Metacognitive Prompting Aids Dynamic Decision-Making

Jarrett Evans (evans@psy.fsu.edu)
Florida State University, Department of Psychology, 1107 W. Call Street
Tallahassee, FL 32306 USA

C.Dominik Güss (dguess@unf.edu)
University of North Florida,
Department of Psychology, 1 UNF Drive, Jacksonville, FL 32224 USA

Walter R. Boot (boot@psy.fsu.edu)
Florida State University, Department of Psychology, 1107 W. Call Street
Tallahassee, FL 32306 USA

Abstract

Recent research suggests that incubation is superior to metacognition in tasks involving many decision alternatives (Dijksterhuis et al., 2006). One explanation for these findings is the limited information processing capacity of working memory. The current study further investigates this topic by using more complex tasks as many errors in Dynamic Decision-Making (DDM) are thought to be related to limited processing. Our results indicate that metacognitive prompting results in better performance in DDM over incubation via a better strategy selection. Results are explained referring to methodological reasons and to literature on metacognition. In addition to the theoretical relevance, findings may be relevant for training programs using DDM simulations.

Keywords: Dynamic Decision Making, Conscious Processing, Incubation, Unconscious Processing, Metacognition

Introduction

Humans have the remarkable ability to find new strategies to solve problems. Have you ever been working on a problem and noticed a better way to do it? Have you started to work on a problem, went to lunch, and thought of a better strategy while you were eating? The first example, where you *consciously* monitored your performance, we will refer to as metacognition, or awareness of one's own performance and regulation of cognitive processes (Flavell, 1981). The second example, where you arrived at a solution *unconsciously*, or without attention directed at performance (Dijksterhuis, Bos, Nordgren, & van Baaren, 2006), we will refer to as incubation as improvements that occur after one task is set aside and an unrelated task is started have been referred to as the 'incubation effect' (Vul & Pashler, 2007; Sio & Ormerod, 2007).

Previous research has indicated that incubation improves the quality of choices as people attempt to select the best apartment, roommate, or automobile (Dijksterhuis, 2004; Dijksterhuis, et al., 2006) and helps decision makers to overcome misleading information (Vul & Pashler, 2007). In contrast, other researchers have found that metacognition, rather than incubation, improves the retention of lecture information (Berthold, Nückles, & Renkl, 2007), and helps decision-makers slow down and process information analytically to reduce errors (Alter, Oppenheimer, Epley, & Eyre, 2007). Findings from the previous studies are somewhat limited because they focused on either incubation or metacognition and each study used a different task making it difficult to directly compare incubation and metacognition strategies. The current study addresses these limitations by assessing the performance outcomes of both metacognition and incubation strategies on the same task using the microworld approach.

Microworlds

The microworld approach is a compromise between a field study and the control of the laboratory and has been used to study individual differences in complex problem solving strategies in situations that are expensive, difficult, or unethical to reproduce (e.g., Güss, Tuason, & Gerhard, 2010). Microworlds are usually computer simulations that require the same cognitive resources as the real-world situation they model (Brehmer & Dörner, 1993). There are four basic requirements for a Dynamic Decision-Making (DDM) microworld: It must be dynamic, complex, contain a hidden variable, and have dynamic complexity (Gonzalez, 2005). To preview, the present study used a simulated fire-fighting task that met these requirements as fires continue to burn in the absence of user input and change due to shifting wind direction (dynamic), there were multiple pieces of equipment and several decision alternatives (complexity), participants did not know where fires would start (hidden variable), and letting a small fire burn would have future consequences as it grew (dynamic complexity).

Successful DDM required participants to use their cognitive, perceptual, and motor skills. In addition to these basic skills, they also needed to form a representation of how they believe the system operated so they could decide the appropriate level of response at the right time while maintaining a higher-order goal (Dörner, Nixon, & Rosen, 1990; Gonzalez, 2005). In sum, goals are established and updated as needed, information is collected and a mental model of the system is also established and updated as needed, from goals and collected data future system states are predicted, a plan of action is chosen and executed from the predictions, the effects of the action taken are monitored, and self-reflection is needed to determine the goodness of the action taken (Dörner & Schaub, 1994; Osman, 2010). DDM is very demanding and we are only focusing on the cognitive skills while ignoring the perceptual skills and motor outputs. Furthermore, the environment, or system behavior in our study, is changing with the uncertainty of where the next fire may start. The inherent difficulty of DDM tasks, and often what is encountered in the real world, is the interaction between the changing environment and the additive effects of prior decisions and acquired knowledge.

