Task selection, task switching and multitasking during computer-based independent study

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Detailed logs of students' computer use, during independent study sessions, were captured in an open-access computer laboratory. Each log consisted of a chronological sequence of tasks representing either the application or the Internet domain displayed in the workstation's active window. Each task was classified using a three-tier schema according to its likely context of use: The top-level categories being *Academic*, *Communication*, *Information, Recreation* and *Applications*. Students switched tasks frequently – median task duration was only 31 seconds. Approximately 30% of all tasks were *Academic* with the majority of these involving the university's learning management system. *Communication* and *Recreation* tasks accounted for 18% and 9% of tasks respectively. Up to one half of all tasks were not related to study. Multitasking was very common during independent study sessions, particularly when *Communication* tasks were active. This study confirms that students are likely to regularly switch tasks, attend to distracting tasks, and multitask during independent study. Each one of these behaviours has the potential to negatively impact on students' learning, and when combined they indicate that students are relatively inefficient at managing competing tasks and their time when studying.

Introduction

Multitasking involving the use of electronic devices and media – often referred to as media multitasking (Foehr, 2006) – is extremely commonplace. It takes place at home and in the workplace, and increasingly in the classroom and other learning contexts. The interaction between multitasking and learning has attracted a lot of recent attention, and while the evidence is somewhat equivocal, most suggests that media multitasking negatively impacts on learning processes. Suggested mechanisms for this vary, but there is good evidence to indicate that multitasking can disrupt the encoding of information into memory (Foerde, Knowlton, & Poldrack, 2006; Trafton & Monk, 2007), which may have downstream effects on both information recall and task performance (Ophir, Nass, & Wagner, 2009; Adler & Benbunan-Fich, 2012). Cognitive effects aside, multitasking can impact on learning by simply disrupting or displacing learning tasks with non-learning activities. Unless these distractions and disruptions are adequately compensated for by extending study times and revisiting missed content, learning may suffer (Wood et al., 2012). To what extent routine learning is affected by multitasking is unclear, although recent studies suggest that under light to moderate multitasking conditions any decline in test performance may only be in the order of a few percent (Conrad & Marsh, 2014; Rosen, Lim, Carrier, & Cheever, 2011). Nevertheless, even small reductions in recall and learning efficiency may have significant knock on effects for students' overall academic success and eventual workplace performance.

Experimental studies of multitasking typically involve a primary and a distracting task, with the types of and contexts of tasks involved ranging from simple to complex and artificial to naturalistic. While this makes direct comparisons difficult, it seems reasonable to expect that different types and contexts of distracting tasks will have varying effects on task behaviour and performance. Task duration appears to be important, with longer interruptions being generally more disruptive than shorter ones, which Trafton and Monk (2007) ascribe to an increase in the time it takes to transition back from a secondary task to the primary task as the time spent on the secondary task increases. Task similarity is also implicated, with more similar primary and secondary tasks both facilitating switching (Arrington, Altmann, & Carr, 2003) and reducing performance on the primary task (Wang et al., 2012).

Less well understood is how, particularly in non-experimental conditions, a primary task and its context of use, impacts on the choice and management of secondary tasks – that is, where the user has a much greater level of control over which tasks are undertaken and how they are prioritised. This is especially pertinent to students' independent study habits, as these typically involve unstructured and unsupervised learning, mixed with relatively unfettered access to a range of digital tools, services and devices. Task selection during independent study can involve a complex blend of competing extrinsic and intrinsic motivations, many of which are not related to study. For example, “if I don’t spend more time on chemistry I might fail” versus “If I don’t keep up with what my friends are doing on Facebook I’ll be left out” (extrinsic) or “chemistry is my best and most interesting subject” versus “I really like chatting with my friends on Facebook” (intrinsic). This is further complicated by factors that may impact on the student’s situational interest levels, for example incoming message alerts. Students with poor self-regulation skills are likely to be least effective at ignoring or at least selectively deferring such distractions (Wei, Wang, & Klausner, 2012). Similarly, students who are less engaged with the primary task are more likely to initiate an interruption (Adler & Benbunan-Fich, 2013). Balancing these competing demands and preferences is likely to be both a driver for and determinant of students’ task switching and multitasking behaviours.

If we view learning as the overarching task (and objective) when a student is engaged in independent study, then the student’s role is to initiate, manage and negotiate a mix of learning and non learning-related tasks within that larger context. That many students find these negotiations difficult is clear, and higher levels of social media use in particular have been linked to measurable reductions in overall academic performance (Junco, 2012; Karpinski, Kirschner, Ozer, Mellott, & Ochwo, 2013; Kirschner & Karpinski, 2010). Multitasking during learning – where social media is the secondary or distracting task – appears to be rife, and recent studies suggest that social media use, and specifically Facebook use, is a key contributor to and initiator of task switching and multitasking behaviours during study (Rosen, Carrier, & Cheever, 2013; Judd, 2014). However, while multitasking may be a major contributor to reduced academic performance among heavy social media users (Karpinski et al., 2013), it is not the only one. A recent study by Frein, Jones and Gerow (2013) reported that heavy Facebook users had poorer recall than light users under identical non-multitasking conditions, and a number of authors have linked high levels of Facebook use to psychological conditions including anxiety and depression (Becker, Alzahabi, & Hopwood, 2013; Rosen, 2012).

While other types of secondary tasks may not have the same impact on learning as Facebook, they can still influence how, when and to what degree students task switch and multitask during independent study. Moreover, not all secondary tasks are necessarily distracting, in a practical rather than a cognitive sense, as they may involve study-related activities and be part of the normal study process – for example using an on-screen calculator to calculate results or a search engine to locate references while using a word processor to write a report. Add in some personal or recreational distractions and overlay individual differences in multitasking behaviour and the picture becomes quite complex. Few studies have attempted to document, let alone make sense of this complexity.

This paper takes an initial step, adopting an exploratory rather than experimental approach, capturing, documenting and analysing the types and contexts of real tasks and task switching behaviours that students engage in during independent computer-based study. The study setting is authentic, taking place in a typical on-campus open-access computer lab, and all data used in the study was collected during normal independent study sessions by students.

