國立雲林科技大學
97學年度博士班招生考試試題

系所別：資訊管理系
科　目：資訊科技文獻

請以中文回答下列問題：

第一部份：

Selecting scientific papers for publication via citation auctions

1. 請說明本篇論文的主要論點。(20%)
2. 請說明作者所提的模式如何運作。(15%)
3. 如何處理新模式運作會遇到的問題。(15%)

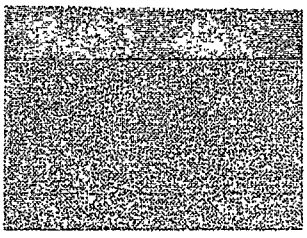
第二部份：

The promise of high-performance reconfigurable computing

4. 請說明本文所提之高效能可重組計算(high-performance reconfigurable computing, HPRC)，是運用何種方式來強化其計算能力。(10%)
5. 本文提到目前之 HPRC 可分成兩種，請說明兩者之間不同及其優缺點。(20%)
6. 請說明「節點層次」及「系統層次」的問題、領域、及所學習到的功課(lessons learned)。(20%)

國立雲林科技大學
97學年度博士班招生考試試題

系所別：資訊管理系
科　目：資訊科技文獻



Selecting Scientific Papers for Publication via Citation Auctions

Josep Lluis de la Rosa, *University of Girona*
Boleslaw K. Szymanski, *Rensselaer Polytechnic Institute*

The scientific community has been suffering from peer review for decades. This process (also called *refereeing*) subjects an author's scientific work or ideas to the scrutiny of one or more experts in the field. Publishers use it to select and screen manuscript submissions, and funding agencies use it to award research funds. The goal is to get authors to meet their discipline's standards and thus achieve scientific objectivity. Publications and awards that haven't undergone peer review are often regarded with suspicion by scholars and professionals in many fields. However, peer review, although universally used, has many drawbacks.

We propose replacing peer review with an auction-based approach: the better the submitted paper, the more scientific currency the author will likely bid to have it published. If the bid correctly reflects the paper's quality, the author will be rewarded in this new scientific currency; otherwise, the author will lose this currency. We argue that citations are an appropriate currency for all scientists.[1] We believe that citation auctions will encourage scientists to better control their submissions' quality. It will likely also inspire them to prepare more exciting talks for accepted papers and to invite discussion of their results at congresses and conferences and among their colleagues. In the long run, citation auctions could have the power to greatly improve scientific research.

Peer review's drawbacks

While some believe that passing peer review is a certificate of validity, others are far more skeptical. One of the most common complaints is that peer review is slow: a submitted paper typically takes several months, or even years in some fields, to appear in print. Such a delay in a fast-growing field is devastating for the propagation of ideas and needs a solution. Another major drawback is its cost in terms of hours of volunteer work devoted to refereeing.

In addition, some sociologists of science argue that peer review makes publication susceptible to control by elites and to personal jealousy. Peer review might suppress dissent against "mainstream" theories. Reviewers tend to be especially critical of conclusions that contradict their own views but happily accept those that accord with them. At the same time, elite scientists are more likely than less established ones to be sought as referees, particularly by high-prestige journals or publishers. As a result, some argue, ideas that harmonize with the elite's views are more likely to be published and to appear in premier journals than iconoclastic or revolutionary ideas. Consequently, the whole process obstructs and delays the emergence of new ideas and scientific revolutions.

However, others have pointed out that scientists have many journals in which to publish, making control of information difficult. In addition, peer review's decision-making process, in which each referee gives an opinion separately without consulting others, is intended to mitigate some of these problems. Nevertheless, this process still doesn't address the cost of peer reviewing and publication delays.

Moreover, peer review tends to accept those weaker papers that have a mix of prestigious and unknown authors. This is because referees typically trust a paper with prestigious authors even if they don't fully understand its contributions, believing that "this must be true, must be good, and the final submission will address any potential drawbacks." This might not systematically be bad, but there are more elegant ways to give opportunities to new authors. For the sake of improving the quality of science, this trust in important coauthors should be reduced. Blind peer review, one possible way to deal with this problem, is still an imperfect solution because it doesn't decrease the cost of reviewing or publication delays.

Citations and their auctions

According to Philip G. Altbach, director of Boston College's Center for International Higher Education, the citation system was invented mainly to understand how scientific discoveries and innovations are communicated and how research functions.[2] On the basis of our research on the innovative use of auctions,[3,4] in May 2006 we considered using this approach to create an alternative to peer review.[5,6] Conferences often suffer from low participation

Some Alternatives to Peer Review

In some fields, such as astronomy, much of the communication about new results no longer takes place through peer-reviewed papers but through preprints submitted to electronic servers such as arXiv.org.

The recently launched online journal *Philica* (www.philica.com) exemplifies one new way to redress many of peer review's problems. Unlike a traditional journal, it immediately publishes all submitted papers; review takes place afterwards. Reviews are still anonymous, but instead of an editor choosing the reviewers, any researcher who wishes to can review an article. Reviews appear at the end of each paper, thus giving the reader criticism or guidance about the paper instead of determining whether it's published. This means that reviewers can't suppress ideas with which they disagree.

Some authors (for example, Stefano Mizzaro[1]) suggest scoring papers and authors, letting readers act directly as referees, and receiving feedback on whether the readers provided good-quality judgments. So, good readers would earn good reputations.

Reference

1. S. Mizzaro, "Quality Control in Scholarly Publishing: A New Proposal," *J. Am. Soc. Information Science and Technology*, vol. 54, no. 11, 2003, pp. 989–1005.

and little discussion of the presented papers, because authors focus on getting their papers to the conference rather than widely disseminating their results. Moreover, organizers extend extraordinary effort selecting the best conference paper, thus creating a heavy refereeing workload. To avoid these pitfalls, we propose an auction system combining citation's predictive value with authors' intimate knowledge of their papers. (For other alternatives to peer review, see the sidebar.)

We can characterize the situation as follows. Nowadays, a scientist wants to publish his or her results in conferences and journals to gain citations and reputation. As evidenced by the acceptance rates, highly ranked and read conferences and journals select only a small number of submitted papers—hopefully, those that will generate the most citations. In our approach, conferences and journals hold an auction to select those papers whose authors have bid the highest. Each bid represents an author's prediction of how many citations that paper will receive. To make this bid trustworthy, we consider the number of citations an author has received for previously published papers as that author's *citations wallet*—the amount of "cash" the author possesses. So, the number of citations in authors' wallets limits their bids, and every auction-winning paper withdraws a number of citations from its authors' wallets.

So, what should the wallet contain? Citations from one conference that has accepted a paper by the author? Citations from a group of related conferences? Citations of all the author's papers? We use the citations from either a group of conferences or all the author's papers. This lets an author collect citations in weaker conferences to get into stronger ones or into a journal. Consequently, rational authors will bid the highest number of citations they think acceptance will require, but to the limit of their wallet's cash (that is, their past performance). Authors might lose cash if their winning bid exceeds the number of citations the paper will generate. Conversely, they might win more cash if the published paper generates more citations than they bid. An author's ultimate goal will be to keep his or her wallet growing.

Our approach has two main benefits. First, it reduces refereeing costs because paper selection via a citation auction doesn't need prior understanding of the paper's content to evaluate its quality. Second, authors will be much more committed to their papers' quality. They will also focus much more on wide dissemination and detailed explanations of their papers to maximize the number of citations. In short, this novel approach emphasizes active promotion of ideas while reducing peer review's high expense.

We're fully aware that making this idea workable involves challenges. Here we discuss the three most important ones.

First, if each author receives credit for all citations to the paper, we'll have wallet inflation. A paper with five authors, five citations, and a bid of five citations will contribute 25 citations total to all the authors' wallets, but the payment will be just five citations from one author's wallet. To avoid the inflation, each citation will earn one unit of credit for the paper, regardless of the number of its authors. Additionally, we'll assign fractions of each citation to the individual authors according to their "citations contract." This contract might reflect the percentage of each author's participation. If no citations contract exists, all citations will be assigned to the first author, who will then decide how to share them. To encourage collaborations, we also let all the paper's authors contribute their citations to a joint bid. This will solve the inflation problem. Coauthors are often students, so they can build their wallets for a future independent career while working with their advisors on their theses.

The second challenge involves self-references. An author could safely bid a number of citations equal to the number of that author's self-citations in the paper. After the paper's publication, the author would automatically receive the credit for the citations, immediately rebuilding the wallet. To avoid this effect, none of the self-citations or citations of papers by a bid's contributors should be added to the author's wallet.

The third challenge regards the wallet's initial content. We assume that the initial content is zero citations. So, new authors (for example, graduate students) or authors who depleted their wallets via too-aggressive bidding wouldn't even be able to try to get their papers published. To avoid such situations, a certain fraction of papers should undergo peer review, but with much higher acceptance criteria. This will also avoid the problem of the boundary-quality papers, which are difficult and time consuming to evaluate.

Alternatively, authors could receive "sponsorship." For example, when one such author looks for credit, another researcher might loan some citations from his or her wallet (likely after the paper's review and after the lender has suggested improvements). For a supervisor or advisor, the

Table 1. A simulation of four citation auction strategies.*

	No. of citations											
	1999		2000		2001		2002		2003		2004	
Author and paper	Bid	Earned	Bid	Earned	Bid	Earned	Bid	Earned	Bid	Earned	Bid	Earned
Author 1 (aggressive)												
Author 1's wallet	13		13		13		8		7		7	
Paper 1												
Paper 2	0											
Paper 3			0		6	1						
Paper 4							4	3				
Paper 5									1	1		
Author 2 (cautious)												
Author 2's wallet	0		6		7		7		5		3	
Paper 1	2 (loan)	8										
Paper 2	1 (loan)	1										
Paper 3			2	3								
Paper 4			1	1								
Paper 5					2	2						
Paper 6							1	1				
Paper 7							1	0				
Paper 8							1	0				
Paper 9									1	0		
Paper 10									1	0		
Author 3 (very cautious)												
Author 3's wallet	0		0		1		2		2		1	
Paper 1	1 (loan)	3										
Paper 2	1 (loan)	0										
Paper 3			0		1	0						
Paper 4					2 (loan)	4						
Paper 5							1	1				
Paper 6									1	0		
Author 4 (no risk)												
Author 4's wallet	0		0		0		0		0		2	
Paper 1	0		0		1 (loan)	1	0					
Paper 2									1 (loan)	3		

* Blue squares indicate unsuccessful bids.

motivation for a loan is clear: lending part of the prestige represented by the citations in his or her wallet is a kind of investment. Hopefully, the student will eventually return the citations, perhaps with extra citations as interest, which an agreement between the two could formalize. We don't believe that this approach would benefit "bad students with famous supervisors" over "good students with unknown supervisors." That's because a donor system based on one scientist's rational criteria

Table 2. Author rankings generated by classic measures, the H-index, and citation auctions.

Author	Accepted papers	Total citations	Earned citations	Total productivity	H-index	Wallet	Earnings	Bid productivity	Losses
A1	4	18	5	1.25	2 or more	7	–6	–1.50	6
A2	10	16	16	1.60	2	3	5	0.50	0
A3	6	8	8	1.33	2	1	1	0.17	0
A4	2	4	4	2.00	1	2	2	1.00	0
The best	A2	A1	A2	A4	A1	A1	A2	A4	A2, A3, A4
Second best	A3	A2	A3	A2	A2 or A3	A2	A4	A2	A2, A3, A4
Third best	A1	A3	A1	A3	A2 or A3	A4	A3	A3	A2, A3, A4
The worst	A4	A4	A4	A1	A4	A3	A1	A1	A1

should be more efficient than bureaucratic systems based on collectives of scientists who have reached a consensus of what's good or bad. Finally, even unrelated researchers might want to invest their citations in a paper by a promising young talent for a profit of future citations.

It's beyond this article's scope to discuss the citation auction diffusion and promotion mechanism, which requires deep insight into the auction model.[3] Clearly, we'll need a new economic model derived from the citation auction to foresee how auctions increase the quality of research, decrease peer review costs and publication time, and so on.

A hypothetical case

Table 1 represents a possible scenario with a simulation of four researchers using different auction strategies (aggressive, cautious, very cautious, and avoiding all risk). The Bid column indicates an author's bid; blue squares indicate unsuccessful bids. The Earned column indicates the number of citations received by each paper published via the auction. For each year in which a paper was published, the Earned column shows the number of citations that as of May 2006 were made to that paper (to increase realism, we used actual data from a group of conferences). For simplicity, we use a *first-price sealed-bid* auction, where every author submits in a closed envelope a bid stating how many citations he or she is offering. This bid supposes to be lower than the number of citations the author will collect after the paper's publication. Some authors who couldn't bid higher than 0 because their citation wallets were empty borrowed citations from colleagues and paid back the loans from the citation earnings.

To measure papers' impact, we can examine several rankings of authors. The first is the citation wallet ranking, based on how many citations remain in an author's wallet after an auction. In this scenario, author 1 clearly leads with seven citations, followed by author 2 with three citations, author 4 with two, and author 3 with one. The wallet values are lower than the total number of citations for each author, which leads to another ranking (author 1, author 2, author 3, and author 4). However, the citation wallet ranking has the advantage of reflecting the actual number of citations (not just the number of expected citations) that the entire set of publications has generated for an author in a given time period. This ranking can track the behavior along a scientist's career, unlike the H-index,[7] which just provides a cumulative analysis of the scientist's best publications. So, these two measure different things. If an author's papers are ranked in descending order of their numbers of citations, the H-rank is the largest rank that is smaller than the number of citations that the corresponding paper has. Hence, the H-index tries to capture the impact of the key papers throughout a scientist's history. Citation wallet ranking tries to catch the impact of all the scientist's publications, which could be equal to the H-index in the case of outstanding scientists but will differ for other scientists (most of us). Table 2 compares several rankings, including the H-index.

Table 2 also shows the outcome compared to expectations from the auctions shown in table 1. The Earned Citations and Total Productivity columns accurately measure the accepted papers' quality. So, authors have incentive to gain the maximum number of citations, at least as many as they invested in the bid. Moreover, this system is self-regulating. If an author repeatedly underperforms in citations (the author's papers receive fewer citations than what he or she bid), the author's wallet will eventually approach zero. This might happen even to productive authors, such as author 1 in table 2, whose bid productivity is negative although the citation productivity is quite high. Such authors will have difficulty assuring the publication of their papers, because they will lose many auctions. Conversely, authors can quickly increase their wallet's size by submitting papers that will be highly cited, thus making it easy to publish papers in the future. Although the wallets of the most conservative strategies tend to grow, the other strategies might oscillate. This effect clearly differs from existing citation measures, which always grow through time.

Making citation auctions usable will involve many steps. The most important are to

- create a proof-of-concept of citation auctions, using a few selected publications;
- explore the most appropriate auction mechanisms;
- develop the technology for a *citation bank* using standard citation engines; and
- study the use of "taxes" for stabilizing the resulting economic model.

The adoption of citation auctions might take decades. However, the increased efficiency of scientific activities arising from their use should let them prevail over the less efficient peer review.

Acknowledgments

This work was supported partly by the EU project grant 34744 (ONE: Open Negotiation

The Promise of High-Performance Reconfigurable Computing

Tarek El-Ghazawi, Esam El-Araby, and Miaoqing Huang, George Washington University
Kris Gaj, George Mason University
Volodymyr Kindratenko, University of Illinois at Urbana-Champaign
Duncan Buell, University of South Carolina

Several high-performance computers now use field-programmable gate arrays as reconfigurable coprocessors. The authors describe the two major contemporary HPRC architectures and explore the pros and cons of each using representative applications from remote sensing, molecular dynamics, bioinformatics, and cryptanalysis.

In the past few years, high-performance computing vendors have introduced many systems containing both microprocessors and field-programmable gate arrays. Three such systems—the Cray XD1, the SRC-6, and the SGI Altix/RASC—are parallel computers that resemble modern HPC architectures, with added FPGA chips. Two of these machines, the Cray XD1 and SGI Altix, also function as traditional HPCs without the reconfigurable chips. In addition, several Beowulf cluster installations contain one or more FPGA cards per node, such as HPTi's reconfigurable cluster from the Air Force Research Laboratory.

In all of these architectures, the FPGAs serve as coprocessors to the microprocessors. The main application executes on the microprocessors, while the FPGAs handle kernels that have a long execution time but lend themselves to hardware implementations. Such kernels are typically data-parallel overlapped computations that can be efficiently implemented as fine-grained architectures, such as single-instruction, multiple-data (SIMD) engines, pipelines, or systolic arrays, to name a few.

Figure 1 shows that a transfer of control can occur during execution of the application on the microprocessor, in which case the system invokes an appropriate architecture in a reconfigurable processor to execute the target operation. To do so, the reconfigurable processor can configure or reconfigure the FPGA "on the fly," while the system's other processors perform computations. This feature is usually referred to as runtime reconfiguration.[1]

From an application development perspective, developers can create the hardware kernel using hardware description languages such as VHDL and Verilog. Other systems allow the use of high-level languages such as SRC Computers' Carte C and Carte Fortran, Impulse Accelerated Technologies' Impulse C, Mitrion C from Mitrionics, and Celoxica's Handel-C. There are also high-level graphical programming development tools such as Annapolis Micro Systems' CoreFire, Starbridge Systems' Viva, Xilinx System Generator, and DSPlogic's Reconfigurable Computing Toolbox.

