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Information Technology and Knowledge Worker Productivity: A Taxonomy of Technology Crowding

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INFORMATION TECHNOLOGY AND KNOWLEDGE WORKER PRODUCTIVITY: A TAXONOMY OF TECHNOLOGY CROWDING

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Abstract

This paper explores unintended consequences of information technology use on knowledge worker productivity in the workplace. Drawing upon economics principles and theoretical frameworks of bounded rationality, task-technology fit, and human interruption theory, we propose a taxonomy of technology crowding which is a phenomenon that occurs at the point in which more technology usage which otherwise improved productivity has reached the point of diminishing marginal returns. This shows that more technology does not always lead to increased productivity and can sometimes, in fact, be counterproductive. We conducted a preliminary field study of 61 knowledge workers using multidimensional scaling techniques to empirically develop and validate the taxonomy. Three salient dimensions of technology crowding were identified: software bloat, information overload, and communication overload. The findings provide initial evidence and an understanding of unintended outcomes of technology use on knowledge workers and offer interesting implications for managers to effectively deploy technology tools to boost their knowledge workers' productivity.

Keywords: Information Technology, Knowledge Workers, Productivity, Economics Principles, Bounded Rationality, Task-Technology Fit, Human Interruption Theory, Technology Crowding

INFORMATION TECHNOLOGY AND KNOWLEDGE WORKER PRODUCTIVITY: A TAXONOMY OF TECHNOLOGY CROWDING

Introduction

Firms continue to invest heavily in computer-based technologies such as electronic communication tools, decision support systems, and business intelligence tools to improve the productivity of their knowledge workers. One fundamental assumption behind these investments is that individual users will always make the best use information technologies, and thus, the more technology, the better the productivity. However, the impacts of information technology on individual performance can depend on actual usage (Devaraj et al. 2003); and additional use of information technology, when exceeding the optimum, can even be counterproductive (Aral et al. 2006). Based on economics principles, we propose a taxonomy of technology crowding which is a phenomenon that occurs at the point in which more technology usage which otherwise improved workers' productivity has reached the point of diminishing marginal returns. Drawing upon theoretical frameworks of task-technology fit, bounded rationality, and human interruption theory, three salient dimensions of technology crowding are proposed: software bloat, information overload, and communication overload. Software bloat occurs when a software package becomes too complex for a given task to the point that knowledge workers' productivity is impeded. Similarly, information overload occurs when knowledge workers' time constraints and cognitive limits are reached. Finally, communication overload happens when knowledge workers encounter numerous interruptions due to the over connectivity which prevent them from being their most productive.

We conducted a field study to develop and test this taxonomy of technology crowding using multidimensional scaling techniques. This paper reports the preliminary results from this field survey of 61 knowledge workers about their perspectives on nonproductive and/or counterproductive uses of information technologies at work. The results show an initial support of this taxonomy. Specifically, we found substantial empirical evidence suggesting that knowledge workers' productivity is inhibited due to software bloat, information overload, and communication overload. For instance, 86% of survey respondents reported some forms of communication overload distracting them from their primary job responsibilities (Figure 1). The findings of this study contribute to our understanding of technology use at work with individual-level evidence of unintended outcomes of information technology usage by knowledge workers. It also provides useful insights for managers to improve their practices to boost knowledge workers' productivity.

The paper is structured as follows: Next section reviews relevant literature to develop the taxonomy. The research method including data collection and data analysis approaches is discussed in the following section. This is followed by the study's results and discussion, implications, limitations and future research extensions, and a brief set of conclusions.