Methods

Data collection

Data collection for this study took place at a large Australian metropolitan university during August and September in 2009. Automated logs of students’ computer-based activities were captured within an open-access computer laboratory containing approximately 50 computer workstations using an automated software-based monitoring system. A software agent installed on each workstation unobtrusively captured the usage data and transferred it to a networked database at the completion of each user session. The laboratory was used by medical and biomedical students for self-directed independent study. Personal and social use of computers and the Internet was permitted and there were very few restrictions placed on Internet use.

Data collection for this study, including the monitoring of students’ computer use, was approved by the Human Research Ethics Committee of the host university and notices were displayed on each workstation informing students that their computer use may be monitored for evaluation and research purposes.

Unmonitored computers were available for use in nearby locations. All data was deidentified prior to analysis.

Definition of Session, tasks and segments

Raw session logs were processed to create simplified session histories. Session histories (from here these are simply referred to as sessions) contain a sequential list of foreground tasks, with each task consisting of a task name (e.g., Facebook, Microsoft Word, Google search) and an elapsed time measured in seconds. Task names were derived from the active application, in the case of non-browser tasks, or the Internet domain in the case of in-browser tasks. Task records were generated each time users opened a new application or website or switched to or reactivated an existing application or website. Data analysis was restricted to sessions of between 20 minutes and 2 hours in length. Sessions less than 20 minutes in duration were excluded because they did not contain at least one full segment for analysis (see explanation of segments below), while sessions of more than 2 hours duration were excluded because they were usually associated with occasional failures of the workstations' automated logout routines.

Valid sessions were broken down into a series of segments, where each segment was 20 minutes in length and overlapped both previous and subsequent segments by 10 minutes. Each segment was classified into one of three types based on task switching behaviour:

1. Focused – segment contains a maximum of two task instances.
2. Sequential – segment contains at least three task instances but no repeated tasks.
3. Multitasking – segment contains more than three task instances and one or more repeated tasks.

The use of overlapping segments was designed to improve the detection of periods of consistent behaviour and transitions between behavioural types. A more detailed description of and rationale for the segmentation of sessions and the three behavioural types is provided in Judd (2013). A repeated task is defined as one that occurs at least three times within a segment. This definition creates and an objective distinction between simple task switching (without returns to previous tasks) and multitasking (with returns to previous tasks). Sequential behaviour implies the former – the user moves through a series of tasks, often in rapid succession, but either does not or only infrequently returns to any previous tasks and is not considered to be intentionally trying to manage two or more concurrent tasks. The definition of multitasking given above, is consistent with the generally accepted sense and implies that the user is intentionally attempting to attend to or manage two or more concurrent tasks.

Categorisation of tasks

Each task was assigned to at least one contextual category. The list of categories was derived from an initial assessment of the range and types of tasks accessed by students during their sessions. Five primary categories were proposed – *Academic*, *Communication*, *Information*, *Recreation*, *Applications* and *Other*. These were each divided into a series of secondary and tertiary sub-categories. Tertiary categories typically mapped onto specific tasks (e.g. *Communication* is the primary category, *Social networking* is the secondary category and *Facebook* is the tertiary category or specific task). In all, over 30 categories were assigned but only some of these were directly relevant to this study and were incorporated into the subsequent analysis. Finally, a small number of key specific tasks were also recognised. Descriptions of these categories, sub-categories and specific tasks are provided in Table 1. Categories were typically exclusive although a small number of tasks were optionally associated with a second category or sub-category. These tasks included the university's student webmail service (*Unimail*), whose primary association was with the *Communication* category but was also associated with the *University* subcategory, and tasks in the *Learning applications* sub-category, whose primary associations were with the *Academic* category but were also associated with the *Applications* category.

More than 3800 unique tasks were identified and each was classified (by the author) according to the schema outlined in Table 1. Each task was classified using a two-stage approach. All tasks were assigned to a primary category on the first pass and to a secondary category, and if appropriate a tertiary category, during the second pass. Classification was a time consuming process and was carried out by loading and viewing each and every unique application or Internet domain associated with a task and assessing its content and likely context of use. Foreign language sites were translated using Google's translation service to help with their classification. Third party reviews of sites were used, where available, if the usage context or purpose of a site was unclear. Any site that could reasonably be expected to be used in a learning context was placed in either an Academic or Information subcategory.

Table 1.
Three-tier classification of user tasks based on their type and/or context of use.

Association *Primary*	*Secondary*	*Specific*	**Description**
Academic			Sites or tools explicitly or most likely to be associated with course related learning activities. Includes websites from all tertiary level educational institutions, libraries, academic publishers, research databases and collections and public and professional organisations and institutions that provide learning or research materials targeted at students or practitioners.
	University		Sites or tools associated with the host university
		LMS	The host university's learning management system
		Library	The host university's library site, includes access to all online collections
	Learning Applications		Multimedia software titles targeting specific medical or bioscience learning issues
		Pathology	Comprehensive interactive self-directed pathology resource
		Anatomy	Encyclopedic interactive anatomy atlas and text
Communication			Tasks whose primary purpose is to facilitate the communication or sharing of information between users
	Social Networking		Social networking services or sites
		Facebook	Facebook website
	Email		Email services or sites
		Hotmail	Popular email service
		Gmail	Popular email service
		University	Host university's webmail service
Information			Tasks associated with locating information (from non-academic sites) that may be associated with learning but are not clearly course or study related. Includes generalist search tools, reference sites and tools, news and current affairs sites, specialist forums and consumer health sites
	Search		Internet search tools
		Google	Leading search engine
	Reference		Encyclopedias, wikis, dictionaries, thesauruses, calculators
		Wikipedia	Leading online encyclopedia
Recreation			Sites associated with personal recreational activities. Includes travel, sport and fitness, gaming, music, food and entertainment related sites
Applications			Desktop applications and services installed on the target workstations
		Finder	Operating system's file management and location service
	Helper		Applications or services used to support learning and/or the use of learning related tasks in other categories. Includes applications for creating, manipulating and viewing documents and media files.
		Preview	PDF and image viewer
		Word	Word processing software
		Flash Player	Flash file and animation viewer
Other			Sites not clearly associated with one of the other categories. Includes commercial and retail advertising, 'junk' sites and dead or expired domains

Session graphs

Graphical representations of selected sessions were used to illustrate the temporal and contextual relationships between various categories of tasks within sessions and segments. The creation and presentation of these *graphs* is described in Judd (2013). Briefly, each session graph consists of a series of stacked horizontal bars (tasks) placed along a time axis. The width of each bar represents elapsed time and multiple bars within a row indicate repeat instances of a task.

