Eye Data, Big Data, Games, and Extreme Expertise
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This is a graduate level course.

Eye Data, Big Data, Games, and Extreme Expertise

1 Requirements

• Group discussion.
  – The most important contribution each person can make is to our discussions of the readings. I believe a seminar course in which everyone actively participates can be the most productive and educational forum in grad school (often for the instructor as well). Bringing together the various backgrounds and training of everyone in the room generally leads to a much richer perspective than would otherwise be possible. There is a lot of individual variability in tendency to speak up in this type of environment, but it is critical to an academic career to be comfortable doing so. You cannot succeed in this field without a willingness (and desire) to share your ideas in the face of criticism, and this is perhaps the best context to practice. If you’re someone who has no qualms about dominating a debate, this is also a good place to practice restraint and listening.

• Written reactions.
  – Each person should bring to each class a brief written reaction to the readings to be discussed. You can email your reactions to me before class, or you can bring a printed copy, but either way they must be complete before class begins. The reactions serve two purposes: as a nominal motivation to ensure everyone reads and carefully thinks about the articles, and as a starting point for the group discussion. Reactions should not be summaries. A few sentences at the beginning to summarize each article are generally useful, both for me to make sure everyone recognizes the critical points and for you to check your own understanding, but the primary content should be your own ideas in response to what you read. These ideas can be anything from connections to other research (from this class or elsewhere); to possible extensions, improvements, or follow-up work; to criticisms of the authors logic or methods.

• Preview presentations.
Each person will sign up to present a preview summary of next week’s readings at the end of this week’s class. We will rotate this responsibility among ourselves and spread it around so that for weeks when multiple readings are assigned, the readings will be divided among multiple people. In general, each presentation should be 10-15 minutes long and structured as though you were presenting your own work at a conference. A useful strategy is to copy key figures and tables out of each article and supplement with (scant) text stating the major points. Focus on summarizing the research, as the authors present it (including motivation, background, methods, results, and conclusions), and save your own reactions for the following week. You will also be in charge of getting the discussion going and answering any clarifying questions people may have after reading the articles themselves. Written reactions are not required for papers you present.

2 Description

A variety of recent topics in Cognitive Science. Some of the topics will be updates on topics covered in prior graduate seminars. A few will be papers that cite and critique work published by the CogWorks Laboratory. The rest will be recent papers on a variety of topics that help us triangulate on research issues and topics of interest.

3 Seminar Topics

New versions of this syllabus will be released during the semester. The new versions will reflect readings on topics and issues that arise during our in-class discussions. The readings will also reflect the new publications on topics related to this class.

1 Requirements

2 Description

3 Seminar Topics

3.1 Statistics – Week 1

3.2 Visualization: History and Review – Week 2

3.3 What Can You Learn from One Subject? And Related Topics

3.4 Learning Problem-Solving, Perceptual Learning, and Decision Making – recent research we need to know about!

3.5 Games

3.6 Spring Break: No Class on Friday, March 18th

3.7 Cognitive Elements of Games

3.8 Classic Tetris
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3.1 Statistics – Week 1


Abstract: The field of psychology, including cognitive science, is vexed in a crisis of confidence. Although the causes and solutions are varied, we focus here on a common logical problem in inference. The default mode of inference is significance testing, and significance testing and inference by confidence intervals have a free lunch property where researchers need not make detailed assumptions about the alternative to test the null hypothesis. We present the argument that there is no free lunch, that is, valid testing requires that researchers test the null against a well-specified alternative. We show how this requirement follows from the basic tenets of conventional and Bayesian probability. Moreover, we show in both the conventional and Bayesian framework that not specifying the alternative leads to rejections of the null hypothesis with scant evidence. We review both frequentist and Bayesian approaches to specifying alternatives, and show how such specifications improve inference. The field of cognitive science will benefit—consideration of reasonable alternatives will undoubtedly sharpen the intellectual underpinnings of research.

3.2 Visualization: History and Review – Week 2


Abstract: This paper reviews cognitive science perspectives on the design of visual-spatial displays and introduces the other papers in this topic. It begins by classifying different types of visual-spatial displays, followed by a discussion of ways in which visual-spatial displays augment cognition and an overview of the perceptual and cognitive processes involved in using displays. The paper then argues for the importance of cognitive science methods to the design of visual displays and reviews some of the main principles of display design that have emerged from these approaches to date. Cognitive scientists have had good success in characterizing the performance of well-defined tasks with relatively simple visual displays, but many challenges remain in understanding the use of complex displays for ill-defined tasks. Current research exemplified by the papers in this topic extends empirical approaches to new displays and domains, informs the development of general principles of graphic design, and addresses current challenges in display design raised by the recent explosion in availability of complex data sets and new technologies for visualizing and interacting with these data.

