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Investir dans les gens, la découverte et l'innovation

FORM 101
Application for a Grant
PART I

Date: 2004/10/31

Family name of applicant	Given name	Initial(s) of all given names	Personal identification no. (PIN)
Fisher	Brian	D	23916

Language of application: [X] English [ ] French

Time (in hours per month) to be devoted to the proposed research / activity: 20

Type of grant applied for: Discovery Grants - Individual

For Strategic Projects, indicate the Target Area and Sub-Target Area, if applicable.

Title of proposal: Information systems for skilled cognition & communication

Provide a maximum of 10 key words that describe this proposal. Use commas to separate them.

human-computer interaction, visual analytics, decision support systems, information visualization, cognitive science, enactive cognition,, perceptual cognition

Research subject code(s)		Area of application code(s)	
Primary	Secondary	Primary	Secondary
2710	6301	1207	801

CERTIFICATION/REQUIREMENTS

If this proposal involves any of the following, check the box(es) and submit the protocol to the university certification committee.

Research involving : Humans [X] Human pluripotent stem cells [ ] Animals [ ] Biohazards [ ]

Does any phase of the research described in this proposal a) take place outside an office or laboratory, or b) involve an undertaking as described in Part 1 of Appendix B?

[X] NO [ ] If YES to either question a) or b) – Appendices A and B must be completed

TOTAL AMOUNT REQUESTED FROM NSERC

Year 1	Year 2	Year 3	Year 4	Year 5

SIGNATURES (Refer to instructions "What do signatures mean?")

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Head of department

Dean of faculty

President of university (or representative)

Applicant's department, university, tel. and fax nos., and e-mail

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Personal identification no. (PIN)	Family name of applicant
23916	Fisher

SUMMARY OF PROPOSAL FOR PUBLIC RELEASE (Use plain language.)

This plain language summary will be available to the public if your proposal is funded. Although it is not mandatory, you may choose to include your business telephone number and/or your e-mail address to facilitate contact with the public and the media about your research.

Business telephone no. (optional): (604) 268 7554

E-mail address (optional): fisherb@sfu.ca

My research utilizes methods and findings from Cognitive Science-- Psychology, Neuroscience, Artificial Intelligence and modeling-- to design highly interactive computer software to support human communication, understanding and decision making. These include computer aided design (CAD) systems and visual analytics decision support systems. CAD and visual analytics exemplify an emerging class of applications where the goals are primarily cognitive (learning, decision-making) or communicative (social software, collaboration).

My previous NSERC-funded research found that individuals respond differently to large visual displays, and I now propose to investigate how interaction with the computer can be customized to take into account differences in users' perception, attention, and motor abilities. One of the most compelling individual differences is the development of skill, in the form of perceptual and motor as well as cognitive abilities. For example, air traffic controllers develop perceptual and attentive skills that help them route aircraft safely to their destinations.

I am involved in a range of applied projects with industry and government partners that build upon the basic research in human interaction with advanced technology that this proposal describes. Partners include GM of Canada, the National Film Board, Nissan Motor Company, the US National Visual Analytics Center and others. A key focus of the visual analytics work is to build applications to aid law enforcement officers in interpreting information from a range of sources, forming hypotheses, testing scenarios etc. in order to anticipate and respond to natural disasters, criminal acts, and acts of terrorism.

Second Language Version of Summary (optional).

 PROTECTED WHEN COMPLETED Version française disponible

Canada

Brian Fisher
23916

Form 101 - Relationship To Other Research Support

My research approach requires me to adapt cognitive science research methods and findings to generate HCI methods, approaches and phenomena to be incorporated into demonstrations and proof-of-concept mockups that are needed to attract later-stage applied research funding from industry and government sources. This intermediate stage of applying cognitive science research to the conditions of use of an application is unlikely to attract industry support, and is the focus of this proposal. It is a key part of the more applied aspects of my research program.

Funded projects include a $20,000 research contract from GM of Canada which was matched with a $40,000 BC ASI grant. This applies the perceptual work described in my Smart Graphics, CHI, and SIGGRAPH publications to the problems encountered in the use of immersive media for automotive design. A follow-on project is under discussion, as is a GM-funded research consortium. A $23,000 project with the SAGE-21 SSHRC Research Network explores the use of biopotentials as indexes of cognitive engagement. Due to shifts in the program direction this project is unlikely to continue past 2005 on that funding. I do intend to seek alternative funds and have applied as a collaborator on SFU Business School professor Dianne Cyr's current proposal to SSHRC to continue that work. If successful this will also support the development of software to integrate video annotation and signal processing analysis of biopotentials. Network collaboration funding comes from a SSHRC New Media Collaboration Network proposal out of Banff Centre and a related proposal on Visualization and Sonification of Text under review by SSHRC. These provide funding for collaboration, however neither have research support budgets for my work.

