Topics in Cognitive Neuroscience, Aging, Modeling, Eye-Tracking, and Expertise.

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Individual Session with Instructor: tbd

Reading Group Session: Thursday 10-13:50
Classroom: Seminar Room; 3rd Fl Carnegie Bldg

1 Description

This seminar will cover a variety of interrelated topics in contemporary cognitive theory. We begin with a review and discussion of Marr’s Levels of Cognitive Explanation by Cooper and Peebles (in press). We then dip very briefly into the discussion that surrounded the publication of Sallice and Cooper’s recent book on cognitive neuroscience.

Our first substantive stop will be looking at Cognitive Aging from the traditional perspective (Salthouse’s overview paper) and from that of the Ramscar Revolution. From there we will dip in and out of the remaining sections which deal with overviews and detailed papers on Cognitive Modeling, Measuring Expertise, and Eye Tracking and Visual Search.

Also note that the class will be structured differently than in the recent past. Although, for some weeks, we will assign different readings to different people, for many of the readings, I will be asking everyone to read, think deeply about, and come prepared to lead and join the discussion on one paper.

2 Readings

2.1 First – the Big View – Wk 01: Aug 28th


We consider approaches to explanation within the cognitive sciences that begin with Marr’s computational level (e.g., purely Bayesian accounts of cognitive phenomena) or Marr’s implementational level (e.g., reductionist accounts of cognitive phenomena based only on neural level evidence) and argue that each is subject to fundamental limitations which impair their ability to provide adequate explanations of cognitive phenomena. For this reason, it is argued, explanation cannot proceed at either level without tight coupling to the algorithmic and representation level. Even at this level, however, we argue that additional constraints...
relating to the decomposition of the cognitive system into a set of interacting subfunctions (i.e., a cognitive architecture) are required. Integrated cognitive architectures that permit abstract specification of the functions of components and that make contact with the neural level provide a powerful bridge for linking the algorithmic and representational level to both the computational level and the implementational level.

2.2 Cognitive Neuroscience – a short aside – Wk 01: Aug 28th

2.3 The Ramscar Revolution – Wks 02-03: Sep 04th & Sep 11th
2.3.1 Wk 02: Sep 04th
First some classic Aging from Salthouse.


Adult age differences in a variety of cognitive abilities are well documented, aid many of those abilities have been found to be related to success in the workplace and in everyday life. However, increased age is seldom associated with lower levels of real-world functioning, and the reasons for this lab-life discrepancy are not well understood. This article briefly reviews research concerned with relations of age to cognition, relations of cognition to successful functioning outside the laboratory, and relations of age to measures of work performance and achievement. The final section discusses several possible explanations for why there are often little or no consequences of age-related cognitive declines in everyday functioning.

Then some Ramscar:


As adults age, their performance on many psychometric tests changes systematically, a finding that is widely taken to reveal that cognitive information-processing capacities decline across adulthood. Contrary to this, we suggest that older adults’ changing performance reflects memory search demands, which escalate as experience grows. A series of simulations show how the performance patterns observed across adulthood emerge naturally in learning models as they acquire knowledge. The simulations correctly identify greater variation in
the cognitive performance of older adults, and successfully predict that older adults will show
greater sensitivity to fine-grained differences in the properties of test stimuli than younger
adults. Our results indicate that older adults' performance on cognitive tests reflects the
predictable consequences of learning on information-processing, and not cognitive decline.
We consider the implications of this for our scientific and cultural understanding of aging.

2.3.2 Wk 03: Sep 11th
Rabbitt's Blog: http://outlookfromhutch.com/2014/02/01/hello-world/
Ramscar Blog: http://ramscar.wordpress.com/2014/02/03/cognitive-ageing-faq/

Ramsar, M. & Love, B. C. (n.d.). Understanding complexity constraints on learning and
plasticity.