Major Sources of Error in DDM

Previous work has identified many sources of error that are of interest. First, is the low capacity of conscious processing which relates to people often restricting future planning and data collection about the current state of the environment as they try to preserve cognitive resources. This makes the understanding of a complex system difficult as important developments may escape attention. Second, people tend to put too much weight on the current problem or system state such that the important short and long-term effects (i.e., dynamic complexity) are not considered. Third, is forgetting, which makes strategy change difficult because even if an optimal strategy was found it may not be adopted if it is not recalled adequately. Finally, is the tendency to guard one's competence, which becomes problematic when control is lost and swift action is taken without regard to the consequences (Dörner, Nixon, & Rosen, 1990; Gonzalez, 2005). Because humans often need to solve complex and dynamic problems, consideration of two possible ways to enhance performance in these tasks by escaping these limits follows.

Unconscious Thought Theory and Incubation Effects

The Unconscious Thought Theory (UTT) was posited by Dijksterhuis and Nordgren (2006) as theoretical framework applicable to decision making. The Unconscious Thought principle states that thought consists of two modes: *conscious* and *unconscious* with attention or inattention to a task as the distinguishing feature. The Weighing principle infers that metacognition, as a limited capacity and rule-based mode, would be ineffective for weighing important task attributes. The authors did not suggest that incubation is always superior as some tasks, like solving a math problem, need precise and rule-based thinking. However, the main prediction of UTT is that increasingly complex decisions need less metacognition and more incubation (Dijksterhuis, et al., 2006). Because complex decisions often do not have a single solution they may require more capability than online processes, which may be limited by bottlenecks like working memory or attention (Pashler, 1992), can provide. Unconscious processing is hypothesized to have an unlimited processing capacity as it is not limited by bottlenecks, making it more capable of handling and integrating large amounts of information. The logical prediction from UTT is that continuing active work on a complex problem is detrimental to finding a solution as continued effort would not help, but an incubation period would help one find a solution that would simply be unavailable during limited conscious processing. Previous research supported this prediction as off-line processes (Strick, Dijksterhuis, & van Baaren, 2010) and weighting of attributes during a period of incubation (Dijksterhuis, Bos, van der Leji, & van Baaren, 2009) resulted in improvement during *static* decision-making tasks like the choice of a car or apartment. It would be an important finding if the core prediction of UTT held in *dynamic* decision-making.

A second line of research indicated that a filled incubation period, meaning that participants were interrupted and worked on an unrelated task as opposed to simply resting, improved performance. One inference made from incubation effect studies is that it helps people overcome fixations as they forget irrelevant details that hinder problem-solving. We also used a filled incubation period because a major source of error in DDM is focusing too much on the current state of the system while ignoring side and long-term effects which limits learning how the system operates.

Metacognition

Flavell (1981) observed that problem solvers often monitored and evaluated their knowledge and strategies and could update both in real time. Osman's (2010) Monitoring and Control (MC) framework suggests that real-time updating is not simply an observed phenomenon, but a critical and important component for complex DDM. The principles of MC posit that people effectively control dynamic systems by task monitoring (understanding through continued hypothesis testing), self-monitoring (tracking decisions), and control behaviors (tracking actions). MC predicts that effortful monitoring is beneficial as the transaction between effort and feedback reduces uncertainty about the task. Reducing uncertainty, via continued and effortful interaction, is the key to improvement in DDM. In other words, reducing uncertainty means that once the basic skills needed to make dynamic decisions are in place, and possibly automated, limited cognitive resources can be allocated toward improving performance instead of system control. Osman notes that when uncertainty is reduced people tend to rely less on biases, are better at noticing and correcting maladaptive strategies, and improve their knowledge regarding actions and outcomes addressing some of the major errors in DDM. The tenets of the MC framework predict improved performance through continued effort and these beneficial processes would likely stop during time away from active work.