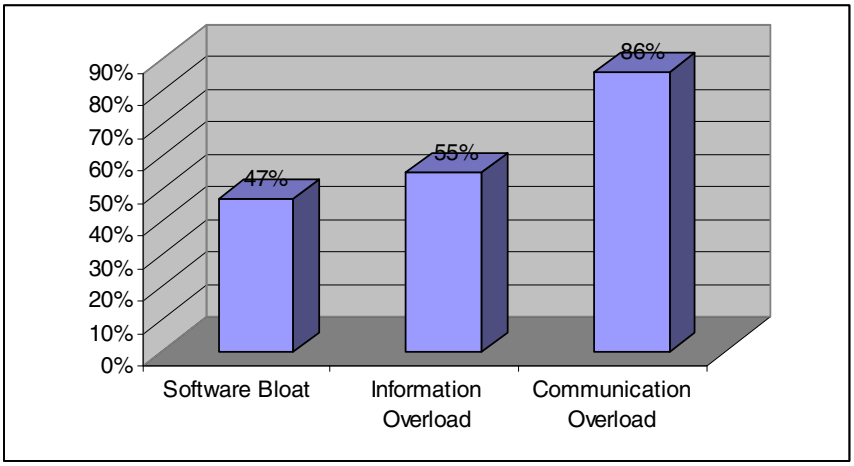


Figure 1 Knowledge Worker Reports of Technology Crowding

Technology Crowding

Theoretical Framework

Knowledge workers are white collared workers engaged in the production, process, or distribution of information, who represent the majority of the US workforce (Aral et al. 2006; Drury et al. 1999). However, prior research found the largest productivity slow down in the service sector; for example, white collared productivity decreased more than six percent from the mid-1970's to the mid-1980's (Dehning et al. 2003). Rooted in economics principles, the law of diminishing marginal returns states that increasing one variable factor while others remain constant, there is a point where the addition of one more unit of that variable will result in a diminishing rate of return and the marginal product will actually decrease (Parkin 1998). A classic example is increasing the number of seeds sown in a parcel of land - the harvest would initially grow in size but at a certain point, any addition of one more seed would create crowding such that the ratio of output to input (or productivity) would fall. Based on this principle, one would expect that technology use, once exceeding the optimum level, can actually incur negative outcomes. In this paper, we label this phenomenon as technology crowding. As illustrated in Figure 2, information technology can be leveraged in a way to confer productivity gains. However, productivity gains would level off and even to the point of becoming counterproductive while technology usage surpassing an optimal level of technology use. For example, a recent study about information, technology, and information worker productivity at the task-level found an inverted-U-shaped relationship between multitasking and productivity – more multitasking enabled by more technologies is found to relate to declining project performance when technologies are used beyond the optimum (Aral et al. 2006).

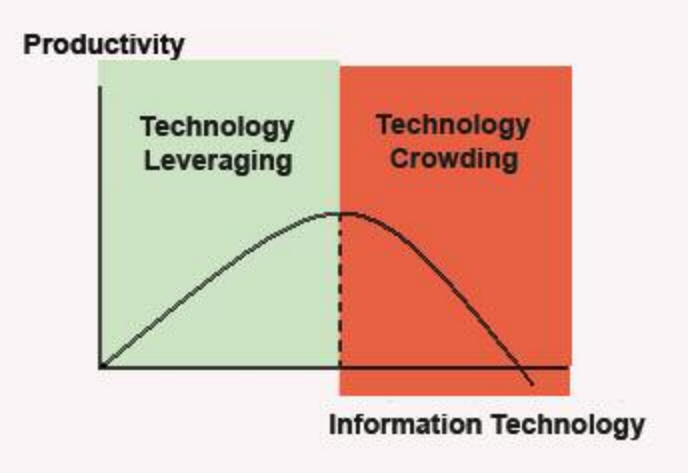


Figure 2 Technology Crowding and the Law of Diminishing Marginal Returns

Three theoretical frameworks support that information technology may not always improve knowledge workers' productivity and it may actually lead to nonproductive or counterproductive outcomes These frameworks include task-technology fit, bounded rationality, and human interruption theory.

Task-Technology Fit

The theory of task-technology fit posits that increased utilization of a system can actually result in poorer individual performance if the technology does not readily support the subset of tasks an individual need to perform (Goodhue et al. 1995). The fundamental argument is that a particular technology must fit the task in order to confer benefits to the user. For instance, one study found that by removing the complex functionality from Word 2000, novice users performed tasks faster and more accurately than users executing the same tasks with the full version (McGrenere et al. 2002). An earlier study with Word '97 found that some users felt "bogged down" by the excessive features that they did not need (McGrenere et al. 2000).

In these cases, the software packages were too complex for the task level required by the users and by better fitting the technology to the task, users were able to significantly improve their performance.