As I take on a new position at SFU, I hope to ease the transition by retaining a significant role in UBC MAGIC. In order to avoid a loss of research momentum and potential loss of follow-on projects by industry partners and collaborators, I will have to build my own laboratory at SFU quite quickly. SFU has proposed $35,000 startup funding, and I was awarded the $5,000 Wendy McDonald Endowed Research Fellowship to generate a total of $40,000 for infrastructure. For this reason I have a minimal proposed equipment budget for the first two years covered under this proposal. Given the high cost of the immersive display technologies that I utilize in much of my work and which was available at UBC, I will no doubt propose a CFI grant for the larger items in the near future.

The largest increase in expenditures proposed here is for salaries, specifically for graduate student support. Given the need to maintain student salaries at UBC to enable those students to finish their degrees, and to begin to build graduate student enrollment at SFU, I am requesting an increase in funding in this application. It is my hope that this will enable me to bridge my UBC and SFU careers without loss of research productivity.

Brian Fisher
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Form 101 – Proposal

I propose to advance the work begun on my previous Discovery Grant to focus on key aspects of individual differences and the development of skill in perceptually rich interface environments. My long-term research goal is to generate applied HCI research methods that are grounded in both higher-level cognitive science analyses and in the conditions of HCI practice. This will support the creation of an emerging class of highly interactive applications whose design are in part cognitive (learning, decision-making) and/or communicative (social software, collaboration).

HCI traditionally draws on psychology concepts of perception, memory, and problem solving. For example Norman adapted Gibson's perspectives on perception and action to generate the ubiquitous HCI affordance of use concept. More recent writing has proposed expansion of the scope of HCI to include an increased emphasis on cognition, affect, and communication. This addresses the goals of seminal computer science thinkers such as ARPAnet founder Vannevar Bush, and interaction guru Douglas Englebart to support the creation of interactive systems for learning, and decision-making. These are described variously as "active media systems, Discovery systems, Augmented Cognition Systems etc. In most cases they proposed new interaction metaphors that differ significantly from the familiar "desktop" GUI.

The mass of the recent work in this area is at Marr's computational theory level of analysis, dealing with the goals of the interaction rather than the specifics of algorithm and mechanism that are to be implemented in system design. Since they lack the level of specificity needed by designers, I will suggest that these theories may be necessary but are not sufficient for effective interaction design.

My approach to this theory-practice gap has been to incorporate empirical methods and theories from cognitive science at the level of cognitive architecture-- the large-scale structure of human information processing. These include the two-visual system theory of Trevathan, as modified by Milner and Goodale, the FINST theory of Pylyshyn, and Psycholinguistic pragmatics theories of Herbert Clark. These theories differ from the more familiar perception work (e.g. colour and form discrimination, visual search) usually utilized in HCI in that they relate more directly to rich perceptual environments such as ubiquitous, immersive, and multimodal displays. At the other extreme, they also differ from the higher-level theories of Gibson, Varela, Andy Clark etc. in more directly addressing the nature of information processing that occurs in those situations. As such they constitute Marr's "middle ground" of processing algorithm analysis that can more precisely inform the specifics of interaction design. They do so by constraining the large design space of highly interactive multimodal display and control technologies, particularly for unstructured design goals (e.g. visual analytics for creative problem solving in a large set of possible counter-terrorism situations) and when acceptable error rates are extremely low (e.g. for air traffic control).

My research has four components:

Sampling behaviour from the environment

Using either observation of performance in practice, either in the situation of use of the interface or of "best practices" in other applications (e.g., psycholinguistic analyses of language and gesture in face-to-face conversation for communication models; video analysis of musical performers for enactive cognition and control intimacy).

Task decomposition based on human cognitive architecture: Using research on the structure of perceptual cognition (e.g. attentional tokens and visual routines) with particular emphasis on perceptual and enactive cognition and how they underlie cognitive processing. A task decomposition based on cognitive architecture provides a way of "carving interaction at its joints", deriving key aspects of interaction that will generalize across situations.