The inclusion of the metacognitive prompting questions in this study addressed a limitation of the studies by Dijksterhuis (2004; Dijksterhuis, et al., 2006) as he had participants look at a blank computer screen for 4 minutes with the instruction to think carefully about their decision. It is not clear that participants did consciously think about the items presented previously. More recent work (Payne, Samper, Bettman, & Luce, 2008) suggests that 4 minutes of deliberation was unnaturally long as they found that when deliberation was self-paced and participants decided when they felt ready to continue, conscious processing out performed unconscious. In order to create the best possible paradigm for the benefits of conscious thought to emerge, we used a filled and self-paced metacognition period and this type of prompting has been previously shown to be effective (Berthold et al., 2007).

The Present Study

In this study, we investigated the impact of metacognition and incubation on the performance of a DDM task. The general question is how does metacognitive processing, operationalized as managing or monitoring the current strategy activated by prompting (Berthold et al., 2007), affect performance in comparison to incubation, operationalized as performing an unrelated task designed to allow processing outside of awareness (Dijksterhuis, 2004)? Proponents of UTT argue that it overcomes the limits of online cognitive processing and weighs important decision attributes more accurately which, as mentioned above, often influence errors in DDM and is why we seek to replicate and extend UTT into DDM. UTT predicts improved performance via bypassing the limits of working memory and attention allowing more information to be integrated and important attributes to be identified, while metacognition and the MC framework (Osman, 2010) predicts improved performance through continued effort in the presence of limited cognitive resources. If the proposed benefits of UTT extend into DDM it would offer an alternative to intense, and possibly maladaptive, cognitive effort.

We tested the following hypothesis: Because both incubation and metacognition have been positively implicated in decision-making we predict that both groups will show superior performance over a control group and consider the difference between metacognition and incubation as exploratory.

Methods

Participants and Design

Participants were 69 (49 females and 19 males, one participant did not report a sex) undergraduate students who participated for course credit. The mean participant age was 21.12 years (*SD* = 3.94) ranging from 18 to 42.

This experiment was a between subjects design with Processing Condition (metacognition, incubation, and control) as the randomly assigned three level independent variable. The dependent variable was percent saved area of forest.

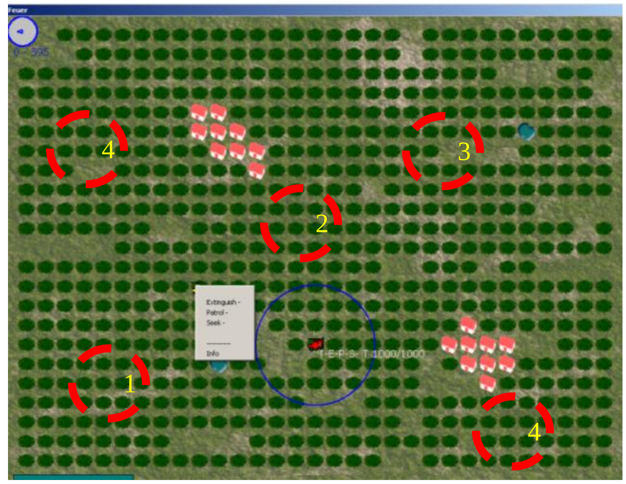

Figure 1. Screenshot of FIRE showing only one truck and helicopter. The grey menu shows how commands are given by selecting specific units. The blue circle around the truck indicates the area it can seek fires in automatically. The red circles indicate the locations and order that the fires started.