Readers should consult *Computer*'s March 2007 special issue on high-performance reconfigurable computing for a good overview of modern HPRC systems, application-development tools and frameworks, and applications.

HPRC ARCHITECTURAL TAXONOMY

Many early HPRC systems, such as the SRC-6E and the Starbridge Hypercomputer, can be seen as attached processors. These systems were designed around one node of microprocessors and another of FPGAs. The

0018-9162/08/$25.00 © 2008 IEEE

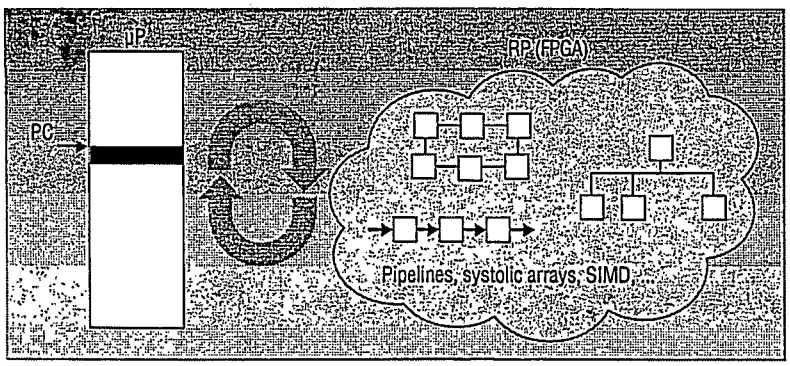


Figure 1. In high-performance reconfigurable computers, field-programmable gate arrays serve as coprocessors to the microprocessors. During execution of the application on the microprocessor, the system invokes an appropriate architecture in the FPGA to execute the target operation.

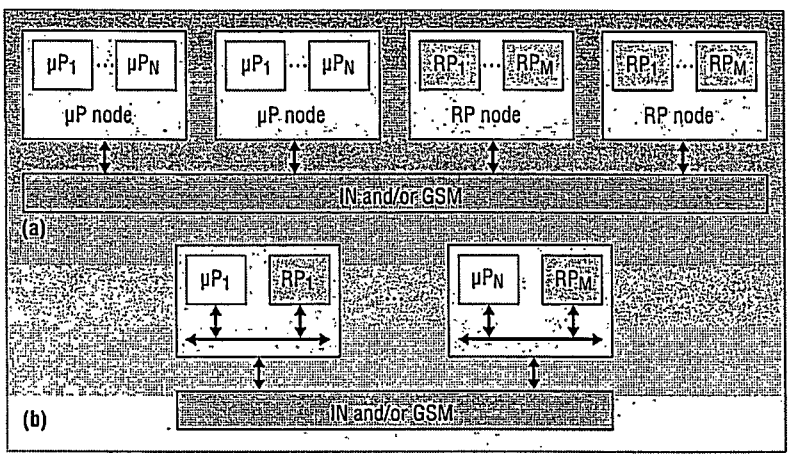


Figure 2. Modern HPRCs can be grouped into two major classes: (a) uniform node nonuniform systems (UNNSs) and (b) nonuniform node uniform systems (NNUSs).

two nodes were connected directly, without a scalable interconnection mechanism.

Here we do not address these early attached processor systems but focus instead on scalable parallel systems such as the Cray XD1, SRC-6, and SGI Altix/RASC as well as reconfigurable Beowulf clusters. These architectures can generally be distinguished by whether each node in the system is homogeneous (uniform) or heterogeneous (nonuniform).[2] A uniform node in this context contains one type of processing element—for example, only microprocessors or FPGAs. Based on this distinction, modern HPRCs can be grouped into two major classes: uniform node nonuniform systems and nonuniform node uniform systems.

Uniform node nonuniform systems

In UNNSs, shown in Figure 2a, nodes strictly have either FPGAs or microprocessors and are linked via an interconnection network to globally shared memory (GSM). Examples of such systems include the SRC-6 and the Altix/RASC. The major advantage of UNNSs is that vendors can vary the ratio of reconfigurable nodes to microprocessor nodes to meet the different demands of customers' applications. This is highly desirable from an economic perspective given the cost difference between FPGAs and microprocessors, and it is particularly suitable for special-purpose systems.

On the downside, having the reconfigurable node and the microprocessor node interact over the shared interconnection network makes them compete for overall bandwidth, and it also increases the latency between the nodes. In addition, code portability could become an issue even within the same type of machine if there is a change in the ratio between the microprocessor nodes and the FPGA nodes.

A representative example of the UNNS is the SRC-6/SRC-7, which consists of one or more general-purpose microprocessor subsystems, one or more MAP reconfigurable subsystems, and global common memory (GCM) nodes of shared memory space. These subsystems are interconnected through a Hi-Bar switch communication layer. The microprocessor boards each include two 2.8-GHz Intel Xeon microprocessors and are connected to the Hi-Bar switch through a SNAP interface. The SNAP card plugs into the dual in-line memory module slot on the microprocessor motherboard to provide higher data transfer rates between the boards than the less efficient but common peripheral component interconnect (PCI) solution. The sustained transfer rate between a microprocessor board and the MAP processors is 1,400 Mbytes per second.

The MAP Series C processor consists of one control FPGA and two user FPGAs, all Xilinx Virtex II-6000-4s. Additionally, each MAP unit contains six interleaved banks of onboard memory (OBM) with a total capacity of 24 Mbytes. The maximum aggregate data transfer rate among all FPGAs and OBM is 4,800 MBps. The user FPGAs are configured such that one is in master mode and the other is in slave mode. A bridge port directly connects a MAP's two FPGAs. Further, MAP processors can be connected via a chain port to create an FPGA array.

Nonuniform node uniform systems

NNUSs, shown in Figure 2b, use only one type of node, thus the system level is uniform. However, each node contains both types of resources, and the FPGAs are connected directly to the microprocessors inside the node.

Examples of such systems are the Cray XD1 and reconfigurable clusters. NNUSs' main drawback is their fixed ratio of FPGAs to microprocessors, which might not suit the traditional vendor-buyer economic model. However, they cater in a straightforward way to the single-program, multiple-data (SPMD) model that most parallel programming paradigms embrace. Further, the latency between the microprocessor and its FPGA coprocessor can be low, and the bandwidth between them will be dedicated—this can mean high performance for many data-intensive applications.

A representative example of the NNUS is the Cray XD1, whose direct-connected processor (DCP) architecture harnesses multiple processors into a single, unified system. The base unit is a chassis, with up to 12 chassis per cabinet. One chassis houses six compute cards, each of which contains two 2.4-GHz AMD Opteron microprocessors and one or two RapidArray Processors (RAPs) that handle communication. The two Opteron microprocessors are connected via AMD's HyperTransport technology with a bandwidth of 3.2 GBps forming a two-way symmetric multiprocessing (SMP) cluster. Each XD1 chassis can be configured with six application-acceleration processors based on Xilinx Virtex-II Pro or Virtex-4 FPGAs. With two RAPs per board, a bandwidth of 8 GBps (4 GBps bidirectional) between boards is available via a RapidArray switch. Half of this switch's 48 links connect to the RAPs on the compute boards within the chassis, while the others can connect to other chassis.

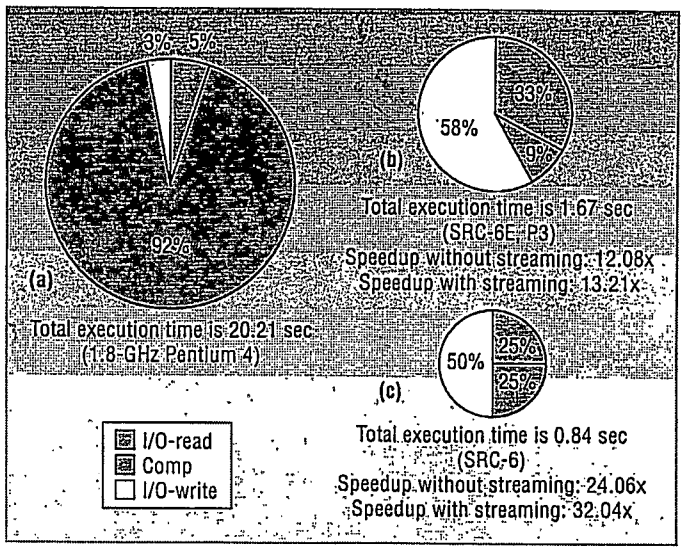


Figure 3. Execution profiles of hyperspectral dimension reduction. (a) Total execution time on 1.8-GHz Pentium 4 microprocessor. (b) Total execution time on SRC-6E. (c) Total execution time on SRC-6.

NODE-LEVEL ISSUES

We have used the SRC-6E and SRC-6 systems to investigate node-level performance of HPRC architectures in processing remote sensing[3] and molecular dynamics[4] applications. These studies included the use of optimization techniques such as pipelining and data transfer overlapping with computation to exploit the inherent temporal and spatial parallelism of such applications.

Remote sensing

Hyperspectral dimension reduction[3] is representative of remote sensing applications with respect to node performance. With FPGAs as coprocessors for the microprocessor, substantial data in this data-intensive application must move back and forth between the microprocessor memory and the FPGA onboard memory. While the bandwidth for such transfers is on the order of GBps, the transfers are an added overhead and represent a challenge on the SRC-6 given the finite size of its OBM.

This overhead can be avoided altogether through the sharing of memory banks, or the bandwidth can be increased to take advantage of FPGAs' outstanding processing speed. Overlapping memory transfers—that is, streaming—between these two processing elements and the computations also can help. As Figure 3a shows, such transfers (I/O read and write operations) take only 8 percent of the application execution time on a 1.8-GHz Pentium 4 microprocessor, while the remaining 92 percent is spent on computations.

As Figure 3b shows, the first-generation SRC-6E achieves a significant speedup over the microprocessor: 12.08× without streaming and 13.21× with streaming. However, the computation time is now only 9 percent of the overall execution time. In the follow-up SRC-6, the bandwidth between the microprocessor and FPGA increases from 380 MBps (sustained) to 1.4 GBps (sustained). As Figure 3c shows, this system achieves a 24.06× speedup (without streaming) and a 32.04× speedup (with streaming) over the microprocessor.

These results clearly demonstrate that bandwidth between the microprocessor and the FPGA must be increased to support more data-intensive applications—an area the third-generation SRC-7 is likely to address. It should be noted, however, that in most HPRCs today, transfers between the microprocessor and FPGA are explicit, further complicating programming models. These two memory subsystems should either be fused into one or integrated into a hierarchy with the objective of reducing or eliminating this overhead and making the transfers transparent.

Molecular dynamics

Nanoscale molecular dynamics (NAMD)[4] is representative of floating-point applications with respect to node performance. A recent case study revealed that when porting such highly optimized code, a sensible approach is to use several design iterations, starting with

the simplest, most straightforward implementation and gradually adding to it until achieving the best solution or running out of FPGA resources.[5]

The study's final dual-FPGA-based implementation was only three times faster than the original code execution. These results, however, are data dependent. For a larger cutoff radius, the original CPU code executes in more than 800 seconds while the FPGA execution time is unchanged, which would constitute a 260× speedup. The need to translate data between the C++ data storage mechanisms and the system-defined MAP/FPGA data storage architecture required considerable development effort. When creating code from scratch to run on an FPGA architecture, a programmer would implement the data storage mechanisms compatible between the CPU and FPGA from the beginning, but this is rarely the case for existing code and adds to the amount of work required to port the code.

Vendor-provided transparent transfers can enhance performance by guaranteeing the most efficient transfer modes for the underlying platform.

Although the "official benchmark" kernel employs double-precision floating-point arithmetic, the NAMD researchers applied algorithmic optimization techniques and implemented their kernel using single-precision floating-point arithmetic for atom locations and 32-bit integer arithmetic for forces. Consequently, the final design occupies most available slices (97 percent), yet utilization of on-chip memory banks (40 percent) and hardware multipliers (28 percent) is low. The fact that the slice limit was reached before any other resource limits suggests that it might be necessary to restructure code to better utilize other available resources. One possible solution is to overlap calculations with data transfer for the next data set to use more available on-chip memory.

Despite the relatively modest speedup achieved, the NAMD study clearly illustrates the potential of HPRC technology. FPGA code development traditionally begins with writing code that implements a textbook algorithm, with little or no optimization. When porting such unoptimized code to an HPRC platform and taking care to optimize the FPGA design, it is easy to obtain a 10×-100× speedup. In contrast, we began with decade-old code optimized to run on the CPU-based platform; such code successfully competes with its FPGA-ported counterpart. It is important to keep in mind that the study's 100-MHz FPGA achieved a 3× application performance improvement over a 2.8-GHz CPU, and FPGAs are on a faster technology growth curve than CPUs.[6]

Lessons learned

Optimization techniques such as overlapping data transfers between the microprocessors and FPGAs with computations are useful for data-intensive, memory-bound applications. However, such applications, including hyperspectral dimension reduction and NAMD, can only achieve good performance when the underlying HPRC architecture supports features such as streaming or overlapping. Streaming can be enabled by architectures that are characterized by high I/O bandwidth and/or tight coupling of FPGAs with associated microprocessors. New promising examples of these are DCP architectures such as AMD's Torrenza initiative for HyperTransport links as well as Intel's QuickAssist technology supporting front side bus (FSB) systems. Large enough memory bandwidth is another equally important feature.

By memory bandwidth we mean that the memory system has sufficient multiplicity as well as speed, width, or depth/size. In other words, because FPGAs can produce and consume data at a high degree of parallelism, the associated memory system should also have an equal degree of multiplicity. Simply put, a large multiple of memory banks with narrow word length of local FPGA memory can be more useful to memory-bound applications on HPRCs than larger and wider memories with fewer parallel banks.

In addition, further node architecture developments are clearly necessary to support programming models with transparent transfers of data between FPGAs and microprocessors by integrating the microprocessor memory and the FPGA memory into the same hierarchy. Vendor-provided transparent transfers can enhance performance by guaranteeing the most efficient transfer modes for the underlying platform. This will let the user focus on algorithmic optimizations that can benefit the application under investigation rather than data transfers or distribution. It also can improve productivity.

SYSTEM-LEVEL ISSUES

We have used the SRC-6 and Cray XD1 systems to investigate system-level performance of HPRC architectures in bioinformatics[7] and cryptanalysis[8-10] applications. These applications provide a near-practical upper bound on HPRC potential performance as well as insight into system-level programmability and performance issues apart from those associated with general high-performance computers. They use integer arithmetic, an area where HPRCs excel, are compute-intensive with lots of computations and not much data transfer between the FPGAs and microprocessors, and inherit both spatial and temporal parallelism.

We distributed the workload of both types of applications over all nodes using the message passing interface (MPI). In the case of DNA and protein analysis, we broadcast a database of reference sequences and scatter sequence queries. The application identified matching scores locally and then gathered them together. Each

				Expected		Measured	
				Throughput (GCUPS)	Speedup	Throughput (GCUPS)	Speedup
FASTA (ssearch34)	Opteron 2.4 GHz	DNA		NA	NA	0.065	1
		Protein		NA	NA	0.130	1
SRC-6 100 MHz (32x1)		DNA	1 Engine/chip	3.2	49.2×	3.19 → 12.2 1 → 4 chips	49 → 188 1 → 4 chips
			4 Engines/chip	12.8	197×	12.4 → 42.7 1 → 4 chips	191 → 656 1 → 4 chips
			8 Engines/chip	25.6	394×	24.1 → 74 1 → 4 chips	371 → 1,138 1 → 4 chips
		Protein		3.2	24.6×	3.12 → 11.7 1 → 4 chips	24 → 90 1 → 4 chips
XD1 200 MHz (32x1)		DNA	1 Engine/chip	6.4	98×	5.9 → 32 1 → 6 chips	91 → 492 1 → 6 chips
			4 Engines/chip	25.6	394×	23.3 → 120.7 1 → 6 chips	359 → 1,857 1 → 6 chips
			8 Engines/chip	51.2	788×	45.2 → 181.6 1 → 6 chips	695 → 2,794 1 → 6 chips
		Protein		6.4	49×	5.9 → 34 1 → 6 chips	45 → 262 1 → 6 chips

Figure 4. DNA and protein sequencing on the SRC-6 and Cray XD1 versus the open source FASTA program. An FPGA with one engine produced a 91× speedup, while eight cores on the same chip collectively achieved a 695× speedup.

FPGA had as many hardware kernels for the basic operation as possible. In the case of cryptanalysis, we broadcast the ciphertext as well as the corresponding plaintext; upon finding the key, a worker node sent it back to the master to terminate the search.

Bioinformatics

Figure 4 compares DNA and protein sequencing on the SRC-6 and Cray XD1 with the open source FASTA program running on a 2.4-GHz Opteron microprocessor. We used giga cell updates per second (GCUPS) as the throughput metric as well as to compute speedup over the Opteron. With its FPGA chips running at 200 MHz, the XD1 had an advantage over the SRC-6, which could run its FPGAs at only 100 MHz.

