Investigating Constraints on Decision Making Strategies

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ABSTRACT

Recently, researchers have focused on how individuals generate different courses of action (i.e., options) on-the-fly, and predict the options to be taken by others. When generating predictive options, previous research supports the use of cognitive mechanisms described by Long Term Working Memory (LTWM) theory (Ericsson & Kintsch, 1995; Ward, Ericsson, & Williams, 2012). However, when generating response options, previous research supports the use of the Take-The-First (TTF) heuristic (Johnson & Raab, 2003). The current research investigates the effect of time constraint on option generation behavior. Our results provide further support for the use of LTWM mechanisms during prediction, but support was observed for TTF only during response without time constraint. When participants responded under time pressure, they shifted towards a LTWM-type strategy. Modifications to the cognitive-process level description of decision making during response are proposed and implications for training during both prediction and response are discussed.

KEYWORDS

Decision Making; Sport; Long Term-Working Memory; Take-The-First heuristic.

INTRODUCTION

Decision making research has historically focused on strategies for choosing between a fixed set of options presented to a participant in a task, meanwhile ignoring the process by which naturalistic decision makers actually come up with alternatives from which to choose (see Johnson & Raab, 2003; Zsambok & Klein, 1997). The latter process is henceforth referred to as option generation and is considered a critical component of decision making in many real-world domains (Klein, 1993).

In a study of handball, Johnson and Raab (2003) proposed that the Take-The-First (TTF) heuristic supports successful decision making. Participants were shown short video clips of handball play that were frozen unexpectedly at a critical decision point, immediately prior to the player with the ball taking a specific course of action (e.g., shoot, pass). Viewing from the perspective of the player with the ball, participants highlighted as quickly as possible the first option they would take that came to mind, and then any additional options they could conceive. These authors found a negative correlation between the total number of options generated and the quality of the final decision. They concluded that an initial option is generated based on association with the environmental structure. As activation spreads, other less relevant options are generated. As a consequence, generating many options decreases the likelihood that one will select the first and best option. In a subsequent study, Raab and Johnson (2007) also demonstrated that as skill level increases, fewer total options are generated. This 'less-is-more' phenomenon has been supported by other models of decision making in similar environments, such as the Recognition-Primed Decision (RPD; Klein, 1993) model.

On the other hand, Long Term-Working Memory (LTWM) theory suggests that experts build a situational model that integrates stored knowledge with new environmental information on-the-fly, producing an updated situational representation (Ericsson & Kintsch, 1995). This allows experts to accurately anticipate the situational consequences and maintain direct access to task-relevant decision alternatives. In three experiments conducted by Ward, Ericsson, and Williams (2012), participants watched video simulations of soccer play similar to those presented by Johnson and Raab (2003) from the perspective of a defender on the opposing team to the team with the ball. Participants anticipated what the player with the ball would do next and generated the options that they were considering when the video was either frozen on screen or occluded from view. Consistent with most models of expertise, players generated few options and better options first. Furthermore, skilled players anticipated situations more accurately than less-skilled players. However, unlike TTF, the number of *task-relevant* options—those considered as high quality options by a domain-specific expert panel—was positively correlated with anticipation accuracy. This relationship held even when clips were occluded rather than frozen on screen. Ward et al. (2012) suggested that the ability to build and maintain access to a well-developed situational model afforded skilled participants the opportunity to generate more, as opposed to less, task-relevant options.

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Current models of expertise (i.e., TTF, LTWM) make opposing predictions regarding strategy use, especially concerning the relationship between option generation and decision quality. These may be influenced by methodological differences between studies—including phase of decision making/decision perspective (Ward, Suss, Eccles, Williams, & Harris, 2011). For instance, when deciding upon a course of action for oneself (e.g., during intervention/response), research supports the use of TTF (Johnson & Raab, 2003; cf. Ward et al., 2011). Alternatively, when assessing the course(s) of action that others in the environment might take and/or predicting the outcome of a situation (e.g., during assessment/prediction), research supports the use of LTWM mechanisms (Ward, et al., 2012; cf. Klein & Peio, 1988). Preliminary data supports this distinction (Belling & Ward, 2012) but this may also be dependent on domain (see Ward, et al., 2011).