Health ageing is associated with changes in cognitive function. While these are usually ex-
plained by changes in neural plasticity, the cellular alterations that directly underpin the brain’s
ability to learn, it is impossible to determine whether learning and plasticity change across the
lifespan without a proper understanding of the functional properties of the learning system.
Here we consider the complexity constraints shaping the development of a canonical functional
system in humans: language. Current models of learning complexity tend to tacitly assumed a
constant additive model, however we show that, empirically, this is wrong, and that once the
true network complexity of knowledge at various levels of linguistic description is considered,
existing models both underestimate the demands on learning in increasingly complex systems, and
concomitantly massively overestimate the degree to which plasticity declines across the lifespan.

2.4 Cognitive Modeling: Recent Work
2.4.1 Overviews
in linguistic tasks: how payoff and architecture shape speed-accuracy trade-offs. Topics

We explore the idea that eye-movement strategies in reading are precisely adapted to the
joint constraints of task structure, task payoff, and processing architecture. We present a
model of saccadic control that separates a parametric control policy space from a parametric
machine architecture, the latter based on a small set of assumptions derived from research on
eye movements in reading (Engbert, Nuthmann, Richter, & Kliegl, 2005; Reichle, Warren, &
McConnell, 2009). The eye-control model is embedded in a decision architecture (a machine
and policy space) that is capable of performing a simple linguistic task integrating information
across saccades. Model predictions are derived by jointly optimizing the control of eye
movements and task decisions under payoffs that quantitatively express different desired speed-
accuracy trade-offs. The model yields distinct eye-movement predictions for the same task
under different payoffs, including single-fixation durations, frequency effects, accuracy effects,
and list position effects, and their modulation by task payoff. The predictions are compared
to—and found to accord with—eye-movement data obtained from human participants
performing the same task under the same payoffs, but they are found not to accord as
well when the assumptions concerning payoff optimization and processing architecture are
varied. These results extend work on rational analysis of oculomotor control and adaptation
of reading strategy (Bicknell & Levy, ; McConkie, Rayner, & Wilson, 1973; Norris, 2009;
Wotschack, 2009) by providing evidence for adaptation at low levels of saccadic control that is shaped by quantitatively varying task demands and the dynamics of processing architecture.


Eye-movement control during scene viewing can be represented as a series of individual decisions about where and when to move the eyes. While substantial behavioral and computational research has been devoted to investigating the placement of fixations in scenes, relatively little is known about the mechanisms that control fixation durations. Here, we propose a computational model (CRISP) that accounts for saccade timing and programming and thus for variations in fixation durations in scene viewing. First, timing signals are modeled as continuous-time random walks. Second, difficulties at the level of visual and cognitive processing can inhibit and thus modulate saccade timing. Inhibition generates moment-by-moment changes in the random walk’s transition rate and processing-related saccade cancellation. Third, saccade programming is completed in 2 stages: an initial, labile stage that is subject to cancellation and a subsequent, nonlabile stage. Several simulation studies tested the model’s adequacy and generality. An initial simulation study explored the role of cognitive factors in scene viewing by examining how fixation durations differed under different viewing task instructions. Additional simulations investigated the degree to which fixation durations were under direct moment-to-moment control of the current visual scene. The present work further supports the conclusion that fixation durations, to a certain degree, reflect perceptual and cognitive activity in scene viewing. Computational model simulations contribute to an understanding of the underlying processes of gaze control.

2.4.2 Interlude


Cognitive neuroscience is motivated by the precept that a discoverable correspondence exists between mental states and brain states. This precept seems to be supported by remarkable observations and conclusions derived from event-related potentials and functional imaging with humans and neurophysiology with behaving monkeys. This review evaluates specific conceptual and technical limits of claims of correspondence between neural events, overt behavior, and hypothesized covert processes examined using data on the neural control of saccadic eye movements.