Analysis

The contents of each session segment were iteratively compared to the lists of tasks compiled for each of the pre-defined tasks associations (Table 1). Frequencies and durations were calculated for each association. Each segment was also scored for each of the associations according to whether it contained one or more of the associated tasks. Where true, a differentiation was made between whether the task (or tasks) was simply present or was accessed at least three times – that is was also a repeated task. Segments were also scored according to whether they conformed to focused, sequential or multitasking task-switching behaviours, facilitating comparisons of task use and task-switching behaviour on a per-association basis.

Results

Task frequencies and durations

A total of 3349 sessions contributed by 1230 unique users were analysed. The combined sessions contained 13350, 20 minute segments comprised of 87666 task instances. The mean and median task durations were 126.8 seconds and 31 seconds respectively (Table 2). Frequencies and durations of all primary task associations and of the key secondary and specific task associations are provided in Table 2. The typically large discrepancy between the mean (higher) and median (lower) task durations is explained by a high proportion of short duration tasks being offset by a relatively small number of very long duration tasks. *Academic* tasks (30.6% of all task instances) were the most common overall, with tasks based around the host university's website (*University*) predominating (82.5% of all *Academic* tasks). The university's learning management system (*LMS*) was the most frequently accessed specific task (15.9% of all task instances and present in 90.6% of all sessions). *Learning applications* tasks accounted for only 1.8% of all task instances and 6.0% of *Academic* task instances. However, this association had by far the largest average task duration (mean – 745.1 seconds; median – 184.5 seconds), suggesting that despite its relatively low frequency of use, it had a substantial influence on users' overall task switching behaviour (see section 3.3).

Application tasks were the next most common (22.8% of all task instances), with two helper applications – (*Preview* – 5.9% of all task instances; *Word* – 5.7% of all task instances), and the operating system's file management application (*Finder* – 5.9% of all task instances) – the most frequently accessed of these. The median duration of *Finder* tasks (14 seconds) was the lowest of any specific task or task association, although this was only slightly lower than for *Search* tasks (16 seconds).

Communication tasks accounted for a further 18.1% of all task instances and these were dominated by four key tools; *Facebook* (49.0% of *Communication* task instances; 92.6% of *Social networking* task instances) and three web email clients, *Hotmail* (16.0% of *Communication* task instances; 36.9% of *Email* task instances), *Unimail* (14.6% of *Communication* task instances; 33.6% of *Email* task instances) and *Gmail* (9.3% of all task instances; 21.3% of *Email* task instances). Interestingly, *Facebook* had the second highest median task duration (45 seconds), which although only one quarter of that for *Learning applications* was still approximately 50% above the overall median task duration.

Information tasks were slightly less common, accounting for 17.2% of all task instances. This association incorporated almost 20% of all unique tasks but only two of these were accessed frequently; *Google* search (5.0% of all task instances; 29.3% of *Information* task instances) and *Wikipedia* (2.5% of all task instances; 14.7% of *Information* task instances). *Search* tasks were among the shortest overall, with a mean of 33.9, and a median of 16 seconds, while *Reference* tasks were among the longest, with a median of 41 seconds.

Recreation related tasks were much less popular overall, accounting for only 8.8% of all task instances. However, this makeup of this category was extremely diverse and included over 40% of all unique tasks. There were no frequently accessed tasks within this category (at least 1% of all task instances), however common secondary associations within this category included *Sport and fitness* (16.5% of *Recreation* tasks), *Technology and software* (14.1% of *Recreation* tasks) and *Travel and accommodation* (10.7% of Recreation tasks). The *Other* association of tasks, which included a combination of less easily classified sites, *junk* sites and dead links (quite a few sites that were active at the time the data was collected in 2009 were no longer active when the classification of sites was undertaken in late 2013), accounted for the final 2.5% of task instances.

Table 2.
Frequencies and durations of key tasks and task associations.

Association			**Frequency**		**Duration**	
Primary	Secondary	Specific			Mean	Median
Any			87666	[3826]	126.8	31
Academic	any		26822	[682]	143.2	31
	University		22118		110.1	24
		LMS	13907		105.1	22
		Library	1673		126.9	41
	Learning applications		1612		745.1	185
		Pathology	975		586.9	153
		Anatomy	346		1393.8	741
Applications	any		19994	[37]	183.2	31
		Finder	5185		80.5	14
	Helper		14540		195.7	41
		Preview	5211		141.8	41
		Word	5026		156.0	42
		Flash player	645		1057.7	154
Communication	any		15867	[90]	109.4	34
	Social networking		8393		137.2	43
		Facebook	7774		138.9	45
	Email		6889		79.7	31
		Hotmail	2540		77.2	31
		Gmail	1470		86.4	31
		Unimail	2318		137.2	43
Information	any		15104	[714]	71.6	21
	Search		4568		33.9	16
		Google	4420		32.5	15
	Reference		3059		111.8	41
		Wikipedia	2220		125.0	42
Recreation	any		7714	[1556]	105.0	34
Other	any		2165	[747]	92.0	23

Note. Values in brackets in the frequency column are the number of unique or independent tasks associated with the various primary task associations. Not all secondary and/or specific task associations are mentioned within each of the primary associations, and as a result the combined frequencies may not add up to the relevant 'any' values.

