The Role of Recognition Primed Decision Making in Human-Automation (H-A) Teaming

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ABSTRACT
In this paper, we explore how the Recognition Primed Decision Making (RPDM) model can be applied to the decision making process of a human-automation team, specifically teams of humans who work together with a synthetic teammate. To better explain and describe the role of the RPDM in human-automation teams we have grounded the discussion in a larger project that has consisted of multiple human-automation teaming experiments over years. Through our own research, we have realized the important role of the RPDM model during the Information-Negotiation-Feedback (INF) process of decision making. In this paper, we detail how RPDM helps to make decisions through utilizing experience in communicating and coordinating with a synthetic teammate.

KEYWORDS
Human-Automation Teams, Naturalistic Decision Making, Recognition Primed Decision Making

INTRODUCTION

Teams are becoming increasingly more important in order to achieve tasks with high cognitive complexity. Traditionally, a team is defined as a heterogeneous and interdependent group of individuals that adaptively interact to reach a common goal (Salas, Dickinson, Converse, & Tannenbaum, 1992). Over time, teams have permeated society and are now used to address many different problems in many different contexts. In addition, there are many different types of teams. More specifically, one type of team that has been the main focus of multiple recent studies is human-automation teams (Langan-Fox, Canty, & Sankey, 2009; Demir & Cooke, 2014). For human-automation teams, there are multiple aspects of the decision making process that make it more complex and difficult than human-human teams. Many of the decision making related challenges of human-automation teams revolve around a lack of intelligent automation. Due to the lack of intelligence, making decisions as a human-automation team is difficult. This difficulty is especially amplified in highly dynamic contexts (such as interdisciplinary scientific institutions, medical care, and military command-control (2C)). These settings require the development of a shared understanding of the current situation in order to make better and faster decisions. Yet, developing a shared understanding to help make a team level decision is extremely complicated in these teams, mainly due to the automated (synthetic) team member not having the intelligence to develop and share knowledge to articulate an understanding of its teammates.

With this in mind, it's important to consider how decisions are made in human-automation teams. One possible decision making perspective to consider within these teams is Naturalistic Decision Making (NDM). NDM was introduced in 1989 and is defined as "the way people use their experience to make decisions in field settings" (Zsambok, 1997, p. 5). Therefore, the focus of NDM is how people make decisions in real world settings. Over the years, many models and theories are directly related or have been built under the NDM framework. Hammond, Hamm, Grassia, & Pearson (1987)'s cognitive continuum theory considers decisions based on intuitive and analytical processes. In addition, Rasmussen's (1983) model of cognitive control focuses on different behaviours based on skill, rule, and knowledge within the context of a decision ladder that permitted heuristic cut-off paths.

The Recognition Primed Decision Making (RPDM) model associated with the NDM framework was introduced by Gary Klein in 1993 and highlights how decision makers use their experience to select a course of action based on recognition of situational dynamics (without having to compare multiple courses of action; Kaemph et al. 1996). Two main processes are taken into consideration in RPDM model: 1) the way decision makers size up the situation for recognition of a course of action that makes sense, and 2) evaluation of the course of action via imagining it (Klein, 1999). Therefore, the basic strategy of the RPDM is divided into three variations: 1) *simple match*-whether situation is typical or familiar, 2) the *situation diagnose* – diagnosing the situation by collecting more information if the current information is unclear, and 3) *evaluate the course of action* – evaluating single options by imagining how the course of action will play out (Klein, 1999).

Thus, in our current human automation team (synthetic teammate an task) project, RPDM is important for two reasons (also emphasized in Fan, Sun, McNeese, & Yen (2005) study): First, through well-structured processes and team-wide collaboration, it allows for better problem solving in ill-structured, time-sensitive situations. These characteristics of the model allow investigation into problems with dynamic information sharing and distributed team cognition. Second, RPDM focuses on the same thing that experts do when making decisions: recognizing similarities between the current situation and past experiences. Each of these reasons are imperative to helping both the synthetic teammate and the human teammates collaborate to make accurate decisions.