By packing eight kernels on each FPGA chip, the Cray XD1 achieved a 2,794× speedup using one chassis with six FPGAs. An FPGA with one engine produced a 91× speedup instead of the expected 98× speedup due to associated overhead such as pipeline latency, resulting in 93 percent efficiency. On the other hand, eight cores on the same chip collectively achieved a 695× speedup instead of the expected 788× speedup due to intranode communication and I/O overhead. The achieved speedup for eight engines/chip was 2,794× instead of the estimated (ideal) of 4,728× due to MPI internode communications overhead, resulting in 59 percent efficiency.

These results demonstrate that, with FPGAs' remarkable speed, overhead such as internode and intranode communication must be at much lower levels in HPRCs than what is accepted in conventional high-performance computers. However, given the speed of HPRCs, very large configurations might not be needed.

Cryptanalysis

The cryptanalysis results, shown in Tables 1 and 2, are even more encouraging, especially since this application has even lower overhead. With the Data Encryption Standard (DES) cipher, the SRC-6 achieved a 6,757× speedup over the microprocessor—again, a 2.4-GHz Opteron—while the Cray XD1 achieved a 12,162× speedup. The application's scalability is almost ideal.

In the case of the Cray XD1, straightforward MPI application resulted in using all nodes. However, it made sense for the node program to run on only one microprocessor and its FPGA; the other microprocessors on each node were not used. On the SRC-6, MPI processes had to run on the microprocessors, and the system had to establish an association between each microprocessor and a MAP processor. Because the SRC-6 was limited to two network interface cards that could not be shared efficiently, two MPI processes were sufficient. This meant the program could only run on one microprocessor and one MAP processor.

Lessons learned

Heterogeneity at the system level—namely, UNNS architectures—can be challenging to most accepted

Table 1. Secret-key cipher cryptanalysis on SRC-6.

Application	Hardware: Number of search engines	Hardware: Throughput (keys/s)	Software: Number of search engines	Software: Throughput (keys/s)	Speedup
Data Encryption Standard (DES) breaking	40	4,000 M	1	0.592 M	6,757×
International Data Encryption Algorithm (IDEA) breaking	16	1,600 M	1	2.498 M	641×
RC5-32/12/16 breaking	4	400 M	1	0.351 M	1,140×
RC5-32/8/8 breaking	8	800 M	1	0.517 M	1,547×

Table 2. Secret-key cipher cryptanalysis on Cray XD1.

Application	Hardware: Number of search engines	Hardware: Throughput (keys/s)	Software: Number of search engines	Software: Throughput (keys/s)	Speedup
Data Encryption Standard (DES) breaking	36	7,200 M	1	0.592 M	12,162×
International Data Encryption Algorithm (IDEA) breaking	30	6,000 M	1	2.498 M	2,402×
RC5-32/8/8 breaking	6	1,200 M	1	0.517 M	2,321×

SPMD programming paradigms. This occurs because current technology utilizes the reconfigurable processors as coprocessors to the main host processor through a single unshared communication channel. In particular, when the ratio of microprocessors, reconfigurable processors, and their communication channels differs from unity, SPMD programs, which generally assume a unity ratio, might underutilize some of the microprocessors. On the other hand, heterogeneity at the node level does not present a problem for such programs.

Heterogeneity at the system level is driven by nontechnological factors such as cost savings, which developers can achieve by tailoring systems to customers using homogeneous node architectures. However, this is at least partly offset by the increased difficulty in code portability. NNUS architectures are more privileged in this respect than their UNNS counterparts.

HPRC PERFORMANCE IMPROVEMENT

To assess the potential of HPRC technology, we exploited the maximum hardware parallelism in the previously cited studies' testbeds at both the chip and system levels. For each application, we filled the chip with as many hardware cores as possible that can run in parallel. We obtained additional system-level parallelism via parallel programming techniques, using the MPI to break the overall problem across all available nodes in order to decrease execution time. After estimating the size of a computer cluster capable of the same level of speedup, we derived the corresponding cost, power, and size savings that can be achieved by an SRC-6, Cray XD1, and SGI Altix 4700 with an RC100 RASC module compared with a conventional high-performance PC cluster.

As Tables 3-5 show, the improvements are many orders of magnitude larger. In this analysis, a 100× speedup indicates that the HPRC's cost, power, and size are compared to those of a 100-processor Beowulf cluster. The estimates are very conservative, because when parallel efficiency is considered, a 100-processor cluster will likely produce a speedup much less than 100×—in other words, we assumed the competing cluster to be 100 percent efficient. We also assumed that one cluster node consumes about 220 watts, and that 100 cluster nodes have a footprint of 6 square feet. Based on actual prices, we estimated the cost ratio to be 1:200 in the case of the SRC-6 and 1:100 in the case of the Cray XD1. The cost reduction is actually much larger than the tables indicate when considering the systems' associated power and size.

These dramatic improvements can be viewed as realistic upper bounds on the promise of HPRC technology because the selected applications are all compute-intensive integer applications, a class at which HPRCs clearly excel. However, with additional FPGA chip improvements in the areas of size and floating-point support, and with improved data-transfer bandwidths between FPGAs and their external local memory as well as between the microprocessor and the FPGA, a much wider range of applications can harness similar levels of

benefits. For example, in the hyperspectral dimension reduction study, data transfer improvements between the SRC-6E and SRC-6, while using the same FPGA chips, almost doubled the speedup.

Our research revealed that HPRCs can achieve up to four orders of magnitude improvement in performance, up to three orders of magnitude reduction in power consumption, and two orders of magnitude savings in cost and size requirements compared with contemporary microprocessors when running compute-intensive applications based on integer arithmetic.

In general, these systems were less successful in processing applications based on floating-point arithmetic, especially double precision, whose high usage of FPGA resources constitutes an upper bound on fine-grained parallelism for application cores. However, they can achieve as high performance on embarrassingly parallel floating-point applications, subject to area constraints, as integer arithmetic applications. FPGA chips will likely become larger and have more integrated cores that can better support floating-point operations.

Our future work will include a comprehensive study of software programming tools and languages and their impact on HPRC productivity, as well as multitasking/multiuser support on HPRCs. Because porting applications from one machine to another, or even to the same machine after a hardware upgrade, is nontrivial, hardware architectural virtualization and runtime systems support for application portability is another good research candidate.

Table 3. Performance improvement of SRC-6 compared with a Beowulf cluster.

		Savings		
Application	Speedup	Cost	Power	Size
DNA and protein sequencing	1,138×	6×	313×	34×
DES breaking	6,757×	34×	856×	203×
IDEA breaking	641×	3×	176×	19×
RC5 breaking	1,140×	6×	313×	34×

Table 4. Performance improvement of Cray XD1 compared with a Beowulf cluster.

		Savings		
Application	Speedup	Cost	Power	Size
DNA and protein sequencing	2,794×	28×	148×	29×
DES breaking	12,162×	122×	608×	127×
IDEA breaking	2,402×	24×	120×	25×
RC5 breaking	2,321×	23×	116×	24×

Table 5. Performance improvement of SGI Altix 4700 with RC100 RASC module compared with a Beowulf cluster.

		Savings		
Application	Speedup	Cost	Power	Size
DNA and protein sequencing	8,723×	22×	779×	253×
DES breaking	28,514×	96×	3,439×	1,116×
IDEA breaking	961×	2×	86×	28×
RC5 breaking	6,838×	17×	610×	198×

References

1. M. Taher and T. El-Ghazawi, "A Segmentation Model for Partial Run-Time Reconfiguration," *Proc. IEEE Int'l Conf. Field Programmable Logic and Applications*, IEEE Press, 2006, pp. 1-4

國立雲林科技大學
96學年度博士班招生入學考試試題

系所別：資訊管理系
科　目：資訊管理文獻

Questions: 題目分成A、B二部份，作答時，請注意各題之比例配分並標示題號

Part A: (30%)

Please briefly describe what the major contributions, in MIS field, of the following authors are:

1. Orlikowski, W. (10%)
2. Delone, W.H. & McLean, E.R. (10%)
3. Davis, F.D. (10%)

Part B: (70%)

1. Please give the abstract, within 200 words in English, of this paper? (10%)

2. Draw the framework of this research, and then briefly describe major research variables. (10%)

3. Describe briefly the procedure of qualitative content analysis and supercode analysis conducted in this research. (10%)

4. Comment on "whether CMC moderates or magnifies the gender difference reported in face-to-face research", based on literature reviewed in this paper on both sides, as well as your own opinion. (10%)

5. Based on findings and insights from this paper suggest ways to implement an e-learning environment with more gender-free, equal-participation and supportive self-disclose characteristics. (10%)

6. Analyze potential mediating variables that might bring out different conclusions with those of this research. (10%)

7. Please explain why the author constructed 21 task codes, 12 linguistic codes, 16 stylistic codes, and 8 paralinguistic codes during his pilot study? (10%)

Available online at www.sciencedirect.com
ScienceDirect
Computers in Human Behavior
ELSEVIER
Computers in Human Behavior 23 (2007) 2240–2255
www.elsevier.com/locate/comphumbeh

Students' linguistic behaviour in online discussion groups: Does gender matter?

Jane Guiller *, Alan Durndell

Department of Psychology, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow G4 0BA, Scotland, United kingdom

Available online 11 May 2006

Abstract

1. Introduction

The increased use of networked computers in contemporary society has changed the ways in which students can engage in peer-based discussion. Consequently, higher education establishments are utilising virtual learning environments such as Blackboard and WebCT to support existing face-to-face undergraduate courses. A feature of such systems is their ability to support many-to-many communication in the form of text-based discussion forums. Asynchronous computer-mediated communication (CMC) refers to communication that takes place over computers in delayed time (e.g., email), in contrast to synchronous CMC (e.g., chat rooms), which takes place in real time. Hence, asynchronous CMC allows people to communicate from different places and at different times. A frequently cited educational advantage of the asynchronous nature of text-based online discussion forums is the time available to read a message and formulate a response, which can improve reflection upon and development of a topic (e.g., Harasim, 1990).

Early psychological studies of the Internet focused on what was lost in text-based CMC. It was predicted that the reduction in social context cues through visual anonymity would greatly reduce the capacity to transmit social and interpersonal information (e.g., Short, Christie, & Williams, 1976; Sproull & Kiesler, 1986). It was theorised that self-awareness was reduced in CMC. Thus, the 'cues-filtered out' approach (Sproull & Kiesler, 1986) predicted that communication will be depersonalised, less 'social' and more uninhibited, in comparison to face-to-face communication. It was assumed that the medium only had the capacity to transmit task-oriented and cognitive material and not socioemotional content. Socioemotional content includes the use of emoticons, expressions of supporting references, self-references, references to others and self-disclosure (Jaffe, Lee, Huang, & Oshagan, 1999).

In contrast to the 'cues-filtered-out' approaches, Walther's (1992) social information processing theory maintained that text-based CMC could support socioemotional and relational communication. This theory assumes that CMC users are affected by the same internal drive of 'affiliation', i.e., interaction with other people, as participants in other communicative contexts (Jaffe et al., 1999). Therefore, it is suggested that CMC users will adapt existing communicative cues, within restrictions of language use and textual display (e.g., paralanguage), in order to convey relational communication. However, a more recent theory of CMC known as the 'rational actor approach' (e.g., Markus, 1994), despite disputing the technological determinism of the 'cues-filtered-out' approach, is in keeping with it in terms of the proposed reduction in interpersonal communication. This has implications for the use of CMC in educational contexts as it suggests that students may be less responsive to the ideas of their peers during CMC, questioning the extent of 'affective learning' (see Biggs, 1987) that can occur in computer-mediated contexts.

Gender may also influence the socioemotional content of computer-mediated discourse. Males are believed to value status more through the process of gender role socialisation, whereas females are thought to value connection or affiliation more, leading to gender-preferential communication styles, differentiated as 'competitive' and 'cooperative', respectively (Coates, 1993; Tannen, 1991). Therefore, females may be more likely than males to express socioemotional responses in CMC, such as expressing support and disclosing opinions, feelings and experiences. However, negative forms that would also qualify as responses to another's ideas, such as expressions of disagreement, are not always included in definitions of socioemotional content.

The absence of social context cues in CMC, i.e., the lack of non-verbal indicators of hierarchy, status and power was also presumed to have a democratising effect on communication, leading to equalised participation (Sproull & Kiesler, 1986). It was suggested that when such cues are missing in CMC, participants who would otherwise defer speaking turns to higher-status participants in face-to-face interaction, become uninhibited and participate more. Therefore, studies began to emerge which examined participation in CMC by gender (e.g., Graddol & Swan, 1989; Selfe & Meyer, 1991), as it had been reported that males dominated mixed-sex interaction in formal face-to-face contexts by speaking more frequently, for longer and interrupting more, than females (e.g., Tannen, 1991; Thorne, Kramarae, & Henley, 1983).

It was suggested that the visual anonymity offered in text-based CMC would result in gender-free equality online and Graddol and Swan's (1989) findings supported this claim initially, as they found equal participation in an anonymous Open University conferencing system. However, this was later shown to be prematurely optimistic as Herring (1993, 1994) reported that males dominate online interaction by making longer and more frequent postings than females and subsequent studies, conducted in a variety of CMC contexts, supported this claim (e.g., Barrett & Lally, 1999; Richardson & French, 2000; Sierpe, 2000; Stewart, Shields, Monolescu, & Taylor, 1999).

Similar to face-to-face research, these results suggest that males dominate interaction, which may deter women from participating in CMC or force them to seek women-only groups online. Indeed, Yates (2001) suggested that altering the social context in the form of women-only online groups can moderate some of the problems experienced by women in educational interactions. However, gender segregation is neither practical, nor desirable, in an educational context. Furthermore, Miller and Durndell (2004) studied participation in an educational context and found that males and females were similar regarding quantitative measures of participation, as no significant gender differences were found in relation to the frequency or length of online postings. This was partly explained through the motivation to participate as marks were on offer for participation in this educational context and also because of the unequal gender balance, as females outnumbered males on the course. However, other studies have shown that relatively few males have still managed to dominate a discussion online (e.g., Herring, 1993; Light, Nesbitt, Light, & Burns, 2000; Sierpe, 2000).

For example, Light et al. (2000) studied purely student–student interaction via asynchronous CMC in the context of a third-year undergraduate course and found that in one group in particular the discussion became dominated by two males 'who shifted the discourse style from more formal contributions to 'testing the boundary' comments' (p. 94). These comments became increasingly directed towards particular individuals and the researchers report that there was evidence of inciting gender reaction 'for fun'. This shows that measuring surface variables in relation to the amount of participation does not address the extent to which participants can dominate through their use of language and interaction style online. Perhaps the presence of an instructor in these groups would have influenced the outcome of this study as Herring (1999) claims that female students participate more and sometimes more than male students in online classrooms in which the teacher controls the interaction, even when the teacher is male.

The removal of status cues such as gender has the potential to moderate the effects of gender on language use online, as Carli (1990) postulated that status may be an important determinant of gender differences in language use. This is known as the 'dominance' approach to

gender and language (e.g., Poynton, 1985), and is often contrasted with the 'difference' approach, advocated by Tannen (1991). It is maintained that status is more of an influence on language use than gender. However, males are traditionally awarded more status and power in society and Sussman and Tyson (2000) suggested that these gendered power differentials in communication style would transfer into computer-mediated environments.

It was suggested that under conditions of anonymity males and females may be less likely to feel that they have to project the socially expected qualities corresponding to their gender (Matheson & Zanna, 1990). However, George (1995) claimed that communication is not neutral and texts are arenas in which to exercise power within social relationships. Moreover, Yates (2001) stated that 'CMC interaction, as with face-to-face communication, is founded upon existing social structures and perceptions which underlie inequalities in the interaction' (p. 27). For example, language may be a means of constructing and maintaining gendered power differentials in society. Therefore, CMC could potentially magnify, as opposed to moderate, the gender differences reported in face-to-face research.

The social identity explanation of deindividuated effects (SIDE) model (Postmes, Spears, & Lea, 2000, 2002; Reicher, Spears, & Postmes, 1995) challenged the anti-normative and deterministic view of the 'cues-filtered-out' approach described earlier. It predicts that visual anonymity of the self to others leads to heightened self-awareness and greater adherence to group norms when a social identity is salient. So, for example, if gender is made a salient social identity in CMC then this could invoke behavioural norms and stereotypes regarding gender appropriate behaviour, influencing expectations and perceptions of CMC users. Similarly, Matheson and Zanna (1990) argued that differences in status may actually be accentuated in CMC if cues to gender are available. Low public-awareness levels in CMC (i.e., decreased concern about others' impressions) are associated with lower social pressures that make the expression of internalised gender biases unacceptable. Therefore, it is possible that the exclusive focus on language in text-based CMC could not only exacerbate existing asymmetrical power differences, but even create them.

