REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
20-01-2009	Final Report	Oct-2005 - Sept-2008

4. TITLE AND SUBTITLE
Model and study of threatening tasks and fatigue

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-03-1-0248

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Ritter, Frank E.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
College of IST, Penn State, University Park, PA 16802

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Attn: Dr. Paul Bello ONR Code: 342
One Liberty Center
875 North Randolph Street, Suite 1425
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited

13. SUPPLEMENTARY NOTES
Laura Cousino Klein (co-PI)

14. ABSTRACT
This was a follow-on project to "Designing, building, and testing behavioral moderators with the ACT-R cognitive architecture". This project (a) prepared a protocol for studying how cognition is affected by a stressor (task appraisal) and a mitigator (caffeine), including software for gathering data on working memory, processing speed, and visual signal detection, and a protocol for serial (repeated) subtraction (SS). (b) We ran 45 Ss using SS and 45 with a simple ATC-like task as the stressor. (c) We have analyzed the data on how performance and physiology are affected by stress. We found that stress influenced performance (probably through working memory changes) and new details of physiology stress. (d) We created cognitive models in ACT-R. (e) We compared the SS model's performance by hand and by using a GA running on a supercomputer. We found that ACT-R is a model of individuals, not groups, multiple parameter sets provided excellent fits even to individuals, and GAs are an excellent way to choose architectural parameters. (f) Opportunistically, we finished a learning model, a book on learning, and a keystroke logger for studies.

15. SUBJECT TERMS
Stress, stress effects on cognition, learning, physiological effects of stress, caffeine, genetic algorithms, ACT-R, model optimization, keystroke logger

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Frank E. Ritter
Unclassified	Unclassified	Unclassified	UU	20	19b. TELEPHONE NUMBER *(Include area code)* ++ 1 (814) 865-4453

Final Report:
Model and study of threatening tasks and fatigue

Submitted to the Office of Naval Research.
Frank E. Ritter
frank.ritter@psu.edu, +1 (814) 865-4453
20 January 2008

N00014-03-1-0248 (January 2003 to September 2008).
Frank E. Ritter (PI), Laura Cousino Klein (Co-PI).
Michael Schoelles was a consultant.
http://acs.ist.psu.edu/cafenav

This was a follow-on project to "Designing, building, and testing behavioral moderators with the ACT-R cognitive architecture". This project (a) prepared a protocol for studying how cognition is affected by a stressor (task appraisal) and a mitigator (caffeine), including software for gathering data on working memory, processing speed, and visual signal detection, and a protocol for serial (repeated) subtraction (SS). (b) We ran 45 Ss using SS and 45 with a simple ATC-like task as the stressor. (c) We have analyzed the data on how performance and physiology are affected by stress. We found that stress influenced performance (probably through working memory changes) and new details of physiology stress. (d) We created cognitive models in ACT-R. (e) We compared the SS model's performance by hand and by using a GA running on a supercomputer. We found that ACT-R is a model of individuals, not groups, multiple parameter sets provided excellent fits even to individuals, and GAs are an excellent way to choose architectural parameters. (f) Opportunistically, we finished a learning model, a book on learning, and a keystroke logger for studies.

Introduction

This project is a follow on to a previous ONR project "Designing, building, and testing behavioral moderators with the ACT-R cognitive architecture." This final report does not include publications and results from the first project except for context. The previous project's final report (Ritter, Ceballos, Reifers, & Klein, 2005) is available online at http://acs.ist.psu.edu/reports/ritterRS05.pdf.

This project started to examine and to grapple with, how cognition changes under stress. The general approach was to gather a broad range of data on performance, cognition, and physiological measures while someone was stressed. And, then use these data to model how the mechanisms of cognition change with stress, using the physiological measures to validate the stress theory.

This approach required a lot of apparatus. Some of it was physical, for example, a heart rate/blood pressure monitor, but it also required a lot of theory (which we are still working on), software to gather data from the subjects and from the models, the models themselves, and in the end, tools to understand the model to data comparison.

In addition to the outcomes noted directly here, these results have been and will be used to argue more generally that cognition is influenced by factors such as task appraisal (Ritter, 2008b, in press), and these results continue to point in a direction for developing cognitive architectures. These effects that moderate behavior such as, lack of sleep, fatigue, fear, cultural appraisal will continue to be important for the Navy. The potential advantages and disadvantages of caffeine as a moderator of these moderators will also be important, particularly if we can help users choose the appropriate amount of caffeine because too much can cause both short-term and long-term problems. These effects are useful for predicting war fighter performance, for predicting causal and uniformed opponents, and for maximizing effects based warfare.

A major finding is a deeper understanding of the complexity of this problem of predicting how stress influences cognition. Nearly all cognitive architectures lack a theory of stress and need to be extended to support model development of complex tasks at the fine grained level required by this project. Because this is an integrated system (perception, cognition, motor) it is even more difficult to develop "architectural overlays", but could be much more rewarding as the prediction power and application would be very broad.

The remainder of the report describes the experiments in more detail. It then describes the models and the model fitting approach developed as theory and as software. It concludes with summary of our findings, lessons for work in this area, and with a listing of the outputs.

Experiments

Serial subtraction

We created a protocol that satisfied multiple criteria. It is shown in Figure 1. The total time was constrained by the time we could keep subjects and that they could make themselves available, as well as the duration of the multiple subtasks.

The details of the protocol are provided in a technical report (Ritter, Ceballos, Reifers, & Klein, 2005). The study took 130 minutes per subject. It was able to use about 1 in 8 subjects that we were able to recruit—the administration of stress and caffeine precluded large numbers of applicants from participating. For example, non-caffeine users could not be given 400 mg of caffeine, and there is a wide range of medicines that interact with caffeine and with stress.

The first study used repeated, running, serial subtraction as the stressor (serial subtraction). Serial subtraction has often been used as a stressor to study physiological responses to stress (Kirschbaum, Pirke, & Hellhammer, 1993). It produces a stress response in many people, particularly when combined with public speaking.

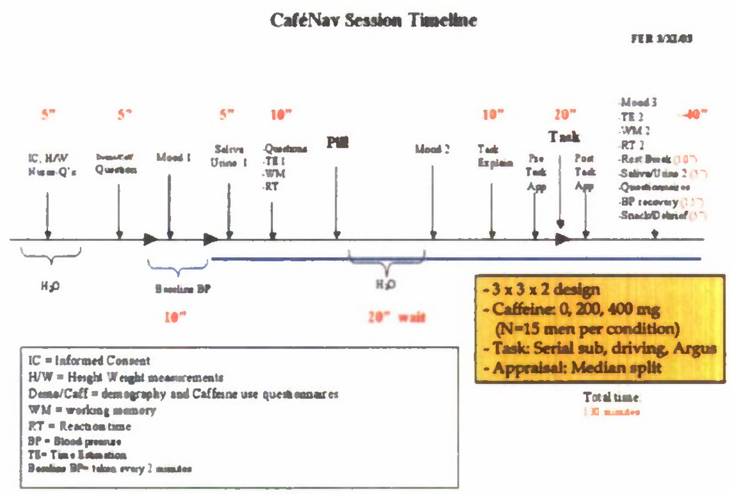

Figure 1. The timeline of the Café Nav studies.

The study gathered cognitive, performance, and physiological data. We gathered working memory capacity, processing speed, and visual signal detection ability before and after the task. We measured performance on the subtraction task and recorded their answers. We recorded their blood pressure and heart rate. We also took saliva samples that allowed us to examine several hormone measures before and after stress (alpha-amylase, cortisol, DHES), and caffeine before and after caffeine ingestion.

We have presented preliminary versions of the results in conference papers, reporting on the neuroendocrine and cardiovascular responses (Klein, Bennett, Whetzel, & Ritter, 2008), on the role of caffeine and stress specifically on cortisol (Bennett, 2006), alpha-amylase (Klein, Whetzel, Bennett, Ritter, & Granger, 2006; Klein, Bennett, Whetzel, Granger, & Ritter, submitted), and DHEA-S (Whetzel, 2006). Several of these reports are being prepared for publication as journal articles.