Bounded Rationality

"We do know how the information processing system called Man, faced with complexity beyond his ken, uses his information processing capacities to seek out alternatives, to calculate consequences, to resolve uncertainties, and thereby – sometimes, not always – to find ways of action that are sufficient unto the day, that satisfice," said economics Nobel Prize winner Herbert Simon (Simon 1979). The basic assertion of bounded rationality is that human decision making is subject to the cognitive limitations that constrain all human beings; for example, our total range of categorizing one-dimensional alternatives is between three and fifteen (Agosto 2002; Simon 1955; Simon 1979). Humans can increase this surprisingly small range by adding additional distinctive features to the alternatives, but then our overall judgment accuracy diminishes (Miller 1956). As such, humans tend to make satisficing decisions versus optimal decisions due to their search and information processing capacity. Applying this theoretical framework, prior research has examined the relationship between cognitive overload due to increased use of technological innovations and knowledge worker productivity. Cognitive overload was defined as the cumulative results of stress, distractions, information overload, and multitasking on workers (Iyer et al. 2005). Nevertheless, this stream of research did not establish an unambiguous consistent relationship between cognitive overload and decreased productivity. In this paper, we will apply this theory to study the impacts of information technology on knowledge workers' productivity once technology use reaches the point of saturation (or the optimal level) and produces diminishing marginal returns.

Human Interruption Theory

Cognitive studies suggest that a certain level of interruption can actually improve performance by increasing an individual's focus on the primary task and allowing the individual to multitask However, they have also shown that excessive interruptions affect human behavior by negatively impacting recall, accuracy, efficiency, stress level, and ultimate performance (Cohen 1980; McFarlane et al. 2002; Van-Bergen 1968). Information technologies have remarkably provided ways to enable multitasking, but at the same time, when individuals handle too many tasks simultaneously that their performance will suffer from inevitable interruptions. It is estimated that such interruptions cost the US economy as much as approximately $650 billion a year (Lohr 2007). For example, one study had participants perform a document editing, media viewing, and search task using a computer while exposing them to different levels of interruptions. The study found significant differences across all tasks between low and high levels of interruptions on annoyance, frustration, time pressure, mental effort, and task respect (Adamczyk et al. 2004).

A Taxonomy

Drawing upon the above theoretical frameworks, a taxonomy of technology crowing is proposed. It includes three salient dimensions: software bloat, information overload, and communication overload.

Software Bloat

Software "bloat" often occurs when the addition of new features "is outweighed by the impact on technical resources and the complexity of use." This can happen through "feature creep" and can result in "a reduction in the conceptual homogeneity or intellectual coherence of the product as experienced by the user" (Hsi et al. 2000; McGrenere et al. 2000). This dimension of technology crowding is based on economic principles and the theory of task-technology fit. The cost of ownership of any software package includes maintenance, upgrades, support, and training in addition to the initial purchase price. As software complexity increases, these costs all tend to increase as well (Banker et al. 1993; D'Amico

2005). Software features may follow the law of diminishing returns. Up to a certain point, adding a new feature increases the marginal utility of the software package. However, at a certain point, the software package becomes too complex and an additional feature will work to crowd out existing usability of the software, reducing end user productivity (Hsi et al. 2000). Some have observed that software packages follow the Pareto principle where most users tend to use only 20% of the features of the software while the other 80% go unused (D'Amico 2005). These unused or underused systems cost U.S. businesses millions of dollars each year (Malhotra et al. 2004). As such, a "three-level priority system" was proposed for choosing software based on capabilities needed, including essential, important, and merely useful capabilities; and managers were recommended to focus on the capabilities they need while ignoring all the bells and whistles they never use (D'Amico 2005).

Information Overload

According to bounded rationality theory, information overload occurs when an individual is presented with more information than the individual has the time or cognitive ability to process (Farhoomand et al. 2002; Ho 2001). Prior research identified three dimensions of information overload as information quantity, information format, and information quality; technology use has exacerbated the cognitive limitation of humans through increased information storage, processing, and retrieval capabilities and the advent of the Internet(Farhoomand et al. 2002; Ho 2001). Although the Internet has undoubtedly increased our search capabilities, the vast amount of information available on the Internet can also "hinder efficiency" (Ho 2001). For example, Internet sources often lack credibility, accuracy, and value (Berghel 1997) and participants' web-based search decisions were characterized by bounded rationality due to time constraints and information overload (Agosto 2002). Moreover, the gigantic amount of information produced each year (nearly 2 billion gigabytes of information) can lead to information overload and chaos (Brynjolfsson et al. 1996). A number of studies have found negative impacts of information overload on job performance. For instance, a 1998 Reuters' survey stated that 47% of American managers believed that information overload led to decreased job satisfaction and performance (Ho 2001). A qualitative study of 125 knowledge workers found that information format, accessibility, and quality contributed to productivity constraints (Drury et al. 1999). A more recent study involving 124 managers found that over 50% of the respondents experienced information overload regularly and 72% cited a loss of time as a result. Other negative effects of information overload included "delays, mistakes, and nonperformance" (Farhoomand et al. 2002). In other words, access to information in and of itself has increased knowledge worker productivity. However, information overload is the point at which additional information leads to diminishing marginal productivity of knowledge workers.