Materials and Procedure

In the FIRE microworld a participant acted as a fire chief charged with protecting an area of forest that contained two small villages. The participant protected the forest for ten minutes using six semiautonomous firefighting units: four trucks and two helicopters. There are three basic commands: Patrol, extinguish, and seek. When the patrol command is activated the fire-fighting units will move at random in a circular area. When the extinguish command is activated the fire-fighting units will spray water to extinguish a fire. If the extinguish command is not activated a unit will not spray water even if it is near a burning area. Dörner and Pfeifer (1993) noted that this may seem foolish, but a unit may need to pass a small fire en route to a larger one. When the seek command is activated a unit will search for fires independently within a circular area, but even with the seek command active a far away fire will not be detected so participants still need to move the unit and if the extinguish command is not active the unit will not spray water when it finds a fire. Each unit can have 0, 1, 2 or all 3 commands active in any combination and the given commands stay active until they are changed. Right mouse-clicking on an individual unit brought up a menu to change and display the active commands on that unit alone, or by using the keyboard shortcuts (e.g., ‘E’ for extinguish) participants could give a command to all the units at once. The movement of the units was accomplished by clicking and holding the left mouse button on an individual unit, which allowed participants to ‘drag’ an individual unit to a destination. Clicking and holding the left mouse button over any area on the screen and pressing ‘M’ on the keyboard directed all the units to the location under the cursor (see Figure 1).

The computerized incubation task consisted of a series of 34 anagrams (e.g. ouseh becomes house) presented to the participants one at a time for a maximum of 40 seconds each. Participants could attempt unlimited solutions within the time limit, but the correct solution or time expiring advanced to the next anagram. The incubation task lasted for six minutes and no participant completed all 34 anagrams. Anagrams, as verbal tasks, are not related to the temporal-spatial demands for FIRE and have been effectively used to activate unconscious thought in prior research (Dijksterhuis, 2004; Dijksterhuis, et al., 2006).

The computerized metacognition task consisted of three open-ended prompting questions adapted from Berthold (2007) and colleagues (Which aspects of the game do I understand well? Which aspects of the game do I not understand well? When I go back to the game, what will I do differently to increase my performance?). The first two prompts were designed to activate positive and negative knowledge about the task to encourage understanding of the task while the third question required hypothesis generation about the relationships between actions and outcomes. Participants were limited to six minutes, two minutes per question, to complete the questionnaire. Although the questions had time limits, it was still self-paced as participants could proceed to the next question when ready. In practice, most participants were proficient typists and did not use all six minutes as Payne and colleagues' (2008) suggested that in order to produce the best results, conscious processing interventions should be self-paced.

After giving informed consent, participants were seated at a computer in a lab setting and were provided with earphones and paper instructions for FIRE that they kept for the duration of the experiment. Participants assigned to the experimental conditions were interrupted at the 5-minute mark during FIRE and those in the metacognition condition completed the prompting questionnaire while those in the incubation condition completed the anagram task. Participants in the control condition were not interrupted. At the end of FIRE all participants completed a computerized demographic survey and were then de-briefed.

Results

To assure a comparable baseline the data were analyzed with a one-way ANOVA comparing performance between the processing conditions at 300 seconds (the interruption time). The difference between the groups on percent forest saved was not significant $F(2, 66) = 1.33$, $p = .271$.

To test our primary hypothesis the data were analyzed with a one-way ANOVA comparing final percent forest saved between the three Processing Conditions. The difference between the groups was significant $F(2, 66) = 4.03$, $p = .022$, $\eta^2 = .11$[1]. Follow up tests revealed that the metacognition group ($M = 78.95$, $SD = 19.71$) significantly $F(1, 66) = 7.94$, $p = .006$, $\eta^2 = .11$ outperformed the control group ($M = 60.83$, $SD = 23.03$) and marginally $F(1, 66) = 3.05$, $p = .085$, $\eta^2 = .04$ outperformed the incubation group ($M = 67.61$, $SD = 22.34$). The difference between the control and incubation group was not significant $F(1, 66) = 1.14$, $p = .29$, $\eta^2 = .01$.

We narrowed our large dataset for further analysis by conducting a series of one-way ANOVA's at each 30 second interval (data were saved every 30 seconds) after the break at 300 seconds. The first reliable group by percent forest saved difference $F(2, 66) = 3.30$, $p = .043$, $MSE = 125.49$, $\eta^2 = .09$ was at 420 seconds. The group differences mirrored the final performance with metacognition reliably ($p = .013$) outperforming the control group and the difference between the metacognition and incubation approached significance ($p = .118$) while the difference between control and incubation was unreliable ($p = .339$). Further support identifying 420 seconds as a critical time was indicated by the pre-programmed pattern of fires as two started simultaneously in the lower right and upper left of the forest at 390 seconds (fire number 4, see Figure 1). In order to explain why one group did better than another, subsequent analysis focused around this critical interval.