3.2.1 Not Read or Discussed


Abstract: The subject of graphical methods for data analysis and for data presentation needs a scientific foundation. In this article we take a few steps in the direction of establishing such a foundation. Our approach is based on graphical perception-the visual decoding of information encoded on graphs-and it includes both theory and experimentation to test the theory. The theory deals with a small but important piece of the whole process of graphical perception. The first part is an identification of a set of elementary perceptual tasks that are carried out when people extract quantitative information from graphs. The second part is an ordering of the tasks on the basis of how accurately people perform them. Elements of the theory are tested by experimentation in which subjects record their judgments of the quantitative information on graphs. The experiments validate these elements but also suggest that
the set of elementary tasks should be expanded. The theory provides a guideline for graph construction: Graphs should employ elementary tasks as high in the ordering as possible. This principle is applied to a variety of graphs, including bar charts, divided bar charts, pie charts, and statistical maps with shading. The conclusion is that radical surgery on these popular graphs is needed, and as replacements we offer alternative graphical forms—dot charts, dot charts with grouping, and framed-rectangle charts.


**Abstract:** The scatterplot is one of our most powerful tools for data analysis. Still, we can add graphical information to scatterplots to make them considerably more powerful. These graphical additions, faces of sorts, can enhance capabilities that scatterplots already have or can add whole new capabilities that faceless scatterplots do not have at all. The additions we discuss here—some new and some old—are (a) sunflowers, (b) category codes, (c) point cloud sizings, (d) smoothings for the dependence of $y$ on $x$ (middle smoothings, spread smoothings, and upper and lower smoothings), and (e) smoothings for the bivariate distribution of $x$ and $y$ (pairs of middle smoothings, sum-difference smoothings, scale-ratio smoothings, and polar smoothings). The development of these additions is based in part on a number of graphical principles that can be applied to the development of statistical graphics in general.

### 3.3 What Can You Learn from One Subject? And Related Topics

#### 3.3.1 Week 3


**Abstract:** Argues that nomothetic theories should be formulated in a way that will allow an immediate individual-differences test. 3 guidelines are discussed as means of developing such theories: (a) The theory must assume at least 2 intervening processes, and these processes must interact in some way to relate the independent variables to the dependent variable. (b) Any assumed process must be tied to at least 1 independent variable. (c) In choosing theoretical processes, if at all possible at least 1 must be chosen which has some possibility of yielding an individual-differences interpretation. It is suggested that such an approach would identify the process variables as a fallout from nomothetic theory construction if the nomothetic theories are dealing with fundamental processes of behavior. (PsycINFO Database Record (c) 2008 APA, all rights reserved).


**Abstract:** ABSTRACT- People often show considerable systematic variability in their ability to perform many different cognitive tasks. In this article, we argue that by combining an individual-differences approach with an experimental-cognitive-neuroscience approach one can often further constrain potential theories of the underlying cognitive mechanisms. In support of this proposal, we outline three basic benefits of using an individual-differences approach: validating neurophysiological measures, demonstrating associations among constructs, and demonstrating dissociations among apparently similar constructs. To illustrate these points, we describe recent work by us and other researchers that utilizes each of these techniques to address specific questions within the domain of visual working memory. It is our hope that some of these techniques for utilizing individual variability may be applied to other domains within cognitive neuroscience.

#### 3.3.2 Week 4

Abstract: Although there are many machine-learning programs that can acquire new problem-solving strategies, it is not known exactly how their processes will manifest themselves in human behavior, if at all. In order to find out, a line-by-line protocol analysis was conducted of a subject discovering problem-solving strategies. A model was developed that could explain 96% of the lines in the protocol. On this analysis, the subject’s learning was confined to 11 rule acquisition events, wherein she temporarily abandoned her normal problem solving and focused on improving her strategic knowledge. Further analysis showed that: (1) Not all rule acquisition events are triggered by impasses; (2) Rules are acquired gradually, both because of competition between new and old rules, and because of the subject’s apparently deliberate policy of gradual generalization. (3) This subject took a scientific approach to strategy discovery, even planning and conducting small experiments.

3.4 Learning Problem-Solving, Perceptual Learning, and Decision Making – recent research we need to know about!

3.4.1 Week 5 – Learning Problem-Solving


Abstract: Learning to solve a class of problems can be characterized as a search through a space of hypotheses about the rules for solving these problems. A series of four experiments studied how different learning conditions affected the search among hypotheses about the solution rule for a simple computational problem. Experiment 1 showed that a problem property such as computational difficulty of the rules biased the search process and so affected learning. Experiment 2 examined the impact of examples as instructional tools and found that their effectiveness was determined by whether they uniquely pointed to the correct rule. Experiment 3 compared verbal directions with examples and found that both could guide search. The final experiment tried to improve learning by using more explicit verbal directions or by adding scaffolding to the example. While both manipulations improved learning, learning still took the form of a search through a hypothesis space of possible rules. We describe a model that embodies two assumptions: (1) the instruction can bias the rules participants hypothesize rather than directly be encoded into a rule; (2) participants do not have memory for past wrong hypotheses and are likely to retry them. These assumptions are realized in a Markov model that fits all the data by estimating two sets of probabilities. First, the learning condition induced one set of Start probabilities of trying various rules. Second, should this first hypothesis prove wrong, the learning condition induced a second set of Choice probabilities of considering various rules. These findings broaden our understanding of effective instruction and provide implications for instructional design.