Matheson and Zanna (1990) found that CMC users reported greater levels of private self-awareness than participants communicating face-to-face. Heightened private self-awareness in CMC is associated with high levels of self-disclosure (Joinson, 2001). This may have implications for the use of visually anonymous and pseudonymous CMC in education as students may be more likely to disclose under these conditions. Furthermore, the sensitive nature of some psychological topics such as mental health, child abuse and eating disorders under these conditions may be conducive to self-disclosure. This may have implications for the use of CMC in psychology courses. As suggested earlier, it is also possible that the level of self-disclosure online may be influenced by gender, in line with traditional sex-role expectations. It could also be the case that in CMC self-disclosure is normative, in the same way that flaming (i.e., swearing, insults and hostile comments) is likely to be context-dependent and normative (see Lea, O'Shea, Fung, & Spears, 1992), as opposed to simply an outcome of the loss of face-to-face cues (e.g., Kiesler, Siegel, & McGuire, 1984).

Gender-related patterns in language style have been found in Internet discussion groups such as email listservs (e.g., Herring, 1993, 1994). Herring reported large differences in language style along the same task-orientated versus socioemotional dimensions as Tannen (1991) had described in face-to-face contexts. Female postings tended to display features of attenuation, such as hedging, apologising, asking questions and a personal orientation, revealing thoughts and feelings and interacting with and supporting others. On the other hand, male postings were lengthy and/or frequent, adversarial and featured strong assertions,

self-promotion, sarcasm and flaming. Herring suggested that gender-based communication styles and the power dynamics associated with these styles carry over to electronic environments, despite the loss of overt face-to-face cues to gender.

Savicki, Lingenfelter, and Kelley (1996) provided some evidence for the gender-related communication styles identified by Herring (1994) in their study of Internet discussion groups. Soukup (1999) observed traditional masculine and feminine forms of discourse in Internet chatrooms. However, Yates (1997) notes that many studies have failed to replicate these findings. Moreover, Michaelson and Pohl (2001) did not find differences along the supportive/emotional versus adversarial/task-oriented dimensions in their study of an email problem-solving task.

Thomson, Murachver, and Green (2001) conducted experiments into the dynamism of linguistic exchange. They investigated how males and females accommodate to gender-preferential language in emails and found that participants used 'male' language when communicating with a male netpal and 'female' language when communicating with a female netpal, supporting the process of accommodation in online dyadic exchanges. In relation to many-to-many exchanges, where CMC participants can be exposed to a variety of styles, Herring (2003) suggests that the majority gender group online will have the greater influence on the shared discursive norms.

Mixed results in terms of gender variations in language use in CMC make it unclear whether CMC moderates or magnifies the gender differences reported in face-to-face research. Perhaps these differences could be attributed to the varying online contexts that have been studied. There is also a methodological issue in terms of the extent to which gender can reliably be inferred by researchers from usernames or email addresses. For example, Jaffe et al. (1999) found that females are more likely to choose a pseudonym to mask their gender when communicating online, which could distort the findings of studies using samples taken directly from the Internet. Miller and Durndell (2004) reported that females were significantly more likely to opt for a numerical pseudonym instead of their real name, in comparison to males.

Although text-based, pseudonymous CMC may be considered 'gender-free', cues to gender may not be restricted to usernames and signatures in CMC. Experimental work by Thomson and Murachver (2001) found evidence for gender-preferential language in informal CMC in a series of experimental studies, showing that readers of email messages used gender-linked language differences within messages to correctly identify the author's gender. Therefore, if linguistic cues to gender are found in real-life CMC contexts, this will have implications for the assumption of gender anonymity online and CMC as a gender-free environment.

The present research is concerned with formal use of CMC on an undergraduate psychology module. Ethical clearance permitted access to background details of the students, so that gender could be reliably inferred in this study. Education is a context in which gender equality is an important issue. If differences in communication style are found to exist in this context then this may have implications for the increasing use of CMC in Higher Education. Yates (2001) provided an overview of the research literature on CMC, gender, language and education and concluded that there is a lack of few large and detailed studies on this topic. This paper reports the results of an extensive project, employing both quantitative and qualitative techniques, that was carried out to investigate the existence of gender-related patterns in language use and interaction style in educational, mixed-gender, online discussion groups.

2. Method

2.1. Participants

The participants were 197 campus-based introductory psychology students (149 females, 48 males) at a Scottish university who had all chosen to take part in the online discussion groups as an optional part of their course. The age range was 17–46 years and the mean age of the sample was 22 years (SD = 6.52).

2.2. Coding scheme

The coding scheme was developed in Atlas.ti 4.2 (computer-assisted qualitative data analysis software) using a qualitative content analysis (QCA) procedure (Mayring, 2000). QCA seeks to conserve some methodological advantages of quantitative content analysis and broaden them to a concept of qualitative procedure. The unit of analysis was at the level of the whole message, resulting in a macro-analysis of whole messages and episodes of interaction, as opposed to a micro-analysis of single words and phrases, as is common in traditional quantitative content analysis.

During a pilot study, the author constructed a code list consisting of 21 task codes (e.g., initiates thread), 12 linguistic codes (e.g., intensifiers), 16 stylistic codes (e.g., challenging) and 8 paralinguistic codes (e.g., capitalisation), which included definitions and examples from the corpus. The majority of linguistic (see Appendix A) and stylistic codes (see Appendix B) were coded in previous studies as potential discriminators of gender (e.g., Herring, 1994; Savicki et al., 1996). The code list was then passed to a second independent rater who coded 20% of the sample (65 postings chosen at random) for 30 of the linguistic and stylistic variables. The second coder did not code for the more objective features such as 'first person pronouns' and 'intensifiers'. The inter-rater reliability measure for the more subjective codes such as 'humour' and 'rhetorical questions' was significant ($\kappa = 0.94$).

After this first level coding, second level coding involved the organisation of code families in Atlas. Codes were grouped into eight major code families. These were female language (e.g., self-disclosure, intensifiers), male language (e.g., humour, rhetorical question), task-orientated (e.g., answers question), socioemotional (e.g., references by name), attenuated (e.g., personal opinion, qualifiers), authoritative (e.g., strong assertion, presuppositions), negative socioemotional (e.g., disagreement) and positive socioemotional (e.g., agreement). A full description of these code families and examples is in Miller (2004). Analyses were then conducted on 'supercodes'. These are stored queries constructed from combinations of code families using Boolean operators in Atlas.ti 4.2 (e.g., 'return all messages coded as containing authoritative language but no attenuated language'). These higher-order codes permit analyses to be conducted into the use of combinations of codes and code families by males and females, allowing the identification of patterns of language use and particular interaction styles.

2.3. Procedure

Students on an introductory psychology module were invited to participate in online discussion groups for coursework credit. They were supplied with instructions on how to access the online forums and told that they must give either their real name or matriculation

number as their user identification when posting messages in order to receive marks for contributing to the discussion. This allowed the gender of participants to be reliably inferred. Informed consent was gained from the online participants to download their contributions for analysis. Ethical clearance permitted access to background details of the students, such as gender. The online discussion forums covered a variety of introductory psychology topics such as eating disorders, intelligence, memory and personality. A total of 699 student postings were collated over four semesters. The mean number of posts was 3.55 and the average length of posts was 126.03 words. Tutors also contributed online but only the student contributions were analysed. Coding was carried out using Atlas.ti 4.2, as described above. Statistical analysis was conducted using the χ^2 Test and Fisher's Exact Test in SPSS 10. Yates' correction was applied to cells that have expected frequencies of less than five.

3. Results

A total of 699 postings (538 female, 161 male) were analysed. The electronic discourse was characterised by extensive first person pronoun usage as 87% of all postings analysed contained some form of first person or plural pronouns (e.g., 'I', 'we'). Also, 38% of student contributions directly responded to the ideas of other students by expressing agreement and/or disagreement. Just over a fifth of all postings contained references to own emotions (e.g., 'I am angry that') or self-disclosure (e.g., 'I myself have been overweight').

Table 1 above shows participants' use of the linguistic variables by gender. The table lists each linguistic variable and the corresponding proportions of males and females making each type of contribution, on which χ^2 analyses were conducted. The percentages of each type of posting, expressed as a percentage of the total male and female postings are also given in the table. As can be seen from the table, a significant result was obtained for only one individual linguistic variable, namely intensifiers. It was found that significantly more females used intensifiers in their postings than males, $\chi^2(1, N = 197) = 6.77$, $p < 0.01$.

Table 2 shows participants' use of stylistic variables by gender. As before, the stylistic variables are listed, as are the corresponding proportions of males and females making each type of contribution, on which χ^2 analyses were conducted. It can be seen from the table

Table 1
Participants' use of linguistic variables by gender: χ^2 of male and female samples

	% of participants		x^2	% of postings	
	Male ($N = 48$)	Female ($N = 149$)		Male ($N = 161$)	Female ($N = 538$)
Absolute adverbials	29% ($N = 14$)	26% ($N = 39$)	0.16	12% ($N = 19$)	11% ($N = 57$)
Exhortations	4% ($N = 2$)	7% ($N = 11$)	0.11	1% ($N = 2$)	2% ($N = 12$)
First person plural pronouns	54% ($N = 26$)	55% ($N = 82$)	0.42	30% ($N = 49$)	28% ($N = 153$)
First person pronouns	83% ($N = 40$)	92% ($N = 137$)	2.46	70% ($N = 113$)	86% ($N = 461$)
Second person address	25% ($N = 12$)	26% ($N = 38$)	0.00	18% ($N = 29$)	12% ($N = 64$)
Imperative verbs	21% ($N = 10$)	15% ($N = 22$)	0.98	7% ($N = 12$)	6% ($N = 30$)
Impersonal truths	17% ($N = 8$)	8% ($N = 12$)	2.46	6% ($N = 10$)	2% ($N = 12$)
Intensifiers	56% ($N = 27$)	76% ($N = 113$)	6.77*	41% ($N = 66$)	50% ($N = 270$)
Interjections	10% ($N = 5$)	15% ($N = 22$)	0.58	4% ($N = 7$)	7% ($N = 36$)
Qualifer/hedge/tag question	46% ($N = 22$)	55% ($N = 82$)	1.23	27% ($N = 43$)	30% ($N = 163$)
References to emotion	35% ($N = 17$)	46% ($N = 69$)	1.75	15% ($N = 24$)	24% ($N = 127$)
Rhetorical questions	33% ($N = 16$)	32% ($N = 47$)	0.05	15% ($N = 24$)	13% ($N = 71$)

* Significant at $p < 0.01$.

Table 2
Participants' use of stylistic variables by gender: χ^2 of male and female samples

	% of participants		x^2	% of postings	
	Male ($N=48$)	Female ($N=149$)		Male ($N=161$)	Female ($N=538$)
Agreement	21% ($N=10$)	48% ($N=72$)	11.30**	9% ($N=15$)	26% ($N=142$)
Challenging	38% ($N=18$)	10% ($N=15$)	19.59***	17% ($N=27$)	4% ($N=20$)
Compliments	10% ($N=5$)	23% ($N=34$)	3.52	4% ($N=6$)	10% ($N=52$)
Controversial	15% ($N=7$)	1% ($N=2$)	14.14***	5% ($N=8$)	0.4% ($N=2$)
Disagreement	44% ($N=21$)	15% ($N=22$)	17.86***	19% ($N=30$)	6% ($N=30$)
Empathic	2% ($N=1$)	13% ($N=20$)	4.91*	1% ($N=2$)	4% ($N=23$)
Humour	31% ($N=15$)	7% ($N=10$)	19.74***	12% ($N=20$)	2% ($N=13$)
Personal experience	23% ($N=11$)	40% ($N=59$)	4.41*	9% ($N=14$)	19% ($N=100$)
Personal orientation	60% ($N=29$)	72% ($N=108$)	2.49	39% ($N=63$)	51% ($N=272$)
Polite forms	19% ($N=9$)	20% ($N=30$)	0.05	6% ($N=10$)	7% ($N=38$)
Presuppositions	67% ($N=32$)	50% ($N=75$)	3.90*	40% ($N=64$)	24% ($N=128$)
Reference to own emotions	6% ($N=3$)	21% ($N=31$)	5.38*	2% ($N=4$)	9% ($N=50$)
Reference to own feelings	15% ($N=7$)	36% ($N=54$)	7.96**	% ($N=10$)	% ($N=85$)
Self-disclosure	6% ($N=3$)	25% ($N=37$)	7.75**	2% ($N=3$)	10% ($N=55$)
Strong assertions	48% ($N=23$)	15% ($N=23$)	21.39***	19% ($N=30$)	6% ($N=30$)
Supporting statements	27% ($N=13$)	42% ($N=63$)	3.54	11% ($N=17$)	21% ($N=114$)

* Significant at $p<0.05$.
** Significant at $p<0.01$.
*** Significant at $p<0.001$.

that 10 of the 16 stylistic codes were found to reveal a significant difference in terms of male and female usage. A significantly higher proportion of females made contributions containing agreement, $\chi^2(1,N=197)=11.30$, $p<0.01$, empathy, $\chi^2(1,N=197)=4.91$, $p<0.05$, personal experience, $\chi^2(1,\ 197)=4.41$, $p<0.05$, and self-disclosure, $\chi^2(1,N=197)=7.75$, $p<0.01$, in comparison to males. Furthermore, significantly more females made reference to their own emotions, $\chi^2(1,N=197)=5.38$, $p<0.01$, and own feelings, $\chi^2(1,N=197)=7.96$, $p<0.01$, in comparison to males. On the other hand, a significantly higher proportion of males made challenging, $\chi^2(1,N=197)=19.59$, $p<0.001$, and controversial contributions, $\chi^2(1,N=197)=14.14$, $p<0.001$, expressed disagreement, $\chi^2(1,N=197)=17.86$, $p<0.05$, used humour, $\chi^2(1,N=197)=19.74$, $p<0.001$, and presuppositions, $\chi^2(1,N=197)=3.90$, $p<0.05$, and strong assertions, $\chi^2(1,N=197)=21.39$, $p<0.001$, in their postings.

The results of the supercode analysis are shown in Table 3. The supercode queries are listed, as are the corresponding proportions of males and females making each type of contribution, on which χ^2 analyses were conducted. The percentages of each type of posting, expressed as a percentage of the total male and female postings are also given in the table. Significantly more females made contributions that were attenuated but not authoritative, $\chi^2(1,N=197)=16.26$, $p<0.001$, and consisted of female language features only, $\chi^2(1,N=197)=19.43$, $p<0.001$, than males. Significantly more males made contributions that were authoritative but not attenuated, $\chi^2(1,N=197)=14.88$, $p<0.001$, and consisted of male language features only, $\chi^2\ (1,N=197)=11.50$, $p<0.001$, than females. There were no significant gender differences found along the task-orientated versus socioemotional dimensions. However, the socioemotional code family was further divided into positive socioemotional and negative socioemotional families. This revealed that significantly more females engaged in positive socioemotional behaviour than males,

Table 3
Interaction style supercode analysis by gender: χ^2 of male and female samples

Supercode	% of participants		x^2	% of postings	
	Male ($N=48$)	Female ($N=149$)		Male ($N=161$)	Female ($N=538$)
Attenuated not authoritative	31% ($N=15$)	64% ($N=96$)	16.26**	16% ($N=26$)	41% ($N=218$)
Authoritative not attenuated	69% ($N=33$)	37% ($N=55$)	14.88**	40% ($N=64$)	16% ($N=85$)
Male not female language	33% ($N=16$)	12% ($N=18$)	11.50**	12% ($N=20$)	4% ($N=19$)
Female not male language	33% ($N=16$)	69% ($N=103$)	19.43**	20% ($N=32$)	44% ($N=235$)
Male and female language	73% ($N=35$)	65% ($N=97$)	1.00	61% ($N=98$)	46% ($N=246$)
Positive not negative	35% ($N=17$)	58% ($N=86$)	7.24*	19% ($N=30$)	35% ($N=190$)
Negative not positive	56% ($N=27$)	19% ($N=28$)	25.32**	27% ($N=44$)	7% ($N=38$)
Task-oriented not socioemotional	56% ($N=27$)	63% ($N=94$)	0.72	36% ($N=58$)	30% ($N=161$)
Socioemotional not task-oriented	33% ($N=16$)	37% ($N=55$)	0.21	16% ($N=25$)	13% ($N=71$)
Task oriented and socioemotional	65% ($N=31$)	73% ($N=109$)	1.29	44% ($N=71$)	52% ($N=279$)

* Significant at $p<0.01$.
** Significant at $p<0.001$.

$\chi^2(1, N=197)=7.24$, $p<0.01$, whereas significantly more males engaged in negative socioemotional behaviour than females, $\chi^2(1, N=197)=25.32$, $p<0.001$.

4. Discussion

This research investigated the existence of gender-related patterns in language use and interaction styles in a formal, educational context. Firstly, participants' use of individual linguistic variables was examined, such as absolute adverbials (e.g., 'obviously') and references to emotion (e.g., 'love'). Only one significant difference was found between males and females regarding use of the 12 linguistic variables. More females used intensifiers such as 'really' and 'totally' in their postings. This does not support the work of Herring (1993) or Savicki et al. (1996) who reported gender differences in use of individual linguistic features in online contexts, such as first person and plural pronouns, absolute adverbials, interjections and qualifiers.

