FEEDFORWARD EFFECTS ON PREDICTIONS IN A DYNAMIC BATTLE SCENARIO

Cleotilde Gonzalez, Michael Martin
Dynamic Decision Making Laboratory
Carnegie Mellon University

Jeffrey T. Hansberger
Army Research Laboratory

Commanders face many challenges in their efforts to control the battlefield. Friction (i.e., sources of delay) in the commander's control system, coupled with the dynamics of the battlefield, requires commanders to act before threatening battlefield events occur. Effective control of the battlefield thus requires accurate predictions. This paper describes the results of a preliminary study concerned with the effect of FeedForward (FF) on the accuracy of predictions in dynamic battle situations. FF, given in the form of expert advice prior to simulated battle, did not reliably improve predictions. Exploratory analyses, however, indicate that FF guided attention to a subset of the task variables important for accurate prediction. Furthermore, FF produced quicker and more decisive victories than practice alone. In conjunction with the positive performance trend for the FF group, these findings indicate that FF facilitates strategy development and may lead to higher levels of Dynamic Decision Making (DDM) performance over time.

INTRODUCTION

Commanders face two general sources of delay in their efforts to control the battlefield. The first is the delay between orders and their effects on battlefield states. The second is the delay between changes in battlefield states and the observation of those changes. To compensate for these delays, commanders must base current orders on predictions about future battlefield states. Put in another way, sources of delay require that commanders use anticipatory control strategies (i.e., feedforward).

FeedForward (FF) control strategies would suffice if battlefields were perfectly predictable, but battlefields are not perfectly predictable. To compensate for the uncertainty associated with battlefields, commanders must incorporate feedback control strategies to amend orders based on observed battlefield states.

The commander's Dynamic Decision Making (DDM) ultimately requires a delicate balance between feedforward and feedback control strategies. Feedforward control strategies compensate for delays in the commander's control system by anticipating and directing future actions. Feedback control strategies compensate for uncertainty in the battlefield by reacting to and correcting unanticipated effects of past actions.

Observations of battlefield states (i.e., feedback) serve two purposes. First, feedback allows commanders to react to unexpected events. Second, it allows commanders to incorporate observations of novel battlefield dynamics into their predictions about future battlefield states; it allows commanders to check the validity of their predictions, and adjust them if necessary.

Timely feedback is crucial for effective battlefield control. Yet adverse delays in the commander's receipt of feedback about battlefield state are almost inevitable. It takes time, for example, to interpret sensor data and distribute reports. Commanders may not have the time to process feedback together with the other activities equally demanding of their attention. The complexity of the battlefield may impede the completion of analyses just when timely feedback is needed most. For any variety of reasons, commanders are often left to work with delayed feedback about battlefield states. Consequently, the actions taken based on such feedback – including the tuning of predictions – are also delayed, threatening their effectiveness.

We propose that our ability to make accurate predictions is directly linked to our ability to process feedback in real-time. The implication is that if we can augment FF control strategies we can decrease functional feedback delays, thereby improving DDM performance. As such, our understanding of how augmented FF and feedback influences our ability to make accurate predictions becomes relevant.

Commanders use FF control strategies to reduce discrepancies between desired and predicted battlefield states. Such strategies could be augmented by sophisticated technology that predicts future states from current states and recommends actions to take. Expert advice is a more practical alternative. FF from experts can be conveyed as relatively simple decision rules or strategies.

Few studies have examined the effects of FF on learning and adaptation in DDM tasks. Sengupta and Abdel-Hamid (1993) demonstrated a performance benefit when FF was combined with outcome feedback (i.e., knowledge of results). Gonzalez (2005) found FF to improve learning and retention in a DDM task, whereas outcome feedback had no effect. We are unaware of any studies that have examined the effect of FF on predictions about DDM performance.

This paper reports a preliminary investigation of the effect of FF on the accuracy of predictions in a dynamic environment. We present a laboratory experiment aimed at elucidating the effectiveness of FF on predictions and performance in a real-time DDM task. The task was a simple but realistic videogame simulation of battle execution.