In this paper, we will explore how the RPDM model can be applied to the decision making process of a human-automation team. To better explain and describe the role of RPDM in human automation teams we will ground the discussion in a larger project that has consisted of multiple human-automation teaming experiments over the years. The rest of the paper will outline our work in a synthetic task environment where human team members are required to interact with a synthetic teammate to complete a mission. We then describe the specific role of RPDM in human-automation teams, explaining how important it is to the communication and coordination of the information-negotiation-feedback process of team decision making.

SYNTHETIC TASK ENVIRONMENT AND SYNTHETIC TEAMMATE

What is the synthetic task environment?

Many kinds of real-world tasks have been systematically represented in what is called the, "Cognitive Engineering Research on Team Tasks Unmanned Aerial Vehicle Synthetic Task Environment" (CERTT-UAV-STE) which provides the context for many different kinds of synthetic tasks (Cooke & Shope, 2004). In the most current study, an updated version of the CERTT-UAV-STE, CERTT-II, is used to simulate teamwork aspects of unmanned air vehicle (UAV) operations. CERT-II hardware includes the following features to support the current study: 1) text chat capability for communications between human teammates and the synthetic teammate; and 2) eight new hardware consoles: four consoles for teammates and four for experimenters (Cooke & Shope, 2004).

In the larger project (in collaboration with government entities), a specific goal has been to develop a cognitively plausible agent to serve as a fully-fledged synthetic teammate. In keeping with this goal, the project is aimed at creating a synthetic teammate as a part of a three-agent UAV ground control crew. The UAV-STE involves three heterogeneous and interdependent teammates, each of which has a different task role in taking good photos for critical waypoints: 1) Air Vehicle Operator (AVO or pilot) controls the UAV's heading, altitude, and airspeed (this role is also the synthetic teammate); 2) Data Exploitation, Mission Planning, and Communications (DEMPC or mission planner) provides a dynamic flight plan and also speed and altitude restrictions; and Payload Operator (PLO) monitors sensor equipment, negotiates with the AVO, and takes photographs of target waypoints (Cooke & Shope, 2004).

The teams' goal is to take photographs of ground targets during simulated reconnaissance missions by interacting with each other through a text-based communications system. In this communication system, team members coordinate with each other based on an optimal coordination sequence (which is depicted in Figure 1) between human and synthetic teammates (also called information, negotiation, and feedback).

In the UAV-STE team, three special kinds of communication (coordination events) can occur during the missions (Cooke, Gorman, Duran, et al., 2007): 1) Information (I), the DEMPC provides information about upcoming target waypoint information to the AVO; 2) Negotiation (N), the PLO and the AVO negotiate an appropriate altitude and airspeed for the target's required camera settings; and 3) Feedback (F), the PLO provides feedback about the status of the target photo. These coordination events (INF, for short) are then used for a dynamical systems analysis of team coordination that is focused on how team's members interact (Cooke & Gorman, 2009).

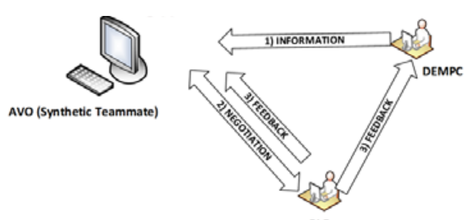

Figure 1. Optimal Coordination Sequence between Human and Synthetic Teammates

What is the synthetic teammate?

The ACT-R computational model provides support for measuring processing time and has been used extensively in the modelling of higher-level cognitive processes (Ball et al., 2010). In the current study, the AVO is a cognitively plausible ACT-R based computational model that serves as a fully-fledged synthetic teammate for a three agent ground crew. Simply, the current study is concerned with developing a cognitively plausible ACT-R based computational model to replace human UAV pilots in three-agent UAV ground control crews (Ball et al., 2010). The larger project addresses questions about the extension of the ACT-R cognitive modeling architecture (Anderson, 2007) and team coordination.