Patterns of neural firing linked to eye movement decisions show that behavioral decisions are predicted by the differential firing rates of cells coding selected and nonelected stimulus alternatives. These results can be interpreted using models developed in mathematical psychology to model behavioral decisions. Current models assume that decisions are made by accumulating noisy stimulus information until sufficient information for a response is obtained. Here, the models, and the techniques used to test them against response-time distribution and accuracy data, are described. Such models provide a quantitative link between the time-course of behavioral decisions and the growth of stimulus information in neural firing data.
2.4.3 Overviews – continued


Three questions have been prominent in the study of visual working memory limitations: (a) What is the nature of mnemonic precision (e. g., quantized or continuous)? (b) How many items are remembered? (c) To what extent do spatial binding errors account for working memory failures? Modeling studies have typically focused on comparing possible answers to a single one of these questions, even though the result of such a comparison might depend on the assumed answers to both others. Here, we consider every possible combination of previously proposed answers to the individual questions. Each model is then a point in a 3-factor model space containing a total of 32 models, of which only 6 have been tested previously. We compare all models on data from 10 delayed-estimation experiments from 6 laboratories (for a total of 164 subjects and 131,452 trials). Consistently across experiments, we find that (a) mnemonic precision is not quantized but continuous and not equal but variable across items and trials; (b) the number of remembered items is likely to be variable across trials, with a mean of 6.4 in the best model (median across subjects); (c) spatial binding errors occur but explain only a small fraction of responses (16.5% at set size 8 in the best model). We find strong evidence against all 6 documented models. Our results demonstrate the value of factorial model comparison in working memory.


Watching another person take actions to complete a goal and making inferences about that person’s knowledge is a relatively natural task for people. This ability can be especially important in educational settings, where the inferences can be used for assessment, diagnosing misconceptions, and providing informative feedback. In this paper, we develop a general framework for automatically making such inferences based on observed actions; this framework is particularly relevant for inferring student knowledge in educational games and other interactive virtual environments. Our approach relies on modeling action planning: We formalize the problem as a Markov decision process in which one must choose what actions to take to complete a goal, where choices will be dependent on one’s beliefs about how actions affect the environment. We use a variation of inverse reinforcement learning to infer these beliefs. Through two lab experiments, we show that this model can recover people’s beliefs in a simple environment, with accuracy comparable to that of human observers. We then demonstrate that the model can be used to provide real-time feedback and to model data from an existing educational game.


A growing body of scientific evidence suggests that visual working memory and statistical learning are intrinsically linked. Although visual working memory is severely resource limited, in many cases, it makes efficient use of its available resources by adapting to statistical regularities in the visual environment. However, experimental evidence also suggests that there are clear limits and biases in statistical learning. This raises the intriguing possibility that performance limitations observed in visual working memory tasks can to some degree be explained in terms of limits and biases in statistical-learning ability, rather than limits in memory capacity.

Although it is widely recognized that response time (RT) distributions are almost always positively skewed and that mathematical psychologists have developed straightforward procedures for capturing characteristics of RT distributions, researchers continue to rely primarily on mean performance, which can be misleading for such data. We review simple procedures for capturing characteristics of underlying RT distributions and show how such procedures have recently been useful to better understand effects from standard cognitive experimental paradigms and individual differences in performance. These well-studied procedures for understanding RT distributions indicate that effects in means can be produced by (a) shifts of RT distributions, (b) stretching of slow tails of RT distributions, or (c) some combination. Importantly, effects in means can actually be obscured by opposing influences on the modal and tail portions of RT distributions. Such disparate patterns demand novel theoretical interpretations.


Navigation behaviour is characterised by a strong interaction between the navigating agent (i.e. human beings) and the environment in which the navigation occurs. As the interaction is time critical, a theory for understanding the navigation behaviour must be capable of simulating navigation along the time dimension. This article introduces the Model Human Processor with Real-Time Constraints (MHP/RT; Toyota, M. and Kitajima, M., 2010a. MHP/RT: model human processor with real time constraints. In: S. Ohlsson and R. Catrambone, eds., Proceedings of the 32nd annual conference of the Cognitive Science Society. Austin, TX: Cognitive Science Society, 529.) as an architecture model for simulating the human navigation behaviour. MHP/RT was created by combining two seminal works in different fields that deal with human behaviour. The first work is the Model Human Processor (MHP) in the field of applied psychology (Card, S. K., Moran, T. P., and Newell, A., 1983. The psychology of human-computer interaction. Hillsdale, NJ: Lawrence Erlbaum Associates.). MHP successfully simulates the human users’ operating information devices to accomplish computerised tasks. The other work focuses on Two Minds that operate in human beings’ economical decisions (Evans, J.S.B.T. and Frankish, K., eds., 2009. In Two Minds: dual processes and beyond. Oxford: Oxford University Press.). This is the basis of the field of behaviour economics founded by D. Kahneman. This study demonstrates how MHP/RT simulates people’s navigation behaviour by drawing a concrete example of navigation in a train station. The results of an observational study that was conducted independently of MHP/RT are introduced and further examined by running the processes defined in MHP/RT. The results of the observed navigation behaviour can be plausibly simulated by MHP/RT, confirming the validity of MHP/RT.