METHOD

Participants played the Defend-the-Egg scenario in Command & Conquer Generals (C&C), a popular real-time strategy game.

The Defend-the-Egg scenario was designed to reflect an actual training scenario used by the U.S. Army, and has been used to explore mental model development in a previous study (Graham, Zheng, & Gonzalez, 2005). In this scenario, participants control a 135-element, combined-arms force (Blue) in their efforts to defend an airfield from a computer-controlled enemy force (Red) seeking to capture it. Mission success requires preventing airfield incursion by destroying Red forces while maintaining at least 75% of Blue force strength.

Twenty-two students with no experience in military tactics and no experience with C&C were assigned to one of two experimental groups: FF and no-FF. The FF group received a list of 10 FF items similar to the examples shown in Table 1. The 10 FF items in the list were advice statements developed by an Army Lieutenant Colonel with 22 years of military experience and familiarity with the Defend-the-Egg scenario in the C&C environment.

Example Feedforward Items
If enemy attack helicopters are detected in an attack, they require immediate attention! Order Missile Defender Soldiers (on foot and/or in Humvees) to eliminate all helicopters.
When the enemy forces are located forward or actual scouts are located in the airfield area, this indicates a precursor to a simultaneous attack at both the front and the rear
Blue commander should concentrate anti-air capability at the air base to defend air insertion. Also, Blue should have an adequate Rapid Reaction Force located at the air base for defense.
If the enemy uses Tomahawk missiles, quickly order units to destroy the Tomahawk missile launchers. They are typically used in the rear of formations due to their lack of defenses, armor, and long range capabilities.

Table 1. Examples of the advice provided to the FF group.

At the beginning of the experiment, participants received instructions that introduced them to the C&C game and the Defend-the-Egg scenario; defined the mission success criteria; and described the capabilities and functions of the various types of units available to them and the Red force. They then completed a 30-minute training session to acquaint them with the videogame interface.

After the training session, participants played the Defend-the-Egg scenario 10 times. All participants began each trial by making a series of predictions about the outcome of the upcoming battle. After making their predictions, the no-FF group immediately entered the Defend-the-Egg scenario. In contrast, the FF group first reviewed the list of 10 FF items and then entered the Defend-the-Egg scenario. The same set of 10 FF items were repeated before each of the 10 trials.

The scenario began with a two-minute preparation phase during which participants positioned their forces. The battle began at the end of the two minutes, and continued until participants lost more than 25% of Blue force strength, or destroyed the Red force, or the Red force invaded the airfield. The scenario terminated with a message of victory or defeat.

A large number of measures including the predicted probability of winning, the observed win probability, the observed number of kills of Red and Blue units of different types, and scenario duration were collected.

RESULTS

Initial analyses indicated that two participants lost all 10 of the battles in the experiment. These participants were removed, leaving nine participants in each of the groups (FF, no-FF). The data were then blocked into two sets of five trials each for subsequent analyses.

To address the question of which task variables distinguish victory from defeat we performed a stepwise logistic regression of battle outcome (victory, defeat) onto task variables that represent the number of Red and Blue units killed. In addition to using simple counts of each unit-type killed as predictors we also included predictors representing all two-way interactions among the unit-types. The logistic regression equation depicted in Figure 1 classifies all but 2 cases correctly.

The equation depicted in Figure 1 can be summarized simply. Victory requires destroying three Red force-protection capabilities plus minimizing Blue losses when engaging Red Comanches with Blue Missile Defenders. The gray bars in Figure 1 depict domain-relevant interpretations of the multiplicative relationship between pairs of units (i.e., two-way interactions) used in the regression analysis. Red Rangers, for example, provide anti-infantry protection for Red Tomahawk Missile Launchers, which, in turn,