3.4.2 Week 6 – Perceptual Learning


Abstract: Although the field of perceptual learning has mostly been concerned with low- to middle-level changes to perceptual systems due to experience, we consider high-level perceptual changes that accompany learning in science and mathematics. In science, we explore the transfer of a scientific principle (competitive specialization) across superficially dissimilar pedagogical simulations. We argue that transfer occurs when students develop perceptual interpretations of an initial simulation and simply continue to use the same interpretational bias when interacting with a second simulation. In arithmetic and algebraic reasoning, we find that proficiency in mathematics involves executing spatially explicit transformations to notational elements. People learn to attend mathematical operations in the order in which they should be executed, and the extent to which students employ their perceptual attention in
this manner is positively correlated with their mathematical experience. For both science and mathematics, relatively sophisticated performance is achieved not by ignoring perceptual features in favor of deep conceptual features, but rather by adapting perceptual processing so as to conform with and support formally sanctioned responses. These “rigged-up perceptual systems” offer a promising approach to educational reform.


**Abstract:** Perceptual modules adapt at evolutionary, lifelong, and moment-to-moment temporal scales to better serve the informational needs of cognizers. Perceptual learning is a powerful way for an individual to become tuned to frequently recurring patterns in its specific local environment that are pertinent to its goals without requiring costly executive control resources to be deployed. Mechanisms like predictive coding, categorical perception, and action-informed vision allow our perceptual systems to interface well with cognition by generating perceptual outputs that are systematically guided by how they will be used. In classic conceptions of perceptual modules, people have access to the modules’ outputs but no ability to adjust their internal workings. However, humans routinely and strategically alter their perceptual systems via training regimes that have predictable and specific outcomes. In fact, employing a combination of strategic and automatic devices for adapting perception is one of the most promising approaches to improving cognition.

### 3.4.3 Not Read or Discussed


**Abstract:** Individuals frequently make use of the body and environment when engaged in a cognitive task. For example, individuals will often spontaneously physically rotate when faced with rotated objects, such as an array of words, to putatively offload the performance costs associated with stimulus rotation. We looked to further examine this idea by independently manipulating the costs associated with both word rotation and array frame rotation. Surprisingly, we found that individuals’ patterns of spontaneous physical rotations did not follow patterns of performance costs or benefits associated with being physically rotated, findings difficult to reconcile with existing theories of strategy selection involving external resources. Individuals’ subjective ratings of perceived benefits, rather, provided an excellent match to the patterns of physical rotations, suggesting that the critical variable when deciding on-the-fly whether to incorporate an external resource is the participant’s metacognitive beliefs regarding expected performance or the effort required for each approach (i.e., internal vs. internal + external). Implications for metacognition’s future in theories of cognitive offloading are discussed.


**Abstract:** It is known that, on average, people adapt their choice of memory strategy to the subjective utility of interaction. What is not known is whether an individual’s choices are boundedly optimal. Two experiments are reported that test the hypothesis that an individual’s decisions about the distribution of remembering between internal and external resources are boundedly optimal where optimality is defined relative to experience, cognitive constraints, and reward. The theory makes predictions that are tested against data, not fitted to it. The experiments use a no-choice/choice utility learning paradigm where the no-choice phase is used to elicit a profile of each participant’s performance across the strategy space and the choice phase is used to test predicted choices within this space. They show that the majority of individuals select strategies that are boundedly optimal. Further, individual differences in what people choose to do are successfully predicted by the analysis. Two issues are discussed: (a) the
performance of the minority of participants who did not find boundedly optimal adaptations, and (b) the possibility that individuals anticipate what, with practice, will become a bounded optimal strategy, rather than what is boundedly optimal during training.

3.5 Games

3.5.1 Week 6 – Overviews


**Abstract**: This work reviews several aspects of the growing research field interested in video games. First, the evolution of this media in the educational field is discussed. Three different fields interested in the cognitive impact playing of video games are reviewed: abilities and skills, attitudes and motivation, knowledge and content learning. However, most studies used video games as new experimental materials and tasks to contribute to their specific field (i.e., attention and perception), and not as a scientific object of interest per se. We claim that the research on video games is in need of a conceptual and methodological framework in which results and effects could be compared, interpreted and generalized. We argue that video games can have multiple effects on players and that these effects can be used as educational potentials. An empirically-based classification of games, depending on their potential effects for an educational purpose, is strongly needed. Likewise, a unified research paradigm and methodologies to carry on reliable research on video games has to be developed.