Communication Overload

Based on the human interruption theory, communication overload occurs when a third party *solicits* the attention of the knowledge worker through such means as e-mail, instant messaging, or mobile devices. A distinction is drawn between information overload and communication overload that knowledge workers *seek* information and excessive information results in information overload. Studies have shown that knowledge workers are interrupted on average every three minutes since the proliferation of communication technologies such as e-mail, instant messaging, and other distractions while it takes workers nearly eight uninterrupted minutes to regroup for productive thinking (Fried 2005). Work interruption is defined as "a synchronous interaction which is not initiated by the recipient, is unscheduled, and results in the recipient discontinuing their current activity" (Rennecker et al. 2005). Interestingly, a series of 80 clinical studies found that technology related interruptions such as email and text messaging reduced workers' IQ's by an average of 10 points while smoking marijuana leading only to a 4 point reduction in IQ (Hewlitt-Packard 2005). Similarly, a study involving 136 undergraduate students found that work interruptions reduce decision quality and speed (Speier et al. 2003).

Email is the most commonly used computer-mediated tool for organizational communication. In 2005, an estimate of 541 million knowledge workers relied on email as a primary means to communicate in the workplace (The Radicati Group 2005). Individuals have to deal with a large numbers of emails on a regular basis and they are often found overloaded with email communications. For instance, a national survey of 484 white collared workers found that individuals on average received 41 emails, read 32 emails, and sent 21 emails a day (Dabbish et al. 2006). Other studies suggest that knowledge workers send and receive an average of 204 emails a day (Speier et al. 2003). A study of 20 email users in 1996 found that individuals had an average of 2482 emails in their inbox at a given time (Whittaker et al. 1996). A recent survey found that email overload is viewed to contribute to a loss of productivity and a significant decrease in task coordination; and the situation was worse for PDA users (Dabbish et al. 2006). For example, forty percent of respondents spent nearly 25% of their

work day responding to emails (Britt 2006). Spam even exacerbated the overload while spam continuing to increase to 90% of the emails we receive (Mann 2006).

Taken together, the above discussed phenomenon indicates the paradox of technology use – while technology has reduced work delays through automation and speed, it has also created work delays through the introduction of numerous distractions and interruptions (Rennecker et al. 2005). For example, about 85% of North American companies have implemented instant messaging within their organizations (Symantec Corporation 2006); during the second quarter of 2006, there were 6.2 million Blackberry subscribers, almost double the number from the pervious year (Rosman 2006). While these communication tools were designed to increase knowledge worker productivity, overuse of these tools can result in communication overload that would crowd out the expected productivity gains from the use of these tools.

Methodology

Multidimensional scaling technique is useful for generating inductive typologies (Kruskal et al. 1978) and is thus employed to develop and validate the proposed taxonomy of technology crowding in this study. This paper reports the preliminary results that focus on identifying salient dimensions of technology crowding.

Data Collection and Coding

We conducted a web-based field survey of 61 knowledge workers to solicit their perceptions of information technology use and their work productivity. We eliminated incomplete survey responses; therefore, a total of 51 surveys were included in the qualitative analysis. "Snowball" sampling procedure was used (Babbie 2004). Specifically, an email message was sent to a participant with a link to the online survey embedded in the message; participants were asked to forward the email to five other knowledge workers so that a wide range of responses could be collected.

Given the lack of understanding of unintended consequences of technology use and the exploratory purpose of this study, we adopted a qualitative approach with open-ended questions about information knowledge workers' technology usage to generate items and categories of technology crowding. Specifically, we asked knowledge workers to report their use of information technology tools and the situations where they were distracted, interrupted, or overwhelmed by information technologies at their jobs. Examples of questions that were asked included: 1) "What kinds of interruptions do you encounter at work?" 2) "Describe at least 10 ways information technology has distracted you from your primary job activities?" 3) "What are some ways you would improve the software packages that you use at work so that you can be your most productive?" 4) "Describe some ways you are overwhelmed with your job responsibilities and would perform better had you been given better tools to do your job." and 5) "Name some information technologies that were beneficial when they were first introduced into your workplace, but now they hinder you in getting your job done."