INTEGRATING RPDM INTO A SYNTHETIC TASK AND TEAMMATE ENVIRONMENT: IMPACT ON COORDONATION- INFORMATION, NEGOTIATION, FEEDBACK

In the optimal coordination sequence perspective (i.e., INF), RPDM is viewed as being extremly important during the information and negotiation periods. In this case, the main decision makers are the DEMPC in the information part and the PLO in the negotiation part. The RPDM model is considered impactful to INF, especially during the Situation Awareness (SA) roadblocks that are presented within the study.

SA incorporates a team member's understanding of the situation as a whole, forming the basis of decision making. Therefore, expert decision makers will act first to classify and understand a situation and then immediately proceed to action selection (Klein, 1988). SA is important to both RPDM and a human-automation teaming. With this in mind, in this study, establishing good SA of both the task and teammates is necessary for both the synthetic teammate and human teammates to function as a good team. Human (the DEMPC and the PLO) and synthetic team members must assess the situation, make decisions, and take action in a coordinated manner. Below we will explain the importance of the RPDM, specifically *recognition* and *evaluation*, to the INF coordination process of making decisions in a human-automation paired team.

In this study, there are two types of situation awareness roadblocks that the participants come across. First is the situation awareness of roadblock scenarios, also called "critical updates". These roadblocks present ad-hoc target waypoints which are vary from mission to mission. These ad-hoc waypoints introduced to the DEMPC by the experimenter (Intel) in a timely manner. The second type of SA roadblock is simply the lack of intelligence exhibited by the synthetic teammate.

Under the RPDM model, decision makers must identify cues (or patterns of cues) among their observations about the current decision situation and then use these cues to recall similar cases within their previous experience. This process is called "feature matching", which the RPDM uses to develop situation awareness in the recognition phase. If the decision maker lacks information or experience and, therefore, cannot find an acceptable solution in their previous experience, then an alternative solution needs to be found during the feature matching process.

In this case, the DEMPC is the main decision maker during the situation awareness roadblocks because the DEMPC's role provides information about upcoming waypoints and, most of the time, is the one who receives critical updates about the situation from the experimenter. After receiving the critical update, the DEMPC identifies whether or not the situation is familiar or typical. Being familiar with the situation depends on the DEMPC's previous experience (directly related to RPDM). If the DEMPC doesn't have previous experience about the situation, then the DEMPC is not familiar with the situation and will need to seek out more information about the current situation. The first critical update of the experiment is not familiar to the DEMPC, but each following critical update becomes more familiar, resulting in the DEMPC learning how to handle each case.

If the situation is familiar, the DEMPC moves to the recognition process of the RPDM, which enables the DEMPC to know four products: 1) *which goals make sense*, that is, the DEMPC selects between target waypoints, the current waypoints, and the waypoints which were mentioned in the critical update; 2) *which cues are relevant*, that is, based on the critical update (which includes some hints such as entry, target, and exit waypoints' names) and how close those waypoints are to the UAV, the DEMPC updates the flight route plan; 3) *what to expect*, the basic expectation from this new flight route plan is to pass the roadblock successfully as a team; and 4) *which actions typically work,* that is, making decisions about the route plan based on the previous experiences. Monitoring the status of expectancy is especially crucial for this study because of the dynamic environment and potential for misinterpretation of the current situation by the DEMPC. For example, the DEMPC may not recognize that the synthetic AVO will fail to perceive the information due to a lack of intelligence.

Based on the recognition process, the DEMPC sends the information to the synthetic agent, the AVO. Even if the DEMPC recognizes the situation as a simple one, completing the appropriate course of action is complex because of the lack of intelligence exhibited by the synthetic teammate. The synthetic teammate cannot recognize the importance of the roadblock or time sensitivity for passing this roadblock. Therefore, the DEMPC needs to send the information in a structured and simple way.

Thus, in the evaluation phase of the RPDM, the DEMPC needs to evaluate the course of action and imagine how it will play out in context. Even if the new flight route plan (based on critical update) allows the team to successfully pass the roadblock in a timely and adaptive manner, the synthetic teammate's lack of intelligence may cause the plan to fail. If a course of action fails in the current situation, then it can be adjusted or rejected by the DEMPC, who will investigate other options until they arrive at a workable solution.