**Abstract**: In this paper we present an analysis of the academic landscape of games research from the last 15 years. We employed a data driven approach utilizing co-word and co-venue analysis on 48 core venues to identify 20 major research themes and 7 distinct communities, with a total of 8,207 articles and 21,552 unique keywords being analyzed. Strategic diagrams and network maps are applied to visualize and further understand interrelationships and underlying trends within the field.

3.5.2 Week 7 – Overviews


**Abstract**: Movement-based digital games are becoming increasingly popular, yet there is limited comprehensive guidance on how to design these games. In this article we discuss a set of guidelines for movement-based game design that were initially presented at CHI 2014 (Mueller & Isbister, 2014). These guidelines were developed through reflection upon our research-based game development practice and then validated and refined through interviews with 14 movement-based game design experts with experience in the academic, independent, and commercial game development domains. In this article, we provide an in-depth contextualization and explanation of the research process that led to the creation of the final guidelines and discuss what human–computer interaction researchers and designers might learn from the guidelines beyond entertainment contexts. The primary contribution of this research is a body of generative intermediate-level knowledge (Höök & Löwgren, 2012) in the design research tradition that is readily accessible and actionable for the design of future movement-based games and other movement-based interfaces.

**Abstract:** Game developers have to ensure their games are appealing to, and playable by, a range of people. However, although there has been interest in the game-play experience, we know little about how learning relates to player involvement. This is despite challenge being an integral part of game-play, providing players with potential opportunities to learn. This article reports on a multiple case-study approach that explored how learning and involvement come together in practice. Participants consisted of a mix of gamers and casual players. Data included interviews, multiple observations of game-play, postplay cued interviews, and diary entries. A set of theoretical claims representing suggested relationships between involvement and learning were developed on the basis of previous literature; these were then assessed through a critical examination of the data set. The resulting theory is presented as 14 refined claims that relate to micro and macro involvement; breakdowns and breakthroughs in action, understanding, and involvement; progress; and agency, meaning and compelling game-play. The claims emphasize how players experience learning via breakthroughs in understanding, where involvement is increased when the player feels responsible for progress. Supporting the relationship between learning and involvement is important for ensuring the success of commercial and educational games.

### 3.6 Spring Break: No Class on Friday, March 18th

### 3.7 Cognitive Elements of Games

#### 3.7.1 Week 8 – Expertise: Metrics and Patterns


**Abstract:** This study introduces the Amsterdam Chess Test (ACT). The ACT measures chess playing proficiency through 5 tasks: a choose-a-move task (comprising two parallel tests), a motivation questionnaire, a predict-a-move task, a verbal knowledge questionnaire, and a recall task. The validity of these tasks was established using external criteria based on the Elo chess rating system. Results from a representative sample of active chess players showed that the ACT is a very reliable test for chess expertise and that ACT has high predictive validity. Several hypotheses about the relationships between chess expertise, chess knowledge, motivation, and memory were tested. Incorporating response latencies in test scores is shown to lead to an increase in criterion validity, particularly for easy items.


**Abstract:** We present TOME, a novel framework that helps developers quantitatively evaluate user interfaces and design iterations by using histories from crowds of end users. TOME collects user-interaction histories via an interface instrumentation library as end users complete tasks; these histories are compiled using the Keystroke-Level Model (KLM) into task completion-time predictions using CogTool. With many histories, TOME can model prevailing strategies for tasks without needing an HCI specialist to describe users’ interaction steps. An unimplemented design change can be evaluated by perturbing a TOME task model in CogTool to reflect the change, giving a new performance prediction. We found that predictions for quick (5–60s) query tasks in an instrumented brain-map interface averaged within 10% of measured expert times. Finally, we modified a TOME model to predict closely the speed-up yielded by a proposed interaction before implementing it.

**Abstract:** A long-term goal of game design research is to achieve end-to-end automation of much of the design process, one aspect of which is creating effective level progressions. A key difficulty is getting the player to practice with interesting combinations of learned skills while maintaining their engagement. Although recent work in task generation and sequencing has reduced this effort, we still lack end-to-end automation of the entire content design process. We approach this goal by incorporating ideas from intelligent tutoring systems and proposing progression strategies that seek to achieve mastery of not only base concepts but arbitrary combinations of these concepts. The input to our system is a model of what the player needs to do to complete each level, expressed as either an imperative procedure for producing solutions or a representation of features common to all solutions. The output is a progression of levels that can be adjusted by changing high-level parameters. We apply our framework to a popular math puzzle game and present results from 2,377 players showing that our automatic level progression is comparable to expert-crafted progression after a few design iterations based on a key engagement metric.