Session graphs

A sample of session graphs is provided in Figure 1. These seven graphs illustrate just some of the task selection and switching behaviours exhibited by students. While such a small number (well over 3000 of these session graphs were generated) of these graphs cannot capture the full diversity of students' behaviour, they have been carefully selected to illustrate how students use of some of the more common types of tasks and how they combine these with academic tasks and each other during their self-directed learning sessions. Single and repeat use of tasks (multitasking) can be clearly identified. More specifically, graph (a) illustrates the relatively prolonged use of a *Learning applications* task followed by repeated use of both *LMS* and *Social networking* tasks. Graphs (b), (c), (e), (f) and (g) illustrate a combination of *Recreation* and *Academic* tasks with *Recreation* tasks dominating in graph (f). *LMS* tasks are included in all of the sample graphs, with their proportional contribution varying from minor to dominant. *Communication* tasks (mostly *Social networking* tasks) are represented in five of the seven graphs. Graph (g) illustrates repeated switching between *LMS* and *Social networking* tasks.

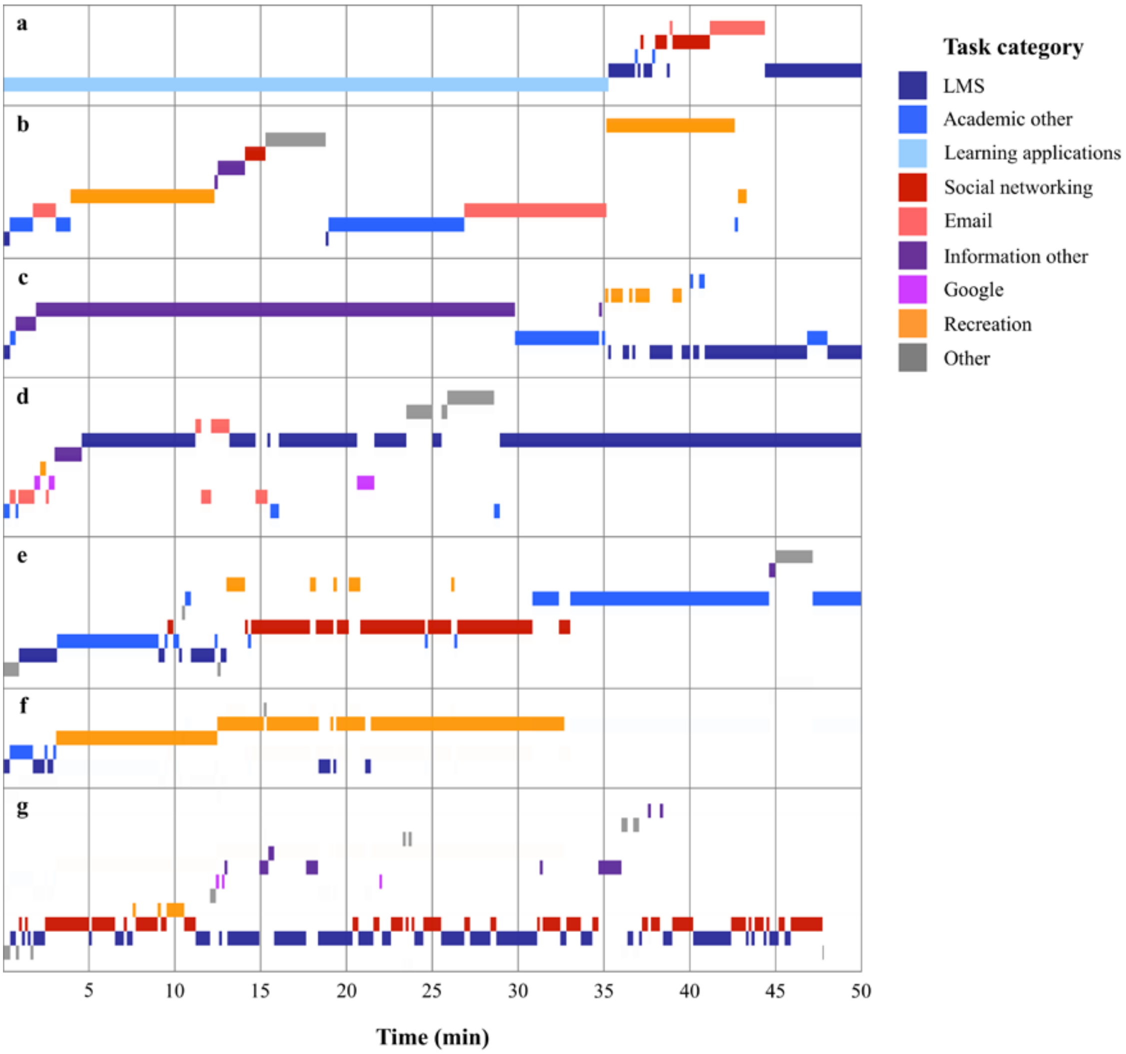

Figure 1. Individual session graphs (a – g) illustrating variation in frequencies of task switching, repeated selection of tasks and combinations of task types and contexts (colour coding).

Note. Each row within the graph represents a task and each block within a row an instance of that task. Multitasking is indicated by at least three blocks in a single row within a 20 minute period. *Academic (other)* category is all Academic tasks except for *LMS* and *Learning applications*. *Information (other)* category is all Information tasks except for *Google* (search).

Inspection of these graphs (and those not presented here) clearly confirms that different categories of tasks are frequently used in combination and these combinations routinely include a mix of *Academic* and non study-related tasks. For example, both *Social Networking* and *Recreation* tasks were approximately twice as likely to be accessed in combination with (i.e. within the same segment) the *LMS* than independently. In fact, this relationship holds true for virtually true for all categories of task when comparing its use with and without the *LMS*.