One of the potential impacts of this work is a deeper understanding of how caffeine interacts with stress hormones. This interaction might have suggestions for managing the effects of chronic stress. It appears that caffeine leads to much higher levels of stress hormones when there is stress (Klein, Bennett, Whetzel, Granger, & Ritter, submitted).

Argus

Using the Café Nav protocol we ran 45 subjects on the Argus task. There were 15 subjects on each caffeine dose condition (0, 200, 400 mg). The Argus task, shown in Figure 2 is a simple air-traffic control like task that includes a secondary tracking task (Schoelles & Gray, 2001).

This was more data than we could analyze. We do know so far that the Argus task was a much less stressful task then the caffeine task.

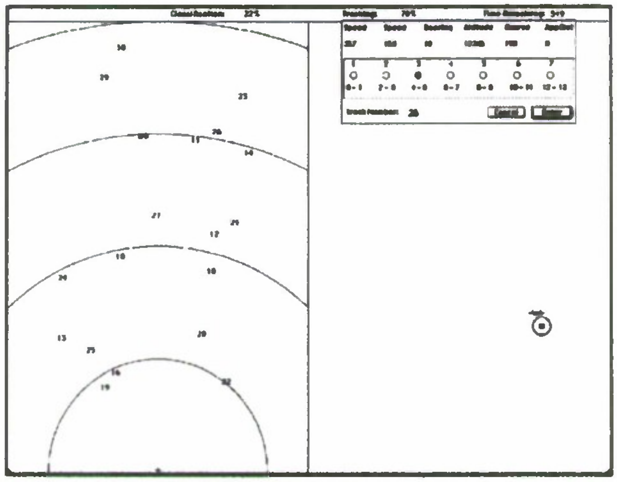

Figure 2. The task was to classify targets on the left using a multidimensional criteria function, and to respond to the tracking task on the right hand side.

Models

We created models of the subtraction task and also of several of the baseline tasks. We created these models within a single modeling language, a cognitive architecture called ACT-R (Anderson, 2007).

ACT-R models, of subtraction and visual signal detection

We created a model of serial subtraction starting with Lebiere's addition model (Lebiere, 1999). We partly chose the serial subtraction task because there was a start of a model available in ACT-R.

We also created a model of the visual signal detection task (Reifers, Ritter, Klein, & Whetzel, 2005).

We used an existing model of the working memory task (Lovett, Daily, & Reder, 2000). We later found that it was in a previous version of ACT-R, so it was hard to integrate and validate.

The Argus task was chosen because it had an existing model in ACT-R (Schoelles & Gray, 2000). There was not a difference in stress across subjects in the Argus task, so it was difficult to model stress with it.

Thus, the major work on modeling was done with the subtraction model.

Application of the overlays and other ACT-R models

A way, perhaps the first and most direct way to model moderators is to represent them as static changes to the architecture. To model the effects of stress on cognition in this was we developed an *overlay* approach (Ritter, Reifers, Schoelles, & Klein, 2007). This is shown diagrammatically in Figure 3. Most cognitive architectures have parameter settings, and ACT-R is no exception. Thus, each stressor can be seen as a change to the cognitive parameters representing how cognition in that state is different.

We have created overlays to test several major theories of how cognition is influenced by stress. A book chapter (Ritter, Reifers, Schoelles, & Klein, 2007) notes the lessons and provides 7 of them; a full set of 20 are available as a tech report (Ritter, Reifers, & Schoelles, 2005).

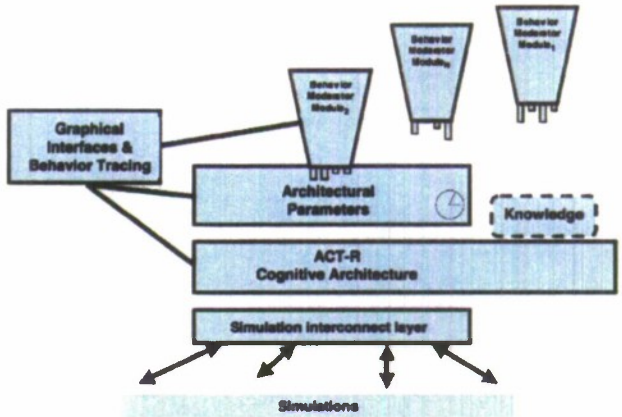

Figure 3. An approach to modeling behavioral moderators by specifying changes to the cognitive architecture through sets of parameter changes.

We have started to compare how these overlays when applied to the model correspond to the data on subtraction.

We have applied these overlays in two other ways. We have used this approach in another architecture called CoJACK (Norling & Ritter, 2004; Ritter & Norling, 2006), and we have applied the overlays to other ACT-R models (Ritter, Van Rooy, St. Amant, & Simpson, 2006; St. Amant, Horton, & Ritter, 2007).

This approach has also been presented at the Cognitive Science Conference in a panel discussion (Gluck, Gunzelmann, Gratch, Hudlicka, & Ritter, 2006), and at Pace University, TU/Berlin, the ABCS Research Group, Max Planck, Berlin, the UCL Interaction Centre (UK), a Darpa workshop, Charles River Analytics, BBN, and at Air Force, Network Science (Ritter, 2008b), and ACT-R workshops.

The future work in this area will be to test the existing overlays, and to create dynamic overlays. These dynamic overlays represent changes to mechanisms due to the passage of time and processing certain kinds of information. These changes should also lead the model to use different strategies to accomplish a task. This type of overlay will be more difficult to create, to test, and to apply, but ultimately more satisfying and more useful for applications as it will provide natural variability, which will be useful for operational analyses and for certain training applications.

Caffeine review

We have reviewed caffeine's cognitive effects. This paper has developed our thinking about the working memory and other tasks that were developed for our lab-based studies. The review of caffeine now includes over 20 studies. It makes three main suggestions for modeling. (a) that processing speed appears to be affected by about 3% but not other existing mechanisms. (b) that vigilance is strongly affected. This is not an easy construct to include in most architectures at this point. and (c) that caffeine and the self-reports of 'alertness' that it leads to are an important affect. These ratings are likely to influence task appraisal, as well as perhaps indicating that alertness is a measure to be included in architectures. We are revising this article for resubmission.

Review of coffee and cardiovascular health

Klein and a biobehavioral health doctoral student (Rodrigues, funded on a previous ONR grant) published a review of the effects of caffeine and coffee consumption on blood markers of cardiovascular disease (Rodrigues & Klein, 2006). This was part of Rodrigues' dissertation where the biobehavioral effects of stress and caffeine administration was tested in men and women with a family history of hypertension, which may be an important moderator of caffeine's effects on blood pressure. Serial subtraction measures were collected along with cortisol and blood pressure. It provides critical pilot information regarding caffeine moderators in women. This study provided hormonal measures for comparison, and additional data on subtraction.

Supercomputer experiments

Testing complex models by hand is probably not appropriate. Essentially, what the scientists are doing are optimizing the fit of a multivariable output function to data, using a multivariable function (a model with multiple parameters). Thus, the comparison of the theories is not really a comparison of the two theories, but a comparison of the theory and how well the author can fit the data by hand, with another theory fit by a hand. This is not a fair comparison of the theories (Ritter, 1991).

A way forward is to use a computer to do the comparison. This requires a lot of computer time. There are multiple parameters to examine. Each run of the model takes time. And the models must be run multiple times to be understood because these models include stochastic elements (Ritter, Quigley, & Klein, under revision October 2007). The parameter space also appears to be non-linear and not continuous.

A natural answer is to cast the model to data comparison fit as an optimization process. We can then use an algorithm that is useful for a broad range of optimization processes, a genetic algorithm (GA). A genetic algorithm, however, takes additional resources to run. We thus have a large need for computing power, and turned to High-performance computing, or a cluster supercomputer. After a few false starts, we were able to run both the GA and parameter sweeps (where parameter spaces are mapped out) using local resources as well as resources from the NSF Teragrid.