**Abstract:** Multiplayer Online Battle Arena (MOBA) games rely primarily on combat to determine the ultimate outcome of the game. Combat in these types of games is highly-dynamic and can be difficult for novice players to learn. Typically, mastery of combat requires that players obtain expert knowledge through practice, which can be difficult to concisely describe. In this paper, we present a data-driven approach for discovering patterns in combat tactics that are common among winning teams in MOBA games. We model combat as a sequence of graphs and extract patterns that predict successful outcomes not just of combat, but of the entire game. To identify those patterns, we attribute features to these graphs using well known graph metrics. These features allow us to describe, in meaningful terms, how different combat tactics contribute to team success. We also present an evaluation of our methodology on the popular MOBA game, DotA 2 (Defense of the Ancients 2). Experiments show that extracted patterns achieve an 80% prediction accuracy when testing on new game logs.

### 3.7.2 Week 9 – part 1


**Abstract:** Mathematical models of learning have been created to capitalize on the regularities that are seen when individuals acquire new skills, which could be useful if implemented in learning management systems. One such mathematical model is the Predictive Performance Equation (PPE). It is the intent that PPE will be used to predict the performance of individuals to inform real-world education and training decisions. However, in order to improve mathematical models of learning, data from multiple samples are needed. Online data repositories, such as Carnegie Mellon University’s DataShop, provide data from multiple studies at fine levels of granularity. In this paper, we describe results from a set of analyses ranging across levels of granularity in order to assess the predictive validity of PPE in educational contexts available in the repository.
3.8 Classic Tetris

### 3.8.1 Week 9 – part 2


**Abstract:** Older adolescents played the video game Tetris for a total of 6 hr each in two separate experiments. None of the subjects had had any prior experience with Tetris, a video game requiring the rapid rotation and placement of seven different-shaped blocks. In Experiment 1, subjects were pre- and post-tested on paper-and-pencil measures of spatial ability. In Experiment 2, computerized measures of mental rotation and visualization skills were administered. In both studies, experimental subjects’ pre-post scores were compared to pre-post scores obtained from a control sample of subjects. Results indicated that playing Tetris improves mental rotation time and spatial visualization time. Consistent with earlier research, reliable and consistent differences between males and females were only obtained on complex mental rotation tasks.

### 3.8.2 Week 10 – Val Sims – Ch. 01


### 3.8.3 Week 11 – Val Sims – Ch. 02

Sims (1996)

### 3.8.4 Week 12 – Val Sims – Ch. 03–04

Sims (1996)

### 3.8.5 Week 13 – Terlecki, Newcome, & Little, 2008


**Abstract:** This study addressed questions about improvement in mental rotation skills: (1) whether growth trajectories differ for men and women with higher or lower spatial experience, (2) whether videogame training has effects on performance and leads to transfer, (3) whether effects of repeated testing or training effects are durable and (4) whether transfer is durable. Undergraduates participated in repeated testing on the MRT or played the videogame Tetris. Analyses showed large improvements in mental rotation with both repeated testing and training; these gains were maintained several months later. MRT scores of men and women did not converge, but men showed faster initial growth and women showed more improvement later. Videogame training showed greater initial growth than repeated testing alone, but final performance did not differ. Effects of videogame training transferred to other spatial tasks exceeding the effects of repeated testing, and this transfer advantage was still evident after several months. Copyright (C) 2007 John Wiley & Sons, Ltd.

### 3.9 Week 14 – Visual and Spatial Skills

Abstract: Having good spatial skills strongly predicts achievement and attainment in science, technology, engineering, and mathematics fields (e.g., Shea, Lubinski, & Benbow, 2001; Wai, Lubinski, & Benbow, 2009). Improving spatial skills is therefore of both theoretical and practical importance. To determine whether and to what extent training and experience can improve these skills, we meta-analyzed 217 research studies investigating the magnitude, moderators, durability, and generalizability of training on spatial skills. After eliminating outliers, the average effect size (Hedges’s g) for training relative to control was 0.47 (SE = 0.04). Training effects were stable and were not affected by delays between training and posttesting. Training also transferred to other spatial tasks that were not directly trained. We analyzed the effects of several moderators, including the presence and type of control groups, sex, age, and type of training. Additionally, we included a theoretically motivated typology of spatial skills that emphasizes 2 dimensions: intrinsic versus extrinsic and static versus dynamic (Newcombe & Shipley, in press). Finally, we consider the potential educational and policy implications of directly training spatial skills. Considered together, the results suggest that spatially enriched education could pay substantial dividends in increasing participation in mathematics, science, and engineering.