### 2.4.4 Predicting Workload Using a Diffusion Model


A one-boundary diffusion model was applied to the data from two experiments in which subjects were performing a simple simulated driving task. In the first experiment, the same subjects were tested on two driving tasks using a PC-based driving simulator and the psychomotor vigilance test. The diffusion model fit the response time distributions for each
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task and individual subject well. Model parameters were found to correlate across tasks, which suggests that common component processes were being tapped in the three tasks. The model was also fit to a distracted driving experiment of Cooper and Strayer (Human Factors, 50, 893-902, 2008). Results showed that distraction altered performance by affecting the rate of evidence accumulation (drift rate) and/or increasing the boundary settings. This provides an interpretation of cognitive distraction whereby conversing on a cell phone diverts attention from the normal accumulation of information in the driving environment.

2.4.5 Big Data + Clever Modeling


Arnon and Snider ((2010). More than words: Frequency effects for multi-word phrases. *Journal of Memory and Language*, 62, 67-82 documented frequency effects for compositional four-grams independently of the frequencies of lower-order n-grams. They argue that comprehenders apparently store frequency information about multi-word units. We show that n-gram frequency effects can emerge in a parameter-free computational model driven by naive discriminative learning, trained on a sample of 300,000 four-word phrases from the British National Corpus. The discriminative learning model is a full decomposition model, associating orthographic input features straightforwardly with meanings. The model does not make use of separate representations for derived or inflected words, nor for compounds, nor for phrases. Nevertheless, frequency effects are correctly predicted for all these linguistic units. Naive discriminative learning provides the simplest and most economical explanation for frequency effects in language processing, obviating the need to posit counters in the head for, and the existence of, hundreds of millions of n-gram representations.

2.4.6 Cognitive Control: The View from Princeton


Cognitive control has long been one of the most active areas of computational modeling work in cognitive science. The focus on computational models as a medium for specifying and developing theory predates the PDP books, and cognitive control was not one of the areas on which they focused. However, the framework they provided has injected work on cognitive control with new energy and new ideas. On the occasion of the books’ anniversary, we review computational modeling in the study of cognitive control, with a focus on the influence that the PDP approach has brought to bear in this area. Rather than providing a comprehensive review, we offer a framework for thinking about past and future modeling efforts in this domain. We define control in terms of the optimal parameterization of task processing. From this vantage point, the development of control systems in the brain can be seen as responding to the structure of naturalistic tasks, through the filter of the brain systems with which control directly interfaces. This perspective lays open a set of fascinating but difficult research questions, which together define an important frontier for future computational research.

2.4.7 Robustness

To function well in an unpredictable environment using unreliable components, a system must have a high degree of robustness. Robustness is fundamental to biological systems and is an objective in the design of engineered systems such as airplane engines and buildings. Cognitive systems, like biological and engineered systems, exist within variable environments. This raises the question, how do cognitive systems achieve similarly high degrees of robustness? The aim of this study was to identify a set of mechanisms that enhance robustness in cognitive systems. We identify three mechanisms that enhance robustness in biological and engineered systems: system control, redundancy, and adaptability. After surveying the psychological literature for evidence of these mechanisms, we provide simulations illustrating how each contributes to robust cognition in a different psychological domain: psychomotor vigilance, semantic memory, and strategy selection. These simulations highlight features of a mathematical approach for quantifying robustness, and they provide concrete examples of mechanisms for robust cognition.

