of multitasking we refer to in this paper. This is in contrast to the fully specifiable task traditional in laboratory studies of micro-multitasking or present in earlier HCI studies.

The Need for a Composite Modelling Approach

Previous reports of our efforts in this area have suggested extension to a specific task analysis method. Since then we have come to the view that what is need is a composite approach. Tasks remain an important thread running through our approach, but the approach also draws on concepts from models of events [4], exceptions, interruptions [10] and the temporal aspects of work [8, 16].

We have three reasons for a composite approach. Firstly, no one approach can be seen as complete. Secondly it is rare in HCI that approaches are combined, and synthesized [c.f., 6]. Yet the challenge of modelling tasks has increased because of the shifts in technology and work practice alluded to in the introduction. Finally, design attempts have often not been based on models; in part this is due to the lack of unified approach to modelling multitasking. We put forward our nascent approach as a first step towards this.

TASK ANALYSIS AND MULTITASKING

Task analysis methods have slowly enriched the set of modelling primitives available, for example, sub role, agent, task type [13, 14]. And in some cases deepened the underlying theory [7, 18]. But in this context we have a number of concerns about Task Analysis (TA) methods. The first is that it is rare to see a task analysis focus on a set of different tasks. Task models are predominantly put forward as generic models of a particular single task-class. But being able to account for the core task of a role is different form understanding how the whole milieu of tasks that a person performs interrelate and interact. Another concern is that they are often normative, abstracting away from the complications and idiosyncrasies of real world task performance, such as events, interruptions and exceptions. Whilst individual work has looked into these issues [4, 10] they have not been integrated into other approaches.

Our next concern is with their ability to express between-task relationships. Many task analysis approaches represent temporal relationships that are internal to specific task for example serialization, choice, parallelism, interleaving [7, 14]. The key observation that can be made of temporal issues in task modelling is that the temporal representations have only been applied to model temporal relations **within** a task, not **between** tasks. While they can capture and represent some aspects of switching between tasks, they miss other aspects, such as what higher level goals "force" the switch and what contextual cues enable or act as a stimulus for the switch. Furthermore, contemporary within-task task temporal representations neglect the temporal contexts as experience as experienced by people. Failing to recognise basic distinctions such as a task is performed at 9.30am and a task is usually performed at 9.30am [16].

SEEDS OF THE APPROACH: WHAT SHOULD BE MODELLED?

A number of studies of multitasking have been undertaken by ourselves [17, 18] and others [2, 5]. Across our own studies [17, 18] the following phenomena were replicated:

- linearization and switching [1, 2], where people perform a seeming continuous stream of activity across a number of task by switching between a set of tasks.
- temporal gaps / lags / natural breaks [4], where the task structure has periods where no activity can be undertaken by the person. For example when awaiting information or permission.
- interruptions [10, 11], where the task receives an interruption, whether from the agent performing the task, or other participant in the task environment.
- Goals and roles are a traditional part task modelling [7]. We and others [2, 5] have observed users with multiple tasks, goals and roles.

New phenomena generated by our own studies:

- Layered goal and task execution choices. We can infer higher level goals than usually modeled by TA methods. These higher level goals can affect how specific task instance is executed. For example, whether to use email, phone or face to face conversation to discuss tasks with a person. Or in how we handle events.
- Groupings [18], where tasks or subtask are grouped according to contextual phenomena such aslocation, participant or deadline.
- Single events and multiple statuses, rather thanan event having one status (i.e., meaning) ascribed to it, multiple

statuses are ascribed. So an event can be an interruption, an exception and an opportunity.

- Genericity across task instances, events can affect all current tasks. E.g., email arriving has the potential to affect all task.
- Temporal issues [17, 18]; factors such as deadlines, the cycles of tasks, pace etc., can affect the planning and execution of tasks.

Overall, this gives a candidate list of phenomena that our candidate composite multitasking model (CMM) needs to model.

A SKETCH OF THE COMPOSITE MULTITASKING MODEL

In this section we outline the composite multitasking modelling approach. Overall the composite approach is presented as a series of interlinked sub-models: the goal complex, the task sub-model; the event-status sub-model; and the temporal sub-model. The CMM can be seen as a composite and elaboration of models and concepts from the following work: TKS, GTA, and CTT [7, 13, 14]; Status-Event analysis [4]; McFarlane's interruption taxonomy [10]; and temporal analysis [8, 16].