Abstract: There is evidence suggesting that children’s play with spatial toys (e.g., puzzles and blocks) correlates with spatial development. Females play less with spatial toys than do males, which arguably accounts for males’ spatial advantages; children with high socioeconomic status (SES) also show an advantage, though SES-related differences in spatial play have been less studied than gender-related differences. Using a large, nationally representative sample from the standardization study of the Wechsler Preschool and Primary Scale of Intelligence—Fourth Edition, and controlling for other cognitive abilities, we observed a specific relation between parent-reported frequency of spatial play and Block Design scores that was invariant across gender and SES. Reported spatial play was higher for boys than for girls, but controlling for spatial play did not eliminate boys’ relative advantage on this subtest. SES groups did not differ in reported frequency of spatial play. Future research should consider quality as well as quantity of play, and should explore underlying mechanisms to evaluate causality.


Abstract: This study focuses on the visual problem-solving process of clinical pathologists. Its aim is to find expertise-related differences in the temporal arrangement of this process, with a special focus on the orientation phase. A theoretical model of the visual diagnostic process of medical specialists is extended with general problem-solving theory. Participants were 13 experts, 12 intermediates, and 13 novices, who all diagnosed seven microscopic images. Their microscope movements and thinking aloud were recorded. To study temporal arrangement of the process, we applied a time-grid to the data. The results reflected several aspects of general problem-solving theory. Experts and intermediates showed a more extensive orientation phase and more refined schemata than novices. Intermediates also showed a control phase at the end of the diagnostic process. Novices showed a uniform process. These phases were reflected in microscope navigation and thinking aloud, which justifies the extension of the theoretical model.

3.10 Week 15 – Teams, Games, and Individuals

Cooke, N. J., Gorman, J. C., Myers, C. W., & Duran, J. L. (2013). Interactive team cognition. Cog-
Abstract: Cognition in work teams has been predominantly understood and explained in terms of shared cognition with a focus on the similarity of static knowledge structures across individual team members. Inspired by the current zeitgeist in cognitive science, as well as by empirical data and pragmatic concerns, we offer an alternative theory of team cognition. Interactive Team Cognition (ITC) theory posits that (1) team cognition is an activity, not a property or a product; (2) team cognition should be measured and studied at the team level; and (3) team cognition is inextricably tied to context. There are implications of ITC for theory building, modeling, measurement, and applications that make teams more effective performers.


Abstract: A common argument about computer games and learning is that the commitment gamers have might be transformed and used in educational practices. In order to unpack gamers’ commitment, the present study investigates collaboration in a Multiplayer Online Role-Playing Game (MMORPG). It investigates gamers’ practices in order to expose their everyday gaming activities and knowledge domains. Drawing on detailed descriptions of team gaming practices, the paper highlights that gamers’ of MMORPGs are hands-on experts in handling a game interface. Their expertise is about skilled stances tied to gaming structures. Also, gamers are members in certain communities and adhere to both community specific epistemologies and to generic ones. These gaming stances are from certain educational approaches difficult to make-sense of, while gamers’ commitments in other perspectives become means for learning. Lastly, in relation to MMORPGs and education, a neglected issue concerns social pressure in gaming communities, resulting in various forms of participation.


Abstract: This paper considers how changes in team composition (such as the number and rate of turnover of team members) are linked to team performance, as assessed in terms of efficiency, effectiveness, and equality (i.e., distribution of effort). Study data are taken from a large-scale, postdisaster debris removal operation in the USA, collected through existing transaction-level data logging systems. The data enable a detailed (and objective) examination of team performance, thus overcoming many shortcomings of retrospective methods such as questionnaires. The results show that the increased turnover diminishes performance along all dimensions, while an increased team size contributes to effectiveness but reduces equality. Implications of this study for theory and future empirical work are both discussed.

3.11 Extras
3.11.1 Dynamic ROIs (dROI) & Eye Tracking During Dynamic Videogames

Abstract: Research has demonstrated that oculomotor visual search is guided by memory for which items or locations within a display have already been inspected. In the study reported here, we used a gaze-contingent search paradigm to examine properties of this memory. Data revealed a memory buffer for search history of three to four items. This buffer was effected in part by a space-based trace attached to a location independently of whether the object that had been seen at that position remained
visible, and was subject to interference from other stimuli seen in the course of a trial.


**Abstract:** Future interactive virtual environments will be “attention-aware,” capable of predicting, reacting to, and ultimately influencing the visual attention of their human operators. Before such environments can be realized, it is necessary to operationalize our understanding of the relevant aspects of visual perception, in the form of fully automated computational heuristics that can efficiently identify locations that would attract human gaze in complex dynamic environments. One promising approach to designing such heuristics draws on ideas from computational neuroscience. We compared several neurobiologically inspired heuristics with eye-movement recordings from five observers playing video games, and found that human gaze was better predicted by heuristics that detect outliers from the global distribution of visual features than by purely local heuristics. Heuristics sensitive to dynamic events performed best overall. Further, heuristic prediction power differed more between games than between different human observers. While other factors clearly also influence eye position, our findings suggest that simple neurally inspired algorithmic methods can account for a significant portion of human gaze behavior in a naturalistic, interactive setting. These algorithms may be useful in the implementation of interactive virtual environments, both to predict the cognitive state of human operators, as well as to effectively endow virtual agents in the system with humanlike visual behavior.