Figure 4 shows one of the first results, that the model's distribution is fairly narrow in number of attempts and percent correct when compared to the human data. This shows that ACT-R models are modals of individuals and not group data, which is appropriate. But, to model group data, then, we will have to provide a distribution of individuals (Ritter, Schoelles, Klein, & Kase, 2007).

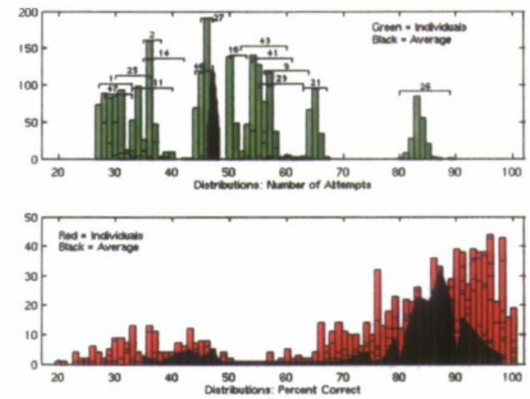

Figure 4. Distribution of the model's performance (black) and the human performance (gray or green and red) for number of attempts in a four-minute block and percent correct.

Figure 5 shows the model's performance for a range of parameters near one of the optimal fits (Kase, 2008; Kase, Ritter, & Schoelles, 2008). We did find that there were multiple fits, some extremely good (within 0.1 on number of attempts and 0.1 on percent correct for a given subject's performance).

These multiple good fits suggest that the architecture and model may be under constrained. We will be exploring how to fix this. Using more data sources is an obvious possibility. We also can explore using the addition task performance on the working memory task and simple reaction time task.

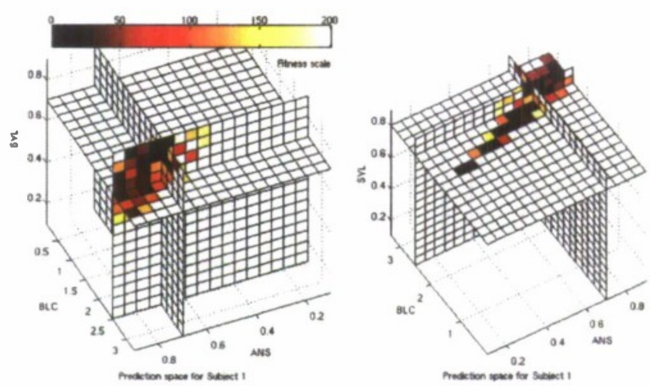

Figure 5. Parameter landscapes for subject 1 (top two plots). Color bar scale (top left-hand plot) 0 to 200 represents fitness values for all plots. (Figure 5.3 from Kase, 2008.)

Diag

During this project on modeling cognition another model was, after extensive revisions, accepted for publication. The model, called Diag, was a model of diagrammatic reasoning and troubleshooting (Ritter & Bibby, 2008). This grant provided partial support for Ritter to complete revisions to this modeling paper. The model shows that Soar's learning mechanisms can be used to model both aggregate and individual learning data. The very close fit to individual learning curves, shown in Figure 6, arose from modeling multiple aspects of learning. The model also described some of the noise that has been seen in learning curves as differential transfer between similar but not equivalent tasks. And it shows that recognition-primed decision making (RPD, G. A. Klein, 1989; Simon & Chase, 1973) can arise from a model that learns, and that both RPDM and problem solving are related to each other.

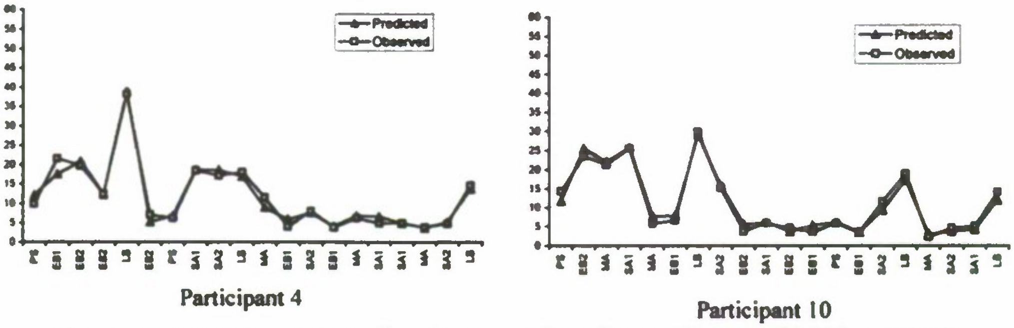

Figure 6. Model and data fit of Diag, taken from Ritter and Bibby (2008).

A visiting graduate student from Bamberg University (Germany), Maik Friedrich has partially duplicated and extended these results as his MS thesis (Friedrich, 2008). Maik will be continuing his PhD studies at Technical University/Chemnitz.

Conclusions

We break the conclusions into three sections: a short summary of the results, lessons for future projects like this (including ours), and future work that is both possible and some that we are still pursuing as we wrap up this project.

Summary of Results

A protocol for testing the effects of stress

We have created a protocol that can be used to measure cognitive performance under stress as measured by physiological measures. This protocol including computer software for gathering data on working memory, processing speed, and visual signal detection, and a paper protocol for performing and acquiring data on serial (repeated) subtraction. This protocol also includes pilot data and some experience in recruiting subjects (e.g., how to recruit and how many applicants are required to get an appropriate subject).

A dataset on stress, cognition, physiology, and caffeine

We have partially analyzed the data on how performance is affected by stress and how the physiology changes during stress. We found that stress influenced performance (through working memory changes) and influenced physiology as measured by cardiac measures and by hormonal assays. It appears that caffeine leads to much higher levels of stress hormones when there is stress.

A set of data on subtraction

In particular, we have a relatively rich dataset on how serial subtraction is performed. This data set includes the time and the answers for 45 subjects in 4 four-minute blocks.

We have submitted a paper on this topic to a journal, and we are revising the paper based on the editor's and reviewers' comments.

A dataset on hormonal and cardiovascular measures

We have a rich dataset on the hormonal and cardiovascular measures of stress on this task and how caffeine interacts with stress on this task. We have reported preliminary results in four conference appears an several of these papers are being prepared for publication.

Importantly, cortisol appears to be elevated by stress and caffeine without improving performance. This result should be explored. The simplest suggestion that is not fully tested is that too much caffeine in a stressful situation does not help performance and may indeed have long-term health implications

(c) We created a model of serial subtraction and of several of the other tasks. We did this for the ACT-R 5 architecture and moved most of the models into the ACT-R6 architecture.

A dataset on caffeine

We have data on how caffeine has influenced performance and we also have data on the pharmacokinetics of caffeine implicitly, how fast caffeine was absorbed and its half-life in the body. We have also created a review paper useful for modeling caffeine (Morgan, Ritter, Stine, & Klein, unpublished mss, 2006).

An example application of a model of stress

We ran a small (N=24) study of how well unmoderated people drive a simple driving game (shown in Figure 7). The results have been analysed, and are reported with a previous paper describing the driving model that interacts directly with the task. The report includes a prediction of how a distracted, dual task driver would perform on the driving task (Ritter, Van Rooy, St. Amant, & Simpson, 2006).

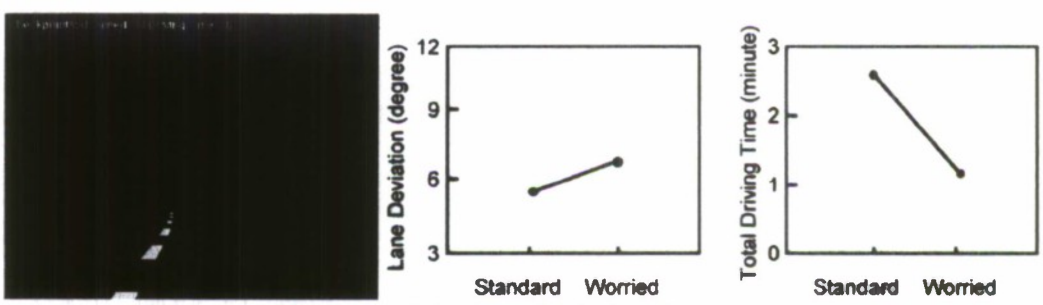

Figure 7. The driving task (left), and the lane deviation (center) and average time before a crash (right) for standard and worried models (Ritter et al., 2006).