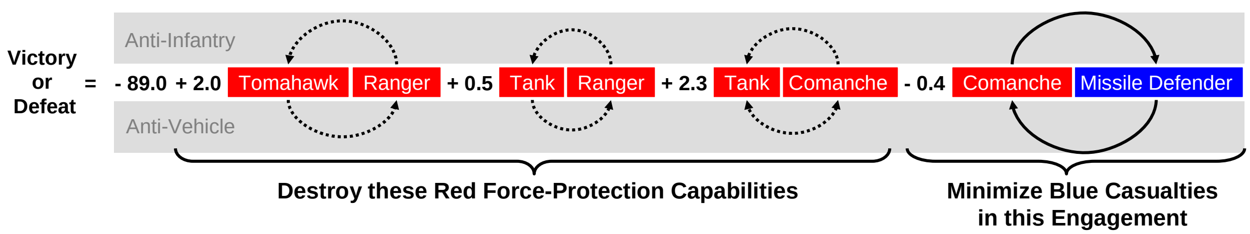

Figure 1. Task variables that distinguish victory (1) from defeat (0).

Separate Group (FF, no-FF) x Block (1, 2) mixed ANOVAs were conducted for predicted probability of winning, the observed probability of winning, and a difference score representing the calibration of participants' predictions with performance (i.e., predicted – observed probability of winning). No reliable differences were found.

Subsequent exploratory analyses examined which task variables were important for victory or defeat and which task variables influenced participants' predictions.

provide anti-vehicle protection for Red Rangers. Blue Missile Defenders and Red Comanches interact via their anti-vehicle (air) and anti-infantry capabilities, respectively.

To correctly predict outcomes, participants should have attended to the items described by the logistic regression equation. . The question then is which task variables were related to participants' predictions?

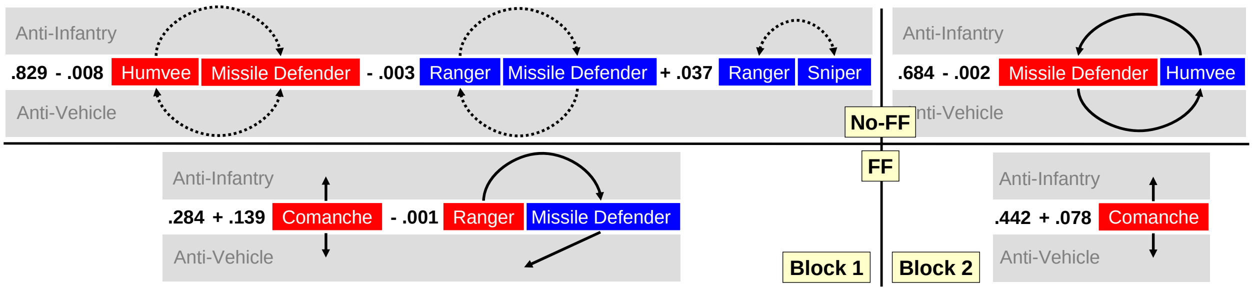

Figure 2.Task variables related to participants' predictions of battle outcomes.

We addressed this question by regressing participants' predictions for a trial onto task variables representing the observed number of unit-type kills in the previous trial, again including all two-way interactions. Separate hierarchical regressions were performed for each cell in the Group x Block design. Variance in participants' predictions due to individual differences was removed, followed by a stepwise regression of the residualized predictions onto unit-type kills from the previous trial. Figure 2 depicts the task variables related to participants' predicted probability of winning in Blocks 1 and 2 for the two Groups (FF, no-FF).

Figure 2 implies that the experimental groups are using different criteria for their predictions. Although neither group appears to be attending to the combat unit relationships that best distinguish victory from defeat, the FF group is focusing on one of the critical elements of success in the scenario, elimination of the Red Force Comanche helicopters. Moreover, this focus is stable across Blocks 1 and 2. The FF group does not yet appear to be basing their predictions on the proper force combination (i.e., Red Comanche x Blue Missile Defender) required to effectively eliminate this key component of the scenario. But they do appear to be on the correct path for more accurate predictions.

Other signs that the FF group is advancing their learning of the scenario and performance in a different manner than the no-FF group are in the performance trends over trials and on the time required for successful trials. The FF group displayed a significant positive performance trend across trials (R^2 = .40, p < .05) whereas the no-FF group displayed a similar positive but non-significant trend (R^2 = .26, p > .05). This shows that the FF group is reliably improving their performance over time. Along with this performance difference, the FF group also obtained victory more quickly and decisively than the no-FF group by Block 2, as indicated by the Group x Block interaction for scenario duration, $F(1, 11)$ = 5.26, p < .05 (see Figure 3).