**Abstract:** Understanding players’ visual attention patterns within an interactive 3D game environment is an important research area that can improve game level design and graphics. Several graphics techniques use a perception based rendering method to enhance graphics quality while achieving the fast rendering speed required for fast-paced 3D video games. Game designers can also enhance game play by adjusting the level design, texture and color choices, and objects’ locations, if such decisions are informed by a study of players’ visual attention patterns in 3D game environments. This paper seeks to address this issue. We present results showing different visual attention patterns that players exhibit in two different game types: action-adventure games and first person shooter games. In addition, analyzing visual attention patterns within a complex 3D game environment presents a new challenge because the environment is very complex with many rapidly changing conditions; the methods used in previous research cannot be used in such environments. In this paper, we will discuss our exploration seeking a new approach to analyze visual attention patterns within interactive 3D environments.


**Abstract:** This paper describes a study carried out in which the eye gaze data of several users playing a simple First Person Shooter (FPS) game has been recorded. This work shows the design and implementation of a simple game and how the execution of the game can be synchronized with an eye tracking system. The motivation behind this work is to determine the existence of visual psycho-perceptual phenomena, which may be of some use in developing appropriate information limits for distributed interactive media compression algorithms. Only 2 degrees of the 140 degrees of human vision has a high level of detail. It may be possible to determine the areas of the screen that a user is focusing on and render it in high detail or pay particular attention to its contents so as to set appropriate dead reckoning limits. Our experiment shows that eye tracking may allow for improvements in rendering and new
compression algorithms to be created for an online FPS game.


Abstract: Eye movements can be used to infer the allocation of covert attention. In this article, we propose to model the allocation of attention in a task-dependent manner based on different eye movement conditions, specifically fixation and pursuit. We show that the image complexity at eye fixation points during fixation, and the pursuit direction during pursuit are significant factors in attention allocation. Results of the study are applied to the design of an interactive computer game. Real-time eye movement information is taken as one of inputs for the game. The utility of such eye information for controlling game difficulty is shown.


Abstract: Visual attention plays a critical role in game playing. A better understanding of the allocation of visual attention can benefit the design of game scenarios. In this paper we propose to design games in different difficulty levels based on the estimation of attention. We use eye movement information in an analysis of attention. Eye fixation and pursuit conditions are considered separately. We find that the image complexity at eye fixation points and the relative position between pursuit direction and disturbance during pursuit eye movements are significant for attention allocation. This result is applied to the design of an interactive 2D game having two difficulty levels. Player response speeds and scores are compared for each difficulty level of the game.

3.11.2 Data Visualization and Understanding Number Sets


Abstract: Comparing datasets, that is, sets of numbers in context, is a critical skill in higher order cognition. Although much is known about how people compare single numbers, little is known about how number sets are represented and compared. We investigated how subjects compared datasets that varied in their statistical properties, including ratio of means, coefficient of variation, and number of observations, by measuring eye fixations, accuracy, and confidence when assessing differences between number sets. Results indicated that participants implicitly create and compare approximate summary values that include information about mean and variance, with no evidence of explicit calculation. Accuracy and confidence increased, while the number of fixations decreased as sets became more distinct (i.e., as mean ratios increase and variance decreases), demonstrating that the statistical properties of datasets were highly related to comparisons. The discussion includes a model proposing how reasoners summarize and compare datasets within the architecture for approximate number representation.

3.11.3 Visual Search in Information Tasks


Abstract: To support effective exploration, it is often stated that interactive visualizations should provide rapid response times. However, the effects of interactive latency on the process and outcomes of exploratory visual analysis have not been systematically studied. We present an experiment measuring user behavior and knowledge discovery with interactive visualizations under varying latency conditions. We observe that an additional delay of 500ms incurs significant costs, decreasing user activity and data
set coverage. Analyzing verbal data from think-aloud protocols, we find that increased latency reduces the rate at which users make observations, draw generalizations and generate hypotheses. Moreover, we note interaction effects in which initial exposure to higher latencies leads to subsequently reduced performance in a low-latency setting. Overall, increased latency causes users to shift exploration strategy, in turn affecting performance. We discuss how these results can inform the design of interactive analysis tools.


**Abstract:** In a simulated aircraft navigation task, a fusion technique known as triangulation was used to improve the accuracy and onscreen availability of location information from two separate radars. Three experiments investigated whether the reduced cognitive processing required to extract information from the fused environment led to impoverished retention of visual-spatial information. Experienced pilots and students completed various simulated flight missions and were required to make a number of location estimates. Following a retention interval, memory for locations was assessed. Experiment 1 demonstrated, in an applied setting, that the retention of fused information was problematic and Experiment 2 replicated this finding under laboratory conditions. Experiment 3 successfully improved the retention of fused information by limiting its availability within the interface, which it is argued, shifted participants’ strategies from over-reliance on the display as an external memory source to more memory-dependent interaction. These results are discussed within the context of intelligent interface design and effective human-machine interaction.