Task-switching behaviours

Relationships between the various task associations and the three main task-switching behaviours (focused, sequential and multitasking) are explored in Table 3. Results are presented as both percentages and ratios (in square brackets) where the percentages represent the proportion of segments that contain at least one instance of a task belonging to the specified association that are focused, sequential or multitasking. For example, for the *Academic-any* association, 18.1% of the 10033 segments containing at least one *Academic* task (value from frequency column) were classified as focused (containing no more than three tasks). Similarly, of the 3619 segments that included the use of *Facebook*, 73.1% were classified as multitasking (containing one or more repeated tasks). The ratio values are simply the percentage values expressed as a proportion of the overall percentage values for the applicable behaviour (first row of values in Table 3). Thus, the 18.1% focused value for *Academic-any* translates to a ratio of 0.66 (18.1/27.4) and the 73.1% multitasking value for *Facebook* to 1.45 (73.1/50.4). A value of close to 1.0 indicates that the distribution of tasks belonging to that association among segments of different behavioural types is similar to the overall distribution for those behaviours – that is, just over a quarter of all segments are focused (27.4%), just under a quarter are sequential (22.2%) and just over a half (50.4%) are multitasking. Ratio values of less than 0.9 and greater than 1.1 indicate slight under and over representation while ratios of less than 0.7 and greater than 1.3 indicate substantial under and over representation.

The two multitasking columns in Table 3 represent the percentage of all multitasking segments in which at least one of the associated tasks is present (+ column) and the percentage of multitasking segments in which at least one of the associated tasks is accessed at least three times (++ column). Comparing Tables 2 and 3 reveals that the number of segments containing *Learning applications* is higher than the number of *Learning applications* task instances, which seems anomalous. However, *Learning applications* were often used exclusively for relatively long periods and because of this single task instances sometimes crossed two or more segment boundaries, and consequently were ‘counted’ two or more times. The greater duration of *Learning applications* tasks also meant that their use was more often associated with focused behaviour – almost half of all segments that involving the use of a *Learning application* were focused. *Applications* tasks, other than *Learning applications*, were also more likely to be associated with focused behaviour than *Communication*, *Information* or *Recreation* tasks but this is at least partially due to the use of a single helper application – *Flash player* (65.1% focused) – which was used to access a series of popular pathology resources. The behaviour profile of the *Flash player* application is therefore much more in line with *Learning applications* tasks than with other *Applications* tasks.

Fewer than 1 in 10 segments that contained a *University* task were focused (Table 3). While this is low relative to *Learning applications*, and similar to that for *Word* (10.4%) it is more than double that for *Communication* or *Recreation* tasks (4.5%), and almost four times that for *Information* tasks (2.6%). Fewer than 1 in 50 focused segments contained *Email* tasks (1.7%) and *Search* tasks were almost never associated with focused segments (0.5%).

The proportion of segments that were sequential was remarkably consistent across most task associations, with ratios for this behavioural type typically falling between 0.9 and 1.1. Only a few associations were slightly under-represented in this category, *Helper* applications (0.86) and *Unimail* (0.86), and only *Flash player* was substantially under-represented (0.68). *Academic* associations were slightly over-represented in this category, with *LMS* returning the highest ratio value (1.20).

Multitasking behaviour was either slightly or substantially over-represented, in 20 out of the 26 associations listed in Table 3. The exceptions being *Learning applications* (any and specific) and the *Flash Player* application, both which were substantially under-represented, returning ratio values of 0.31 and 0.71 respectively. *Communication*, *Information* and *Recreation* tasks were all substantially overrepresented within multitasking segments, returning ratio values of above 1.4.

The multitasking presence values (+ column) for the primary task associations range from a high of 85.4% for *Academic*, to a low of 32.4% for *Recreation*. The values of specific tasks cover an even larger range, from 69.4% for *LMS* to as low as 1.9% for the *Anatomy* learning application – a more than thirty-fold difference despite an only eight-fold difference in their overall frequencies. The multitasking repeated values (++ column) are also interesting as they suggest that over-representation of an association within multitasking segments is not necessarily accompanied by increased multitasking of one or more of its constituent tasks. This analysis is somewhat confounded by the proportion of segments that involve associated tasks (less common tasks are less likely to be repeated), which accounts for the relatively low overall value (27.9%) when all associations and segments are considered. Nevertheless, there are a number of values here that are worth noting. For example, *Academic* tasks are more likely to be used repeatedly during multitasking segments – with one clear exception. While the proportion of multitasking segments in which five of the six *Academic* task associations include a repeated task varies between 51.9% (*LMS*) and 68.0% (*Pathology*) the equivalent value for the *Anatomy* learning application is only 24.6%. This indicates that *Anatomy* is strongly under-represented both within multitasking segments and as a repeated task. Other interesting results include:

- The *Finder* application is overrepresented by around 30% within multitasking segments but is itself a repeated task in only one in five of these segments. This contrasts with the *Word* application, which is over-represented in multitasking segments by almost 50% and is a repeated task in two out of three multitasking segments in which it occurs.
- Multitasking ratio values are similar for *Social networking* and *Email* tasks (1.45 vs. 1.51), yet *Social networking* tasks are much more likely to be accessed repeatedly within multitasking segments that they occur in than are *Email* tasks (59.3% vs. 38.5%).
- *Search* tasks are most commonly associated with multitasking segments (77.2% of segments that include *Search* tasks are multitasking) but fewer than 40% of those segments include repeated use of *Search* tasks.

Table 3.
Relationships between established task associations (see Table 1) and task-switching behaviours.