We also collected other pertinent contextual information including demographics and background information. We then performed open/template coding based on the taxonomy deducted from theoretical frameworks and created new categories to code responses that did not fit into the predefined taxonomy. We analyzed all the open ended responses across all questions for each respondent to identify instances of reported software bloat, information overload, and communication overload. We measured whether or not each type of technology crowding was or was not reported by each respondent instead of the intensity in which each type of technology crowding was reported. Therefore, when we reported that forty-seven percent of respondents experienced some kind of software bloat (Figure 1), that implies that 24 of the 51 respondents reported issues associated with software bloat. This paper focuses on the preliminary analysis of the survey data and future studies will provide a more granular qualitative coding of the data to further explore this phenomenon.

Sample Characteristics

Eighty percent of the respondents were between 25 and 50 years old. Fifty-two percent of the respondents were male, and 48% of the respondents were female. Figure 3 illustrates the education level of the participants, and figure 4 shows the industry sectors represented in the sample. Participants' job titles included engineers, analysts, managers, accountants, software developers, professors, consultants, and others. Primary job responsibilities included sales, management,

development, planning, educating, design, forecasting, and data processing. On average, the respondents reported spending 6.44 hours of an eight hour work day on a computer with a standard deviation of 1.65 hours.

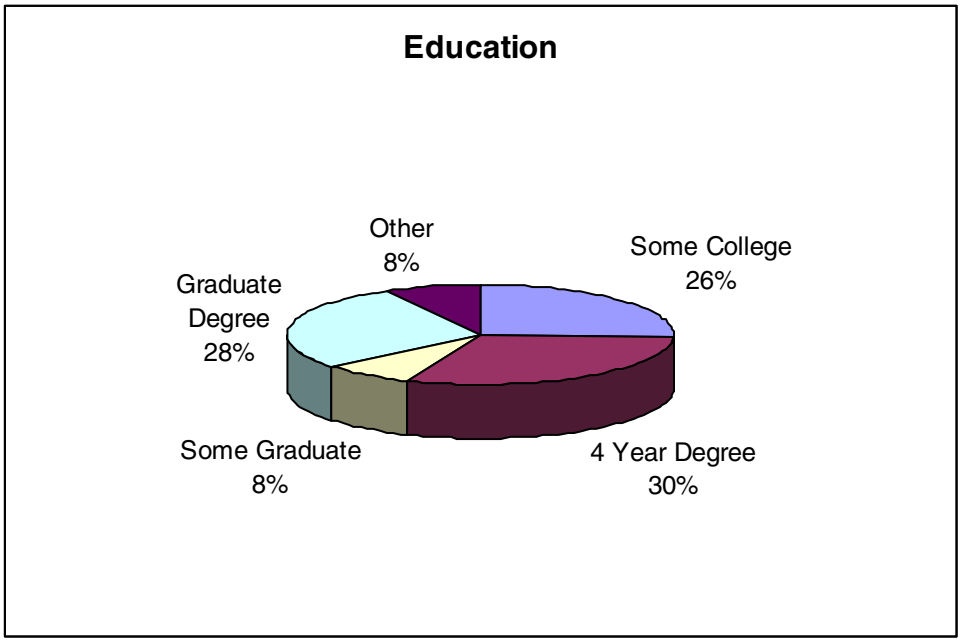


Figure 3 Educational Levels of Knowledge Workers in Sample

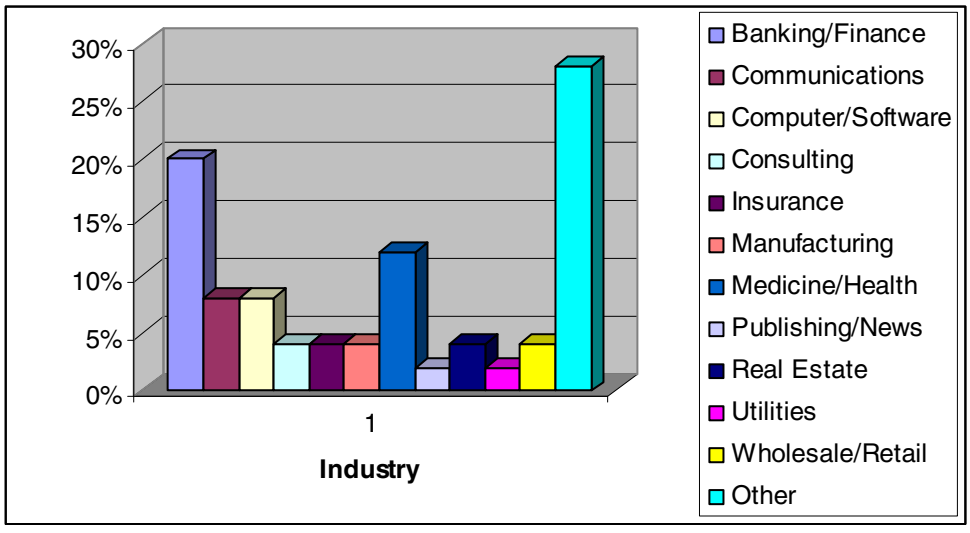


Figure 4 Industry Sectors of Knowledge Workers in Sample

Data Analysis and Results

Communication overload was cited as the primary source of interruption; one should note the distinction between communication overload and information overload because information is sought and communication is solicited. Information overload seemed to correspond most closely to participants' feeling of being overwhelmed as supported by the theory of bounded rationality. Software bloat was most prevalent when respondents were asked specifically answer questions concerning software packages they used to perform their jobs. The following analysis will delineate the support we found for the "technology crowding" taxonomy.