Issue / Phenomena	Modelling Element
Linearization and switching	Task sub-model Goal complex
Temporal gaps/lags/natural breaks	Task sub-model
Multiple goals & roles	Task sub-model Goal complex Temporal sub-model
Events: Interruptions; Exceptions; Opportunities; Single events & multiple status	Event and status sub-model: McFarlane's taxonomy; Task model; Goal complex ; Task sub-model/goal complex
Grouping	Task sub-model (pre and post conditions) Temporal issues Contextual issues (e.g., location, participants)
Layered goal and task execution choices	Goal complex, task sub-model
Genericity issues	Task sub-model Event and status sub-model
Temporal issues	Temporal model

Table 1: Summarising the CMM in relation multitasking phenomena.

Table 1 shows how the components of the model(s) relate to related work into multiple tasks. Each subsequent subsection discusses these models in more detail.

The Goal Complex

The first and most novel aspect of the CMM is the goal complex. Traditionally in approaches such as TKS and GTA goals are a "specification" of an intent to change or maintain a domain. However, more generally, goals differ in how abstract-concrete, general-specific or high-low level they might be. Lower level goals generally correspond to the task goals. Higher level goals refer to more generalised goals relating to task quality (speed, accuracy, privacy), resource consumption (i.e., save time, minimise interruptions) and priorities and values (e.g., good customer service, ethical investment). The goal complex represents the relationship between these higher and lower goals. It is important to note that these relationships are not hierarchical. Rather, in most cases lower level goals are a means to achieving a higher level goal. However, the higher level cannot be decomposed into the lower level goals in the traditional manner of TKS or GTA. The relationships are hetrachical [c.f., 3] or means end relationships [15]. For example, doing most tasks conflicts with a goal to "create_more_free_time" but such a higher level goal may affect how the manner in which the tasks are performed. Also represented in the goal complex are commonalities between tasks: including information pertinent to task groupings [c.f. 18] such as deadline, participant and location. Also included are the between-task relationships such as priority, deadline and status. The goal complex is brought into play when planning task performance and handling events.

The Task Sub-Model

This draw heavily from TKS [7] CTT [13] and GTA [14]. Overall the task models the following aspects of single and multiple tasks: the individual goal taxonomies (goals, subgoals, within-task relations [c.f., 13], pre- and post-conditions, priority); the individual object taxonomies; strategies (including task grouping strategies [18]); agents and participants; roles (sub-roles, within- and between-role relations). Further to this, this the temporal operators of CTT [13] are applied to between-task relations when cross referenced with the event and temporal sub-models, and the goal complex. Although in practice the independent operator (| | |) tends to be applied a lot, as the relationships are not easily expressed by CTT.

Temporal Sub-Model

The temporal sub-model concerns time as experienced and represented by people multitasking. The first more formal approach has been developed out of work applying Lee's [8] temporal approach in conjunction with TKS [16]. The second more informal representation of temporal issues is the use of the temporal representations that people find useful. These can range from the mundane and obvious diary, through to knowledge of office hours working practices and shift patterns.

The more formal part if this sub-model draws on the work of Lee [8]. Lee provides 6 dimensions for the analysis of temporal issues: 1) *duration*, the amount of time spent to complete a task; 2) *temporal location*, the location of activities and tasks at particular points over a period of time; 3) *sequence*, the order in which tasks are carried out; 4) *deadline*, the fixed time to which task are to be completed; 5) *cycle*, the periodic regularity of tasks; and 6) *rhythm*, the alternation in the intensity of task performance. When we consider TA methods *duration*, *cycle* and *rhythm*, can be elicited in observations and interviews. These elements would need to be represented in the task model and scenarios. Card sorting and related techniques could also be used to assess typical and atypical durations. *Temporal location* is very rarely covered in a task model but implicitly addressed in use of scenarios and can be elicited from interviews and observations and represented in the scenarios accompanying task models. *Sequence* is explicitly covered in the use of LOTOS-like temporal operators [7, 13]. *Deadlines* are very rarely covered in a task models but can be implicitly addressed in use of scenarios and is in the expression of quality goals [see also 18].

Event and Status Sub-Model

The events and status model, draws on the work of Dix on Events and Status [4], and MacFarlane's work on Interruptions [10].