"Toy world" studies focused on key aspects:
Devising small focused studies that examine the impact of specific aspects of the interaction on key perceptual and cognitive processes. For example, my work with air traffic control applications applied spatial indexing models to generate a test of the robustness of tracking multiple display targets over global transformations typical of fishtank VR approaches. Findings supported an allocentric model of attentional tracking, which would indicate that the deployment of attention in air traffic control would be robust against a wide range of display changes.

Sophisticated analysis techniques, including:
Use of indicator variables that correlated with subject of interest. Sensitivity of the dependent measure in any empirical study is critical. In an applied study with many variables of interest, a sensitive DV enables us to study interactions and attribute effect to cause. As a result, studies conducted in the context of an iterative design cycle preferentially utilize real-time measures that can be tracked and mapped onto display events rather than more ecologically valid but less sensitive measures such as overall performance, which are relegated to summative studies at the conclusion of the design cycle.

Focus on individual and subgroup patterns of results. The goal of the natural sciences is to uncover general laws of nature. Social and cognitive sciences have adopted these goals, and seek to uncover general principles of mental life. In contrast as interaction designers, we seek to support individual users from a specific user community. This requires us to determine not only the general rules, but also the ways in which those rules can be parameterized so as to customize interaction for a particular individual.

My work on space constancy, funded by my previous NSERC Discovery Grant, serves as an example of this process. While the basic phenomena were known to psychology for some time, the elicitation of individual differences in performance combined psychological approaches with HCI manipulations such as level of visual feedback and temporal lag. These variables are not at all central to the development of general models of perceptual processing and so have received little study within psychology. Similarly individual differences themselves are of limited importance in deriving global information processing models, and so have not received a great deal of attention. From the perspective of interaction design however, the former grounds the research in practical issues while the latter supports interface customization to support a given user's perceptual abilities and characteristics.

In the course of these studies, doctoral candidate Barry Po and I found evidence of clear individual differences in the impact of these theories on performance on gesture versus verbal responses in large-screen display environments. While nearly all subjects showed the general pattern of increased context-induced localization errors in verbal report versus pointing (a prediction of the two-visual-system hypothesis), changes in interaction characteristics such as visual feedback and performance lag affected different subjects in strikingly different ways. Follow-on studies on reaching tasks for targets in upper versus lower visual fields found a similar pattern, as did preliminary findings from research conducted in collaboration with Doctoral student Reynald Hoskinson and Masters student Caitlin Akai on depth judgments using active stereo (shutterglasses) technology.

The common thread in these diverse set of findings is that the creation of large screen and ubiquitous computing environments, coupled with the use of more direct interaction techniques such as pointing and reaching place a greater burden on users' ability to recalibrate their perceptuomotor systems to deal with geometry errors and temporal lags. Different individuals will respond differently to these errors, based on their basic level of recalibration ability, perceptual experience, fatigue, age etc. Findings from our studies confirmed that there was no global optimal setting for the population of subjects. Rather, each individual's low-level perceptuomotor systems appeared to place different emphasis on different aspects of the interaction. Given the range of situations that present similar conflicts, it seems likely that these findings will generalize to other visual, auditory, and haptic cross-modal feedback discrepancies.

In the next phase of my research I will expand and extend my work on individual differences to address new challenges in the design of highly interactive systems. In addition I will examine the development of perceptual and motor expertise by users of advanced interactive applications, and how that can best support their cognitive and communicative processes. This leads to my first thread of investigation:

Skilled adaptation to perceptual conflicts in rich multimodal environments.

I predict that optimal interaction design for a population of users will require customization for a given user's characteristic ability to adapt to the conditions of the interface, something that I am calling the user's "personal equation of interaction". This would consist of obvious static factors such as stereo sensitivity and colour discrimination together with adaptation factors such as the ability to recalibrate auditory space based on visual evidence (the ventriloquism after-effect), the tendency to utilize more robust but less accurate (dorsal system) visuomotor representations rather than more accurate but more context-sensitive (ventral system) representations in a given task. Both research and anecdotal evidence from skilled GM automotive CAD designers suggests that the ability to recalibrate perception to reduce conflicts is high among skilled CAD users.

The research methodology is to begin with systematically varying the agreement between location cues of objects displayed on stereo displays walls. This will provide a rich data source that may enable us to derive mathematical approximations of multi-cue integration (e.g. fuzzy logic) and decision (e.g. Bayes) to generate an overall interpretation of the position of the object in depth. Our early findings (in collaboration with GM of Canada) support a systematic deviation of depth perception in these environments for a proportion of users.