Did one group keep more units closer to the fires? We defined a unit as near a fire if it was within a radius of 32 pixels of any burning section. Participants could have between zero and six units near a fire. At the 300 second baseline the difference between the groups was not significant $F(2,66) = 1.52$, $p = .226$. We used Tukey's HSD for Type I error control for the pair-wise comparisons at the only two time points the overall omnibus was significant. At 390 seconds the control group ($M = 4.75$, $SD = 1.73$) had significantly ($p = .048$) more units near active fires than the metacognition group ($M = 3.32$, $SD = 2.34$), but not more than the incubation group ($M = 4.35$, $SD = 1.95$). There were no other reliable group differences at 390 seconds. At 420 seconds the control group ($M = 4.83$, $SD = 1.63$) had significantly ($p = .024$) more units near active fires than the metacognition group ($M = 3.36$, $SD = 2.13$), but not more than the incubation group ($M = 4.22$, $SD = 1.78$). There were no other reliable differences at 420 seconds. These results indicate that the control and incubation groups appropriately kept units near the burning areas as both groups had more fires burning than the metacognitive group (see Figure 2).

Why did the metacognitive group perform better with fewer units near the fires? We investigated the command selections for each unit. As with the units near a fire, participants could have between zero and six units with any command active. At the 300 second baseline the difference between the groups was not significant on number of units with extinguish, patrol, or seek commands active (all F's < 1). Furthermore, no reliable differences were found at any time period for the patrol or seek commands as they were used infrequently. The extinguish command is the last source of variance. We again used Tukey's HSD for Type I error control for all pair-wise comparisons at the only two time points the overall omnibus was significant. At 330 seconds the metacognition group ($M = 4.82$, $SD = 1.18$) had significantly ($p = .029$) more units with the extinguish

[1] MSE=474.82 for the overall omnibus and the one degree of freedom F-tests.

command active than the control group (*M* = 3.58, *SD* = 1.93), but not more than the incubation (*M* = 4.57, *SD* = 1.56) group. There were no other reliable group differences at 330 seconds. At 360 seconds the metacognition group (*M* = 4.64, *SD* = 1.47) had marginally significantly (p = .066) more units with the extinguish command active than the control group (*M* = 3.54, *SD* = 1.64), but not more than the incubation (*M* = 4.52, *SD* = 1.76) group. There were no other reliable differences at 360 seconds. These results indicate that the metacognition group gave extinguish commands to the units right after the break explaining the sudden improvement in performance indicated on the lower panel of figure 2 at 360 seconds and kept them active allowing them to fight the fires with fewer units near the fires. In the same interval the incubation and control groups de-activated units in the presence of active fires until around 390 seconds when the two critical fires started. It appears that the metacognition group could have handled more fires with their reserve units while the other groups were still learning how to use the commands.

Inspecting the upper panel of figure 2 it is clear that the difference for number of units with the extinguish command active between metacogntion, control, and incubation is small at one to one and half units. To estimate what each additional unit with the extinguish command active contributed to performance at each time interval we regressed percent forest saved on number of units number of units extinguishing 30 seconds prior with our groups dummy coded (control group as the reference). Number of units with the extinguish command active at 330 seconds significantly (β = 1.20, t = 2.50, p = .015, partial r =.30) predicted percent forest saved at 360 seconds with each additional unit saving an additional 1.2 % of the forest. Units with the extinguish command active at 360 seconds also significantly predicted performance at 390 seconds (β = 1.50, t = 2.34, p = .022, partial r =.28) with each unit with the extinguish command active saving an average of 1.5 % of the forest in 30 seconds. The number of units with the extinguish command active remained a marginally significant or significant predictor over and above group at every interval after 330 seconds. The additive effect of one additional unit saving 1.5% additional every 30 seconds for 300 seconds, or ten intervals, adds up to 15% almost matching the 18% difference between the control and metacogntion group at the end of FIRE.