2.4.8 Modeling Rational Analysis and/or Rational Analysis Modeling


A large-sample \((n = 75)\) fMRI study guided the development of a theory of how people extend their problem-solving procedures by reflecting on them. Both children and adults were trained on a new mathematical procedure and then were challenged with novel problems that required them to change and extend their procedure to solve these problems. The fMRI data were analyzed using a combination of hidden Markov models (HMMs) and multi-voxel pattern analysis (MVPA). This HMM–MVPA analysis revealed the existence of 4 stages: Encoding, Planning, Solving, and Responding. Using this analysis as a guide, an ACT-R model was developed that improved the performance of the HMM–MVPA and explained the variation in the durations of the stages across 128 different problems. The model assumes that participants can reflect on declarative representations of the steps of their problem-solving procedures. A Metacognitive module can hold these steps, modify them, create new declarative steps, and rehearse them. The Metacognitive module is associated with activity in the rostrolateral prefrontal cortex (RLPFC). The ACT-R model predicts the activity in the RLPFC and other regions associated with its other cognitive modules (e.g., vision, retrieval). Differences between children and adults seemed related to differences in background knowledge and computational fluency, but not to the differences in their capability to modify procedures.


Human languages vary in many ways but also show striking cross-linguistic universals. Why do these universals exist? Recent theoretical results demonstrate that Bayesian learners transmitting language to each other through iterated learning will converge on a distribution of languages that depends only on their prior biases about language and the quantity of data transmitted at each point; the structure of the world being communicated about plays no role (Griffiths & Kalish, 2005, 2007). We revisit these findings and show that when certain assumptions about the relationship between language and the world are abandoned, learners will converge to languages that depend on the structure of the world as well as their prior biases. These theoretical results are supported with a series of experiments showing that when human learners acquire language through iterated learning, the ultimate structure of those languages is shaped by the structure of the meanings to be communicated.
2.4.9 Controlled versus Automatic Processes


Semantic priming has long been recognized to reflect, along with automatic semantic mechanisms, the contribution of controlled strategies. However, previous theories of controlled priming were mostly qualitative, lacking common grounds with modern mathematical models of automatic priming based on neural networks. Recently, we introduced a novel attractor network model of automatic semantic priming with latching dynamics. Here, we extend this work to show how the same model can also account for important findings regarding controlled processes. Assuming the rate of semantic transitions in the network can be adapted using simple reinforcement learning, we show how basic findings attributed to controlled processes in priming can be achieved, including their dependency on stimulus onset asynchrony and relatedness proportion and their unique effect on associative, category-exemplar, mediated and backward prime-target relations. We discuss how our mechanism relates to the classic expectancy theory and how it can be further extended in future developments of the model.

2.5 Measuring Expertise: The Battle Continues


More than 20 years ago, researchers proposed that individual differences in performance in such domains as music, sports, and games largely reflect individual differences in amount of deliberate practice, which was defined as engagement in structured activities created specifically to improve performance in a domain. This view is a frequent topic of popular-science writing—but is it supported by empirical evidence? To answer this question, we conducted a meta-analysis covering all major domains in which deliberate practice has been investigated. We found that deliberate practice explained 26% of the variance in performance for games, 21% for music, 18% for sports, 4% for education, and less than 1% for professions. We conclude that deliberate practice is important, but not as important as has been argued.


The dictionary and the expert performance approach view an expert as one who, after sufficient training and experience in a domain, can perform the requisite tasks above a threshold level. In contrast, we argue for a performance-based approach that implies expertise is a continuum; the experts are the best performers. Most tasks in which expertise can be demonstrated have an underlying core of judgment, including domains in which the tasks call for judgment to be overlaid with performance, prediction, or instruction. To evaluate judgment, we employ the metaphor of the judge as a measuring instrument. Like an instrument, expert judgment according to the performance-based approach has three key properties: discrimination, consistency, and validity. Validity requires ground truth and is usually difficult to establish; but the other two properties are readily observable, and they are combined in the Cochran–Weiss–Shanteau index.