A way to test and understand cognitive models using high-performance computing

We have developed software and an approach for testing cognitive models using a genetic algorithm to optimize the fit of the model to the data. In this process, the resulting fit tells us interesting things about the architecture. It tells us what can and cannot be fit, it tells us useful parameter values, and it has suggested a wider range of parameter values that most modelers use when fitting by hand.

This work has also shown us that sets of data when it is fit to models in the ACT-R architecture should be fit using sets of parameters to represent the individuals rather than a global parameter. This is because the distribution of the model's performance appears much more like single subject's performance than the broader distribution generated by a set of subjects.

A deeper understanding of the depth and breadth of how stress influences cognition

Finally, this project taken together shows that discussion about stress and cognition is often too simple. Stress appears not to be a single concept, but a complex concept. There are multiple causes of stress, including task related stress. Performance is influenced at least by appraisal and by moderators like caffeine. Future studies should take appraisal measures so that we have some normative values. Future studies in general should measure the caffeine consumption of the subjects because caffeine clearly influences performance. And, we hope, we will also see further work using and modeling hormonal and cardiovascular measures.

Lessons

We gathered both more data than we could use and although not enough in spots to publish. We took an enormous amount of data on the 90 subjects. The data was large, not only in the amount taken (some measures every two minutes), but its breadth in that it took at least a pair of researchers to perform analyses across the set. The physiology and cognitive data use different assumptions and different types of analyses. In the future, projects like this should budget not at 1:1 for data to analysis, but budget 1:2 or 1:3 for data gathering to data analysis. Data modeling may require a yet larger ratio of 1:4 or 1:8. We would have been better off with more than 15 subjects in each cell. While the study was carefully controlled, 15 in a cell sometimes was not enough to provide significant results but only marginally significant results, which are much harder to report.

Graduate students were the core workers on this project. This was a complex project for graduate students, particularly first year students to understand and contribute to. Future projects should either be less ambitious, or should use more senior graduate students (which are not always available), use post-docs (which have some advantages), or use research faculty in combination with these types of researchers. Thus, the creation, maintenance, and retention of students across a multi-year project should be kept in mind particularly in complex projects like this. A few of our publications, in the edited book (i.e., *In order to learn*) and a tutorial on ACT-R we created (Schoelles & Ritter, 2003), were created to support the education of students.

This project will perhaps have a longer live that some other grants. It took longer than expected to set up, pilot, and run the study. It is a complex study combining methodological constraints from two different areas, cognitive psychology and physiology.

The models proposed were more complex than could be built and maintained. We proposed to create a set of 5 models (working memory, processing speed, visual SDT, subtraction, and Argus). This was more difficult than we had planed. While we started with models for three of these, several of the models required modifications to fit this protocol and to each other, and one was in a quite old version of ACT-R. And, in the middle of the project ACT-R released a major new version. We started to migrate to this new version, which also added delay.

We should have required more regular meetings both within each team and across teams. A time budget of support and time should have been used, and the PI should use this budget both to assure effort and to ensure that not too much is planned, which seems to have happened with this project: building apparatus for humans, gathering data, building apparatus for models, building several models (including moving the models to a new version of ACT-R), and then model comparison and adjustment to data is not one project, but six projects.

And yet, we accomplished several things, which we noted here, including several exciting applications of this work.

Future work

This project suggested several new projects, two of which we have piloted. There are also several papers that are either drafted, being drafted, or being revised for submission.

Further analysis of these datasets

The data we collected we are still analyzing. The list of draft papers notes a few of the directions we are pursuing. These include summarizing the hormonal assays as measures of stress, reporting the serial subtraction performance in a journal article, and looking at the caffeine's effects on performance.

Predicting factors that influence post-traumatic stress disorder

The model of task appraisal suggests that people and models are constantly appraising the environment, their actions, and their performance. High levels of threatening appraisals could and should adversely affect performance, yet, most models do not account for this because the underlying architecture does not provide an adequate theory of task appraisal. Including task appraisal would require extending models to have new types of knowledge about tasks and task progress that have only rarely been created, and it would require modifying the architecture.

In addition, if appraisals did not match actions cognitive dissonance or worse could arise. Grossman (1996) has argued that when there is a mismatch between appraisal about a particular task, that is, to participate in a military engagement and actual participation (e.g., accidents, direct orders for less than standard military actions), could contribute to the development of post-traumatic stress disorder.

We have modified the dTank simulation (Ritter, 2008a) to illustrate this and developed this idea briefly. Figure 8 shows that Grossman's equation for participation can be implemented, and a workshop paper (Ritter, 2008b) explores some of these issues for application to network science.

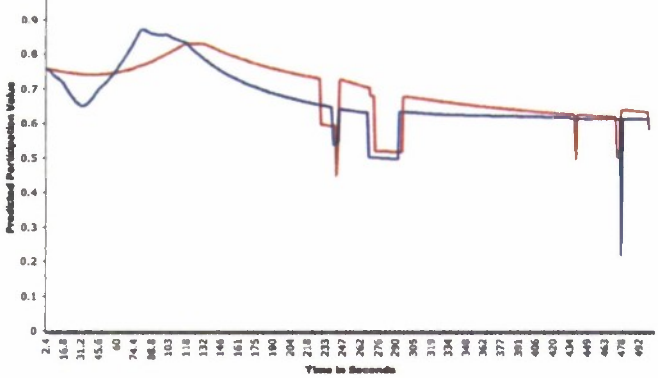

Figure 8. Example implementation of Grossman's equation in the dTank simulation.

Caffeine predictor

We created a prototype of a caffeine predictor using the review we created of caffeine and cognition (Morgan, Ritter, Stine, & Klein, unpublished mss, 2006). Figure 9 shows the interface. The interface allows the user to input when they consume caffeine and provides a few choices of caffeine inputs. These inputs are displayed and the caffeine level (the pharmacokinetics) is computed using the best data we could find (sped up here by a factor of 10 for illustration purposes). Our current best predictions of the cognitive target zone and the level of caffeine that disturbs sleep are also shown.

This prototype could use further work to make it more accurate and usable. It should provide users with a way to predict when they should have another cup of coffee or another stick of caffeine gum, and, perhaps more importantly, when they should not, both for cognitive performance as well as for later sleep. This could be very useful in normal office environments as well as operational environments. This would require further programming time, and testing time and could be done fairly quickly with the right resources. If the users data were collected, we could also refine the theory of caffeine, including the constants that generate the curves (i.e., caffeine half-life), the factors that influence these constants (e.g., fatigue, nicotine), and the set points, which are predicted and some data are available, but which when put into this simulator appear to need refining.

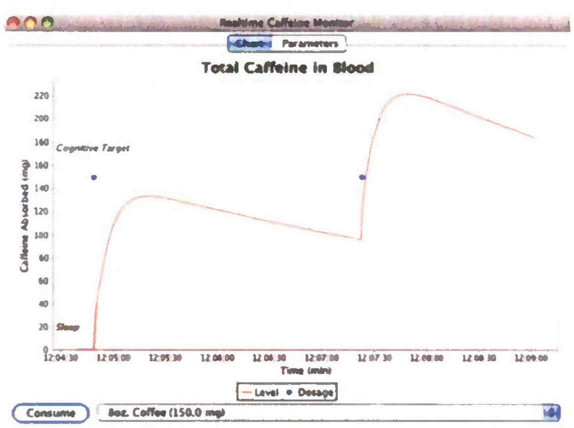

Figure 9. A draft of a prototype tool for predicting caffeine and for supporting more rational caffeine use. Note that the caffeine half-life is greatly accelerated for illustrating the effects.