Software Bloat

Forty-seven percent of survey respondents dealt with issues of software bloat or lack of task-technology fit in doing their jobs. None of the respondents specifically referred to software bloat as a means of distraction, but they alluded to it 24 times in the survey. For instance, respondents commented that they would waste time "playing" or "mucking" around with various software packages. They also complained about pop-up reminders acting as a distraction to their work. For example, an IT project analyst reported, "Microsoft's programs in general are too 'user friendly' for me and it can get annoying to use some of the programs after a while." In general, respondents complained about software design, compatibility issues, and ease of use along with the delays associated with constant software upgrades. A contract manager suggested that "some IT systems are poorly designed and are foisted upon employees because management likes them." An Architect described frustration with how software tools kept getting more complex: "Tools are fine, maybe quit adding on to them to slow the processing down or having to upgrade." Others described problems where the technology was not a good fit for the task. For instance, a Broker commented, "Top Producer is my contact management software. It isn't exactly intuitive even for me as a former IT professional." Further, respondents also reported that some technologies were initially useful but have become a hindrance to productivity later on. For example, one IT Project Analyst said, "Outlook was pretty handy in the beginning in being able to email pretty much anyone in the organization and get a response fairly quickly, but Outlook has its set of quirks and can be fairly cumbersome to use after a while to perform certain, seemingly simple, tasks." A Director of Systems Architecture commented that Microsoft Office products are "too helpful." A Web Developer answered, "Frontpage. Good when it was the only option but now it hurts. Same with Word, they've made it handle too many things but not really well." These comments suggest that knowledge workers initially benefited from productivity gains through technology tools, but software bloat has lead to diminishing marginal returns in their overall productivity at job.