Association			**Freq.**	**Behaviour**			**Multitasking**	
Primary	Secondary	Specific		Focused	Sequential	Multitask	+	++
any			13350	27.4	22.2	50.4	-	27.9
Academic	Any	–	10033	18.1 [0.66]	24.6 [1.11]	57.3 [1.14]	85.4	66.2
	University	–	8365	9.6 [0.35]	26.5 [1.19]	64.0 [1.27]	79.5	62.1
		LMS	6167	8.1 [0.29]	26.7 [1.20]	65.2 [1.29]	69.4	51.9
		Library	787	3.9 [0.14]	23.9 [1.08]	72.2 [1.43]	8.4	62.3
	Learning applications	–	2081	47.8 [1.75]	23.4 [1.05]	28.8 [0.57]	8.9	54.0
		Pathology	969	43.3 [1.58]	20.8 [0.94]	35.8 [0.71]	5.2	68.0
		Anatomy	784	57.9 [2.12]	26.0 [1.17]	16.1 [0.32]	1.9	24.6
Applications	Any	–	7905	20.2 [0.74]	20.7 [0.93]	59.1 [1.05]	69.4	58.5
		Finder	3156	9.8 [0.36]	23.3 [1.05]	66.9 [1.33]	31.4	20.3
	Helper	–	6531	19.9 [0.73]	19.0 [0.86]	61.1 [1.21]	59.2	64.1
		Preview	2969	5.1 [0.19]	18.3 [0.82]	76.6 [1.53]	33.8	48.4
		Word	2104	10.4 [0.38]	15.2 [0.68]	74.4 [1.48]	23.3	68.8
		Flash Player*	1068	65.1 [2.38]	19.2 [0.86]	16.6 [0.31]	2.5	64.3
Communication	Any	–	5774	4.5 [0.17]	22.7 [1.02]	72.7 [1.44]	62.4	57.0
	Social networking	–	3806	5.3 [0.19]	21.8 [0.98]	73.0 [1.45]	41.3	59.3
		Facebook	3619	5.0 [0.18]	22.0 [0.99]	73.1 [1.45]	39.3	59.5
	Email	–	3314	1.7 [0.06]	22.1 [0.99]	76.3 [1.51]	37.6	38.5
		Hotmail	1452	1.9 [0.07]	21.4 [0.96]	76.7 [1.52]	16.5	35.0
		Gmail	754	1.5 [0.05]	21.0 [0.94]	77.6 [1.54]	8.7	40.9
		University	1477	1.1 [0.04]	19.2 [0.86]	78.3 [1.58]	17.5	28.3
Information	Any	–	5629	2.6 [0.09]	24.1 [1.08]	73.4 [1.45]	61.3	48.8
	Search	–	2843	0.5 [0.02]	22.4 [1.01]	77.2 [1.53]	32.6	37.7
		Google	2793	0.5 [0.02]	22.3 [1.00]	77.2 [1.52]	32.0	37.3
	Reference	–	2099	3.5 [0.13]	22.2 [1.00]	74.3 [1.47]	23.2	37.8
		Wikipedia	1666	3.5 [0.10]	22.7 [1.02]	73.8 [1.46]	18.3	37.8
Recreation	Any	–	2941	4.5 [0.17]	21.4 [1.02]	74.1 [1.47]	32.4	45.3

Note. Frequency values are the number of segments containing at least one instance of a task belonging to the association. Non-bracketed values in behaviour columns are the percentage of segments containing at least one constituent task of the association that are focused, sequential or multitasking. Bracketed values are these same values expressed as a proportion of the overall percentages for the relevant behaviour (first row of data in table). Values larger than 1.1 indicate over-representation and below 0.9 under-representation. Multitasking columns are percentages and represent the proportion of all multitasking segments in which there is at least one instance of a task belonging to the association (+ column) and the proportion of multitasking segments that include a task or tasks belonging to the association in which at least one of those tasks is repeated (++ column). * Flash player is included in the Applications category but is more closely aligned with the Learning applications category (see section 3.3).

Discussion

Task frequencies and durations

Task durations in this study were consistently low. With the exception of *Learning applications*, all task associations had median task durations of 45 seconds or less. *Learning applications* tasks were maintained for much longer, a median of 185 seconds, but even this indicates that students typically spend no more than a few minutes on task. While there are few comparable studies available, this is considerably shorter than previously reported task durations, with students switching tasks on average every 5.1 minutes in a study based on the self-reported behaviour of information system students (Benbunan-Fich, Adler, & Mavalova, 2011), and every 5.6 minutes based on observations of education students (Rosen, Carrier & Cheever, 2013).

Study-related tasks are very common and tend to dominate students' independent study sessions, although not all are necessarily associated with students' core learning activities. At our university, and presumably in many others, learning content and resources are usually distributed via a centralised learning management system (*LMS*), which in conjunction with the institution's library, mediates access to a wide selection of online resources, such as lecture notes and recordings, journals and text, academic databases and specialised resource collections. Our university's *LMS* was easily the most common specific task association accessed by students in this study (15.9% of task instances, see Table 2). *Library* usage was low (1.9% of task instances), and much less common than other university related tasks (7.5% of task instances) or other external *Academic* tasks (5.4% of task instances). *Information* seeking and gathering tasks that could not be expressly linked to academic study accounted for an additional 17.2% of all tasks. Unfortunately, without a deeper analysis of the content associated with these tasks, which could for example, include parsing out the specific topics associated with *Wikipedia* page visits or the search terms associated with *Google* search requests (e.g., Judd & Kennedy, 2011), it is impossible to accurately apportion individual *Information* tasks between academic and personal use. The low frequency of *Library* use is concerning, particularly given that many of the users in this study (medical and biomedical students) are expected to access and use scholarly information. However, this isn't an entirely unexpected result and is consistent with previous findings (Judd & Kennedy, 2011; Kennedy & Judd, 2011). It also suggests that students aren't necessarily information literate and that we should actively assist and encourage them to develop and implement appropriate information seeking strategies.

Communication tasks are also likely to comprise a mix of personal and study-related exchanges, but again it is difficult to accurately apportion them one way or another based on the available data. While the overall proportion of students using Facebook is very high (Smith & Caruso, 2010), and many use it on a daily basis (Dahlstrom, deBoor, Gunwald, Vockley, & Oblinger, 2011), academic use of Facebook may account for only a small component of this (Selwyn, 2009). According to an Australian study (Gray, Annabell, & Kennedy, 2010), just over 25% of surveyed medical students who used Facebook reported that they had used it for educational purposes at least once, while in a UK study, 10% of students reported using Facebook to discuss academic work with other students on a daily basis (Madge, Meek, Wellens, & Hooley, 2009). However, actual academic use, as against reported academic use, may be much lower, with a content analysis of over 68000 Facebook posts by over 900 UK students revealing than only 4% were related to study (Selwyn, 2009). There appears to be little if any reliable data on the relative use of email for personal versus academic purposes. However, according to Vrocharidou and Efthymiou (2011), students perceive email to have a higher academic and lower social utility than social networking services, in which case informal academic use of email is likely to be higher than it is for Facebook. Email is also much more likely to be used by institutions, and preferred by students, to support formal academic communication (Dahlstrom et al., 2011; Dahlstrom, 2012). Whether this combination of formal and informal academic use amounts to just a few percent or a large component of students' overall email use remains unclear.