Dix's [4] explicit concern is with the ecology of interaction and the consequences of longer term tasks. A key starting point is the analysis of events and their status, that is what meaning relevance and consequence is ascribed to it. Unlike mainstream computer science, events and their status are not simultaneous, that sometimes events are missed; sometimes there is a delay between an event and something occurring in reaction.

We extrapolate from Dix's work and allow more than one status to an event. That is, events can have multiple statuses assigned to it. An event can be an interruption, an exception and an opportunity.

McFarlane [10] developed a taxonomy to describe interruptions that draws on view of humans as goal driven, capable of multitasking, but resource constrained and contextually sensitive. The main components of the taxonomy are: 1) the source of interruption; 2) the individual characteristics of the person receiving the interruption; 3) the method of coordination; 4) the meaning of the interruption; 5) the method of expression; 6) the channel of conveyance; 7) the human activity changed by interruption; and 8) effect of interruption [10. p. 73]. The taxonomy provides a rich theoretical tool with which to describe and classify interruptions.

We believe that supplementation with more refined notion of task is possible and desirable to McFarlane's taxonomy. This is addressed by cross referencing interruptions with the task sub-model. Further to this we can generalise his theoretical taxonomy to events and their status. Of the dimensions McFarlane puts forward we believe that 1, 3, 5 and 6 are generic in that they can describe all events. In turn the remaining dimensions 2, 4, 7 & 8 are applicable to the status ascribed to an event.

We also draw from TKS's notion of centrality and representativeness [7]. Card sorting can be applied to develop empirically grounded assessments about the centrality and representativeness of events. We assume that more central events are those intrinsic to the task. Events can also be more or less representative. Mail & email arriving, and phone calls, are more representative events in offices than pigeons carrying messages.

Cross references are made with the task and temporal sub-models. For example, the human activity and the source of the agent cross-reference the task sub-model. Events that are intrinsic to the task or set of tasks will be reflected in the core of the task model, rather than in the exception model. Events obviously have a temporal location, duration; they may also have cycles of repetition and deadline for response.

Event descriptors	Status descriptors
source of event; method of coordination; method of expression; channel of conveyance;	characteristics of the person receiving the event; the meaning of the event (central, interruption, exception, opportunity) the human activity changed by event (see task sub-model); effect of event

Table 2: A Representation of the Event-Status Sub-Model

ILLUSTRATING THE COMPOSITE MULTITASKING MODEL

The empirical study used to illustrate the composite model is an hour in the life of a research scientist [17]. Space prevents us providing all the relevant data. We provide an overview of the data and then illustrate the key sub-models of the CMM with examples from this study. Through the use of participant observation and video recording a near to naturalistic study as possible was undertaken.

The subject had 6 main roles which generated attempts to plan and execute 18 distinct tasks during the observed period. The subject was the explicit recipient of 5 interruptions by other agents. She also interrupted her own task performance on 9 occasions and she interrupted other people 14 times. These interruptions and other events meant that task suspension and switching/interleaving was common. In terms of the wider environment the subject interacted with 16 different participants (35 cumulatively). Over the hour, tasks and interactions took place in 8 different locations excluding traversed corridors.

Table 3 illustrates the major tasks inferred or observed from the data. It does not represent when the tasks were suspended or resumed.

Tidy Desk (1)	Allocate tapes (9)
Planning / To Do List (2)	Planning Tutoring (10)
Buy card (3)	Consult PhD students (11)
Check email (4) Add details to diary (4.1) Check meeting (4.2)	Order storage cabinet (12) Consult P-RC2 (13)
Email Project partner (5)	Select Reading Group paper (15)
Email Audio Visual (6)	Photocopying (14/16)
Read Post (7)	Make coffee (17)
Money (8)	See Student (18)

Table 3: Summary of Tasks

Whilst table 4, gives presents how some of the tasks were performed in time.

03.46	Write Email To colleague
07.38	File print of email
	check for other tasks
08.00	Write email to audio visual (AV) (task suspended)
	Open post (task suspended)
08.27	Put money in purse interleaved with below
08.27	Confirm or rearrange meeting time
08.54	Delegate to colleague: subtask (reduce no. of articles to read)
09.42	Read pension letter (task suspended)
10.08	complete AV email
12.15	Receive and allocate camcorder tapes Delegate to colleague: expenses claim for camcorder tapes)
	pass on tapes to colleague (task suspended)
15.05	Restart: pass on tapes to colleague
15.30	Software engineering teaching planning. New subtask Consult colleague (task suspended)
	Consult PHD students
15.32	Security card forgotten
	PHD2 not available
16.50	Delegate to PH1: let PHD2 know
17.29	Consult colleague to order secure cabinet

Table 4: Real time task illustration.