Drafts of papers/mss in process

Bennett, J. M., Ritter, F. E., Whetzel, C. A., & Klein, L. C. (being revised, September 2007). The biobehavioral effects of stress, caffeine treatment, and withdrawal in healthy young men

Friedrich, M. A report on thesis results extending Diag with data and theory for a journal such as Cognitive Science.

Kase, S. A paper on Kase's thesis for the BRIMS conference.

Kase, S. A paper on Kase's thesis reporting HCP and model fitting as a technique and results for modeling ACT-R, for a journal such as *Cognitive Systems Research.*

Ritter, F. E., Bennett, J. M., Kase, S. E., Rodrigues, I., Klein, L. C. (being revised, November, 2008). Cognitive performance on a serial subtraction task. *Memory and Cognition.*

Ritter, F. E., Schoelles, M. J., Quigley, K. S., & Klein, L. C. (being revised, January 2008). Determining the number of model runs: Treating user models as theories by not sampling their behavior.

Schoelles, M., Ritter, F. E., et al. (in preparation). An empirical testing of seven theories of stress.

Outputs

Students

Jeanette Bennett

Jeanette Bennett was supported for several semesters. She is currently preparing for her PhD comprehensive examination in Biobehavioral Health. She helped prepare the serial subtraction data (both cognitive and physiological) for analysis and helped with its analysis.

Sue Kase

Sue Kase was partially supported by this project. She received a PhD in December 2008. Her thesis was on using high performance computing to optimize the fit of ACT-R models to the serial subtraction data. She is currently a post-doc working at the Defense Threat Reduction Agency in Washington, DC.

Andrew Reifers

Andrew Reifers was supported on the previous project for several years. In November 2005 he took a job in industry and changed his research topic to internet security. He is currently working on a PhD on visualizing internet security while working in this area for a consulting firm.

Bill Stevenson

Bill Stevenson was supported for one semester. He passed his thesis proposal in December 2006 on "Does subitizing capacity Improve with practice?". Subitizing is the ability to count 4 or less objects more quickly per object than more than 4. In this thesis he proposed to use and test an existing ACT-R model of subitizing. He helped create the ACT-R subtraction model, and has helped with the RUI keystroke logger. He is currently a project manager at Apple.

Courtney Whetzel

Courtney Whetzel was supported for several semesters. She received her PhD in Biobehavioral Health. She helped collect the serial subtraction data (both cognitive and physiological) and helped with its analysis.

Software

This project produced several pieces of software that can or have been reused.

We created a modified (shortened) version of Marsha Lovett's MODS task (Lovett, Daily, & Reder, 2000) than measures working memory size. It is in ePrime and has been reused in a student project this year in the Biobehavioral Health Department at Penn State.

We created a simple visual signal detection task and reaction time task in Common Lisp.

We provided partial support for the development and continuing refinement of RUI, which is a keystroke and mouse move logger (Kukreja, Stevenson, & Ritter, 2006). It has been reused at CMU and William and Mary, and is reused by another ONR sponsored project at Penn State on modeling learning and forgetting.

We provided partial support dismal, a spreadsheet program that works as part of the GNU Emacs editor (Ritter & Wood, 2005). Dismal has been reused as part of another ONR project on modeling learning and forgetting as a novel spreadsheet to learn.

Publications

I have put copies of all outputs here for ease of use. Most will also appear in the references. Copies of most papers are available at http://acs.ist.psu.edu/papers.

Journal articles

Klein, L. C., Bennett, J. M., Whetzel, C. A., Granger, D. A.,& Ritter, F. E. (submitted January, 2009). Effects of caffeine and stress on salivary alpha-amylase in young men.

Klein, L. C., Faraday, M., Quigley, K. S., & Grunberg, N. E. (2004). Gender differences in biobehavioral aftereffects of stress on eating, frustration, and cardiovascular responses. *Journal of Applied Social Psychology. 34*(3), 538-562.

Kukreja, U., Stevenson, W.E., & Ritter, F.E. (2006). RUI—Recording User Input from interfaces under Windows and Mac OS X. *Behavior Research Methods 38(4)*, 656–659.

Ritter, F. E. (invited, accepted October, 2008). Two cognitive modeling frontiers: Emotions and usability. Journal of Japanese AI Research.

Ritter, F. E., & Bibby, P. A. (2008). Modeling how, when, and what learning happens in a diagrammatic reasoning task. Cognitive Science, 32, 862-892.

Ritter, F. E., Van Rooy, D., St. Amant, R., & Simpson, K. (2006). Providing user models direct access to interfaces: An exploratory study of a simple interface with implications for HRI and HCI. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans. 36(3). 592-601.

Ritter, F. E., & Wood, A. B. (2005). Dismal: A spreadsheet for sequential data analysis and HCI experimentation. Behavior Research Methods, 37(1), 71-81.

Rodrigues, I.M., & Klein, L.C. (2006). Boiled or filtered coffee? Effects of coffee and caffeine on cholesterol, fibrinogen, and C-reactive protein. *Toxicological Reviews 25(1)*, 55-69.

St. Amant, R., Horton, T. E., & Ritter, F. E. (2007). Model-based evaluation of expert cell phone menu interaction. ACM Transactions on Computer-Human Interaction, 14(1), Article 1 (May 2007), 24 pages.

Books and book chapters

Nerb, J., Ritter, F. E., & Langley, P. (2007). Rules of order: Process models of human learning. In F. E. Ritter, J. Nerb, T. O'Shea, & E. Lehtinen (Eds.), *In order to learn: How the sequences of topics affect learning.* 57-69. Oxford University Press.

Ritter, F. E., Lehtinen, E., & Nerb, J. (2007). Getting things in order: Collecting and analyzing data on learning. In F. E. Ritter, J. Nerb, T. O'Shea, & E. Lehtinen (Eds.), *In order to learn: How the sequences of topics affect learning.* 81-92. Oxford University Press.

Ritter, F. E., & Nerb, J. (2007). Call to order: How sequence effects in humans and artificial systems illuminate each other. In F. E. Ritter, J. Nerb, T. O'Shea, & E. Lehtinen (Eds.), *In order to learn: How the sequences of topics affect learning.* 3-15. New York, NY. Oxford University Press.

Ritter, F. E., Nerb, J., O'Shea, T., & Lehtinen, E. (Eds.), (2007). *In order to learn: How the sequence of topics influence learning.* New York, NY: Oxford University Press.

Ritter, F. E., Reifers, A. L., Klein, L. C., & Schoelles, M. (2007). Lessons from defining theories of stress. *Integrated Models of Cognitive Systems (IMoCS)*, Wayne D. Gray (ed.). 254-262. New York, NY: Oxford University Press.

Conference papers

Bennett, J. M., Whetzel, C. A., Ritter, F. E., Reifers, A., & Klein, L. C. (2006). Effects of caffeine and stress on cortisol and serial subtraction performance in young healthy men. *Psychosomatic Medicine 68*(1). A-62. [abstract of poster presented at the annual meeting of the American Psychosomatic Society, Denver, CO.]

Gluck, K. A., Gunzelmann, G., Gratch, J., Hudlicka, E., & Ritter, F. E. (2006). Modeling the impact of cognitive moderators on human cognition and performance. In *Proceedings of the 2006 Conference of the Cognitive Science Society.* 2658. Mahwah, NJ: Erlbaum.

Kase, S. E., Ritter, F. E., & Schoelles, M. (2008). From modeler-free individual data fitting to 3-D parametric prediction landscapes: A research expedition. In *Proceedings of the 30th Annual Conference of the Cognitive Science Society*, 1398-1403. Cognitive Science Society: Austin, TX.

Klein, L.C., Bennett, J.M., Whetzel, C.A., & Ritter, F. E. (2008). Daily caffeine use impacts neuroendocrine and cardiovascular responses to laboratory stress in healthy men. Presented at the annual meeting of the American Psychosomatic Society, Baltimore, MD. *Psychosomatic Medicine, 70*(3), A-58.