In this context, first person pronoun usage did not vary by gender. The electronic discourse showed extensive first person pronoun usage and 87% of postings were of this nature. Also, over a third of postings expressed agreement or disagreement with other students. Just over a fifth of all student postings contained references to own emotions or self-disclosure. These findings in this formal context suggest that the computer-mediated context is perhaps not as impersonal as previously implied (e.g., Markus, 1994; Sproull & Kiesler, 1986) and provides support for social information processing theory (Walther, 1992) in that CMC can support socioemotional communication. However, the discourse was also characterised by a lack of emoticons. This could be due to the formal, asynchronous context or a lack of participants' experience with CMC. Alternatively, participants may have felt that they were able to convey meaning adequately through their language use and did not have to resort to using emoticons to convey the tone of their message. There was some evidence of the use of paralanguage to convey tone, although this was relatively rare.

Although use of only one linguistic variable was found to significantly differ by gender, 11 out of the 16 stylistic variables produced significant results. It was found that significantly more females made contributions containing empathic utterances, personal experience,

self-disclosure, references to own emotion and references to own feelings, than males. On the other hand, more males than females sent postings containing controversial statements, humour, strong assertions and presuppositions.

The 'supercode' analysis in Atlas.ti 4.2, which examined use of combinations of language and interaction styles, showed that females were more likely to make attenuated contributions and use only traditional female language features in their postings. On the other hand, males were more likely to make authoritative postings and use only male language features. These findings provide empirical support for the existence of gendered styles of communication, as opposed to the influence of gender on use of individual language features. They also support the communication styles identified by Herring (1994) to an extent. However, they suggest differences in the degree to which gendered discourse styles are utilised, as opposed to differences in kind. The male style that Herring (1994) described was a considerably more extreme authoritative and adversarial style that included sarcasm and flaming, which did not occur often in the present research. This could have been due to the differences in context, in that Herring (1994) examined public discussion lists and the present research was concerned with private discussion forums in which instructors were present.

However, the results do support Herring's work in that females were found to employ personal and emotional forms of language more than males, who in turn used more authoritative language. It is possible that participants, especially females, developed ways of overcoming what could be perceived as an impersonal environment through the development of a discursive norm of explicitly personal writing. For example, the tendency to disclose personal information beyond that of opinions and feelings. It should be noted here that the coding category of self-disclosure was taken to mean high self-disclosure in the form of personal information beyond that of thoughts, feelings and experiences, which were distinct coding categories in themselves. It is interesting to note that Herring's prediction that the minority gender group will accommodate to the style of the majority was not supported in that gender differences were found in interaction style and males did not generally conform to the female norm of explicitly personal writing.

The findings here support Matheson and Zanna's (1990) claims that CMC users are more likely to experience high-private self-awareness, as opposed to deindividuation. High levels of first person pronoun use were observed and participants disclosed personal opinions, feelings, emotions and experiences, which may indicate a high level of private self-awareness. It is interesting to note that the pseudonymity offered in this research was not found to affect the level of self-disclosure, as similar proportions of pseudonymous and real name participants self-disclosed. However, gender was found to significantly influence the level of self-disclosure online as more females self-disclosed than males.

Therefore, previous work in the area of gender and language, both offline and online, is supported to some extent. Herring (1994), Savicki et al. (1996) and Soukup (1999) found that males used more authoritative language than females and that more females revealed thoughts and feelings than males. However, Michaelson and Pohl (2001) did not report any gender differences along the supportive/emotional versus adversarial/task-oriented dimension in their study of CMC interactions. Although this study did support the supportive/emotional versus adversarial distinction to an extent, it did not support the task-orientated versus socioemotional distinction in relation to gender. It is argued here that this distinction is too simplistic. Males and females were just as likely to send messages of each type and, more commonly, messages containing both task-orientated and

socioemotional content. The distinction between these categories was problematic as participants were frequently engaging in task behaviours due to the specific formal purpose, some of which could also be classed as socioemotional behaviour (e.g., requests opinions).

Furthermore, as indicated in the introduction, definitions appear to focus on the positive elements of socioemotional discourse such as expressions of support. However, disagreement and challenging utterances were also categorised as socioemotional discourse in this research, as they also involved references to others and reacting to others. Thus, a distinction was made between positive and negative socioemotional behaviour. Gender-related patterns were found as males had a tendency to post negative responses, whereas females were more likely to respond positively to other participants, with expressions of agreement and similarity in opinion and experience.

The finding that males tend to express disagreement more, whereas females tend to express agreement, supports Coates (1993) and Tannen (1991) that the male style is based on competitiveness and the female style is based on cooperativeness. It could also reflect gender-related learning preferences, as females may prefer to learn through connectedness and cooperativeness, whereas males may prefer a more independent and argumentative learning environment (see Belenky, Clinchy, Goldberger, & Tarule, 1997; Gilligan, 1992). These differing epistemologies and communication styles may influence the sharing and acquisition of knowledge in mixed-gender, computer-mediated educational interactions. For example, the increased tendency for females to agree and support, as opposed to disagreeing and rejecting suggestions, could be interpreted as taking a low-power role in the discussion. Tannen (1991) states that women typically use more supportive language patterns, which have the effect of diminishing the power of their own contributions. Thus, some participants, particularly males, may devalue and potentially ignore contributions of a personal and attenuated nature.

Furthermore, Taylor (1978) noted that women are often criticised for using language that is too personal. It is presumed that such writing blunts the 'argumentative edge', which is a conventional hallmark of effectual exposition. The issue of the perceived credibility of a contribution that uses personal and attenuated language is worthy of further investigation, as these linguistic forms are often associated with negative stereotyping, which may affect the perceived power and persuasiveness of the communication. For example, an authoritative and challenging contribution may be perceived as a more convincing argument and a more valuable contribution to knowledge than a personal and cooperative one by other participants and perhaps even instructors, who may be assessing the quality of online contributions.

The emerging female discursive norm of self-disclosure is likely to have been influenced by the nature of some of the psychological topics under discussion, which appeared to be personally relevant to some participants (e.g., eating disorders, depression). Indeed, Wallace (1999, p. 151) argued that the 'tendency to disclose more to a computer...is an important ingredient of what seems to be happening on the Internet'. Therefore, an increased tendency to self-disclose online, combined with the discussion of potentially sensitive topics, raises an ethical issue for the use of CMC in psychology courses, which instructors should be aware of.

It is also recommended that instructors should take the gender differences in communication styles identified in this research into account when using computer-mediated discussion forums in education, particularly when establishing 'ground rules' for electronic discourse and producing guidelines for the use of such forums. There is the possibility that some CMC participants could be intimidated by contributions that use an authoritative

style to critique ideas and express disagreement and find them unconstructive. Indeed, Herring (1994) suggested that differences in communication ethics between males and females regarding what is both acceptable and credible forms of communication are likely to result in male dominance and female submission in CMC. However, this perhaps implies a conscious and ethical choice to post in a particular style, rather than a reflection of a subconscious gender identity. Further research is needed to investigate this issue.

It is possible that the gender-related patterns reported here, which are similar to traditional gender role stereotypes, were found as the salience of gender as a social category may have invoked norms and stereotypical expectations regarding gender appropriate behaviour (Matheson & Zanna, 1990; Reicher et al., 1995). Gender was made a salient social category in the online discussion to an extent, as threads developed surrounding the issue of gender in relation to the topics of eating disorders, abortion and even task behaviour. Moreover, some participants used their real name online and the tendency for females to opt for a numerical identification more than males could perhaps have acted as a gender marker in itself. It was also found that some participants revealed their gender in the content of their contributions (e.g., 'as a gay guy', 'as a 19-year-old girl'), showing that pseudonymous conditions do not necessarily prevent gender from being revealed online.

Matheson (1991) suggested that high private self-awareness would facilitate access to internalised frameworks for processing and responding to social cues such as gender. Therefore, the combination of high private self-awareness and the salience of gender cues may lead to expectations of gender-appropriate behaviour based on traditional stereotypes. These expectations could promote self-fulfilling prophecies, as Snyder (1984) suggested, resulting in stereotypically gendered behaviour. Therefore, this could account for the gender-related patterns in language use and interaction style found in the present research. For example, it could be the case that more females were found to self-disclose than males because the salience of gender as social category may have invoked behavioural norms and expectations based on stereotypes regarding gender appropriate behaviour, effectively increasing the level of self-disclosure by females and lowering the level of self-disclosure by males.

The notion that gender does not matter online seems overly optimistic, especially considering that one of the most popular first questions asked in recreational chat rooms is 'asl', which stands for 'age, sex, location?'. Internet users use this initial question to get a sense of who they are talking to and sex (or gender) is one of the major social categories that are considered, often making it a salient social category in online contexts. For example, Huffaker and Calvert (2005) found that both males and females often reveal personal information online such as their real names, ages and locations.

Finally, the unequal male and female sample sizes were unavoidable in this context as female students often outnumber male students on psychology modules and it is argued that studying gender and CMC in a meaningful context outweighs this potential drawback. Future research should investigate the extent to which the gender-related patterns found here can be extrapolated to other educational computer-mediated contexts, for example male-majority courses such as engineering. The relationship between gender identity and expression and manipulation of that identity in online text-based contexts is also deemed worthy of attention.

In conclusion, the results provide support for gendered styles of communication online, showing that CMC does not guarantee a gender-free environment. Cues to gender were found to exist in the language used by CMC participants and as the work by Thomson and Murachver (2001) suggests, CMC users may be able to identify gender based on these

cues alone. The gender gap may be closing in terms of being online, although women still remain less frequent users of the Internet (Ono & Zavodny, 2003). It is likely however that different results will be found depending on the context in which Internet use is being studied. For example, Miller and Durndell (2004) found evidence for equal participation in the context of online discussion groups in education. However, the present study indicates that even within the educational domain, if you scratch beneath the surface, gender differences in language use and interaction style can be revealed. This suggests that existing gender-related patterns of power and communication may carry over into online environments and compromise the extent to which an equitable environment can be maintained. Therefore, it seems that gender does matter online.

Appendix A. Descriptions and examples of linguistic variables

Code	Description	Examples from corpora
Absolute adverbial	Strong assertion	'obviously', 'certainly'
Exhortation	Phrased as suggestion	'let's', 'why don't we'
First person plural pronoun	Refer to group including writer	'our', 'we', 'us'
First person pronoun	Refer to writer	'me', 'my', 'I', 'myself'
Second person address	Refers to another group member	'you', 'your'
Imperative verb	Expresses a command	'think about it'
Impersonal truths	Presupposed fact	'it is a fact that'
Intensifier	Reinforces meaning upwards or downwards on a scale of intensity	'so', 'really', 'very', 'totally', 'quite', 'hardly'
Interjection	Exclamation, usually emotive in meaning	'ah!', 'oh!', 'eh?', 'oops', 'well', 'boy!'
Qualifier/hedge/tag question	Word or phrase that modifies the meaning of another word or phrase	'perhaps', 'may', 'seems', 'sort of', 'isn't it?'
Reference to emotion	Use of emotive word	'happy', 'depressing'
Rhetorical question	Assertive question not meant to be taken literally	'but isn't this a 2-way street?'

Appendix B. Descriptions and examples of stylistic variables

Code	Description	Examples from corpora
Agreement	Makes explicit statement of agreement	'I totally agree with you'
Challenging	Statements that challenge others' ideas or opinions	'How can you possibly think that'
Compliments	Author praises participant for contribution	'I thought the points you made were very good'

Appendix B (*continued*)

Code	Description	Examples from corpora
Controversial	Makes controversial statement, statements likely to 'wind people up'	'People without the intellectual capacity should be discriminated against'
Disagreement	Makes explicit statement of disagreement	'I don't agree with you'
Empathic	Shows empathy (sense and understand someone else's feelings as if they were one's own)	'They have a lot of pressure on them'
Humour	Quality of being amusing	'Unless you wanted to be an accountant, which is crazy anyway!'
Personal experience	Refers to speaker's own experience	'When I was at school'
Personal orientation	Refers to speaker's personal orientation	'In my opinion', 'I think that'
Polite forms	Polite forms of language such as thanking and apologising	'Thankyou for your response', 'I'm sorry'
Presuppositions	Statements that assume certain facts or opinions	'People would end up as robots'
Reference to own emotion	Makes reference to speaker's own emotions	'It makes me sad'
Reference to own feelings	Makes reference to speaker's feelings	'I am very interested in'
Self-disclosure	Shares personal information beyond that of opinion, experience and emotion	'I am bulimic'
Strong assertions	Assertions made without or with involved modalities	'I am very sure that'
Supporting statements	Statements that support a previous view or argument (with or without an explicit statement of agreement)	'(I agree) There is no way of being certain that cloned scientists or nobel prize winners will have good intentions'

References

Barrett, E., & Lally, V. (1999). Gender differences in an on-line learning environment. *Journal of Computer Assisted Learning, 15*, 48–60.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1997). *Women's ways of knowing*. New York: Basic Books.

Biggs, J. (1987). *Student approaches to learning and studying*. Hawthorn, Victoria: Australian Council for Educational Research.

國立雲林科技大學
97學年度博士班招生考試試題

系所別：資訊管理系
科　目：資訊管理文獻

第一部份：

Preparing to work in the virtual organization

1. Please describe the business model of the following three items base on information technology concept. （15%）
   (i). e-Hub;　(ii). 4PL (第四方物流);　(iii). VPN (virtual private network).
2. Describe the method, algorithm and findings of this research（10%）
3. What are the main characteristics and skill to work effectively in a virtual organization? （5%）
4. What is the virtual team organization?（5%）
5. What is the implication of this research? （8%）
6. What expected to the data analysis of this research (7%)

第二部份：

The effects of perceived risk and technology type on users' acceptance of technologies

7. Please briefly describe what the major concepts of the following theories are（15%）
   (i)Auction Theory; (ii) Resource Dependence Theory; (iii) Social Exchange Theory
8. Please give the abstract, within 150 words in English, of this journal paper. (.10%)
9. Please Draw the framework of this paper based on the hypotheses(H1 to H4). （15%）
10. Please describe the findings of this paper and give examples for further researches.（10%）

Preparing to work in the virtual organization

1. Introduction

The modern business world has always worked in teams, but today the phenomenon of virtual teams and virtual organizations (VOs) is becoming common. Organizational members can be oceans apart or they can work in offices down the hall, but complex projects require collaboration and working across boundaries. There is no place where teams and virtual teamwork are needed more than in the information field, where teams are created to evaluate, develop, and implement IS. Effective teams are important in the real world, and they are a part of the growing virtual environment for organizations that operate multiple sites or those that form international alliances. Virtual teams meet by using e-mail, teleconferencing, and often do their work by phone, fax, or compressed video; moreover they must learn to trust and to rely on partners that they may never see face-to-face.

Team learning has become common in graduate schools, since universities prepare students for working in the knowledge organizations that are dominating

* Corresponding author. Tel.: +1-732-932-7590; fax: +1-732-932-6916.
E-mail addresses: kai.larsen@colorado.edu (K.R.T. Larsen), clairemc@scils.rutgers.edu (C.R. McInerney).
[1] Tel.: +1-303-735-6448; fax: +1-303-492-5962.

0378-7206/02/$ – see front matter
PII: S0378-7206(01)00108-2

the work place today. Of course, these organizations may also be VOs with some team members telecommuting, others working out of client sites, or traveling from week to week to different work locations. Our concepts of time, place, and proximity have been transformed by the ability to work electronically using the Web and other information and communication technologies.

The purpose of this paper is to discuss methods and practices used in a cooperative effort to teach graduate students in four universities about working together to create an information product in a virtual environment. Faculty and students took the lead for the project in a graduate course at the School of Information Science and Policy at the University at Albany. The course, "Ethics and the Knowledge Organization", helped students use critical thinking and analytical methods to approach ethical problems that they might experience in an IT organization. The students used cases, structured controversy, stakeholder analysis, implication exercises, etc. to understand issues and formulate ethical decisions.

Part of the learning process involved forming teams with students in three other universities: The University of South Florida (Public Administration); Carnegie Mellon (Management) and Indiana University (Library and Information Science). The students were charged with writing a white paper cooperatively with students in other schools that they met through the Internet. The faculty members involved had their own electronic discussion list for discussing the assignments and approaches to be used. The students used Web conferencing to plan their paper and exchange files. Student surveys submitted at the end of the course demonstrated the benefits and learning that took place as well as frustrations and difficulties.

2. VOs in theory and practice

The literature on the topic of work and work satisfaction is voluminous. This paper will only touch on some aspects of it, however. One assumption was that educators might change and adjust learning methodologies to prepare students for change in society and the workplace. Although VO research and writing is less plentiful than the published material on work, in general, it is a growing topic of interest.

2.1. A changing world of work

When Alvin Toffler wrote about the "electronic cottage" in *The Third Wave*, few people expected that his prediction of workers wired to their jobs from home would so rapidly become a reality [33]. This was before the proliferation of PC's, the Internet, etc. However, 20 years later, such methods are integral to the life of business. Toffler's follow-up, *Powershift: Knowledge, Wealth, and Violence at the Edge of the 21st Century*, pointed to the value of knowledge in a global economy [32]. Work has become mobile, and workers are often remote from each other. Thus, workers need mechanisms that give them remote access to knowledge repositories and networks that can connect novices with experts.