The Goal Complex

#	Goal	Goal Complex Cross reference
G1	Tidy desk	
G2	Create and maintain to do list	
G3	Buy card	
G4	Checking email	
G5	Add meeting to diary	
G6	Consult colleague about meeting	S
G7	Email off site colleague	D S
G8	Order secure cabinet	* L
G9	Consult RC2	* P
G10	Renew Audi Visual booking	D L
G11	Choose and copy paper for reading group	S L
G12	Software engineering planning	R
G13	Consult PhD students	
G14	Deal with post -> fill in pension documents	L
G15	Receive money	
G16	Allocate tapes	*
G17	Make coffee	
G18	Photocopying article	L
G19	Deal with student	*
G20	Offer copy of interview transcript to colleague	

Table 5: Goals and Goal Complex Cross References.

Table 5, lists the observed and inferred goals from the data. However, further to these in a subject interview, suggested other high level goals relating to her new status in the department: 1) learning how things were done in the department; 2) developing good social relations with colleagues; and 3) clear time for research analysis.

As a partial representation of the goal complex the following annotations indicate two of the higher level goals and the four task groupings observed [c.f., 18]. [1] S, social relationships; L, learn how things are done; D grouping by deadline; * grouping by location; R grouping by Role; P grouping by participant.

One other phenomena is how higher level goals affect the task execution tasks. Goal 9, consult RC2 could have been executed via a phone call, an email exchange or by face-to-face conversation. However, the higher level goal of developing good social relations with colleagues, determined that the final strategy was undertaken. Indeed when the person was not available at the time of the study this goal was suspended indefinitely.

The Task Sub-Model

Clearly with over 15 major tasks, 6 roles/subroles individual task models are beyond the scope of this paper. We hope to give a flavour of the additions. Examples of different views of sample data can be found in tables 3 and 4.

Between-Task Relations

Table 6 illustrates an attempt to apply a CTT like approach to the between-task relationships. As mentioned I in outline of the Task Sub-Model, most of the tasks are independent of each other. Or the relationships between them are not easily expressible in such a format.

<table>
<tr><td>Write Email To colleague</td></tr>
<tr><td>> > (Enables)</td></tr>
<tr><td>File print of email | | | (independent) check for other tasks</td></tr>
<tr><td>Write email to audio visual (AV) (task suspended)</td></tr>
<tr><td>|> (suspend) Open post (task suspended)</td></tr>
<tr><td>Put money in purse interleaved with below</td></tr>
<tr><td>| | | (independent)</td></tr>
<tr><td>Confirm or rearrange meeting time</td></tr>
<tr><td>| | | (independent)</td></tr>
<tr><td>Delegate to colleague: subtask (reduce no. of articles to read)</td></tr>
<tr><td>| | | (independent)</td></tr>
<tr><td>Read pension letter (task suspended)</td></tr>
<tr><td>|> (resume) complete AV email</td></tr>
<tr><td>Consult colleague to order secure cabinet</td></tr>
</table>

Table 6: Some example between task relations

Groupings

Table 7 [see also 18], illustrates four task groupings that occurred. Such groupings increase the salience that pre- and post-conditions take on. There is no longer just one set of pre- and post-conditions activated during task performance. There is now a set of pre-conditions for the individual tasks in the grouping plus any conditions that have to be met for the grouping to be successful.

[1] This is not illustrated as the whole afternoon was devoted to this goal.

Deadline	Two tasks with hard and soft deadlines were performed as soon as possible. PreC: email system active, contents of emails known
Location	A number of tasks that needed to be performed outside of the office were grouped together. PreC: Locations of colleagues & resources is known.
Participant	A number of tasks were grouped in relation to a specific participant, whose help was needed for all the tasks. PreC: Participant available, room known, performer has pen, diary, to do list.
Role	The subject cleared time for one role (research) and allocated time in her diary to focus on another role (teaching). PreC: AV equipment booked, data source available. PostC: Data source removed from AV equipment.

Table 7: Task groupings

The Event and Status Sub-Model

Here we provide several examples of the updated status-event format. Including examples with multiple statuses assigned to a single event.