Recreation tasks are perhaps the least relevant to students' learning activities. Although relatively common and diverse (more than 40% of all unique tasks were recreation related) *Recreation* tasks accounted for only 8.8% of task instances and just 7.3% of the cumulative session time. Given previous reports of relatively high frequencies of off task media use, in classrooms or lectures (Krushaar & Novak, 2010; Gehlen-Baum & Weinberger, 2012) or during independent study (Brett & Nagra, 2005; Rosen, Carrier & Cheever, 2013) this seems quite low. However, it assumes that all tasks other than those in the *Recreation* category are study related, which is unlikely. If instead we adopt a more realistic set of assumptions (based on the values provided in Table 2) that none of the *Recreation* and *Other* categories of tasks and only around half of *Applications, Information* and *Communication* tasks are study related then the overall proportions of non study related tasks and time on task rises to around just over 40%. Adopting higher and lower estimates of 75% or 25% study-related use for *Applications*, *Information* and *Communication* tasks suggests that the value for non-study related use of falls somewhere between 25 and 55%. The lower value is consistent with an earlier study by Brett and Nagra (2005), which similar to this study, was based on observations of students computer use in a shared on-campus learning space. However, unlike this study, Brett and Nagra's study predates the widespread adoption and frequent use of Facebook and other social media tools.

Off-topic computer and media use during study could be expected to be even higher at home, although the (limited) available evidence doesn't necessarily support this. According to a recent study (Junco, 2014), which like this one uses software agents to capture students' actual computer-based application and online use over time, students spent an average of 14 minutes per day on their LMS, 12 minutes using word processing software and 8 minutes using search and reference tools – a total of 34 minutes per day. Social media and email use accounted for an additional 37 minutes per day and games a further 12 minutes per day. Assuming that all word processing and search and reference use was study related as was half of all social media and email produces an estimate that approximately one third of computer use is not related to study. Again, this rises to as high as 50% if we assume lower rates of study-related social media and email use. Similarly, Rosen, Carrier and Cheever (2013) estimated, based on 15 minute observations of students studying in their own homes, that approximately one third of students' study time was spent off task. While each of these studies adopts different methodologies and metrics of task use, the results appear consistent enough to suggest that at somewhere in the order of one third of the time that students allocate to independent study involves non study-related or distracting tasks.

As previously mentioned (section 3.2), the ratio of combined to independent use of various task categories and the *LMS* is surprisingly consistent (approximately 1:1). If the *LMS* acts as the students' primary task in most situations then this suggests that its use, and by implication the fact that the student is engaged in study-related activities, does not appear to unduly inhibit or influence their selection, initiation or continued use of secondary or distracting tasks. This seems to fit with previous studies of laptops use during lectures, where students frequently attend to other, often non study-related, tasks. For example, in a 2010 study of undergraduate business students (Kraushaar & Novak, 2010), users accessed an average of 65 tasks (windows) per lecture, of which 65% were classified as distractive (not related to the lecture material) and distractive tasks were active for 42% of the lecture time – which is in line with the estimates for off-topic task use in this study. However, estimates of off-task laptop and smartphone use during lectures do vary considerably, with recent results ranging from as high as 84% (Gehlen-Baum & Weinberger, 2012) to as low as 16% (Aguilar-Roca, Williams, & O'Dowd, 2012).

Task switching behaviours

Multitasking by students during their independent study sessions was very much the norm, occurring in around 70% of all session segments. The clear exception to this was when students used a series of *Learning applications* (multimedia resources) that dealt with specific biomedical domains or issues – session segments including these tasks tended to be dominated by focused behaviour. The tendency towards focused behaviour when using *Learning applications* is interesting because although it represents a preferred study behaviour, these rich multimedia resources appear to have become less popular with both our students and teaching staff in recent years. As with game-based learning (Gros, 2007; Pivec, 2007), the intention of these applications is to address problematic learning issues by combining rich media content with meaningful and engaging interactive learning tasks (Herrington & Oliver, 1997). Supporters of game-based learning argue that learners who are deeply engaged are more likely to experience *flow* – a state in which the user is fully immersed and absorbed in their current activity, and tends to be less aware of and responsive to external events or stimuli (Csikszentmihalyi, 1990; Chen, 2007) – the implication being that these learners are more likely remain on-task for extended periods. Learning activities that are highly engaging and potentially stimulate the development of flow are therefore likely to reduce students' tendency to task switch and multitask, which fits with our observations of students' use of *Learning applications*. However, we more typically focus on delivering, and students on accessing, relatively simple online resources, such as lecture notes and lecture recordings. Just as interactive gaming and multimedia environments are specifically designed to promote engagement, a preponderance of non- or low- interactivity resources may have the reverse effect (Kennedy, 2004). A consistent lack of interactivity and engagement can increase a student's likelihood to frequently switch tasks and multitask (Adler & Benbunan-Fich, 2013) and there is good evidence that this can negatively impact on both learning effectiveness and outcomes (Wood et al, 2012; Junco, 2012; Junco & Cotton, 2012).