Ericsson, K. A. (2014). How to gain the benefits of the expert performance approach in domains where the correctness of decisions are not readily available: a reply to weiss
Weiss and Shanteau criticize the expert-performance approach and argue that this approach has not, and most importantly, cannot be applied to the study of ‘experts’ in domains that lack readily available objective measures of performance, such as accuracy of judgments. In this response, I demonstrate that it is not necessary to use fictitious stimuli for the judgments, for which no correct responses can be identified, and where only their Cochrane, Weiss, and Shanteau index can be calculated. Instead, the expert performance approach regenerates the judgment situation for actual cases and tracks down their subsequent observed real-world outcomes. Participants’ judgments of the stimuli can then be directly scored against the actual outcomes. Opportunities for training and deliberate practice are discussed.


Something a bit different:


The power law of practice holds that a power function best interrelates skill performance and amount of practice. However, the law’s validity and generality are moot. Some researchers argue that it is an artifact of averaging individual exponential curves while others question whether the law generalizes to complex skills and to performance measures other than response time. The present study tested the power law’s generality to development over many years of a very complex cognitive skill, chess playing, with 387 skilled participants, most of whom were grandmasters. A power or logarithmic function best fit grouped data but individuals showed much variability. An exponential function usually was the worst fit to individual data. Groups differing in chess talent were compared and a power function best fit the group curve for the more talented players while a quadratic function best fit that for the less talented. After extreme amounts of practice, a logarithmic function best fit grouped data but a quadratic function best fit most individual curves. Individual variability is great and the power law or an exponential law are not the best descriptions of individual chess skill development.


Theoretical models of working memory suggest that the simultaneous processing and storage of information is carried out either as separate or binded mechanisms. We explored working memory capacity and strategy in two elite groups of experts to test the separate versus binded hypotheses. Visuospatial and verbal abilities were measured in elite nationally ranked SCRABBLE and crossword experts and compared with college students matched on quantitative and verbal SAT scores, both exceeding 700 on average. SCRABBLE and crossword experts significantly outperformed college students on all cognitive measures. The crossword experts scored significantly higher on a test of analogies than SCRABBLE experts, but performance for cognitive ability tasks did not significantly differ between expert groups. The techniques and strategies used during competitive play, however, did differ significantly. Findings suggest that visuospatial and verbal working memory capacities of SCRABBLE and crossword experts are binded and occur at extraordinarily high levels.
2.6 Eye Tracking and Visual Search: Updates and Old Controversies

2.6.1 Saccadic Interaction Routines, Microstrategies, and Scanpaths


Saccadic eye movements are usually assumed to be directed to locations containing important or useful information, but such assumptions fail to take into account that planning saccades to such locations might be too costly in terms of effort or attention required. To investigate costs of saccadic planning, subjects searched for a target letter that was contained in either one of two clusters located on either side of a central fixation target. A target was present on each trial and was more likely (probability = 0.8) to appear in one cluster than the other. Probabilities were disclosed by differences in cluster intensities. The distance between each cluster and central fixation varied (60'-300'). The presentation time was limited (500 ms) to ensure that a successful search would require a wisely chosen saccadic plan. The best chance of finding the target would be to direct the first saccade to the high-probability location, but only one of the six subjects tested followed this strategy consistently. The rest (to varying degrees) preferred to aim the first saccade to the closer location, often followed by an attempted search of the remaining location. Two-location searches were unsuccessful; performance at both locations was poor due to insufficient time. Preferences for such ineffective strategies were surprising. They suggest that saccadic plans were influenced by attempts to minimize the cognitive and attentional load attached to planning and to maximize the number of new foveal views that can be acquired in a limited period of time. These strategies, though disastrous in our task, may be crucial in natural scanning, when many cognitive operations are performed at once, and the risk attached to a few errant glances at unimportant places is small. (C) 2001 Elsevier Science Ltd. All rights reserved.


Method: Scanpaths of 25 professional ATCs (“experts”) were recorded using a medium-fidelity air traffic control simulation with realistic scripted traffic that included aircraft pairs that would lose separation. A total of 20 novices were exposed to experts scanpaths (“treatment”), and their performance (for both loss of separation detection rates and false alarm rates) was compared to that of 20 novices given no treatment or instructions (“control”) and 20 novices who were verbally instructed to attend to altitude (“instruction-only”). Interviews were held about the helpfulness of the exposure. The scanpaths were analyzed to find pattern differences among the three groups.