Therefore, when evaluating the course of action, the DEMPC needs to consider several situations: 1) whether the synthetic teammate will perceive the new flight plan in a timely manner; and 2) if it does perceive the plan, how long will it take the synthetic teammate to begin the course of action; and, 3) even if these first two situations resolve efficiently, what if there is a negotiation issue between the synthetic teammate and photographer (PLO). The negotiation of an appropriate altitude and airspeed for a target between the synthetic AVO and the PLO might take more time or the AVO might not perceive the information from the PLO. If the evaluation of the course of action by the DEMPC doesn't work, then the DEMPC can continue the previous route plan (addressing the roadblock afterwards) or can skip the roadblock because of the time limits.

If the course of action happens, but the synthetic teammate does not perceive the new information, then the DEMPC needs to go back and evaluate the course of action again and, based on that, either continue with the previous flight route or send the new route again to the AVO. If it still does not perceive the new route plan, then the DEMPC needs to go back to the situation analysis and add the critical update waypoints. Throughout this continued refinement of the course of action, RPDM is playing a significant role in helping the DEMPC gain experience and then appropriately adjust to the synthetic teammates failings.

If the synthetic AVO perceived the information about the critical update, and took course of action, then it is time to the PLO to make decision in the optimal coordination sequence. During negotiation, the PLO needs to send appropriate altitude and airspeed settings to the AVO that are in accordance with the required settings of the target photo. When the PLO sends appropriate altitude and airspeed settings, and the AVO does not perceive (or does not respond to) the information, then the PLO must consider this situation and identify a viable course of action based on this roadblock. In this case, the PLO can also collaborate with the other human teammate, the DEMPC, regarding the viable course of action to make the synthetic teammate perceive the information.

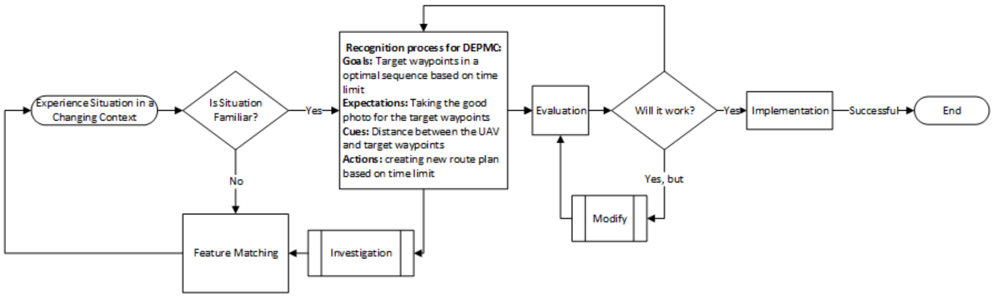

Figure 2. Recognition Primed Decion Making Model and INF (adapted from Klein, 1999; Fan et al., 2005**)**

In order to take good photos of target waypoints, the synthetic teammate needs to attend the process in a timely and adaptive manner. Otherwise, even if the human teammates makes decisions based on critical updates, due to the lack of intelligence of the synthetic teammate, the goal may not be achieved in a timely manner. Therefore, and optimally, the synthetic teammate model needs to build on RPDM in order to support human-agent collaborations in experience and expectancy based decision adaptations. In this case, using domain knowledge, past experiences, and the current situation awareness to produce a new (or adapt an existing) decision by synthetic teammate needs to be achieved. Currently, the synthetic teammate lacks this specific intelligence and therefore the knowledge contained in the RPDM model, but future research will look at further developing the synthetic teammate to account for understanding and learning from experience and situation awareness.

CONCLUSION

In this paper, we have reviewed the relationship of RPDM to that of human-automation teams, specifically teams of humans who work together with a synthetic teammate. Through our own research, we have realized the important role of RPDM during the INF process of decision making. Our future work will specifically look to further validate how RPDM can be better integrated into human- automation teams.

ACKNOWLEDGEMENT

This research was partially supported by ONR Award N000141110844 (Program Managers: Marc Steinberg, Paul Bello).

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