The Virtual Community [27] documents everyday life in cyberspace by recounting the human side of the electronic cottage. The workplace is also part of our social fabric, and being able to exchange information and knowledge rapidly has dramatically changed the power structure in companies, universities, etc. [31,37]. Now messages are often sent directly from upper management to the organization. Workers of any status have also been able to disseminate information electronically without having to go through hierarchical channels.

Of course, as Nonaka and Takeuchi point out, the de-valuing of middle managers may be a mistake [25]. The middle manager's role has traditionally been to interpret the vision from top management within the constraints of day-to-day work. Then managers are key to knowledge creation for the organization, because they can help take the tacit knowledge possessed by front-line workers and translate it into explicit knowledge in the organization.

Technology has not been able to replace these managers because they are often the knowledge coordinators, and once they leave, organizational knowledge leaves with them [8]. Now organizations are working to capture the tacit and explicit knowledge, codify it, store it, and make it available to all employees [4]. As Winslow and Bramer state, "Knowledge, and knowledge work, dominate the value chains of virtually all companies, whether in services or manufacturing" [35]. Since the knowledge they have and use well makes organizations viable and profitable [9], it must be handled carefully.

Global competition, leaner work forces, and more knowledgeable customers have all had firms scrambling to provide better service and high quality. At the same time robotic mechanisms are replacing workers, ATMs are replacing bank tellers, and smart machinery is now doing the work of farmers, security guards, highway toll takers, and parking lot attendants. Economist Rifkin [29] cautions that we are losing thousands of jobs per year due to technological advances and other influences, such as re-engineering, and that the resulting unused human labor pool could be a force for destitution and lawlessness. On the other hand, he says that lost jobs might simply translate into shorter workdays or workweeks, and the resourcefulness resulting from dealing with a decline in "jobs" might be good outcomes. Harvard economist Juliet Schor argues that Americans work too much and that the time squeeze imposed on families and the general velocity of life caused by overwork is harmful in the long run [30]. Large numbers of workers are already realizing they can escape the nine to five "rat race" and earn a living independently from home. They can create new organizations that communicate, sell, and buy products and services through the World Wide Web.

The highly mobile or independent worker needs a different kind of management than those who work in a traditional environment [19]. Employees who cannot be seen need clear communication about expectations and need to be evaluated on outcomes. Managers also need to understand how to encourage trust and team productivity [34]. Despite the movement to independence and autonomy, begun with quality circles, work today is run by teams [6,10,12]. Alliances are finding that teams bring diversity and creativity to the work process. Innovation demands teamwork [1].

Teams do not necessarily translate into organizational loyalty, though. The present layoffs and those threatened by downsizing, re-engineering, and the constant activity of mergers and acquisitions has changed the loyalty factor for both organizations and workers. There is no such thing as lifetime employment anymore, and workers are willing and ready to switch jobs more frequently, because they feel that no job is secure anymore [7]. So, managing now involves overseeing projects where workers might be anywhere; they work in teams and there is a constant changeover of employees. Management by results has replaced management by observation, but those who manage may not have the experience or background or oversee their employees in this way. Traditional hierarchies are certainly under pressure. As Zuboff says, "control relies on delicate human interactions. The challenge of how to manage and how to organize work in VOs is formidable".

2.2. *Virtual organizations*

Though there are almost as many definitions of VOs as there are researchers, a literature review found Bultje and van Vijk's definition to be rich, based on existing literature, and the result of careful analysis [5]. The first part of their definition is based on the primary characteristics of the VO. We will use this here.

> A virtual organization is primarily characterized as being a network of independent, geographically dispersed organizations with a partial mission overlap. Within the network, all partners provide their own core competencies and the co-operation is based on semi-stable relations. The products and services provided by a virtual organization are dependent on innovation and are strongly customer-based.

It is interesting to note that even though they examined a set of 27 characteristics of VOs, they left out the *teamwork characteristic*: it will be included here. VO characteristics and the nature/value of the university virtual experience are shown in Table 1.

Virtuality, as a workplace process, requires new ways of thinking about management, communication, teamwork, and adapted skill sets to meet the needs of members who work at a distance.

2.3. *Skills for workers and managers in a VO*

What are the skill sets needed to work effectively in a VO? The ability to work in teams is especially important. Groups are often brought together on an ad hoc basis to respond to a need or a situation. In the business arena, Jones and Bowie [18] say:

> ... we believe that one of the chief differences between traditional strategic alliances and virtual alliances is that the latter will be fleeting and temporary. The *components* of any given virtual corporation may achieve some stability over time as they continually enter into new and changing

Table 1
Characteristics of the virtual organization and university preparation for virtual work

Characteristics	Of the virtual organization	Found in the inter-university project
customer-based and mass customization	This characteristic refers to the ability to customize the product or service to the customer. Gilmore and Pine [13] suggest four levels of customization based on whether the product had been changed or not, and whether the representation had been changed or not	For the students there are two customers: their professor and the stakeholder group they are representing. Their mission is to lobby and speak for their stakeholders in such a manner that would satisfy the requirements of the course. In this way, each work team has to customize their "product" for the intended audience. The fact that one product may have to satisfy several different professors adds complexity to the class VO experience
Network of independent organizations	Virtual organizations are often considered a subset of the much older research area of networked organizations [17]. A network refers to a set of people or organizations that are tied by relational, positional, or spatial proximity [28]. For virtual organizations, focus is usually on networks that are created or controlled by technological means, and thus positional and spatial proximity is not considered important	Although each university and each course is an autonomous organization, the teams are tied together by the project and the task at hand. The challenge is to produce one paper together, even though each student is based at a distinct institution working under different constraints. Even the individual students' departments or schools are distinct. Because of the diversity of organizations, departments, schools, and courses, most members of a group have different schedules and time commitments
Semi-stable relations	The literature disagrees about the temporal nature of virtual organizations, however, most researchers seem to agree that the virtual organization is a temporary structure [20]	Work teams are by nature temporary. Student class teams are organized around a project, and disperse when the project is complete. When students form teams within a department, a major, or a school, chances are they will at least see, if not work, with the team members again. In the course, however, students are not likely to meet or see any of their team members again. This very temporary nature of the class teams is at least somewhat similar to work teams in virtual organizations when groups of people around the world develop a product but never meet face-to-face
Geographical dispersion	The geographical dispersion of organizations may be one of the main differences between a virtual organization and other types of partnerships. Whereas other types of partnerships rely on co-locating staff, VOs avoid this by using information technology	Universities participating in this project were in geographical locations far away from each other, just like companies that form alliances with other organizations in various parts of the country or the world. Students need to communicate through e-mail, e-lists, and teleconferencing. Most likely, student commitment to the organization will be related to the richness of the communication media used
Based on core competencies	Most organizations, naturally, have areas where they have higher quality competencies as well as areas where they have lower quality competencies. The thinking behind virtual organizations is that several organizations should pool their talents, with each organization contributing their high quality competencies	Teams in this project were not chosen with competencies in mind. By nature of the various programs in which the students were enrolled, however, they brought certain competencies to the task of developing a stakeholder white paper. The cooperation between classes from divergent areas of study, by the nature of the different focus of prior coursework, will enable teams to work together in a manner displaying the importance of different core competencies. The nature of the VO project is important to ensure the above effect

Dependent on innovation	Some researchers see virtual organizations as a response to opportunities in the marketplace. When such opportunities arise, virtual organizations are created quickly to take advantage of the opportunities by creating unique and innovative solutions	Success in student projects is dependent on the ability of students to work in unconventional situations using methods that are different from other courses. Those with the ability to accept change, ambiguity, and to develop innovative ways to accomplish their work may find such an exercise interesting and challenging. By using the right case approach, the need for innovation may be simulated
Based on teamwork	Teams, the building blocks of a virtual organization have received much attention from researchers. Even so, many aspects of their dynamics continue to elude researchers. This is especially true for teams basing their communication on technology	Whereas some students have extensive experience in teamwork, others are novices, and have never produced major products through work in teams. Because of the importance of effective teams in today's knowledge-based organizations, extensive experience with this form of work is essential for most degree programs in information studies
Partial mission overlap	Partial mission overlap suggests that the VO partners are also doing business outside the context of the VO. Partners that are doing business only within the context of the VO would have full mission overlap	While students are working within the virtual organization, they also have weekly reading assignments/essays in information ethics and have to participate in small groups within the class. Each course has a variety of assignments and readings outside of the case study project. Students also have other courses and responsibilities within their respective departments, schools, and universities

alliances, but the virtual corporation itself will disappear once a given project is completed.

The speed with which VOs must form demands that workers can deal with rapid change. Although research on teamwork suggests that teams function optimally after they have worked together [15,16,22], teams in VOs may not have the luxury of establishing working relationships over extended time periods. However, this view may change if VOs are studied longitudinally. From the managerial point of view, knowledge of working in VOs will influence their approach to training, coordination and control.

2.4. The matter of trust

Teams brought together for temporary projects and the generally fast-paced nature of VOs in a business setting can be faced with what Jones and Bowie call the 'virtual paradox' that teams must work quickly and with flexibility in order to be innovative and meet the needs of the customer. This requires an environment of "high levels of trust and cooperation". However, trusting, collaborative alliances usually develop only in long-term relationships.

Trust may be an elusive factor, but it is critical in the operation of a VO. As Nonaka and Takeuchi point out, "... participants in the (virtual) project should develop a sufficient level of trust among themselves. Building trust requires the use of mutually understandable, explicit language and often prolonged socialization or two-way, face-to-face dialogue that provides reassurance about points of doubt that leads to willingness to respect the other party's sincerity".

Trusting relationships must be mediated by workers' effectiveness and efficiency. Even in professions, such as journalism, where the employees are accustomed to being out of the office for extended periods of time, they are still expected to return to a central place for meetings, conferences, and reporting. In the past, managers have had to see people in the office in order to confirm that they are working [14].

Some organizations that employ telecommuters have a rule that they be available at their phones during the "usual" business day (e.g. 9 a.m. to 5 p.m.). In addition, some managers make it a habit to call to see if, in fact, employees are working.

The US Office of Technology Assessment reported that, in 1988, 10 million American workers were monitored through video cameras or computer software [3].

Electronic monitoring is really counterproductive, however, because one of the advantages of virtual work, and one that employees really value is that workers have flexibility in their workday [21]. When working with virtual teams, there must be some element of trust to accomplish the goals and objectives. Charles Handy says, "If we are to enjoy the efficiencies and other benefits of the VO, we will have to rediscover how to run organizations based more on trust than on control". Oversight must still be there, but it must be a different type of care taking.

Moral character can overcome the virtual corporation paradox. Traditionally, partners learn to trust each other through face-to-face contact and by learning about a firm's reputation. Some research shows that when a temporary group is formed for a particular purpose, a kind of "swift trust" can develop that allows the group to function [23]. Economic self-interest and social embeddedness can explain some types of swift trust, but a moral character type of trust is needed to overcome the virtual corporation paradox.

Jones and Bowie caution that this is not blind trusting relationship, but one where partners are scrutinized rigorously and means are taken to safeguard a firm's assets. It is mutually beneficial to operate with a commitment to trust, though, and VOs that develop a character of trust have much more to gain than to lose.

Handy points to several principles of trust that must be followed to realize a VO. One needs to know people in order to trust them, but getting to know them at a distance takes more effort and is more difficult. Trust also requires bonding for teams to coalesce and deliver results. Trust is also related to learning, so members of a VO do well to be nimble and flexible adapting readily to rapid change and innovation. Individuals need the capacity for self-renewal. Leaders rather than managers inspire the holistic view that is the mission of the VO, but they also take special efforts to make and retain personal contacts.

When the confidence or trust in an individual is misplaced because the person does not carry through on responsibilities, then the work team suffers. Leaders must serve as role models in work and communication; they persuade their teams to complete work as promised, and they can help their teams by offering opportunities for groups to meet "in person"

whenever possible. In person, or approximating *in person* can mean actual face-to-face meetings, synchronous teleconferences, or synchronous online chats and Web conferencing.

3. How can students prepare to work in VOs?

With few exceptions [11], little work seems to have been done on the topic of preparing students for work in the VO. The present belongs to traditional educational methods. Which methods of teaching will be successful in helping students? Foreman believes that

> ... a conventional knowledge transfer (either face-to-face or in a conservative distance learning form) cannot cultivate the complex set of behaviors and attitudes required in VOs. What is needed is a learning process that is experimental and that simulates what happens in 'real' VOs.

4. Project description

Our case study was associated with the course *Ethics and the Knowledge Organization* taught to allow students to approach ethical problems they might experience in their future work life. The students used cases, structured controversy, stakeholder analysis, implication exercises, and other methods to understand ethical issues and formulate ethical decisions. An equally important goal was to simulate VOs so that the students could prepare to work in such organizations.

4.1. Cybercity

The learning process involved forming teams with students in three other universities. The students were charged with writing a white paper cooperatively with students they met exclusively through the Internet. The students used Web conferencing to plan their paper and exchange files. Although students met in person at their own universities for regular graduate coursework, they formed VOs in order to develop the policy white papers in an electronically networked city: *Cybercity*.

All teams consisted of graduate students but they were enrolled in different degree programs. The five courses were offered through different schools or departments also: Business Administration, Public Administration, Library and Information Science, and Information Science and Policy. Each team was assigned a separate stakeholder group to represent in the scenario's city:

- city residents;
- homeless people;
- city administration (manager and professional staff);
- city council (elected officials);
- schools (elementary and high schools);
- libraries;
- health services providers;
- telecommunications industry representatives;
- local universities and colleges.

The scenario required each stakeholder group to take a position regarding the wiring of the city for high speed Internet access and telecommunications services among public buildings, schools, libraries, hospitals and clinics, and universities and colleges. They were to report in the form of a white paper, which was to consider implications for using city resources to accomplish access. The students started working on the project at the mid-way point in the semester, but technical difficulties arose. The Cybercity scenario was a public domain educational tool obtained from an Internet Web site.

The faculty chose education utility software that included group chat functions, e-mail, hypertext links, and archiving of communication. TopClass was the original platform chosen. However, it was very difficult to upload whole papers to the conferencing program. The next choice was NetForum, a public domain utility available on the Internet. This fulfilled most expectations. Students planned the project, discussed the issues, wrote drafts of their papers, and revised them using NetForum. Faculty were also able to participate and view the discussions, but they deliberately took an observer role after getting things started and posting details of the assignment.

5. Research method

In the MIS field, there are three generally accepted approaches to research: positivist, interpretive, and

critical [24,26]. Within each approach, many different methods may be applied. Because of the explorative nature of the study, a positivist case study approach [2,36] was selected.

With the student project designed to work like an educational simulation of several VOs, observation was an important element in researchers understanding of the situations. The observational data not only helped, but also enabled the development of a survey probing topics of special interest. Survey development also benefited from examination of NetForum logs and feedback from students.

At the completion of the course, the survey instrument was used to evaluate the learning methods and to investigate how well the educational simulation worked. The respondents were the student participants, all 34 of whom received the survey.

While participation in the survey was voluntary and in no way affected class grades, 29 students returned complete surveys for a response rate of 85%. The students from one university where papers were not required were not asked to fill out the survey. Students were asked questions on the following areas:

- the teamwork experience;
- the learning experience;
- satisfaction with the course;
- satisfaction with the team;
- satisfaction with NetForum;
- satisfaction with the final paper;
- trust among the team members;
- what they enjoyed most about the Cybercity assignment;
- the effort they expended;
- the time spent on the project;
- the nature of the team experience;
- the relevance of the course to preparation for professional work;
- communication obstacles;
- barriers to learning;
- how they would approach the assignment differently next time;
- how the project was different than working with an in-class in-person team;
- how much of the project the student actually did herself/himself;
- means of communication used and
- methods of collaboration.

The survey instrument contained a mix of quantitative, open-ended, and ranking questions. Some of the quantitative questions were measured with Likert-type scales; while others were measured with a 7-point scale anchored with "not satisfied" and "very satisfied".

The evidence was examined using analysis of embedded units as suggested by Yin with the VOs from the educational simulation being the embedded units [36].

6. Analysis

The most interesting findings emerged from the open-ended and ranking question, whereas the quantitative measures served to establish baselines for follow-up work and replications.

Table 2 outlines the descriptive statistics. The average student had participated in approximately two to three teams in a University setting, and between three and four teams in the workplace in writing joint papers. The high level of experience was not surprising, considering that the students were in graduate classes. The experience, however, was quite unevenly divided among the students, as is clear from the high standard deviations. The "VOs" had approximately four students each. It is interesting to note that they were very satisfied with the course, but much less so with the VO experience.

Further exploration indicated that, on the average, students agreed somewhat that the VO exercise made the course both more interesting and more current, and that the exercise would benefit their professional work. The average student also claimed to have invested between a moderate and great deal of effort on the exercise.

Table 2
Participating students: selected descriptive statistics

Variable	Mean	S.D.
No. of teams in university experience	2.41	3.18
No. of teams in workplace experience	3.68	5.44
No. of people on virtual organization (VO) team	3.86	0.69
Satisfaction with course (7-point scale)	6.00	1.22
Satisfaction with VO experience (7-point scale)	4.79	1.68

6.1. The advantages of inter-university team learning

The respondents were asked to state three items that they would not have learned had they been doing the same project with people in their class. The results were organized according to the eight categories of VO characteristics.

