Further Reading on Cognitive Modeling
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The purpose of this document is to provide some basic pointers to publications or web sites in which you can read further about the topics discussed in the seminar. These sources generally have extensive lists of papers and other resources.

Kieras's sites
Anonymous ftp for documents:
`ftp://www.eecs.umich.edu/people/kieras`
Web home page:
`http://www.eecs.umich.edu/~kieras/`

John's sites
Cognitive modeling research papers
`http://www.cs.cmu.edu/~bej/BEJResearch.html#COGNITIVEMODELING`
The CogTool Project:
`http://www.cs.cmu.edu/~bej/cogtool/`
Web home page:
`http://www.cs.cmu.edu/~bej/`

Model-based Evaluation

While there are many precursors, the credit for popularizing the idea of using models to evaluate user interface designs can be given to:

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Much of this presentation is based on:

Kieras, D.E. (2003). Model-based evaluation. In Jacko, J.A. & Sears, A. (Eds) *The human-computer interaction handbook*. Mahwah, New Jersey: Lawrence Erlbaum Associates, pp. 1139-1151.

There are lots of references in this chapter. A preprint can be downloaded from:
`ftp://www.eecs.umich.edu/people/kieras/TA_Modeling/Model-based_eval.pdf.`

A related paper, where the main body is basically a condensation of Kieras's slides can be found on the archive site:

Chipman, S. F. & Kieras, D. E. (2004). Operator centered design of ship systems. In *Proceedings of Engineering the Total Ship Symposium, 2004* Held at NIST, Gaithersburg, MD March 17-18, 2004, organized by the American Society of Naval Engineers.

For a good introduction to cognitive architectures in the context of HCI work, see

Byrne, M. D. (2003). Cognitive architecture. In J. Jacko & A. Sears (Eds), *Human-Computer Interaction Handbook*. Mahwah, N.J.: Lawrence Erlbaum Associates. pp. 97-117.

To learn more about the development of psychological theory, try reading the introductory chapters of the following books by John Anderson, the developer of the ACT-R architecture; they provide excellent overviews:

Anderson, J. R. & Bower, G. H. (1973). *Human associative memory*. Washington, D.C.: Winston.
Anderson, J. R. (1976). *Language, memory, and thought*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

An Example Cognitive Architecture: EPIC

A good survey of recent work in human vision that has influenced EPIC's visual system can be found in:

Findlay, J.M., & Gilchrist, I.D. (2003). *Active Vision*. Oxford: Oxford University Press.

You can read more about EPIC and its implications in:

Kieras, D. & Meyer, D.E. (1997). An overview of the EPIC architecture for cognition and performance with application to human-computer interaction. *Human-Computer Interaction*., **12**, 391-438.

Meyer, D. E., & Kieras, D. E. (1997). A computational theory of executive cognitive processes and multiple-task performance: Part 1. Basic mechanisms. *Psychological Review*, **104**, 3-65.

Meyer, D. E., & Kieras, D. E. (1997). A computational theory of executive control processes and human multiple-task performance: Part 2. Accounts of Psychological Refractory-Period Phenomena. *Psychological Review*. **104**, 749-791.

Meyer, D. E., & Kieras, D. E. (1999). Precis to a practical unified theory of cognition and action: Some lessons from computational modeling of human multiple-task performance. In

D. Gopher & A. Koriat (Eds.), *Attention and Performance XVII*.(pp. 15-88) Cambridge, MA: M.I.T. Press.

Kieras, D. E., Meyer, D. E., Ballas, J. A., & Lauber, E. J. (2000). Modern computational perspectives on executive mental control: Where to from here? In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 681-712). Cambridge, MA: M.I.T. Press.

To compare an EPIC architectural model with CPM-GOMS, read both the Gray, John, & Atwood paper (see below) and

Kieras, D.E., Wood, S.D., & Meyer, D.E. (1997). Predictive engineering models based on the EPIC architecture for a multimodal high-performance human-computer interaction task. ACM *Transactions on Computer-Human Interaction*.**4**, 230-275.

If you want to run EPIC on some sample tasks and learn more about using it, contact David Kieras, or perhaps download the tutorial materials and models from Kieras's ftp site at:

`ftp://www.eecs.umich.edu/people/kieras/EPICtutorial`

GOMS Models - Simplified Cognitive Architectures

This family of models was presented in Chapter 5 of

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

A complete overview of GOMS models and their application can be found in:

John, B. E., & Kieras, D. E. (1996). Using GOMS for user interface design and evaluation: Which technique? *ACM Transactions on Computer-Human Interaction*, **3**, 287-319.

John, B. E., & Kieras, D. E. (1996). The GOMS family of user interface analysis techniques: Comparison and contrast. *ACM Transactions on Computer-Human Interaction*, **3**, 320-351.