Task switching and multitasking were particularly common when *Communication* or *Search* tasks were involved. *Search* tasks were so strongly associated with task switching and multitasking that only 1 in 200 session segments that included a *Search* task was focused, while the equivalent figure for *Email* was 1 in 60. Previous research suggests that a relatively small proportion of students who use *Facebook* tend to do so more or less exclusively over extended periods during independent study sessions (Judd, 2014), which fits with the data from this study (1 in 20 segments including *Facebook* are focused). *Email*, it seems, is rarely used in this way. However, not all task switching and multitasking, and particularly that associated with *Communication* or *Search* tasks, is either detrimental to or inconsistent with preferred or expected learning behaviours. Academic searching necessarily involves frequent task switching, and may include a range of different task types and domains, as students alternate between reviewing and assessing their search results and refining their search terms. Similarly, regular and effective online communication is increasingly a part of routine learning activities and practices. For example, when researching an assignment, a student's actions might include accessing the assignment and associated resources via their institution's *LMS*, searching for and accessing online information and resources (*Google* or *Library* search, *Wikipedia*), creating or editing their notes (*Word*) and seeking advice or exchange information and ideas with fellow students and staff (*Facebook* or *Email*). Regular and repeated switching between these tasks can be part of a normal study process. The natural frequency of task switching and multitasking will therefore be increased or decreased and the negative impacts of frequent task switching on learning exacerbated or ameliorated depending on the type and context of tasks and whether these are associated with students' active learning goals. Learning outcomes are most likely to suffer when switches are unnecessarily frequent and/or involve the use of unrelated or distracting tasks. Given that the overall median task time for our students was only 31 seconds and non study-related tasks probably account for between one third and one half of all tasks, that may well be the norm rather than the exception.

Limitations of the study

The age of the data (collected in 2009) is an obvious limitation of the study. Some notable changes in the way that students use and access technology have occurred since then – particularly with respect to social media and mobile devices – and an analysis of more recent data would certainly have been preferable. However, at our institution (and presumably others) the ability to easily collect these types of data has been lost as the university has shifted its emphasis from the central provision of shared computing facilities to a BYOD (bring your own device) model that encourages students use their own laptops, tablets and smartphones and to wirelessly access learning and other content from anywhere on campus. Collecting detailed usage data from large numbers of personal devices is extremely difficult – both practically and ethically – effectively limiting us to an analysis of an older dataset. Nevertheless, the study's key findings are important and remain relevant as there is little or no evidence to suggest that students' task selection and switching behaviours have fundamentally changed in the last few years. In fact, we would argue that the changes in social media and mobile device use that have taken place since 2009 are more likely to have increased than decreased students' tendency to switch tasks and attend to distracting tasks, in which case this study may well underestimate the possible impact of these behaviours on students' study habits and learning outcomes. Facebook may be more widely used by current students to support their learning than in 2009 (most of our current medical students belong to at least one

Facebook study group) but it is still one of their key personal and social communication tools. Many are also likely to be regular users of other popular social media tools (e.g.Twitter, Instagram and Snapchat). Mobile devices distract users with regular notifications and make it extremely easy to switch between tasks. Many students routinely use two or more devices simultaneously.

We must also acknowledge that an element of subjectivity was inevitably involved in classifying tasks that were not unambiguously associated with one of the predefined contextual categories (see Table 1). Similarly, an implied context of use of a task (defined by its classification) might not always match its actual context of use. All efforts were made to minimise the first issue during the classification process (see section 2.3) while the sheer scale and scope of the dataset mean that it is almost impossible to avoid at least some instances of the second issue during analysis. Examining sequences of tasks (see Figure 1) might provide some additional information about the context of use of individual tasks – based on the makeup of previous and subsequent tasks. Analysis of sequential data can be complex, however, and is well outside the scope of this study.

Conclusions and implications of findings

This study confirms previous findings that task switching and multitasking by students involving digital devices are extremely commonplace. It also adds to a small but growing body of research based on physical or electronic observations of device use (e.g. Rosen, Carrier & Cheever, 2013; Krushaar & Novak, 2010), that the frequency with which students switch tasks is very high and that students routinely stay on task for no more than a few minutes at a time. Such high frequencies of task switching have the capacity to disrupt the encoding of memory (Foerde, Knowlton & Poldrack, 2006; Trafton & Monk, 2007), potentially reducing the effectiveness of learning. Based on our estimates, up to half of students' independent study time is also spent engaged in personal or recreational tasks. According to Hanson, Drumheller, Mallard, McKee and Schlegel (2010), students spend roughly the same amount of time engaged in independent study as they do actually attending classes. If students' in-class time also includes the use of mobile devices for personal or recreational use (e.g. Krushaar & Novak, 2010; Gehlen-Baum & Weinberger, 2012), or they skip attending lectures in favour of accessing online lecture notes or recordings during independent study (Traphagan, Kucsera, & Kishi, 2010; Williams, Birch & Hancock, 2012; Gupta & Saks, 2013), then the efficiency of many students' study routines seems questionable, even from a simple time management perspective. However, if we combine the distracting and disrupting effects of non study-related tasks with the negative cognitive impacts of rapid task switching then the multitasking driven learning behaviours we describe may well be restricting students' capacity to learn.

Time is precious to many students as they juggle work, personal, social and study commitments. Based on our, and other results, there appears to be substantial scope for students to reclaim and reallocate non-productive study time to other aspects of their lives (more efficient study) and, at the same time, to improve their learning outcomes (more effective study). Digital devices are a key part of today's students' lives and are increasingly integral to their study practices. They offer many affordances to study – the ability to manage multiple tasks is one of these – but these are somewhat undermined by the ease with which distracting tasks can be initiated and switched between. Providing students with a variety of meaningful and engaging independent learning tasks can help reduce the impact of these switches and distractions, and we can undoubtedly do more in this area. However, we should also acknowledge that developing such tasks, and the resources to support them, can be time consuming and costly and that these individual tasks, no matter how engaging, are only ever likely to occupy a fraction of students' independent study time. Greater efficiencies may well be achieved by encouraging students to improve their study habits and better manage their study time. We need to be proactive here, but simply mandating or expecting students to stay on task for long periods and to completely ignore non study-related distractions is unlikely to succeed. Rosen, Carrier and Cheever (2013) outline a series of simple yet effective strategies for students and educators to help minimise distractions. These include taking regular technology breaks and deferring responses to incoming messages. The potential also exists to use technology to help monitor and regulate students' study habits. This could even involve adopting techniques similar to those used to monitor and analyse task contexts and switches in this study. For example, such data could be used to provide real-time feedback to students on how much time they are spending on- and off-task and to restrict or delay access to distracting tasks during independent study.

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