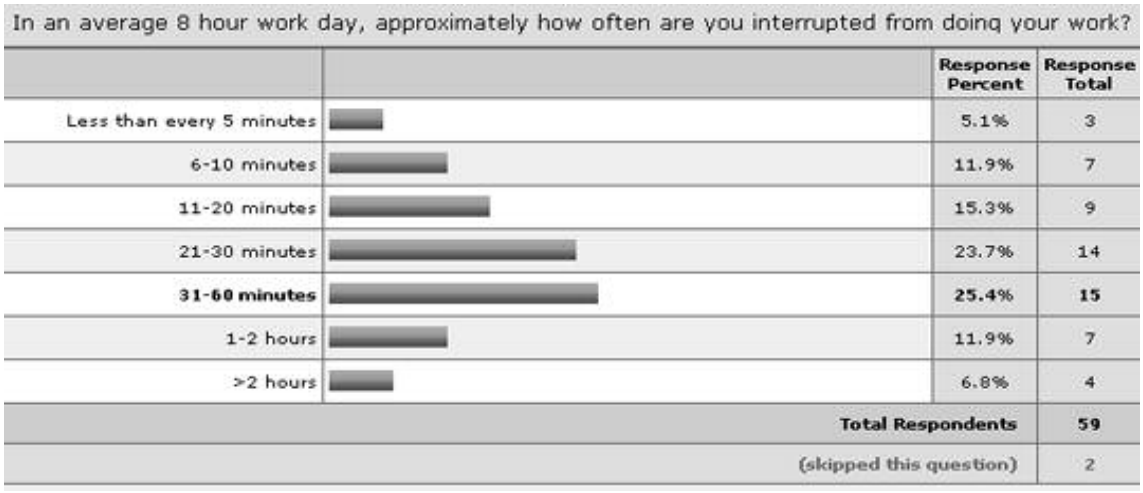
Information Overload

Fifty-five percent of survey respondents reported situations of information overload. Personal uses of the Internet such as blogging, surfing MySpace, or other illegitimate uses of the Internet were not included in this analysis. However, we did find that participants found them distracted by news websites, pop up ads, company intranet websites, web searches, and web browsing. A Data Manager said that there was "more information than I really need, so [I] read extra," and that he or she was "not finding info I need easily." Some respondents mentioned that they were asked to produce extraneous reports or were overloading by having to track new technologies. Participants seemed to have a hard time efficiently browsing the web for information that was pertinent to their primary job responsibilities because they had to filter through irrelevant information or were distracted by links taking them away from websites that were relevant. Participants also showed signs of bounded rationality through complaints such as, "'Not enough time to complete all tasks," too high expectations, and the need for "better knowledge search tools."

Some respondents found that information technology helped gather useful information but later the amount of information became so overwhelming that it became counterproductive. "News gathering things -- at first it seemed like a time saver but then it turned into another time waster," said a Manager. Many of the respondents cited the Internet and Google as sources of information overload because the variety of information available can be distracting and the amount of information available can be overwhelming. "Sometimes too many options are worse than too few." A Director commented that, "too much information leads to analysis paralysis" while a Financial Analyst observed that "sometimes we just have everything coming at us at once and there is no real time for focus."

Communication Overload

Eight-six percent of the survey respondents reported some evidence of communication overload. When respondents were asked how often they felt they were interrupted during work hours, 49.1% reported interruptions between every 21 to 60 minutes (Figure 5). However, when asked what kind of interruptions they encountered, only 29% of respondents mentioned email or instant messaging as source of interruption. Therefore, participants either had few interruptions due to emails and instant messages, or they did not associate them as interruptions. In some cases, respondents left out the means in which communication was handled and just mentioned that they received various interruptions throughout their day.



In an average 8 hour work day, approximately how often are you interrupted from doing your work?

	Response Percent	Response Total
Less than every 5 minutes	5.1%	3
6-10 minutes	11.9%	7
11-20 minutes	15.3%	9
21-30 minutes	23.7%	14
31-60 minutes	**25.4%**	**15**
1-2 hours	11.9%	7
>2 hours	6.8%	4
Total Respondents		**59**
(skipped this question)		2

Figure 5 Work Interruptions

For example, a Director of Strategic Planning said that there are "too many ways for people to interrupt: email, fax, phone, blackberry, etc. . . . too much access overall." Participants described emails coming in as constant, bogus, frivolous, over used, spam, unexpected, unnecessary, random, and illegitimate. There were complaints that employees needlessly carbon copied email recipients on outgoing emails. An analyst commented that "every day we are distracted by emails not intended for business use." Another respondent complained of "constant interruptions pulling you into other tasks," that made it "difficult to work on anything requiring concentration." Finally, an IT Project Analyst said that "email can be very distracting if you're either getting bombarded with email or the email you receive is not very helpful." In additional, numerous chat programs were listed as distractions including IBM Sametime, Yahoo instant messenger, and Microsoft Communicator. These tools were originally thought to have a positive affect of productivity, but "too many business contacts that feel free to contact you at any time. Initially it was a great tool for exchanging info," said an Account Director. Many respondents suggested setting away messages or not even installing chat clients as ways to eliminate distractions. Another communication technology that was often cited as a source of disruption was personal digital assistants. As a response to technologies that were originally helpful and have been counterproductive, a Compensation Specialist said, "Blackberry and Blackberry and Blackberry. Worst technology ever invented. Managers sit in meetings and use their Blackberries and don't pay attention to what's going on in the meetings." In general, most of the participants faced the same challenges with communication technologies because it has become, 'very hard to concentrate on one thing today, because the next minute you are either receiving an email, fax or a phone call," said an Account Manager.