The Keystroke-Level Model first appears in

Card, S.K., Moran, T.P., & Newell, A. (1980a). The keystroke-level model for user performance time with interactive systems. *Communications of the ACM* , 23(7), 396-410.
Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

A handout on how to use the Keystroke-Level Model can be found at:

ftp://www.eecs.umich.edu/people/kieras/GOMS/KLM.pdf

A recent sophisticated application of the Keystroke-Level Model for doing a cost-effectiveness analysis:

http://www.taskz.com/mayhew_keystroke_indepth.php

The basic papers on Cognitive Complexity Theory:

Kieras, D. E., & Polson, P. G. (1985). An approach to the formal analysis of user complexity. *International Journal of Man-Machine Studies*, **22**, 365-394.

Bovair, S., Kieras, D. E., & Polson, P. G. (1990). The acquisition and performance of text editing skill: A cognitive complexity analysis. *Human-Computer Interaction,* **5**, 1-48.

For a presentation of NGOMSL models, see

Kieras, D. E. (1997). A Guide to GOMS model usability evaluation using NGOMSL. In M. Helander, T. Landauer, and P. Prabhu (Eds.), *Handbook of human-computer interaction*. (Second Edition). Amsterdam: North-Holland. 733-766.

The use of CPM-GOMS in analyzing telephone operator tasks appears in:

Gray, W. D., John, B. E., & Atwood, M. E. (1993). Project Ernestine: Validating a GOMS analysis for predicting and explaning real-world task performance. *Human-Computer Interaction*, **8**, 3, pp. 237-209.

GLEAN and GOMSL are described in

Kieras, D.E. (1999). A Guide to GOMS Model Usability Evaluation using GOMSL and GLEAN3. Document and software available via anonymous ftp at ftp://www.eecs.umich.edu/people/kieras/GOMS

For more on the modeling of the Navy team task, see

Santoro, T.P, Kieras, D., & Pharmer, J. Verification and validation of latency and workload predictions for a team of humans by a team of computational models. (Tech. Rep. No. TR1227). Groton, CT, Naval Submarine Medical Research Laboratory. May 1, 2003. Also available at: ftp://www.eecs.umich.edu/people/kieras/GOMS/Santoro_et_al.pdf

Kieras. D.E. & Santoro, T.P. (2004). Computational GOMS Modeling of a Complex Team Task: Lessons Learned. In *Proceedings of CHI 2004: Human Factors in Computing Systems*. New York: ACM, Inc.

A great paper about functionality failures:

Goransson, B., Lind, M., Pettersson, E., Sandblad, B., & Schwalbe, P. (1987). The interface is often not the problem. In *Proceedings of CHI+GI 1987*. New York: ACM.

For more about high-level GOMS models, see

Kieras, D. E. (2004). Task analysis and the design of functionality. In A. Tucker (Ed.) *The Computer Science and Engineering Handbook (2nd Ed)*. Boca Raton, CRC Inc. pp. 46-1 - 46-25. Preprint available at:
ftp://www.eecs.umich.edu/people/kieras/TA_Modeling/TaskAnalysisV2.pdf

For a discussion of the current state of the task analysis art, including its relation to human performance modeling, see the chapters by the editors in:

Diaper, D., & Stanton, N.A. (Eds.), *The handbook of task analysis for human-computer interaction*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

The following paper by Bonnie John's group briefly describes and compares some different computational tools for doing GOMS modeling.

Baumeister, L., John, B. E. and Byrne, M. A. Comparison of Tools for Building GOMS Models. In *CHI 2000, ACM Conference on Human Factors in Computing Systems,* CHI Letters 2(1), 502-509.

A Survey of Cognitive Architectures

Since many of these are changing rapidly, consult the cited web sites - these are the best source of up-to-date information as well as cited and downloadable books, papers, and reports.

In addition to the Byrne chapter (see first session), an excellent overview of many of these cognitive architectures from the point of view of representing human behavior in military simulations is available in Chapter 3 of:

R. Pew & A.S. Mavor (Eds). (1998). Modeling human and organizational behavior: Application to military simulations. Washington D.C.: National Academy Press.

The successor to the APEX/CPM-GOMS work is CORE: See links on
http://hci.arc.nasa.gov/
http://hci.arc.nasa.gov/pages/2004/10/corexprt.html#more

Papers can be downloaded from:
http://www.cf.ac.uk/psych/howesa/ccm/articles.htm

Practical Issues

For more on the bracketing heuristic, see

Kieras, D. E., & Meyer, D. E. (2000). The role of cognitive task analysis in the application of predictive models of human performance. In J. M. C. Schraagen, S. E. Chipman, & V. L. Shalin (Eds.), *Cognitive task analysis*. Mahwah, NJ: Lawrence Erlbaum, 2000. 237-260.

A technique for coupling a simulated human to an intact Windows application is described in

St. Amant, R., and Riedl, M.O. (2001). A perception/action substrate for cognitive modeling in HCI. *International Journal of Human-Computer Studies*, 55(1), 15-39.

See the following for a classic presentation of the importance of getting the details right, even over the interface style - done back before almost everything was Windows!

Whiteside, J., Jones, S., Levy, P. S., & Wixon, D. (1985). User performance with command, menu, and iconic interfaces. In *Proceedings of CHI '85*. New York: ACM.