Klein, L. C., Whetzel, C. A., Bennett, J. M., Ritter, F. E., & Granger, D. A. (2006). Effects of caffeine and stress on salivary alpha-amylase in young men: A salivary biomarker of sympathetic activity. *Psychosomatic Medicine 68*(1). A-4. [abstract of talk presented at the annual meeting of the American Psychosomatic Society, Denver, CO.] http://www.psychosomaticmedicine.org/misc/AbstractsForJournal062-9final.pdf

Ritter, F. E., Reifers, A., Klein, L. C., Quigley, K., & Schoelles, M. (2004). Using cognitive modeling to study behavior moderators: Pre-task appraisal and anxiety. In *Proceedings of the Human Factors and Ergonomics Society.* 2121-2125. Santa Monica, CA: Human Factors and Ergonomics Society.

Ritter, F. E., Schoelles, M., Klein, L. C., & Kase, S. E. (2007). Modeling the range of performance on the serial subtraction task. In *Proceedings of the 8th International Conference on Cognitive Modeling.* 299-304. Oxford, UK: Taylor & Francis/Psychology Press.

Whetzel, C. A., Ritter, F. E., & Klein, L. C. (2006). DHEA-S and cortisol responses to stress and caffeine in healthy young men: Is DHEA-S a reliable marker for stress? *Psychosomatic Medicine 68*(1). A-77. [abstract of poster presented at the annual meeting of the American Psychosomatic Society, Denver, CO.]

Other publications

Inguscio, L., & Ritter, F. E. (2005). Applied Cognitive Science Laboratory at the Pennsylvania State University (Laboratory Notes). *Cognitive Processing: International Quarterly of Cognitive Science. 6*(2). 142-146. [refereed].

Ritter, F. E., Bennett, J., & Klein, L. C. (2006). Serial subtraction performance in the cycling study (Tech. Report No. ACS 2006-1). Applied Cognitive Science Lab, School of Information Sciences and Technology, Penn State. acs.ist.psu.edu/reports/ritterBK06.pdf

Ritter, F. E., Reifers, A. L., & Schoelles, M. J. (2005). Defining testable theories of pre-task appraisal stress (Tech. Report No. ACS 2005-2). Applied Cognitive Science Lab, School of Information Sciences and Technology, Penn State. acs.ist.psu.edu/reports/ritterRKS05.pdf

Presentations [excluding conference presentations]

Kase, S. (17 May 2007). Invited talk ' ACT-R and TeraGrid DAC' at the Cognitive Modeling Volunteer Computing Symposium, Performance and Learning Models Lab, Air Force Research site Mesa, AZ.

Kase, S. (2007). Poster presentation 'Automating the fit of cognitive models: Responses to a mental arithmetic stressor'. At the San Diego Supercomputing Center Summer Computing Institute 2007. [some travel support provided by them.]

Kase, S. (2007). 'A systematic approach to cognitive model fitting: Individual differences on a mental arithmetic stressor'. Doctoral Consortium, International Conference on Cognitive Modeling, Ann Arbor, MI.

Ritter, F. E., Klein, L. C., Quigley, K. S., Councill, I. G., Avraamides, M. N., Reifers, A. L., Whetzel, C. A., Simpson, K., Stine, M. M., Ceballos, R. M., Morgan, G. P., & Ghandi, M. (2003). Using cognitive modeling to study behavior moderators: Pre-task appraisal, anxiety, and caffeine. ONR Cognitive and Computational Models of Cortex Workshop, November, 2003. (invited)
also presented at RPI's series on "Issues in Cognitive Science", January 2004.
also presented as part of IST 590, colloquium version, Spring 2004.

Reifers, A., Ritter, F., Klein, L., Whetzel, C. (2005). Modeling the effects of caffeine on visual signal detection (VSD) in a cognitive architecture. Poster presented at "Attention: From Theory to Practice" (A festschrift for Chris Wickens).

Reifers, A. L., Schenck, I. N., & Ritter, F. E. (2005). Modeling pre-attentive visual search in ACT-R. In *Proceedings of the Cognitive Science Society.* 2545. Mahwah, NJ: Erlbaum.

Ritter, F. E., Klein, L., Reifers, A., & Schoelles, M. (2005). Defining 10 testable theories of pre-task appraisal stress: Types 1 & Type 2 & Type 3. Presented at the AFOSR Integrated Models of Cognitive Systems Workshop.

Ritter, F. E., Klein, L. C., Reifers, A., & Ceballos, R. (2004). The effects of pre-task appraisals and caffeine on cognition: Data and models. Presentation and abstract at ONR Neural Computation 2004 Annual Investigator Conference, U. of Nevada at Reno, August 20 to August 22. (invited from another program.)

Ritter, F. E. (March 2005). Steps towards a CAD/CAM system for Human-Computer Interfaces. Air Force Investments in Computational Cognitive Process Modeling Working Group.

Ritter, F. E. (2006). Some stress theories: Terms, tasks, models, theories, and overlays. ACT-R DARPA BICA 2006 Workshop, 10-11 Feb 2006.
Charles River Analytics, March 2006.
Bolt Beranek and Newman, March 2006.

Ritter, F. E. (2006). An Introduction to ACT-R and to The Herbal High Level Behavior Representation Language Tutorial (with Mark Cohen and others). Defense Science and Technology Lab, Farnborough, UK, June 2006.

Ritter, F. E., Klein, L., Reifers, A., & Schoelles, M. (2005). Defining 10 testable theories of pre-task appraisal stress: Types 1 & Type 2 & Type 3. Presented at the AFOSR Integrated Models of Cognitive Systems Workshop.

Ritter, F. E., Reifers, A., Klein, L. C., Whetzel, C., Schoelles, M., Quigley, K. (2005). The effects of pre-task appraisal and caffeine on cognition: Data and models. In *Proceedings of the 12th ACT-R Workshop.* Universita degli Studi di Trieste, Italy.
ABCS Research Group, Max Planck, Berlin (November, 2005).

Ritter, F. E., Avraamides, M. N., Councill, I., Rooy, D. V., Quigley, K. S., Klein, L. C., McNeese, M. D., Stine, M. M., & Rodrigues, I. M. (2002). Pre-task appraisal and caffeine: An architectural overlay for ACT-R. Air Force Workshop on ACT-R

Models of Human-System Interaction, Mesa, AZ, January 2002. www.dtic.mil/AFRL/afrl.html

ONR Cognitive Architectures Workshop, January 2002.

Ritter, F. E, St. Amant, R., Reifers, A., Morgan, G., Schenck, I. N., & Cohen, M. (2005). Steps towards a CAD/CAM system for Human-Computer Interfaces. School of Computer Science and Information Systems, Pace University.

also at TU Berlin (November, 2005).

also at HCI Unit, University College, London (November, 2005).

Schoelles, M., & Ritter, F. E. (2003). Hands on tutorial for ACT-R (HOT4 ACT-R). Applied Cognitive Science Lab, Summer, 2003.

Published workshop papers and posters

Kase, S. E., Ritter, F. E., & Schoelles, M. (2008). HPC + PGA + ACT-R = perfect fits (lacking validation?): Presented at the Large-Scale Computing Resources and ACT-R Modeling Symposium, Kevin Gluck, organizer. In Proceedings of the 15th ACT-R Workshop. 66. Pittsburgh, PA: ACT-R Group, CMU.

Reifers, A., Schenck, I., Ritter, F. E., & Inguscio, L. (2005). Using ACT-R to progress theories of pre-attentive visual search. In *Proceedings of the 12th ACT-R Workshop.* Universita degli Studi di Trieste, Italy.

Reifers, A. L., Schenck, I. N., & Ritter, F. E. (2005). Modeling pre-attentive visual search in ACT-R. In *Proceedings of the Cognitive Science Society.* 2545. Mahwah, NJ: Erlbaum.

Ritter, F. E. (2008). High-level behavior representation languages and moderators of behavior. *The USMA Network Science Workshop,* 15-17 October, 2008, West Point, NY.