**Abstract:** An important question for Human-Computer Interaction is to understand how and why visual search strategy is adapted to the demands imposed by the task of searching the results of a search engine. There is emerging evidence that a key part of the answer concerns the expected information gain of each of the set of available information gathering actions. We build on previous research to show that people are acutely sensitive to differences in the density and in the number of items returned by the search engine. These factors cause shifts in the efficiency of the available actions. We focus on an image browsing task, and show that, as a consequence of changes to the efficiency of available actions, people make small but significant changes to eye-movement strategy.


**Abstract:** One reason that human interaction with technology is difficult to understand is because the way in which people perform interactive tasks is highly adaptive. One such interactive task is menu search. In the current article we test the hypothesis that menu search is rationally adapted to (1) the ecological structure of interaction, (2) cognitive and perceptual limits, and (3) the goal to maximise the trade-off between speed and accuracy. Unlike in previous models, no assumptions are made about the strategies available to or adopted by users, rather the menu search problem is specified as a reinforcement learning problem and behaviour emerges by finding the optimal policy. The model is tested against existing empirical findings concerning the effect of menu organisation and menu length. The model predicts the effect of these variables on task completion time and eye movements. The discussion considers the pros and cons of the modelling approach relative to other well-known modelling approaches.
Please note that the above list of topics and papers is not the reading syllabus but is meant to be suggestive of the topics that will be covered.

4 Participation

There are three parts to this course each part is associated with a weekly meeting.

4.1 Individual Session

Each enrolled student will meet once each week with the instructor for an hour-long meeting. The focus of the meeting will be the student’s current research and readings. It is expected that each week, the student will be able to discuss with the instructor new readings relevant to their research topic, discuss the design, conduct, and analysis of empirical studies, as well as the design, conduct, and evaluation of computational cognitive modeling. It is NOT expected that all three of these topics will be discussed each week.

4.2 Research Issues Session

All students will meet once each week with the instructor for an hour-long group meeting. This meeting will also include any and all undergraduate students who are engaged in collaborative research with the graduate student and/or engaged in research related to the graduate student’s. The focus of this meeting will be on methods and techniques for experimental data collection, data analysis, display of data, and modeling. On different weeks, different students will present work-in-progress to the group.

4.3 Reading Seminar Session

All students will meet together, once each week with the instructor for a 3-4 hour reading seminar discussion. This semester’s discussions will be centered around the weekly readings listed in this syllabus as well as readings that may arise during the semester as related to papers on the syllabus.

The class will be run as a graduate seminar. On some weeks, all students will be expected to read and be prepared to lead a discussion on any or all assigned readings. On other weeks, different students will read and present different papers. (On those weeks, it will not be expected that each student reads all papers but it will be expected that each presentation will be supported by slides.)

All students will be expected to comment and discuss the readings based on how the author frames and presents his or her work. That is, all of our grad students are capable of free-associating and generating, at times, interesting ideas without reading the material. However, that is not acceptable. If you have not done the work expected for that week’s class, do not come to class.

5 PreRequisites

Permission of the instructor. This is a graduate research seminar. However, interested undergraduates are encouraged to contact the instructor to discuss their participation in the seminar. Responsibilities and assignments for undergraduates will be discussed and agreed on, in writing, by the student and the instructor.

6 About the Instructor

Professor Gray has been a member of the Cognitive Science Department at RPI since the Fall of 2002. For details on his research interests and activities see his homepage.
7 Honors Policy

My expectation is that all of the work you do for me in this class will be the work of one individual. Exceptions to this rule will be broadcast to the class by email.

As you will all find out, I explicitly encourage you to engage in public (using email and other media to broadcast a message to the entire) or private (one-to-one) discourse regarding the readings and topics raised in this class. Study groups are encouraged.

If any of you have any questions regarding current situations or future situations, remember that I am your first contact on this. Please contact me.

8 Grading Policy

8.1 Examinations
There are no examinations

8.2 Grading
• Group Discussion
  – 45% for active participation in all discussions on all weeks in which the seminar is held. Exceptions due to professional travel or other activities need to be discussed with the instructor ahead of time.

• Written Reactions
  – 20% Due before class, preferably the night before but definitely before class starts.

• Presentations: Leading the discussions and summarizing the readings
  – 40%
(Yes. I expect 105% out of you!)

9 References

Please note that this listing includes both misses and false alarms! That is, it excludes some papers that will be read and discussed and includes some that will not be read and discussed. Please consider this list as representative of the types of papers that will be read and discussed.