Unclassified Responses

Responses that did not follow the phenomena of interest were also reported but will be considered outside the scope of this research. These included hardware and software performance issues, training issues, and personal uses of information technology outside of work responsibilities. For instance, a possible addition to the phenomena of "technology crowding"

may be "physical exertion." Studies have been done on ergonomics and work place productivity. One study relating bounded rationality to web decision making also found physical limitations of computer users as an upper bound to overall performance. One respondent commented that, "the workload is high, and the performance expectations are very high. Getting a lunch break would be helpful, to relax and recover a bit, but instead the expectation is to press on and juggle everything." We did not include this factor in our taxonomy because it is questionable as to whether this should be considered more of a human factor or a factor that is augmented through technology. Since we did not find adequate support through our empirical evidence, we chose to make mention of this issue and not incorporate it in our framework.

Discussion

Research Implications

The implications of "technology crowding" leading to diminishing knowledge workers' productivity through software bloat, information overload, and communication overload are far reaching. The empirical evidence reported above shows an initial support of the phenomenon that is suggested by economic principles and several theoretical frameworks. For researchers, the findings provide initial evidence of unintended negative consequences of technology use on knowledge workers' productivity at job. More studies can be done to investigate the complimentary effects of software bloat, information overload, and communication overload on knowledge workers. Researchers may identify additional categories to add to the technology crowding taxonomy. Overall, further research in this area is needed and can lead to a good understanding of technology use by knowledge workers at the workplace.

For practitioners, the findings offer useful insights for managers to effectively deploy technologies at workplace as well as to prudently make decisions about technology choices. For instance, managers may invest in lighter versions of software packages instead of complex, bloated enterprise versions with features that will never be used and may even impede knowledge worker performance. On the other hand, they may choose to implement more training with full versions of the software packages to more favorably boost the productivity of their knowledge workers. Similarly, managers may implement knowledge management systems to streamline information retrieval within organizations to reduce information overload. Likewise, it may be beneficial for organizations to shape social norms that discourage PDA use in meetings or outside of normal work hours. In addition, they may create corporate email and instant messaging policies to help knowledge workers manage communication overload.

Limitations and Future Research

Since little research has previously been done to understand the unintended negative outcomes of technology use at work, we proposed a taxonomyof technology crowding to synthesize concepts such as software bloat, information overload, and communication overload into a cohesive framework. A qualitative method was used to induct items and categories using open-ended qualitative data from the population of interest. As with any qualitative analysis, researcher bias could have been introduced. To mitigate this, we tried to include direct quotes from survey respondents to let the readers make educated judgments about the accuracy of our coding. The next step is to conduct quantitative research to further investigate this phenomenon and this study can be extended in several ways. First, the taxonomy will be further refined and validated to generate a conceptualized construct of technology crowding and to develop an instrument to measure the extent of "technology crowding" due to software bloat, information overload, and communication overload. Second, research will be conducted to create a model that incorporates solutions to the different types of technology crowding, and finding accurate ways to measure impacts of technology use on knowledge worker productivity. There are many viable solutions to technology crowding that can mitigate the effects of diminishing returns of technology use on knowledge worker productivity. For instance, Internet developers have tried to combat information overload include infomediaries, search engines, and Really Simple Syndication (RSS) feeds (Berghel 1997; Ho 2001). These approaches attempt to summarize pertinent information for users to so that information can be manageable. As mentioned earlier, software bloat studies have shown that software customization through simplification can increase end user productivity. Personalization may also be a successful approach to reduce software bloat, information overload, and communication overload. Previous studies have found that web personalization agents effectively increase end user decision making (Tam et al. 2006). Once the problem of

technology crowding has been adequately defined and the solutions to the various types of technology crowding have been synthesized, the next goal would be to design empirical studies to test the effects of each type of technology crowding and the interactions between each type of crowding on knowledge worker productivity. The ultimate research goal would be to find strategies to arrive at without surpassing the optimal level of information technology usage to maximize knowledge worker productivity.

Conclusion

Drawing from economics principles and applying theoretical frameworks of task-technology fit, bounded rationality, and human interruption theory we proposed a taxonomy of technology crowding as the underlying explanation of nonproductive and/or counterproductive uses of information technology by knowledge workers at jobs. Technology crowding were found to have three salient dimensions: software bloat, information overload, and communication overload. The preliminary results from a field survey of 61 knowledge workers showed initial support of our proposed taxonomy. We also discussed the implications of this taxonomy of technology crowding for both researchers and managers and suggested some possible directions for future research.

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