Discussion

Our results indicate how metacognition improved DDM in our task. The use of the extinguish command reliably predicted performance while controlling for group differences with each additional unit extinguishing saving significantly more forest area with the passage of time.

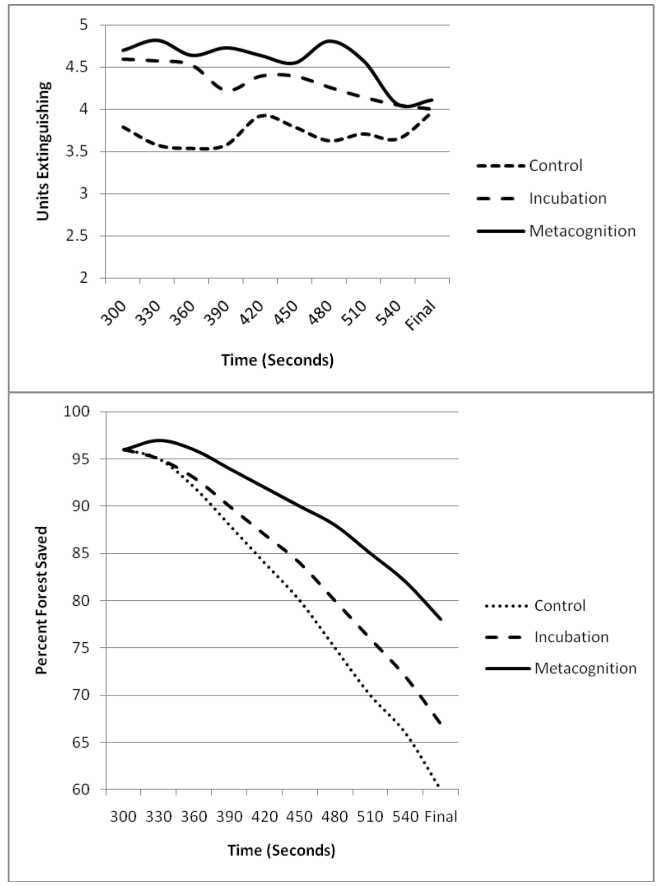

Figure 2. Comparing the group differences over time, starting at the break at 300 seconds. The upper panel indicates the number of units with the extinguish command active. The lower panel shows percent forest saved by group and the repeated measures quadratic component collapsed across groups was significant $F(1,68)$ = 110.57, $p <$ .001, MSE=9.49.

This occurred because the fires were programmed to spread exponentially (see figure 2) to mimic their natural behavior and is an important element of DDM highlighting the interaction between user decisions and the influence of the changing environment as a small fire that was neglected turned into a larger one.

The group results at each time period indicate that the important difference was learning that the units would not extinguish until activated and the results illustrate how the effects of earlier decisions enabled the metacognition group to stay ahead of the fires. Our data suggest that all the groups learned this, but the metacognition group learned faster than incubation and control and this advantage kept the fires from spreading out of control. The control group had more units near the burning areas even though they would not extinguish. Osman's (2010) MC framework predicts this behavior when a person doubts their ability to control or predict future events. The inability to connect actions to outcomes, maladaptive strategies, and important details escaping attention occur under conditions of high uncertainty. FIRE may have been more difficult than anticipated and may explain why the advanced commands were rarely used. Ten minutes may not have been enough time for participants to learn the relationships between the commands even though participants were provided with detailed written instructions.

Our results showed little support for incubation effects. Our study is novel because we directly compared incubation and metacognitive prompting using a dynamic task. It may be that the benefits of UTT only occur for static, not dynamic decisions when the environment itself and not the individual in a hurry, is creating time pressure. Also, in our task learning was an important factor and UTT may not help learning as Dijksterhuis and Nordgren (2006) noted, "decisions are of course likely to be best when they are based on information that is encoded thoroughly and consciously" (p.106). Our participants may have needed more time or trials with FIRE to show incubation effects.