Ritter, F. E., Reifers, A., Klein, L. C., Whetzel, C., Schoelles, M., Quigley, K. (2005). The effects of pre-task appraisal and caffeine on cognition: Data and models. In *Proceedings of the 12th ACT-R Workshop.* Universita degli Studi di Trieste, Italy. ABCS Research Group, Max Planck, Berlin (November, 2005).

Reifers, A., Ritter, F., Klein, L., Whetzel, C. (2005). Modeling the effects of caffeine on visual signal detection (VSD) in a cognitive architecture. Poster presented at "Attention: From Theory to Practice" (A festschrift for Chris Wickens).

Ritter, F. E., Schoelles, M., Kase, S. E., & Klein, L. C. (2008). Simulating pre-task appraisal of serial subtraction. In Proceedings of the 15th ACT-R Workshop. 26. Pittsburgh, PA: ACT-R Group, CMU

Press coverage

Barker, T. (2008). Modeling the mind. *NCSA Access, Fall*, 16-19.

Eric Nagouney, Vital Sign, "Applying Math and Counting the Cups", The New York Times, Tuesday, March 14, 2006.

Computers can help you to perform difficult tasks better. September 29, 2004. webindia123.com

Giving computers the jitters helps explain human behavior. 29.09.2004. www.innovations-report.com

Giving computers the jitters helps explain human behavior. 2004-09-29. www.sciencedaily.com/releases/2004/09/040928111357.htm

Giving computers the jitters helps explain human behavior. September 29, 2004. Science Blog. www.scienceblog.com/community/modules.php?name=News&File=article&sid=4212

Giving computers the jitters helps explain human behavior. Plebius Press, Psychology Resource Center. psychology.plebius.org/news.php?nh=10&new_topic=19.

Computers can help you perform difficult tasks better. not dated. newkerala.com

A truth universally acknowledged, Thursday December 16, 2004, education.guardian.co.uk/higher/research/story/0,9865,1374387,00.html

Steve Biddle, "Giving computers the jitters helps explain human behavior". Morning news, WPSU radio. 12 October 2004.

Tia Bochnakova, "Study mimics human jitters", Daily Collegian, 12 October 2004.

Related projects and related funding

There are three additional resources that we obtained related to this project and three related projects. We received three grants of supercomputer time. We had extensive interaction with the Army Research Lab, and eventually found that we could not implement our system for optimizing the fit of models using their system. There was no single problem, but the turnaround time on each sub-task (installing a test system such as a version of Lisp, running it, getting feedback), was too long. Upon request we documented these problems for their chief scientist.

Work with the NSF Teragrid (of supercomputers) was more productive. The Teragrid provided the resources for Sue Kase's runs to understand the model fits using supercomputer runs.

ARL (May 2003 to May 2005). Optimizing the fit of cognitive models using genetic algorithms. CRADA for 2,500 hours of supercomputer time.

NSF Teragrid. 2007. Optimizing the fitting of a serial subtraction cognitive model. 10,000 units of supercomputer time. Extended to 30,000 units. Sue Kase, Co-PI.

NSF Teragrid. 2008. Visualizing the parameter space of a serial subtraction cognitive model. 30,000 units of supercomputer time. Sue Kase, Co-PI. Another long-term project completed during this grant, which as a book exploring how sequence of topics influences learning (Ritter, Nerb, O'Shea, & Lehtinen, 2007). This project provided some of Ritter's time to finish the editing of this book. The book uses cognitive models as a way to summarize learning and to illustrate how learning is influenced by the topic order. The introductory chapters (Nerb, Ritter, & Langley, 2007; Ritter, Nerb, & Lehtinen, 2007) were written to provide to training materials for research assistants like those used in this project.

Technology Transfer

Transfer to cognitive architectures and synthetic environments

This work has applications to cognitive architectures and for models used in computer-generated forces. It shows that we can create architectural overlays -- modifications that change a cognitive architecture's information processing. This approach of architectural overlays could be used to modify other models, in particular, ACT-R models.

These overlays could be extended to include additional moderators of behavior. Our overlays would already be useful to include in computer-generated forces because they modify behavior in ways representing major theories, and the modifiers, task appraisal and caffeine, are directly relevant to the performance of computer-generated forces. We have participated in discussion about the next generation of synthetic environments (OOS, the OneSAF Objective System, a next generation synthetic environment), and passed the OOS developers copies of reports from this project. This work was informally briefed and informed discussions at the US/UK OOS Programme Agreement Workshop, 11/12 April 2006, and later in November 2006.

Three projects are directly using the results, broadly defined, of this project. A UK MoD project to create a cognitive architecture version of the Java Agent Construction Kit (Co-JACK) has used this overlay approach and the reviews and data on serial subtraction to validate the new COJACK cognitive architecture and moderator overlay to it (Ritter & Norling, 2006). As it is in support of modeling human variability in computer-generated forces, it shows one of the obvious applications of this project. An award-winning (at BRIMS) project for DMSO has then applied the COJACK architecture to model moderators influence in a military scenario.

We are applying lessons from this project on modeling IED development for ONR (in that agents may appraise whether to participate in IED development networks), and using ACT-R to model learning and forgetting for ONR, but the connections are less direct.

Applications to Navy personnel health

The results about caffeine and cortisol have implications for long-term health in the Navy. It could be that acute cortisol elevations may lead to enhanced cognitive performance in response to caffeine administration and stress. Under repeated stress, however, this chronic cortisol elevation may result in memory impairment and psychological disorders that can affect cognition such as depression and anxiety. Whether caffeine administration exacerbates or attenuates this stress-cortisol affect is unclear and this caffeine result needs to be examined further in light of the other data.

Application to other labs and committees

Ritter's was appointed to the NAS's Committee on Human-System Design., which has prepared a report on how to better include humans in system design to reduce risk.

Transitioned and Leveraged funding

We have received support from the NSF Teragrid for supercomputer time. This support will help with testing our models. It has also helped Sue Kase define and perform her PhD thesis.

Future plans

In a discussion with Bello and Vodyanoy (June 2007), the idea of a caffeine level predictor was developed. This is an exciting practical output. We are actively developing it. It could help summarise caffeine data across labs, help users of caffeine in the field, and help their flight surgeons and commanders.

References

Anderson, J. R. (2007). *How can the human mind exist in the physical universe?* New York, NY: Oxford University Press.

Bennett, J. M., Whetzel, C. A., Ritter, F. E., Reifers, A., & Klein, L. C. . (2006). Effects of caffeine and stress on cortisol and serial subtraction performance in young healthy men. [abstract of poster presented at the annual meeting of the American Psychosomatic Society, Denver, CO]. *Psychosomatic Medicine, 68*(1), A-62.

Friedrich, M. B. (2008). *Implementing diagrammatic reasoning strategies in a high level language: Extending and testing the existing model results by gathering additional data and creating additional strategies.* Faculty of Information Systems and Applied Computer Science, University of Bamberg, Germany.

Gluck, K. A., Gunzelmann, G., Gratch, J., Hudlicka, E., & Ritter, F. E. (2006). Modeling the impact of cognitive moderators on human cognition and performance. In *Proceedings of the 2006 Conference of the Cognitive Science Society*, 2658. Erlbaum: Mahwah, NJ.

Grossman, D. (1996). *on killing: The psychological cost of learning to kill in war and society.* New York, NY: Back Bay Books, Little Brown and Company.

Kase, S. E. (2008). *HPC and PGA optimization of a cognitive model: Investigating performance on a math stressor task.* Unpublished PhD thesis, College of IST, Penn State University, University Park, PA.

Kase, S. E., Ritter, F. E., & Schoelles, M. (2008). From modeler-free individual data fitting to 3-D parametric prediction landscapes: A research expedition. In *Proceedings of the 30th Annual Conference of the Cognitive Science Society*, 1398-1403. Cognitive Science Society: Austin, TX.

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The Trier Social Stress Test—A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*, 76-81.