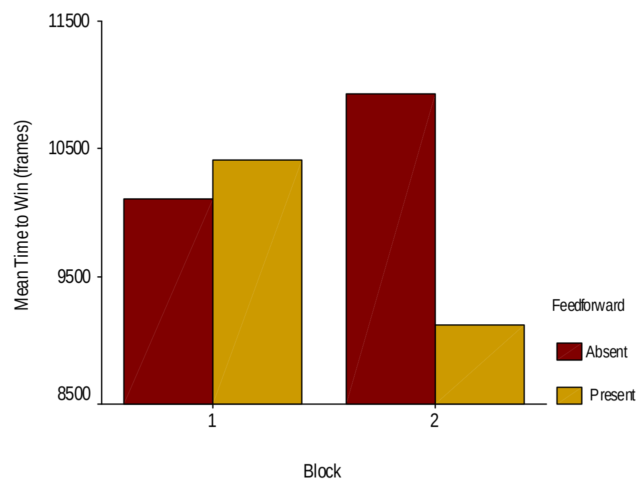

Figure 3. Group x Block interaction in speed of victory.

The combination of more decisive victories with the positive performance trend over time, along with indications the FF group is attending to important combat unit relationships and strategies suggest that FF is having a positive effect.

DISCUSSION

This study explored the effect of FF in a DDM task. Even though group differences in predictive accuracy and the probability of winning were unreliable, there were several indications that the FF and no-FF groups were approaching and interacting with the DDM task differently.

The first indicator was the identification of the Red Comanche helicopter as an important and critical enemy unit. This is congruent with both expert input, as one of the FF items specifically addressed this importance, and the logistic regression, which identified its elimination as critical for success. The FF group had not completely discovered the appropriate strategy to eliminate these enemy units but they were on the correct path for such strategy discovery compared to the no-FF group. Past research in strategy development (Hansberger, Schunn, & Holt, in press) suggests strategy development similar to that being displayed by the FF group significantly improves performance and understanding of a DDM task over time.

The presence of improved strategy development and learning in the FF group is also supported by the positive trend in their performance compared to the no-FF group. If these trends continue, the FF group would outperform the no-FF group over a longer period of time than the 10 trials provided in this experiment. Additional experimentation is needed to explore this finding and hypothesis.

The last indicator that suggested a difference between FF and no-FF groups is the time required for victory. Timeliness for decision, action, and execution is a critical characteristic for many DDM tasks in the military and in other time critical domains. The indication that the FF group is obtaining victory in a faster and more decisive manner suggests that they have tapped into some of the critical strategies and information that lead to success.

We plan on continued exploration of these issues as well as other FF related issues in future research: level of specificity in FF advice items, matching level of expertise with novice-expert FF items, and presentation format of FF items.

The level of specificity for the FF items may have a strong effect on the participant's ability to comprehend and apply that information in a DDM task. Most of the FF items provided in this study were general and were not tied specifically to task and environmental cues and situations. With the help of expert military commanders, we are currently revising the FF items to provide a more concrete set of actions for the same game scenario.

Second, given that the items were developed by an expert military commander, it is possible that the FF advice items are more appropriate for an experienced population. The inexperienced participants we used in this experiment may have not understood or been able to appropriately apply the information provided to them due to the lack of general military tactics and strategies that an expert would possess. Thus, we plan to run this experiment with a more experienced population (military personnel).

Third, the FF advice items were presented in text form to our participants. We presented one by one each of the items, making sure each of them was read, but not necessarily understood. It is possible that, at least for a novice population, the FF advice items would be more effective if they are exemplified or demonstrated by the expert. Thus, we are considering options for providing FF items in more communicative forms. Perhaps the decision rules and strategies described in expert advice should be graphically represented or possibly animated so that students can see a situation and the expert's corresponding action.

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