Results: Chi-square tests showed significant differences for false alarm rates across the three groups (p = .001). Pairwise MannWhitney tests showed that the number of false alarms for the treatment group was significantly lower than that for the control group (p = .005), and trended lower than the instruction-only group (p = .08). Treatment group participants responded that experts scanpaths helped. Analysis of scanpaths showed an increased tendency of the scanpath treatment group to follow the experts scanpath.

Conclusion: The scanpath training intervention improved novice performance by reducing false alarms.

Application: Implementing experts’ scanpaths into novices’ active learning process shows
promise in enhancing training effectiveness and reducing training time.

2.6.2 What Influences Visual Search?


Two experiments explored how users perform visual search to locate a target in a computer command menu. In Experiment 1, users searched for menu items while their eye movements were monitored. Visual search was well characterized by an unsystematic search model in which the user may search the same place more than once. This model predicted the distribution of search times, the lack of an item position effect, and the frequency of saccade directions. In Experiment 2, the unsystematic search model was used to describe the effects on search time of three menu-item arrangements and of practice. Initially, the arrangement of the menu, whether alphabetic, random, or categorical, influenced the time required by the search. But with practice, the user eventually learned the location of each item in the menu, rendering the arrangement of the menu unimportant.


Set size and crowding affect search efficiency by limiting attention for recognition and attention against competition; however, these factors can be difficult to quantify in complex search tasks. The current experiments use a quantitative measure of the amount and variability of visual information (i.e., clutter) in highly complex stimuli (i.e., digital aeronautical charts) to examine limits of attention in visual search. Undergraduates at a large southern university searched for a target among 4, 8, or 16 distractors in charts with high, medium, or low global clutter. The target was in a high or low local-clutter region of the chart. In Experiment 1, reaction time increased as global clutter increased, particularly when the target was in a high local-clutter region. However, there was no effect of distractor set size, supporting the notion that global clutter is a better measure of attention against competition in complex visual search tasks. As a control, Experiment 2 demonstrated that increasing the number of distractors leads to a typical set size effect when there is no additional clutter (i.e., no chart). In Experiment 3, the effects of global and local clutter were minimized when the target was highly salient. When the target was nonsalient, more fixations were observed in high global clutter charts, indicating that the number of elements competing with the target for attention was also high. The results suggest design techniques that could improve pilots’ search performance in aeronautical charts.


Previous research has indicated that saccade target selection during visual search is influenced by scanning history. Already inspected items are less likely to be chosen as saccade targets as long as the number intervening saccades is small. Here, we adapted Jacoby’s (1991) process dissociation procedure to assess the role of intentional and automatic processes in saccade target selection. Results indicate a large automatic component biasing participants to move their eyes to unexamined locations. However, an intentional component allowed participants to both reinspect old items and aid their selection of new items. A second experiment examined inhibition of return (IOR) as a candidate for the observed automatic
component. IOR was found for items that had been previously examined. It is concluded that both automatic and intentional memory traces are available to guide the eyes during search.


Finding information by successively selecting, hyperlinks on web pages is a typical task performed on websites. A number of web Usability Studies have provided important insights about how web visitors carry out this search, and have concluded that “following information scent” is the fundamental process involved in the behavior. The purpose of this paper is to explore the relationship between the strength of information scent and web visitors’ eye movements. Four web page types with different usability problems were considered. In an eyetracking experiment, eleven participants were asked to find all articles on a simulated encyclopedia website by first selecting a heading from among nine provided headings, then selecting the appropriate topic link under the selected heading. The number of eye fixations, the duration of the fixations, and the task completion times were analyzed. The eye-tracking study reported in this paper added further insight to the knowledge gained from traditional web usability studies, in which visitors’ performance are measured by the total number of clicks and task completion times. Website visitors’ performance will not exhibit any differences in the initial heading selection stage irrespective of whether or not the pages have Usability problems. However, performance will deteriorate in terms of the total number of fixations in the subsequent link selection stage when the web page hits any kind of usability problem.