Event descriptors (Time 08.11)	Status descriptors
source of interruption. Colleague puts post on desk method of coordination Real time negotiation method of expression physical placement on desk channel of conveyance face-to-face	characteristics of the person receiving the event engaged in writing email the meaning of the event An interruption, the human activity changed by event (see task sub-model) see tables: 3 task 6; table 4, rows 4 through 8; table 5 goal 10; effect of interruption current task suspended, post read, other tasks initiated

Table 8: Event-Status sub-model of a specific interruption.

Event descriptors (Time 26.12)	Status descriptors
source of event. Photocopier ceases to work method of coordination Real time negotiation method of expression physical actions of Photocopier channel of conveyance co-present	characteristics of the person receiving the event engaged in observing the Photocopier *the meaning of the event* interruption, exception and opportunity the human activity changed by event (see task sub-model) see tables: 3 task 14; table 5 goal 18; effect of event task suspended, exception task undertaken (refill paper), one less copy than needed is made.

Table 9: Event-Status sub-model of an event that has multiple statuses.

In this example a colleague enters the room and places the subject's post on their desk. This results in the post being opened. This opens up a series of small exchanges concerning tasks that were added to the subjects to do list whilst the colleague was out of the room.

Within this example the subject is undertaking photocopying of a reading group article. When the paper runs out of paper this generates an exception task; it could in theory be ignored, but this event gives the subject the opportunity to learn: a) where spare paper is; and b) how to reload the photocopier. This supports the second higher level goal of learning how things are done. However, in doing this one less copy than needed is made. This however is exploited later in (see table 3 task 16), when this exception task is conjoined with another photocopying task.

The Temporal Sub-Model

Using Lee's dimensions as an interpretative framework the following can be considered. *Duration*: so much was started and left unfinished and the end of the observed period, some of this reflects lags in tasks, some the failure to perform a task in an expected duration. The *temporal location* was shortly after lunch, therefore, the creation of a plan and to-do-list and checking of emails, were important activities. But also the temporal location overlapped with other key agent's lunch hour. The *sequence* of tasks showed little explicit parallelism talking and stirring coffee being the only example. As for *deadlines***,** both soft and hard deadlines were present [c.f., 8]. The hard deadline concerned booking AV equipment and had an immediate failure criterion, no AV no research. The soft deadline was to pass on information as soon as possible. *Cycles*, could be observed at varying levels of granularity. Email was continuously referred back to and there was a constant replanning of tasks to reflect shifts in the environment and the acquisition of new information. Some of the activity shows cyclical nature of tasks, such as teaching preparation and project meetings. The *rhythm* or intensity of performance shifts across the time. There were quieter more periods focus is on one main task email and a more reflective period where the work is reading, reflecting and planning of tutoring material.

CONCLUSIONS AND FUTURE WORK

This paper has taken its concern with the need for a composite modelling approach to model people multitasking. We have an overview of our nascent approach the composite multitasking model (CMM) and illustrated it with data from one of our studies [17]. Future work entails greater refinement and more in depth elaboration. Further work relates to the representation of multitasking and deepening theory.

Representation: A number of ad-hoc and informal representations have been developed to report our work to ourselves and subjects. They have not yet been applied systematically with developers or users. This is an obvious avenue of research relating to CMM.

Furthermore, the overall grammar of the model needs to be explicated and comparisons with Limbourg, and Vanderdonckt's [9] task model schema need to be made.

Deepening Theory: We want to deepen the theory behind the approach. As presented albeit limited by space the theoretical aspect has been implicit, drawing on the underlying theory of the approaches that compose the CMM. To deepen theory we retain the theoretical basis of one of the main underlying theories, TKS [7] even though the CMM goes beyond the core set of primitives of TKS.

TKS theory holds that a TKS is a conceptual representation held in long-term memory and processed in working memory during task performance. Clearly when applied to multitasking this needs extending. The key to this extension is the recent work of Barsolou [19]. He argues that conceptual representations retain features relating to the concepts use in the world. So for example the conceptual representation of a chair, is related to uses for chairs, both typical (sitting, sleeping eating, working) and atypical (to elevate height, to block doors). By stating that people will actually have a mental representation of many of the phenomena associated with multitasking behaviour, we draw a twofold analogy with Barsalou. One, that other phenomena associated with the TKS conceptual representation of a set of tasks will be retained in memory (e.g., typical events, participants). Secondly, contextual relations between concepts can be retained in memory. Conceptual relations between tasks, however simplistic (e.g., they take place in the same location), are stored and used in the performance of tasks [c.f., 18]. In effect TKS's as representations of task knowledge, become bigger and more complex, being further embedded in the contextual representations of tasks.