If successful, this will extend my previous work on utilizing the parameterization of mathematical models of information integration (e.g. fuzzy-logic, Bayes) on the ways in which display artifacts can disassociate the process of multimodal event integration for motor performance and cognitive event understanding.

In this new phase I will extend my studies to examine the development of perceptual, attentive, and motor performance skill. Through examination of skilled perceptuomotor performance (i.e. using musical instruments).

Attentional parsing of large-screen, immersive, and ubiquitous displays:

As Gibson stated "Education is the education of attention". My focus in this thread will be on development of attentional parsing. I propose to continue my work on visual parsing of large-screen, complex animated visual displays. In collaboration with Zenon Pylyshyn at Rutgers University, I will continue to examine the allocation of pre-attentive processing, multiple spatially isolated attentional tokens (FINSTs), and focal attention in both small display versus large-screen and immersive environments. This will enable me to examine the ways in which display events move from pre-attentive to attentive processing, and how multiple events can be processed.

Dynamics of interaction in highly responsive interactive environments

"Visual Analytics" was coined to differentiate a highly interactive dialog with information from a more passive information visualization approach. This emphasis on real-time interaction with data will require an applied Cognitive Science of enactive cognition in dynamic display environments. I will work in collaboration with Radan Martinec at the London Institute to test theories of the interaction of rhythmic patterns of display dynamics with user actions [] as an indicator of cognitive engagement (e.g. Csikszentmihalyi's "flow") measured by frequency matching and phase locking of user control actions, biopotentials and eye movements with display events. This will address issues of enhancing control intimacy of interaction in information spaces.

Significance of the research

This work has the potential to impact a large an increasing number of applications which have as a design goal the facilitation of cognitive processes. Areas such as knowledge management, e-learning, design and authoring, and decision support exemplify this large and growing area of use.

CAD: Presumably automotive CAD users are both self-selected and trained for ability to utilize these displays, and so we would predict that as user populations become more diverse the problem will increase. We note that our collaborators both at GM of Canada and at Boeing are particularly interested in extending the use of these displays to other user populations for cross-functional collaborative design and design review. Understanding the development of perceptual skill in recalibrating sensory systems may lead to training techniques as well as customization methods.

Visual Analytics: A critical area where these factors exist is in the new field of visual analytics. Visual analytics combines information visualization with scenario testing, creating tight perception-control loop interaction in order to support decision making with large data sets that contain a high level of and uncertain data. Users are a diverse set of law enforcement officials, intelligence agents and public safety officials. The development of these systems is seen as a priority for the US Department of Homeland Security in order to detect possible terrorist acts and prevent them from taking place. As a result, they have asked Lawrence Livermore labs and Battelle Pacific Northwest National Laboratory to create NVAC, the National Visual Analytics Centre to coordinate the development of these systems.

I believe that the success of visual analytics will depend upon the ability to coordinate spatial and temporal interaction patterns to support performance of individual operators. I have been asked by the US National Visual Analytics Centre to write a section of an upcoming US government Research Grand Challenge in Visual Analytics book that will set out funding agendas for the US department of homeland security.

Training aspects

My previous NSERC has contributed to the training of a number of Ph.D., MSc. And B.Sc. students. I co-supervised Barry Po on his Masters, and have continued to work with him on his Ph.D. as evidenced by our shared publications in this area. I also co-supervised James Gauthier on his Masters, with a thesis based on application of this work to a problem posed by the National Film Board of Canada with regards to their Kids' Site on the Web. Both of these students received RA funding from my previous Discovery Grant.

I am currently co-supervising Jonathan Sillito for the Ph.D., examining the application of this work to integrated development environments to support enhanced understanding of cross-cutting issues in object oriented code development. Caitlin Akai (MSc.) and Reynald Hoskinson (Ph.D) are working with me on the GM work, supported by GM of Canada. Masters students David Sprague and Phillip Jeffrey are working with me and a colleague on e-learning applications, both are co-supervised by me and have received funds from my Discovery Grant. I have also worked with a number of other Masters students, including R.Graeme McCaig who I have agreed to co-supervise for his Doctorate. Graeme worked on the biopotential project and is currently working to apply the personal equation perspective to deficits resulting from Parkinsons Disease. He is now working in the laboratory of CRC Neuroscience Chair Martin McKeown, who I am beginning a collaboration with on issues related to his research on Parkinsons Disease. It is expected that this proposal will help to continue to support these students as they finish their degrees as well as my new students at SFU Surrey.

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