Measures of scanpath similarity are essential in many domains of eye tracking research. Depending on the question, different calculations are adequate. We (Foerster, Carbone, Koesling, & Schneider, 2011) developed a method with a functional matching procedure suitable for sequential tasks. Here, we report two extensions. We introduced an alignment variant making the method more robust across tasks. We added the possibility to compare scanpaths according to multiple characteristics. The extended method, here called “functionally sequenced scanpath similarity method (FuncSim)” reveals whether gaze characteristics are similar in the same functional units of a task, opposed to when participants are engaged in different functional units. Finally, the advantages of our method are presented and compared to other methods of scanpath similarity calculation.

2.7 Models and Games


Describes the “Memory-Aided Pattern Perceiver” (MAPP), an information-processing model, implemented as a computer program, that simulates the processes Ss use to remember and reproduce chess positions they have seen briefly. The model incorporates processes adapted from PERCEIVER, an information-processing theory of eye movements in chess perception,
and EPAM, a theory of rote verbal learning. The data from MAPP show good agreement with the performance of strong chess players in identical tasks.


For many years, the game of chess has provided an invaluable task environment for research on cognition, in particular on the differences between novices and experts and the learning that removes these differences, and upon the structure of human memory and its parameters. The template theory presented by Gobet and Simon based on the EPAM theory offers precise predictions on cognitive processes during the presentation and recoil of chess positions. This article describes the behavior of CHREST, a computer implementation of the template theory, in a memory task when the presentation time is varied from one second to sixty, on the recoil of game and random positions, and compares the model to human data. Strong players are better than weak players in both types of positions, especially with long presentation times, but even after brief presentations. CHREST predicts the date, both qualitatively and quantitatively. Strong players’ superiority with random positions is explained by the large number of chunks they hold in LTM. Their excellent recall with short presentation times is explained by templates, a special class of chunks. CHREST is compared to other theories of chess skill, which either cannot account for the superiority of Masters in random positions or predict too strong a performance of Masters in such positions.


Humans and many other species selectively attend to stimuli or stimulus dimensions but why should an animal constrain information input in this way? To investigate the adaptive functions of attention, we used a genetic algorithm to evolve simple connectionist networks that had to make categorization decisions in a variety of environmental structures. The results of these simulations show that while learned attention is not universally adaptive, its benefit is not restricted to the reduction of input complexity in order to keep it within an organism’s processing capacity limitations. Instead, being able to shift attention provides adaptive benefit by allowing faster learning with fewer errors in a range of ecologically plausible environments.


Abstract Various combinations of perceptual features are relevant for learning and action-selection. However, the storage of all possible feature combinations presents computationally impractical, and psychologically implausible, memory requirements in non-trivial environments due to a state-space explosion. Some psychological models suggest that feature combinations, or chunks, should be generated at a conservative rate (Feigenbaum and Simon, 1984). Other models suggest that chunk retrieval is based on statistical regularities in the environment; i.e., recency and frequency (Anderson and Schooler, 1991). We present a computational model for chunk learning based on these two principles, and demonstrate how combining these principles alleviates state-space explosion, producing exponential memory savings while maintaining a high level of performance.

*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.

3 References


### 4 Participation

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.**

Finally, as this is a graduate seminar, certain types of behavior are assumed that might not be assumed of undergraduates. For example, your full mental as well as physical presence is required during the seminar. Refrain from checking or composing email, checking the state of running programs, or any other use of your personal computer, phones, etc. It is acceptable to use your computer to access the paper we are discussing, your notes on it, or something on the web that strikes you as extremely relevant to the class and which you intend to show and tell us about. Finally, for graduate seminars, “participation” includes actually discussing the strong and weak points of the papers you read, highlighting parts that you found obscure or difficult, and generally joining the instructor and other students in wringing understanding and relevance out of the seminar material; i.e., it requires much more than simply showing up.

### 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 Active Participation
65% For reading papers and 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.

45%\(^1\) Formal presentations based on assigned readings.

In general, 1-2 students will be assigned the discussion leaders for each week’s readings. The discussion leaders will prepare slides to organize and structure the discussion of their paper. All students are expected to join in the active discussion.

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.

\(^1\)Yes. I expect 110% out of you!