This issue also pushes forwards to design and evaluation. Empirical work with TKS provided strong supporting evidence that users will impose their own task model upon interfaces that partially or fully fail to reflect that task structure. With a badly structured interface, errors and slower task execution are partly due to the need to translate the TKS of the task into an execution path. In contrast an interactive system that fully supported the TKS of a task by obeying the principles, resulted in higher measures of objective and subjective usability [7]. Interactive systems (IS) can be expected to be less effective if their interaction with other IS, go against the higher level structures people have developed to represent and perform multiple tasks. We have outlined related higher order grouping strategies [18]. There maybe other higher level grouping principles for a set of multiple tasks.

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REFERENCES

1. Cypher, A. The Structure of User's Activities. in Norman, D.A. and Draper, S. eds. User Centred systems Design, LEA, Hillsdale NJ., 1986, 243-263.
2. Czerwinski, M., Horvitz, E. and Wilhite, S., A Diary Study of Task Switching and Interruptions. in CHI 2004, 175-182.
3. Diaper, D. Understanding Task Analysis for HCI. in Diaper, D. and Stanton, N.A. eds. The Handbook Of Task Analysis For Human-Computer Interaction, LEA, Mahwah, NJ., 2004, 5-47.
4. Dix, A., Ramduny, D. and Wilkinson, J. Interacting in the Large. Interacting with Computers, 11 (1). 9-32.
5. González, V.M. and Mark, G., Constant, Constant, Multi-tasking Craziness. in CHI 2004, 113-119.
6. Johnson, H., O'Neill, E.J. and Johnson, P., Workshop on 'Interaction in the Large. in CHI'99, ACM Press.
7. Johnson, P., Johnson, H. and Hamilton, F. Getting The Knowledge Into HCI. in Schraagen, J.M., Chipman, S.F. and Shalin, V.L. eds. Cognitive Task Analysis, LEA, Mahwah, NJ, 2000, 201-214.
8. Lee, H. Time and Information Technology: Monochronicity, Polychronicity and Temporal Symmetry. European Journal of Information Systems, 8 (1). 16-26.
9. Limbourg, J. and Vanderdonckt, J. Comparing Task Models for User Interface Design. in Diaper, D. and Stanton, N.A. eds. The Handbook Of Task Analysis For HCI, LEA, Mahwah, NJ., 2004, 135-154.
10. McFarlane, D.C. Interruption of People in Human-Computer Interaction, Navy Center for Applied Research in Artificial Intelligence Information Technology Division, Washington, 1997.
11. Miyata, Y. and Norman, D.A. Psychological Issues in Support of Multiple Activities. in Norman, D.A. and Draper, S. eds. User Centred systems Design, LEA, Hillsdale NJ., 1986, 265-284.
12. Pashler, H. Task Switching and Multitask Performance. in Monsell, S. and Driver, J. eds. Attention and Performance XVIII, MIT Press, Cambridge, 2000.
13. Paternò, F. ConcurTaskTrees: An Engineered Notation for Task Models. in Diaper, D. and Stanton, N.A. eds. The Handbook Of Task Analysis For HCI, LEA, Mahwah, NJ., 2004, 483-501.
14. van Welie, M. and van der Veer, G.C. Groupware Task Analysis. in Hollnagel, E. ed. Handbook Of Cognitive Task Design, LEA., NJ, 2003, 447-476.
15. Vicente, K.J. Cognitive Work Analysis. LEA, Mahwah, 1999.
16. Wild, P.J. and Johnson, P., Deepening Consideration of Temporal Factors in Task Knowledge Structures. position paper presented at, Workshop on 'Temporal Aspects of Work for HCI'. CHI'2004,.

17. Wild, P.J., Johnson, P. and Johnson, H., An Hour In The Life, in CHI'2003, ACM Press, 1016-1017.
18. Wild, P.J., Johnson, P. and Johnson, H., Understanding Task Grouping Strategies, Proceedings of HCI 2003: Designing for Society, Springer-Verlag, 3-20, (2003).
19. Yeh, W. and Barsalou, L.W. The Situated Character of Concepts. Under review, downloaded March 2002.