The *customer-based and mass customization* category had no responses. This is not surprising, considering the task assigned. The *network of independent organizations* and *partial mission overlap* characteristics were considered similar enough to be treated together. Respondents believed that setting objectives and cooperating with strangers was the main learning experience.

The *semi-stable relations* category contained lessons about how to deal with time pressure, with time pressure more intense than in ordinary projects due to the asynchronous nature of the communication medium. Because a Web-based conferencing tool was used, respondents waited lengthy periods to get a response to their questions and suggestions. Some issues often resolved in the first face-to-face meeting were not resolved until later into the project.

The students learned about the *geographical dispersion* of VOs through the communication barriers they encountered. They had to develop trust with people they could not see and with whom they had never shared the same physical space. One respondent suggested that an important lesson was that "you never have to physically see the person to get things done". The respondents learned that "online computer communication is frustrating and a waste of time", that face-to-face communication is more effective, and that it is not always easy to explain things in text. On a more positive note, the respondents suggested that the specific technology makes "a big difference", and that the project taught them how to deal with new types of technology. One respondent also liked having responses verbatim, allowing re-analysis of personal and other people's styles of communication.

The responses to the *based on core competencies* and *dependent on innovation* categories were merged because the responses were found to be quite similar. One of the main ways to bring about innovations is to mix different core competencies. The respondents pointed out that it was "interesting" to work with strangers, that the VO project enhanced creative thinking, and that "different ideas came from different areas of the country". Students merged the knowledge and expertise of all the members (at least those who participated fully) with research findings to create new knowledge about the Cybercity. This is the knowledge creation process recommended by Nonaka and Takeuchi.

That VOs are *based on teamwork* was learned through developing teams at a distance, a task found to be quite a challenge. An aspect of teamwork is managerial, and respondents sometimes felt ignored and that they needed to be heard.

One respondent pointed out that it was a great challenge to try to make sure that everyone "did their share without stepping on anyone's toes or being too pushy". The two major learning experiences, however, seemed to stem from finding out how to "alter the direction of the group to take advantage of strengths rather than butting heads", and that "things are not always as out of control as they seem".

6.2. The obstacles to product development in a virtual setting

The respondents were asked to name three communication obstacles. These results were organized according to the eight VO categories.

With respect to the *network of independent organizations* and *partial mission overlap*, a few respondents pointed to problems in understanding who was in the group and what it was. Many of the obstacles may stem from the fact that the respondents had different schedules and missions both inside and outside of class. The *semi-stable relations* caused unique problems: it was very hard to communicate; finishing one "chain of thought" could take 1 or 2 weeks. Because the students were not accustomed to this way of communicating, they adopted a real-time discussion approaches. They would ask a one-dimensional question, and log out of the system while waiting for an answer. This led to confusion and slow progress.

The *geographical dispersion* of the students led mainly to technical problems. The specific tool seemed to lack the speed needed. Another major problem was the time lag; students were not notified when a new posting had been made, they had to check as often as they had the opportunity or interest.

This is likely to have had a demoralizing effect. In terms of general technology problems, platform incompatibilities were listed as the main problem.

Students in professional schools face some of the same challenges as those knowledge professionals who work away from their offices and need to log into remote servers through Internet Service Providers that may be slow and inaccessible. Even workers in Fortune 500 companies find that they work odd hours, and they need good equipment, high bandwidth, and technical support when things go wrong.

The dimensions of the workday are no longer limited to nine to five, 5 days a week for professional information and knowledge workers. Telecommuters, for example, do not differentiate between work-time and time at home. Students work long hours to be able to pay tuition; they often have family obligations and they are expected to use technology tools for research and creative work. Like many others who experience an increased velocity in their work lives, students in VOs feel the tension and stress that VOs present.

The *based on core competencies* and *dependent on innovation* characteristics were not considered to be a source of problems. Only two respondents pointed to differences in goals between people from the different classes. *Based on teamwork* was cited as one of the biggest obstacles. It was especially difficult to get used to not having real time conversations. One student claimed that his team members did not post unless someone else was also online. It is therefore not surprising that several groups found one self-appointed leader, in essence becoming the "benevolent dictator".

6.3. Overcoming the obstacles

The respondents were asked to name three things they would do differently, given the same assignment with different teammates. It is important to note that some are lessons that students learn by experience.

In the *network of independent organizations and partial mission overlap* category, the respondents wanted a clear definition and their roles needed to be clearer; one respondent mentioned that their paper was changed at the last minute by one person, leaving the rest of the team frustrated and angry.

Two major issues surfaced in terms of how to deal with *geographical dispersion*. First, the need to ensure better communication through the use of all alternative media was expressed. In addition to specifying designated times to meet on the Web-based forum, suggestions included extra use of the phone, and use of Internet chat rooms. The few items about *based on core competencies* and *dependent on innovation* characteristics focused on making sure that the team members had certain core competencies such as technical abilities and writing skills.

6.4. The importance of trust

When asked, "How much did you trust your team members?" the mean response of respondents was 4.9 on a 7-point scale, consequently, it seems like most of the participants had some level of trust. When dividing the respondents into low, medium, and high level of trust, only two individuals fell into the low level of trust category.

One respondent explained his/her low level of trust by saying that this student had "difficulty trusting someone I don't know, someone whose work I have never seen before". Other students explained a low level of trust by saying that there was a lack of communication and too long a time lag in responses. Among the reasons cited for having a high level of trust in the team members was a belief that everyone had an equal stake in the project or the team had split up the assignment in such a way that each one could do his or her own part and expect other team members to do their parts too.

While the level of trust was reasonably high, this may have been due primarily to the shared background of the participants. VOs may be implemented internationally where cultural or organizational boundaries may exist.

Walt Disney's animation studios use communications technologies to connect people working on movie projects from geographical locations such as California, Florida, France, Canada, Japan, and Australia. Individuals from many of those locations find themselves working on movie projects using technologies such as e-mail, phone, videoconferencing, and courier pouches. These individuals are likely to become teammates of people they already "know" from earlier projects. It is quite likely that VOs will experience similar reconstitutions, and this is likely to increase levels of trust.

6.5. Implications for project management

In this case study, no team leaders were assigned, and the respondents pointed out problems caused by this lack of leadership. During the *initiation phase*, goals need to be clearly defined and communicated to all participants. At the same time, ground rules must be specified. Another important factor to consider is the allocation of people with different skills and abilities to make the project "well rounded". An important lesson learned by some of the participants who felt they needed to become de-facto project leaders was how to change the direction of the group to take advantage of individual strengths. While the respondents considered having equal stakes in the project is important, it is unlikely that practitioners will all find their partners having equal stakes in the project.

During the *work phase*, the tasks need to be defined and assigned to participants, giving each task its deadline. With individual participants having different missions and schedules, some individuals were not properly utilized, whereas others received too many tasks to handle.

7. Conclusion

Clearly, work practices in our time have changed dramatically. Work teams often have members who are at a distance and communicate using information and communication technology. These teams are often called virtual organizations or VOs. The educational simulation involving faculty and students in four universities was an effort to help students learn how to work in VOs.

The VO educational experience was a partial simulation of the characteristics of a VO creating a customer-based and customized product within a network of independent organizations that have semi-stable relationships. The teams, working on a white paper representing a city stakeholder group, were geographically dispersed and brought core competencies to the project. Although the teams shared goals, their organizations 'missions overlapped to some extent. Effective teamwork skills, tools, and strategies were critical to a successful completion of the project.

No doubt the graduate students with varied backgrounds were influenced by previous experience, but this was the first time that these individuals had participated in a project with members from different universities. On the whole students were quite satisfied with the course and indicated that they learned a great deal, however, their experiences were also marked by frustrations. Trust was critical to the work teams, but some students had difficulty in trusting colleagues whom they had never seen nor spoken with in real time. The other major problem involved the management of time, especially when communication was asynchronous. The experience of the participants paralleled the literature on trust and VOs.

References

[1] C. Argyris, Integrating the Individual and the Organization, Wiley, New York, 1964.
[2] I. Benbasat, D. Goldstein, M. Mead, The case research strategy in studies of information systems, MIS Quarterly 11 (3), 1987, pp. 369–386.
[3] N.E. Bowie, Business Ethics: A Kantian Perspective, Blackwell, Oxford, 1999.
[4] M. Broadbent, The phenomenon of knowledge management: what does it mean to the information profession? Information Outlook 2 (5), 1998, pp. 23–35.
[5] R. Bultje, J. van Wijk, Typology of virtual organisations, based on definitions, characteristics and typology, Virtual-Organization.net Newsletter 2 (3), 1998, pp. 7–21.
[6] P.M.J. Christie, R.R. Levary, Virtual corporations: recipe for success, Industrial Management 4 (4), 1998, pp. 7–11.
[7] N.F. Crandall, M.J. Wallace, Inside the virtual workplace: forging a new deal for work and rewards, Compensation & Benefits Review 29 (1), 1997, pp. 27–36.
[8] T. Davenport, L. Prusak, Working Knowledge: How Organizations Manage What They Know, Harvard Business School Press, Boston, 1998.
[9] P. Drucker, Beyond the information revolution, The Atlantic Monthly 284 (4), 1999, pp. 47–57.
[10] M. Duffy, Ten prescriptions for surviving and thriving in the virtual organization, Public Relations Quarterly 39 (2), 1994, pp. 28–32.
[11] J. Foreman, Distance learning and virtual organization, Virtual-Organization.net Newsletter 2 (4), 1998, pp. 21–25.
[12] L.R. Frey, D.S. Gouran, M.S. Poole (Eds.), The Handbook of Group Communication Theory and Research, Sage, Thousand Oaks, CA, 1999.
[13] J.H. Gilmore, B.J. Pine II, The four faces of mass customization, Harvard Business Review 75 (1), 1997, pp. 91–101.
[14] C. Handy, Trust and the virtual organization, Harvard Business Review 73, 1995, pp. 40–50.
[15] A.P. Hare, Handbook of Small Group Research, Free Press, New York, 1976.

The effects of perceived risk and technology type on users' acceptance of technologies☆

Il Im [a,*], Yongbeom Kim [b], Hyo-Joo Han [c]

[a] *School of Business, Yonsei University, Seoul, Republic of Korea*
[b] *Silberman College of Business, Fairleigh Dickinson University, Madison, NJ 07940, USA*
[c] *Department of IS, College of IT, Georgia Southern University, Statesboro, GA 30460, USA*

Received 5 August 2005; received in revised form 16 October 2006; accepted 21 March 2007
Available online 18 June 2007

Abstract

Previous studies on technology adoption disagree regarding the relative magnitude of the effects of perceived usefulness and perceived ease of use. However these studies did not consider moderating variables. We investigated four potential moderating variables – perceived risk, technology type, user experience, and gender – in users' technology adoption. Their moderating effects were tested in an empirical study of 161 subjects. Results showed that perceived risk, technology type, and gender were significant moderating variables. However the effects of user experience were marginal after the variance of errors was removed.

Keywords: Technology acceptance; Perceived risk; Technology type; User experience; Gender; UTAUT; Moderating variable

1. Introduction

Venkatesh et al. [26] compared and tested the variables in eight different models about users' technology acceptance including the technology acceptance model (TAM) [6] and diffusion of innovation (DOI) [22]. Subsequently, they proposed a unified theory of acceptance and use of technology (UTAUT), which consisted of four core determinants of acceptance/use and four moderating factors.

Although such models explain much of the variance, there seem to be two critical factors that are overlooked or have received inadequate attention—perceived risk (PR) and technology type. PR has been recognized as an important factor and was modeled as an antecedent of perceived usefulness (PU), and a sub-construct of others, such as trust (or as its antecedent [21]). However, PR was not considered in UTAUT.

When people decide whether or not to use a technology, the technology type affects their decision. In marketing, for example, it is widely acknowledged that consumers' decision-making criteria vary across different types of products [20,23]. It is not reasonable to assume that the effects of PU and perceived ease of use (PEU) on behavioral intension (BI) would be similar for different technologies.

The main object of our study was therefore to refine UTAUT, by considering the effect of PR and technology type on it. We also re-evaluated the effect of two moderating variables: gender and experience.

2. Prior research and theoretical background

Davis' original TAM had three key constructs—PU, PEU, and system usage (SU). Hong et al. [12] added two categories of external variables – individual differences and system characteristics – and Chau [4] modified it by using only four constructs—PEU, perceived long-term usefulness,

☆ This research was partially supported by NSF Grants, DUE-0434998 and DUE-0434581.
* Corresponding author. Tel.: +82 2 2123 5480; fax: +82 2 364 7828.
E-mail address: il.im@yonsei.ac.kr (I. Im).

0378-7206/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.im.2007.03.005

perceived short-term usefulness, and behavioral intention to use. Gefen et al. [11] combined 'trust' in explaining users' acceptance of online shopping.

The UTAUT had four core constructs – performance expectancy, effort expectancy, social influence, and facilitating conditions – and four moderating variables – gender, age, experience, and voluntariness of use. It integrated eight major theories and has been tested using real world data.

2.1. Perceived risk (PR)

PR or uncertainty affects people's confidence in their decisions. Risky situations can be those where the probabilities of outcomes are not known and the outcome is known or unknown. In previous studies on consumer research, PR was defined as the perceived uncertainty in a purchase situation. PEU was defined as people's subjective appraisal of performance and effort; usually discrepancies exist between people's judgments and actual performance. This entails a 'risk' because users do not know the significance of this discrepancy. If a technology fails to deliver its expected outcome, it will result in a loss to the user (financial, psychological, physical, or social).

UTAUT examined a construct similar to PR: anxiety. However, it differed from PR, because it was mainly about the concerns or fears in trying a new technology rather than a long term effect. In practical terms, anxiety can be mitigated whereas PR will remain unchanged for some time.

An important issue about PR in technology acceptance is thus whether PR directly affects PU/PEU or BI (as an antecedent) or whether it moderates the effects of PU/PEU on BI (as a moderator). These different roles are depicted in Fig. 1.

Understanding whether PR is a moderating variable or an antecedent is obviously important. In TAM studies, PR was mostly considered an antecedent of PU, trust, or BI. However, when PR is modeled as an antecedent of PU, it is assumed that PU and PR are related, whereas they are independent of one another.

Therefore, we expected that PR would modify the effects of PU and PEU on BI. The relationships between PU/PEU and BI would be attenuated as users perceived higher risk.

Hypothesis 1. With higher PR

(a) The effect of PU on BI will be attenuated.
(b) The effect of PEU on BI will be attenuated.

2.2. Technology type

Most TAM studies have not considered the effect of different technologies. UTAUT was no exception. Adams et al. [1] did look at several technologies—e-mail, voice mail, word processor, spreadsheet, and graphics software. They found that the effects of PU and PEU on BI for those

technologies differed substantially. They argued that it may have been because the importance of PEU diminished as users gained experience with the technology.

Gefen and Straub [9] theorized that the effect of PEU on BI would be affected by the nature of the task. Their study showed that PEU affected BI when users searched product information at an online bookstore, while it did not when users purchased books from a traditional store. Another way to categorize technologies is into hedonic and utilitarian types. This has been used in past marketing literature to categorize different types of products. Hedonic systems aim at providing self-fulfilling value to the user, rather than just being utilitarian. A recent study demonstrated that PEU had greater effects on BI than PU for a hedonic technology [24]. Conversely, PU would be more important when the technology was more job-related or utilitarian. When a technology is job related, the user considers usefulness more important than ease of use. Lin et al. [17] investigated the adoption of a technology in law enforcement, and found that PU correlated closely with BI. Other studies [19,29] also found similar results: strong effects of PU on BI when the technology is job-related. The categorization of hedonic and utilitarian technology thus seemed relevant.

Hypothesis 2. When the technology is hedonic

(a) The effect of PU on BI will be attenuated.
(b) The effect of PEU on BI will be strengthened.

2.3. Experience with the technology

There is great variety in past studies in terms of the subjects' familiarity with the technology. Apparently there is a significant difference in PU and PEU before and after the use of technology [7]. The effect of PU on BI was more significant after use of the technology, while PEU lost its effect on BI after users used the technology. Karahanna et al. [16] examined the decision to adopt technology (pre-adoption) versus the actual use (post-adoption). They found that potential users' intentions were based on a richer set of behavioral variables while actual users' intentions were continuously determined by PU and image. In their longitudinal study, Venkatesh et al. [25] emphasized the importance of training and developed an integrated model of longitudinal perspective, examining the influence of pre- and post-training environments over time.

The effect of experience was also examined in UTAUT. The researchers examined the changes of the constructs in the model as users gained experience. It was found that the effect of PU became stronger while the effect of PEU became weaker as users gained experience. Thus, we formulated hypotheses to confirm such results.

Hypothesis 3. When users' experience with the technology increases (or after users gain experience with the technology)

(a) The effect of PU on BI will become strengthened.
(b) The effect of PEU on BI will become attenuated.