Klein, G. A. (1989). Recognition-primed decisions. In W. B. Rouse (Ed.), *Advances in Man-Machine Systems Research, Vol. 5* (Vol. 5, pp. 47-92). Greenwich, CT: JAI.

Klein, L. C., Bennett, J. M., Whetzel, C. A., & Ritter, F. E. (2008). Daily caffeine use impacts neuroendocrine and cardiovascular responses to laboratory stress in healthy men. Presented at the annual meeting of the American Psychosomatic Society, Baltimore, MD. *Psychosomatic Medicine, 70*(3), A-58.

Klein, L. C., Bennett, J. M., Whetzel, C. A., Granger, D. A., & Ritter, F. E. (submitted January, 2009). Effects of caffeine and stress on salivary α-amylase in young men.

Klein, L. C., Whetzel, C. A., Bennett, J. M., Ritter, F. E., & Granger, D. A. (2006). Effects of caffeine and stress on salivary alpha-amylase in young men: A salivary biomarker of sympathetic activity. [abstract of talk presented at the annual meeting of the American Psychosomatic Society, Denver, CO.]. *Psychosomatic Medicine, 68*(1), A-4.

Kukreja, U., Stevenson, W. E., & Ritter, F. E. (2006). RUI—Recording User Input from interfaces under Windows and Mac OS X. *Behavior Research Methods, 38*(4), 656–659.

Lebiere, C. (1999). The dynamics of cognition: An ACT-R model of cognitive arithmetic. *Kognitionswissenschaft, 8*, 5-19.

Lovett, M. C., Daily, L. Z., & Reder, L. M. (2000). A source activation theory of working memory: Cross-task prediction of performance in ACT-R. *Journal of Cognitive Systems Research, 1*, 99-118.

Morgan, G. P., Ritter, F. E., Stine, M. M., & Klein, L. C. (unpublished mss, 2006). The cognitive effects of caffeine: Implications for models of users.

Nerb, J., Ritter, F. E., & Langley, P. (2007). Rules of order: Process models of human learning. In F. E. Ritter, J. Nerb, T. O'Shea & E. Lehtinen (Eds.), *In order to learn: How the sequences of topics affect learning* (pp. 57-69). New York, NY: Oxford University Press.

Norling, E., & Ritter, F. E. (2004). A parameter set to support psychologically plausible variability in agent-based human modelling. In *The Third International Joint Conference on Autonomous Agents and Multi Agent Systems (AAMAS04)*, 758-765. ACM: New York, NY.

Reifers, A., Ritter, F. E., Klein, L., & Whetzel, C. (2005). Modeling the effects of caffeine on visual signal detection (VSD) in a cognitive architecture: Poster presented at "Attention: From Theory to Practice" (A festschrift for Chris Wickens).

Ritter, F. E. (1991). Towards fair comparisons of connectionist algorithms through automatically generated parameter sets. In *Proceedings of the 13th Annual Conference of the Cognitive Science Society*, 877-881. Erlbaum: Hillsdale, NJ.

Ritter, F. E. (2008a). dTank: A lightweight synthetic environment for teaching and theoretical research in the Human Behavioral Synthetic Research Environments (HB-SRE) Symposium. In *Proceedings of the 16th Conference on Behavior Representation in Modeling and Simulation*, 08-BRIMS-034. U. of Central Florida: Orlando, FL.

Ritter, F. E. (2008b). High-level behavior representation languages and moderators of behavior. In *The USMA Network Science Workshop, 15-17 October, 2008, West Point, NY*. http://www.netscience.usma.edu/NSW3/Program/Index.htm.

Ritter, F. E. (in press). Two cognitive modeling frontiers: Emotions and usability. *Journal of Japanese AI Research.*

Ritter, F. E., & Bibby, P. A. (2008). Modeling how, when, and what learning happens in a diagrammatic reasoning task. *Cognitive Science, 32*, 862-892.

Ritter, F. E., Ceballos, R., Reifers, A. L., & Klein, L. C. (2005). *Measuring the effect of dental work as a stressor on cognition* (Tech. Report No. 2005-1): Applied Cognitive Science Lab, School of Information Sciences and Technology, Penn State. acs.ist.psu.edu/acs-lab/reports/ritterCRK05.pdf.

Ritter, F. E., Nerb, J., & Lehtinen, E. (2007). Getting things in order: Collecting and analysing data on learning. In F. E. Ritter, J. Nerb, T. O'Shea & E. Lehtinen (Eds.), *In* *order to learn: How the sequences of topics affect learning* (pp. 81-92). New York, NY: Oxford.

Ritter, F. E., Nerb, J., O'Shea, T. M., & Lehtinen, E. (Eds.). (2007). *In order to learn: How the sequences of topics affect learning*. New York, NY: Oxford University Press.

Ritter, F. E., & Norling, E. (2006). Including human variability in a cognitive architecture to improve team simulation. In R. Sun (Ed.), *Cognition and multi-agent interaction: From cognitive modeling to social simulation* (pp. 417-427). Cambridge, UK: Cambridge University Press.

Ritter, F. E., Quigley, K. S., & Klein, L. C. (under revision October 2007). Determining the number of model runs: Treating cognitive models as theories by not sampling their behavior.

Ritter, F. E., Reifers, A. L., Schoelles, M. J., & Klein, L. C. (2007). Lessons from defining theories of stress for architectures. In W. Gray (Ed.), *Integrated models of cognitive systems* (pp. 254-262). New York, NY: Oxford University Press.

Ritter, F. E., Reifers, A. L., & Schoelles, M. J. (2005). *Defining testable theories of pre-task appraisal stress* (Tech. Report No. ACS 2005-2). Applied Cognitive Science Lab, School of Information Sciences and Technology, Penn State. acs.ist.psu.edu/reports/ritterRKS05.pdf.

Ritter, F. E., Schoelles, M. J., Klein, L. C., & Kase, S. E. (2007). Modeling the range of performance on the serial subtraction task. In *Proceedings of the 8th International Conference on Cognitive Modeling*, 299-304. Oxford, UK: Taylor & Francis/Psychology Press.

Ritter, F. E., Van Rooy, D., St. Amant, R., & Simpson, K. (2006). Providing user models direct access to interfaces: An exploratory study of a simple interface with implications for HRI and HCI. *IEEE Transactions on System, Man, and Cybernetics, Part A: Systems and Humans, 36*(3), 592-601.

Ritter, F. E., & Wood, A. B. (2005). Dismal: A spreadsheet for sequential data analysis and HCI experimentation. *Behavior Research Methods, 37*(1), 71-81.

Rodrigues, I. M., & Klein, L. C. (2006). Boiled or filtered coffee? Effects of coffee and caffeine on cholesterol, fibrinogen, and C-reactive protein. *Toxicological Reviews, 25*(1), 55-69.

Schoelles, M. J., & Gray, W. D. (2000). Argus Prime: Modeling emergent microstrategies in a complex simulated task environment. In *Proceedings of the 3rd International Conference on Cognitive Modelling*, 260-270. Universal Press: Veenendaal, The Netherlands.

Schoelles, M. J., & Gray, W. D. (2001). Argus: A suite of tools for research in complex cognition. *Behavior Research Methods, Instruments, & Computers, 33*(2), 130-140.

Schoelles, M. J., & Ritter, F. E. (2003). Hands on tutorial for ACT-R (HOT4 ACT-R): Applied Cognitive Science Lab, Summer, 2003.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American Scientist, 61*(393-403).

St. Amant, R., Horton, T. E., & Ritter, F. E. (2007). Model-based evaluation of expert cell phone menu interaction. *ACM Transactions on Computer-Human Interaction, 14*(1), 24 pages.

Whetzel, C. A., Ritter, F. E., & Klein, L. C. . (2006). DHEA-S and cortisol responses to stress and caffeine in healthy young men: Is DHEA-S a reliable marker for stress? [abstract of poster presented at the annual meeting of the American Psychosomatic Society, Denver, CO] *Psychosomatic Medicine, 68*(1), A-77.