Our results fit well into the existing literature on metacognition as our participants showed improvement when they followed one of the many paths suggested by Flavell (1981) such that when metacognitive knowledge, or thinking about your own knowledge, is activated it can lead to a metacognitive experience that adds to, deletes, or revises that knowledge and this is likely to occur in situations where conscious thought is required. Self-reflection and learning are critical in DDM (Osman, 2010).

Our study was limited as we cannot determine how our participants learned to activate the extinguish command or how they determined it was not active. Our participants had three options to discover how to activate the command. They could have looked at the instruction sheet, recalled the information from memory, or happened to come across the solution by trial-and-error during FIRE. All three of these alternatives are intriguing for education and training if prompting helps learners refer to text, search their memory, or continue exploring. This could be a form of electronic scaffolding similar to how a skilled teacher prompts a student to learn and continue working on a problem.

Acknowledgments

This research was supported by a Humboldt Fellowship for Experienced Researchers to the second author. We would also like to thank Kristen Ballentine, Devon Murray, and Erik Krueger for their help during data collection.

References

Alter, A. L., Oppenheimer, D. M., Epley, N., & Eyre, R. N. (2007). Overcoming intuition: Metacognitive difficulty activates analytic reasoning. *Journal of Experimental Psychology: General, 136*, 569-576.

Berthold, K., Nückles, M., & Renkl, A. (2007). Do learning protocols support learning strategies and outcomes? The role of cognitive and metacognitive prompts. *Learning and Instruction, 17*, 564-577.

Brehmer, B., & Dörner, D. (1993). Experiments with computer-simulated microworlds: Escaping both the narrow straits of the laboratory and the deep blue sea of the field study. *Computers in Human Behavior, 9,* 171-184.

Dijksterhuis, A. (2004). Think different: The merits of unconscious thought in preference development and decision making. *Journal of Personality and Social Psychology, 87,* 586-598.

Dijksterhuis, A., Bos, M. W., Nordgren, L. F., & van Baaren, R. B. (2006). On making the right choice: The deliberation-without-attention effect. *Science, 311*, 1005-1007.

Dijksterhuis, A., & Nordgren, L. F. (2006). A theory of unconscious thought. *Perspectives on Psychological Science, 1*, 95-109.

Dijksterhuis, A.,Bos, M.W., van der Leji, A., & van Baaren, R. B. (2009). Predicting soccer matches after unconscious and conscious processing as a function of expertise. *Psychological Science, 20,* 1381-1387.

Dörner, D., Nixon, P., & Rosen, S.D. (1990). The logic of failure. *Philosophical Transactions of the Royal Society of London: Series B. Biological Sciences, 327*, 463-473.

Dörner, D., & Pfeifer, E. (1993). Strategic thinking and stress. *Ergonomics, 36*, 1345-1360.

Dörner, D., & Schaub, H. (1994). Errors in planning and decision-making and the nature of human information processing. *Applied Psychology: An International Review, 43*(4), 433-453.

Flavell, J.H. (1981). Cognitive monitoring. In W.P. Dickinson (Ed.), *Children's oral communication skills* (pp. 35-60). New York, NY: Academic Press.

Gonzalez, C. (2005). Decision support for real-time, dynamic decision-making tasks. *Organizational Behavior and Human Decision Processes, 96,* 142-154.

Güss, C. D., Tuason, M. T., & Gerhard, C. (2010). Cross-national comparisons of complex problem-solving strategies in two microworlds. *Cognitive Science, 34*, 489-520.

Osman, M. (2010). Controlling uncertainty: A review of human behavior in complex dynamic environments. *Psychological Bulletin, 139*, 65-86. doi: 10.1037/a0017815

Pashler, H. (1992). Attentional limitations in doing two tasks at the same time. *Current Directions in Psychological Science, 1*, 44-48.

Payne, J.W., Samper, A., Bettman, J.R., & Luce, M.F. (2008). Boundary conditions on unconscious thought in complex decision making. *Psychological Science,19*, 1118-1123.

Strick, M., Dijksterhuis, A., & van Baaren, R. B. (2010). Unconscious thought effects take place off-line, not on-line. *Psychological Science, 21*, 484-488.

Vul, E., & Pashler, H. (2007). Incubation benefits only after people have been misdirected. *Memory & Cognition, 35*, 701-710.