2.4. Gender

In UTAUT, it was found that gender and age moderate the effects of PU and PEU on BI. Most studies have indicated that males perceive less risk than females in a similarly framed situation. In UTAUT, gender was found to be a significant moderating variable—the effect of PU on BI was stronger for males while the effect of PEU was stronger for females. We therefore examined the effects of gender postulating the following hypotheses:

Hypothesis 4. For male users

(a) The effect of PU on BI will be strengthened.
(b) The effect of PEU on BI will be attenuated.

3. Empirical study

We tested our hypotheses using data collected from subjects who participated in a group task experiment. For each subject, two identical questionnaires were used to measure the variables of interest before and after the experiment.

3.1. Experiment procedure

The authors recruited students who were taking undergraduate and graduate courses in a university in the northeastern US. Subjects were asked to work on a group decision-making task for a period of 2 weeks. The task was to develop specifications for web-based applications for the Exchange Student Service Center at the university, including its functionality and services, user interface design, definition of business values, and making decisions on priorities for the developing of each function. There were three different treatments:

(1) Those using only asynchronous communication technology (a bulletin board called "Webboard").
(2) Those using both asynchronous (Webboard) and synchronous (MSN Messenger) communication technologies.
(3) Those with mobile devices (wireless PDA) using both asynchronous and synchronous communication technologies.

Prior to this study, the majority of the recruited students had experience with Webboard since it had been used in courses at the university. MSN messenger, although it had sometimes been used in courses (e.g., for online office hours), had been used mostly for personal communication among students. Wireless PDA use had been somewhat

mixed, because students could use it for personal use or for courses.

The decision-making task in this experiment required the subjects to use a technology in an utilitarian way, no matter whether it could be classified as hedonic or utilitarian. It was reasonable to assume that a subject's intention to use the technology (which was a question he or she answered in the post-experiment survey) reflected an overall evaluation of the technology.

The questionnaire was uploaded to Webboard and the subjects were asked to download, fill out, and return it via email. Of the 197 participants, 195 pre-task and 170 post-task questionnaires were collected. The number of subjects who completed all the relevant survey forms was 161; these provided the data used for analysis.

3.2. Measurement instruments

The questionnaires asked students their opinions about BI, PU, PEU, and PR. For PU, PEU, and BI, the standard TAM and UTAUT measurement instruments were used. Data for user experience and gender were collected from the background questionnaire. For PR, the measurement instruments were developed by the authors from the literature on risk. There are five commonly used categories in marketing literature [3,14,23]; all were included: financial (worth the cost), performance (effectiveness), social (changes in work), psychological (frustration), and physical (comparison to other products). The instruments were refined through a pilot session after three graduate students filled out the questionnaire, checking if there were any unclear or misleading questions.

3.3. Analysis of results

The hypotheses were tested using Structural Equation Modeling (SEM). SPSS/PC Version 11.5 and AMOS Version 4 were used. Table 1 shows the demographics of the subjects.

3.3.1. Confirmatory factor analysis and construct validity

Although the validity of the three constructs – PU, PEU, and BI – had been tested in previous studies, their validity was retested in our study. The data from the pre- and post-task results were pooled to check the overall construct validity. A confirmatory factor analysis (CFA) was conducted for all constructs—PU, PEU, BI, and PR. Similarly, the measurement model was revised by dropping items with low (<0.50) factor loading. As a result, all items, except one from PR, were retained in our analysis. The final list of retained items is given in Table 2. The final CFA results are acceptable ($\chi^2 = 292.3$, d.f. = 113, GFI = 0.903, AGFI = 0.868, CFI = 0.951, NFI = 0.924, RMR = 0.055, RMSE = 0.07). In order to check discriminant validity, every pair of the four constructs was united (setting covariance = 1) and tested if the change in χ^2 was statistically significant. The χ^2 of the original model was significantly ($p < 0.01$) smaller than any possible union of any two constructs, which indicated the discriminant validity of the constructs. Next, the reliability of the constructs was examined with Cronbach's α, composite reliability, and average variance extracted (AVE) shown in Table 2. All Cronbach's αs and composite reliabilities were over 0.7, the cut-off for confirmatory research [10]. The AVE of each construct was over 0.5 and, as shown in Appendix A, the square root of AVE of each construct was larger than the construct's correlations with other constructs, which also indicated good convergent and discriminant validity.

As summarized in Tables 3 and 4 (marked as 'whole sample'), the model showed a very good fit as most fit indices were in the desirable range.

Table 1
Demographic background of subjects ($N = 161$)

Gender	Class	Age
Male: 109 (67.7%)	Undergraduate: 81 (50.3%)	Under 23: 60 (37.3%)
Female: 52 (32.3%)	Graduate: 80 (49.7%)	23–30: 82 (40.9%)
		Over 30: 19 (11.8%)

3.3.2. Test of moderating variables

The common way of testing moderating effects in SEM is to divide the data set into two groups (high and low value of the candidate moderating variable) and to compare the model fitting across groups. For example, for gender the dataset is divided into two sub-sets, and SEM applied to one of the two groups (male group, for example). Once the model is identified for the male group, the statistics are used to conduct tests for the female group. Two models for the female group are then compared—one without any constraints and one with the coefficients set to that for the male group. If the model without any constraints is significantly better (smaller χ^2) than the constrained one, the female group's coefficients differ from those of the male. If the changes of χ^2 are significant, a moderating effect exists.

Although this method is straightforward, it does not test whether (or how much) the differences are determined by the error variance (direct effect) or factor loadings and coefficients (moderating effect) of the dependent variables. A more rigorous method based on Jöreskog and Sörbom [13] was proposed by Dabholkar and Bagozzi [5]. Their methodology is similar to the above method: the dataset is divided into groups and the statistics from one are used to constrain models off the other. It also tests to find whether the change of χ^2 is statistically significant given the change in the degree of freedom ($\Delta\chi^2/\Delta$d.f.). In order to test if the changes of χ^2 were caused by the moderating variable,

Table 2
Factor loadings and reliability

Construct	Operational variable (item in the questionnaire)	Factor loading	Cronbach's α	Composite reliability	AVE
Intention to use (BI)	I predict I would use it	0.830	0.894	0.757	0.711
	It would be one of my favorite technologies for my work	0.818			
	I intend to use it	0.593			
Perceived usefulness(PU)	... would enhance my effectiveness in my job	0.903	0.951	0.952	0.798
	... would make it easier to do my job	0.881			
	... would increase my productivity	0.879			
	... would improve my performance in my job	0.856			
	... to be useful in my job	0.855			
Perceived ease of use (PEU)	Learning to operate ... would be easy for me	0.825	0.838	0.849	0.531
	My interaction with ... would be clear and understandable	0.811			
	It would be easy for me to become skillful at using ...	0.782			
	I would find it easy to get ... to do what I want to do	0.732			
	Interacting with ... would not require a lot of my mental effort	0.723			
Perceived risk (PR)	It is probable that ... would not be worth its cost	0.791	0.749	0.906	0.510
	It is probable that ... would frustrate me because of its poor performance	0.781			
	Comparing with other technologies, using ... has more uncertainties	0.714			
	It is uncertain whether ... would be as effective as I think	0.705			

however, this method compares four models for each moderating variable:

- Model A has all factor loadings constrained across groups, and error variances of the items for endogenous variables are constrained.
- Model B has the factor loadings free but error variances are constrained.
- Model C has both factor loadings and error variances are free.
- Model D has factor loadings constrained but error variances are free.

If models A and D (or models B and C) are different, it is caused by error variances in dependent variables. If models A and B are significantly different from each other (or if models C and D are different from each other), this is caused by the different factor loadings and path coefficients, which implies that there is a significant moderating effect. Thus by comparing these models, the difference due to error variance

Table 3
Test result of moderating effects

Variables	Model	χ^2	d.f.	GFI	AGFI	NFI	CFI	RMR	RMSEA	$\Delta\chi^2/\Delta$d.f.
Whole sample		195.8	62	0.914	0.875	0.942	0.959	0.055	0.082	N/A
Perceived risk	A	235.0	80	0.820	0.795	0.858	0.902	0.061	0.113	N/A
	B	206.0	70	0.837	0.788	0.876	0.914	0.045	0.113	$2.9^{*,a}$
	C	153.8	62	0.870	0.810	0.907	0.942	0.046	0.098	$6.5^{**,b}$
Technology type (Webboard and MSN)[c]	A	346.7	80	0.750	0.715	0.791	0.831	0.120	0.154	N/A
	B	277.0	70	0.785	0.720	0.833	0.869	0.074	0.145	$6.9^{***,a}$
	C	191.1	62	0.832	0.753	0.885	0.918	0.065	0.122	$10.7^{***,b}$
Gender	A	473.4	80	0.716	0.677	0.789	0.819	0.087	0.151	N/A
	B	443.9	70	0.723	0.639	0.802	0.828	0.067	0.157	$2.9^{*,a}$
	C	179.9	62	0.885	0.831	0.920	0.946	0.062	0.094	$33.0^{***,b}$
Experience (pre- and post)	A	167.2	80	0.873	0.855	0.920	0.957	0.074	0.083	N/A
	B	150.1	70	0.882	0.847	0.928	0.960	0.059	0.085	1.7^{a}
	C	110.8	62	0.905	0.861	0.947	0.976	0.059	0.070	$4.9^{**,b}$

[a] Difference between model A and model B.
[b] Difference between model B and model C.
[c] Due to the small sample size of PDA ($n = 40$), only Webboard and MSN were compared.
* Significant at $\alpha = 0.1$ level.
** Significant at $\alpha = 0.05$ level.
*** Significant at $\alpha = 0.01$ level.

Table 4
Changes in standardized β coefficients

Standardized β	Whole sample	Perceived risk		Technology type		Gender	
		Low	High	MSN	Webboard	Male	Female
PEU → PU	0.306**	0.168*	0.291**	0.396**	0.260**	0.262**	0.395**
PU → BI	0.686**	0.771**	0.486**	0.522**	0.780**	0.694**	0.636**
PEU → BI	0.224**	0.163**	0.395**	0.294**	0.193**	0.228**	0.251**

* Significant at $\alpha = 0.1$ level.
** Significant at $\alpha = 0.01$ level.

can be separated from the difference from factor loadings and path coefficients.

The effects of the four variables – PR, technology type, user experience, and gender – were tested following this procedure. Because PR was not a categorical variable, the groups were divided into high and low groups using the median [2,5]. PR was divided by the median of the sum of the two items displayed in Table 2.

Table 3 illustrates the comparisons of models A, B, and C with fitting indices and $\Delta\chi^2/\Delta$d.f. Model D did not need to be compared, because the comparison was redundant. The test results of moderating effects and significant coefficients of the paths were determined.

3.3.3. Perceived risk (PR)

PR moderates the effects of PU and PEU in the model (2.9 in the $\Delta\chi^2/\Delta$d.f. column in Table 3). For users perceiving a higher risk in using the technology, PU has smaller effects on BI (PU → BI coefficients, 0.486 and 0.771 in Table 4) than those perceiving a lower risk, which supports Hypothesis 1(a). However, PEU has a bigger effect on BI (PEU → BI coefficients, 0.168 and 0.291 in Table 4) for the high perceived risk group than the low perceived risk group; this did not support Hypothesis 1(b).

PR has often been modeled as an antecedent of PU or BI in many previous studies [8,11,15,18,28]. The three models in Fig. 1 were tested by running different SEM models as shown in Table 5.

The five models were:

- Model I: original model (Fig. 1(a)).
- Model II: PR was modeled as an antecedent of PU (Fig. 1(b)).
- Model III: PR was modeled as an antecedent of BI (Fig. 1(c)).
- Models IV and V: PR was modeled as a moderating variable. The sample was divided into a high-risk group (model IV) and a low-risk group (model V) and the original model, the same as model I, was run for each group (Fig. 1(d)).

For more accurate comparisons, $\Delta\chi^2/\Delta$d.f. values were computed. The $\Delta\chi^2/\Delta$d.f. value for model III was statistically significant, which indicated that the increase in χ^2 when PR was added to the model exceeded the increase in d.f.. The $\Delta\chi^2/\Delta$d.f. value for model II was also large, although statistically insignificant. Therefore, it could be concluded that model I (without PR) was a better fit than models II and III (with PR as an antecedent).

Models IV and V had the same constructs as the original model (model I), but they had different sample sizes. Therefore, they could not be compared head-to-head with the original model (the value of Chi-square likelihood ratio statistics was directly dependent on the sample size). A Normed Fit Index (NFI), the percentage of observed-measure covariance explained by a given measurement or a structural model, was used. In the table, the NFI for models IV and V were slightly lower than those for model I. Since the value of χ^2 dropped significantly, without sacrificing other statistics, when PR was modeled as a moderating variable, it could be concluded that users' acceptance behavior was better explained when PR was modeled as a moderating variable.

3.3.4. Technology type

The type of technology affected the coefficients (see 6.9 in the $\Delta\chi^2/\Delta$d.f. column of Table 3) – PU was more important in using Webboard than in using MSN messenger (the coefficients were 0.780 versus 0.522) and PEU was more important for MSN messenger than Webboard (with coefficients of 0.193 versus 0.294). MSN messenger was

Table 5
Test result of different conceptualizations of PR

Modeling of PR	χ^2	d.f.	GFI	AGFI	NFI	CFI	RMR	RMSEA	$\Delta\chi^2/\Delta$d.f.
I. Without PR (original model)	195.8	62	0.914	0.875	0.942	0.959	0.055	0.082	N/A
II. An antecedent of PU	325.0	115	0.895	0.860	0.915	0.943	0.096	0.075	2.44
III. An antecedent of BI	357.1	115	0.883	0.844	0.907	0.934	0.142	0.081	3.04*
IV. A moderating variable (high PR)	153.8	62	0.870	0.810	0.907	0.942	0.046	0.098	N/A
V. A moderating variable (low PR)	145.9	62	0.880	0.824	0.914	0.948	0.069	0.090	N/A

* Significant at $\alpha = 0.1$ level.

believed to be more hedonic than Webboard, as has been stated in several media reports which have identified instant messenger programs as the preferred medium (over email or Webboard-like applications) for private communications between employees in the workplace. The larger effect of PEU on MSN messenger and the greater coefficient of PU on Webboard support Hypothesis 2.

3.3.5. Experience and gender

Whereas gender moderated the effects of PU and PEU in the model, experience did not (see 2.9 and 1.7 in the $\Delta\chi^2/\Delta$d.f. column of Table 3). Thus Hypothesis 3 were not supported.

Gender is a significant moderating variable. The effect of PU on BI was slightly stronger for male (coefficients of 0.694 versus 0.634) and the effect of PEU on BI was slightly stronger for women (0.251 versus 0.228).

3.3.6. Interactions between perceived risk and other variables

Since it was not practical to test several moderating effects together using SEM, the moderating variables were not tested together. However, it is possible that PR and experience are correlated-users perceive a higher risk before they use the technology than after they use it. This was examined by testing the difference in PR between pre- and post-use (see Table 6). There was no significant difference (all $p > 0.05$) in PR between pre- and post-use of technology.

Another pair of variables that might have been correlated were PR and technology type. A t-test on PR across the two technologies (Webboard and MSN) showed that there was a significant difference in PR across these technologies for both pre-use and post-use ($p < 0.01$).

The difference of PR across gender was also tested. It is interesting that female subjects perceived lower risks before they used the technology than males; this is contrary to many past studies. However, a study also showed that the gender difference in PR varied across different problem domains [27].

4. Discussions

4.1. Limitations

Our study had several limitations due to the sampling methods and measurement instruments. First, the sample was a student group in a university; the sample was relatively homogeneous and does not represent the real world population. However, the subjects were diverse in terms of ethnic background, job experience, and age. Also, though the sample size of 161 was not too small for a model with 3 or 4 constructs, a bigger sample size would have been better. Second, the technologies examined in our study were of one type—technology for communications. Studies with other technologies may have resulted in different results and thus they cannot be generalized. Third, the subjects' familiarity with the technology was not controlled. Subjects were more familiar with MSN messenger than Webboard or wireless PDA. Therefore, it is possible that the different level of familiarity might have affected the results. Finally, this study examined only a limited set of constructs, which is small considering the variety of those studied in other research.

4.2. Implications

PR changes the effects of PU and PEU on BI. Users who perceive a higher risk about adopting the technology will be affected by how easy it can be used. This has several implications for managers. When they deploy a technology perceived risky, they need to emphasize 'ease of use' However, when users perceive a low risk, managers have to focus on communicating 'usefulness' of the technology.

Technology type is a significant moderator variable of use. Managers need to emphasize 'ease of use' when they market a technology that is hedonic or for personal use. On the other hand, if the technology is utilitarian, managers should try to convince users that it is of value in their jobs.

Table 6
PR before and after use of the technology

	Webboard		MS messenger		Wireless PDA	
	Pre-use	Post-use	Pre-use	Post-use	Pre-use	Post-use
PR*	15.8	16.0	18.5	18.8	14.6	12.6

	Perceived risk* (pre-use)		Perceived risk* (post-use)	
Technology				
Webboard	15.8	$p < 0.01$	16.0	$p < 0.01$
MS messenger	18.5		18.8	
Gender				
Male	18.0	$p < 0.01$	16.8	Not sig.
Female	16.0		16.5	

* Sum of four items used in the main analysis (1 = high risk, 7 = low risk, for each item).