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13. ABSTRACT *(Maximum 200 words)*

This report is a summary of work done on a project to develop a hybrid learning architecture for decision making tasks that involve generation, revision and evaluation of explanatory hypotheses in the context of the CIC (Combat Information Center) tactical decision making task. The project studied how people acquire and use statistical information. It specifically investigated the acquisition of prior and conditional probabilities, how the order of evidence affects probabilistic decision making (i.e., order effects), and how experience affects order effects. The experimental results were modeled using a hybrid symbolic-connectionist cognitive model that used Soar as the symbolic component and a modified version of Echo as the connectionist component. Although subjects can accurately acquire probabilities through experience with a tactical decision making task, order effects are still present without extended training. However, with extended training (i.e., experience on the task) order effects disappear. In addition, changing situations (such as from hostile to peaceful) can negatively affect decision making, but has less of an effect than predicted by normative models. The hybrid symbolic-connectionist cognitive model produced under this grant can predict the amount of training needed to eliminate order effects and to adequately prepare a person for a different situation.

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FINAL REPORT

GRANT #: N000149510241

PRINCIPAL INVESTIGATOR: Dr. Todd R. Johnson

INSTITUTION: The University of Texas Houston Health Science Center

GRANT TITLE: A Hybrid Learning Model of Tactical Decision Making

AWARD PERIOD: 1 Jan 1995 - 15 May 1999.

OBJECTIVE: To develop a hybrid learning architecture for decision making tasks that involve generation, revision and evaluation of explanatory hypotheses; to investigate learning in the context of the CIC (Combat Information Center) tactical decision making task.

APPROACH: We studied how people acquire and use statistical information in the CIC tactical decision making task. We specifically investigated the acquisition of prior and conditional probabilities, how the order of evidence affects probabilistic decision making (i.e., order effects), and how experience affects order effects. We modeled the experimental results using a hybrid symbolic-connectionist cognitive model. We used Soar as the symbolic component and a modified version of Echo as the connectionist component.

Accomplishments: We completed several experiments examining the acquisition and use of probabilistic information and its relation to order of data presentation effects. The order effect occurs when individuals come to different beliefs based only on the order in which evidence is presented to them. We found that individuals could acquire and use probabilities (as predicted by several current theories), but that their judgments still exhibited order effects, a result that was inconsistent with existing models of probability learning and use. We constructed a symbolic-connectionist model, based on Thagard's Echo, that could acquire probabilities and exhibit order effects similar to those found in human subjects. The result is an extended version of Echo that is potentially applicable to a wide range of tasks.

We conducted one experiment to examine the effects of different types of training on tactical decision making. In particular, we examined the role of Cohen's metacognitive training on tactical decisions. Cohen had shown that this training enhanced decision making in the real-world CIC tactical decision making task when used with experienced decision makers. Metacognitive reasoning involves the forced consideration of alternative possibilities. Our goal was to see if the same training might affect novice decision makers. We found no effect of the metacognitive training on the CIC decisions. However, we believe that this has more to do with the paucity of knowledge in the CIC simulation, and not the experience level of the subjects. If novice subjects were given a richer knowledge base, they might benefit from metacognitive training.

We also conducted several experiments to examine how situational shifts (such as from a peaceful to a hostile situation) would affect decision making. We found that such shifts produced nonmonotonic changes to decision making, in which the decision maker would rapidly change their decisions to better match the new situation. Our results suggest that probability acquisition is subject to a recency effect, wherein problem solvers give more weight to recent experience than to distant experience.

In the past year, Hongbin Wang, the graduate research assistant on this project, successfully defended his PhD thesis, which was based completely on this project. The most significant finding from this work is that order effects in human belief revision (such as recency and primacy induced by the order in which evidence is presented) disappear with experience. That is, as subjects get more practice with a belief revision task, the order effects slowly disappear and their beliefs more closely match the normative probabilities. We have also produced a cognitive model of belief revision that models these results. This model is generally applicable to any belief revision task.

One of the problems with the CIC simulation task was the lack of a gold standard for each scenario. This made it difficult to study learning using CIC and to compare the results of different learning models. In particular, there was no way to give clear feedback to subjects about whether or not their decisions were

right or wrong. In collaboration with Sandra Marshall (who is funded under a related ONR Hybrid Learning grant), we developed a set of scenarios based on expert decision making in the original TADMUS (Tactical Decision Making Under Stress) scenarios. These scenarios allowed us to collect learning data on novice subjects and to compare this data against the expert decisions and different models of learning for the CIC, tactical decision-making task. Although we have collected and distributed this data, it has not yet been analyzed.

Conclusions: Although subjects can accurately acquire probabilities through experience with a tactical decision making task, order effects are still present without extended training. However, with extended training (i.e., experience on the task) order effects disappear. In addition, changing situations (such as from hostile to peaceful) can negatively affect decision making, but has less of an effect than predicted by normative models. The hybrid symbolic-connectionist cognitive model produced under this grant can predict the amount of training needed to eliminate order effects and to adequately prepare a person for a different situation.

Significance: The resulting theory and model of probability acquisition and use is generally applicable to a wide range of decision-making tasks. Furthermore, the model integrates existing phenomena regarding the learning and use of probabilities, order effects in decision making, and newly discovered phenomena regarding the relationship between probability acquisition and order effects.

Patent Information: NONE

Award Information: The PI, Todd R. Johnson, was awarded tenure during the period of this grant. Hongbin Wang, a graduate student supported by this grant, was awarded the Marr Award from the Cognitive Science Society for the paper "UEcho: A model of uncertainty management in human abductive reasoning." This paper reports on a portion of the research conducted under this grant. The Marr Award is given annually to the best student paper submitted to the Conference of the Cognitive Science Society.

Publications and Abstracts:

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2. Johnson, T. R., Zhang, J., & Wang, H. (1997). A hybrid learning model of abductive reasoning. In R. Sun & F. Alexandre (Eds.), Connectionist Symbolic Integration. (pp. 91-112). Hillsdale, NJ: Lawrence Erlbaum.

3. Zhang, J., Johnson, T. R., & Wang, H. (1997). The relation between order effect and frequency learning in tactical decision making. Thinking and Reasoning, 4(2), 123-145.

4. Johnson, T. R. (1997). Control in Act-R and Soar. In M. Shafto & P. Langley (Eds.), Proceedings of the Nineteenth Annual Conference of the Cognitive Science Society (pp. 343-348): Hillsdale, NJ: Lawrence Erlbaum Associates.

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6. Johnson, T. R., Wang, H., & Zhang, J. (1998). Modeling speed-up and transfer of declarative and procedural knowledge. In Proceedings of the Twentieth Annual Conference of the Cognitive Science Society. (pp. 531-536). Hillsdale, NJ: Lawrence Erlbaum.

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8. Wang, H., Zhang, J., & Johnson, T. R. (1999). Order effects in human belief revision. [Abstract] In Proceedings of the Twenty First Conference of the Cognitive Science Society (p 823). Hillsdale, NJ: Lawrence Erlbaum.