Time constraint may also affect strategy use. For instance, Calderwood, Klein, and Crandall (1988) found that moves selected by Master players in time-pressured games did not degrade relative to those selected in standard tournament games. In contrast, less skilled chess players showed a significant decrement. Furthermore, Gobet and Simon (1996) compared Gary Kasparov's performance during standard and simultaneous chess games, which reduced time available per move. They concluded that recognition skill was primarily responsible for Kasparov's superior situational assessment and move selection because performance did not decrease under time pressure (cf. Chabris & Hearst, 2003). In the experiments conducted by Johnson and Raab, participants were permitted different amounts of time (i.e., from 45 to 6s) to view the last frame of action frozen on screen, during which participants generated options. However, time to respond with the final decision was unlimited. While time exposure to stimiuli were not experimentally manipulated in their research, no obvious skill-based differences were observed in option generation behavior across time exposures.

The current research aims to investigate the effects of time constraint on option generation behavior during both situational assessment/prediction (henceforth prediction) and intervention/response (henceforth response) phases of decision making (see Ward et al., 2011) to investigate *when* the respective strategies are employed and constrained by environmental factors. Consistent with LTWM theory, we hypothesize that the number of task-relevant options generated will be positively related to performance during prediction trials. Following TTF, we hypothesize that the total number of options generated will be negatively related to performance during response trials. Based on research that has examined the effect of time pressure on move selection, we speculate that participants will favor a TTF-type strategy when under additional time pressure, irrespective of decision phase.

METHODS

Participants and Materials. Twenty-one (17 male) recreational-level players with an average age of 19.8 years (*SD* = 1.94) participated in this study. Twenty-four video clips were created using footage of a live soccer match. The video was filmed from a slightly elevated angle above and behind the goal. Each clip lasted approximately 10 seconds and was edited to end (i.e., occluded) at a critical decision point—immediately prior to the player with the ball pursuing a course of action (e.g., shoot, pass, dribble). A blank white screen with black lines representing the field lines and ball (i.e., the occlusion image) appeared at the point of occlusion—all other perceptual information was removed (see Ward, et al., 2012). Response sheets for each trial were created that matched the image on screen.

Procedure. Participants completed 12 prediction and 12 response trials. During prediction trials, participants were asked to envision themselves as a defensive player and generate options that they were concerned the offensive player with the ball might do next. During response trials, participants were asked to envision themselves as the player with the ball and generate the options that they would consider pursuing next. Participants responded by drawing options—which consisted of any combination of players, their actions, field positions, movements, and ball position and movement—onto their response sheet using a simple notation scheme. Next, for prediction trials, they rated how likely it was that the opposing player with the ball would choose each generated option as their next move and how concerned they felt that option was to their defense. For response trials, they rated how likely it was that *they* (i.e., the participant) would pursue each generated option as *their* next move and how good they felt that option was. Because all trials were occluded at the critical decision point, no additional time was given to inspect the final image (cf. Johnson & Raab, 2003). During half of all prediction and response trials, participants were given only 10 seconds to *generate* and *mark* options on the response sheet. Time to *rate* each option was not restricted. During the remaining half of trials, no time constraint was implemented.

RESULTS

Measures. For each prediction trial, we recorded the total, task-relevant, and task-irrelevant number of options generated. To assess performance, we recorded the ability to accurately anticipate the outcome of each simulation (i.e., assign the highest likelihood rating to the actual outcome). We also also recorded other measures of performance that were potentially interesting, including the ability to generate the most threatening/concerning criterion option as determined by SMEs (irrespective of serial position/rating), rate the most threatening criterion option as being of most concern, and anticipate (albeit incorrectly) that the most threatening criterion option would happen next.

For each response trial, we recorded the total, task-relevant, and task-irrelevant number of options generated. To assess performance, we recorded the ability to select the criterion best option as the intended course of action (i.e., assign the highest likelihood rating to the best option). We also recorded other potentially interesteing measures: the ability to generate the criterion best option (irrespective of serial position/rating), and the ability to accurately rate the criterion best option as best (i.e., assign the highest quality rating to the best option).

Time constraint, performance and option generation. Paired samples t-tests were used to assess the effect of time constraint on performance. During prediction trials, no significant differences were observed between time constraint conditions in the abillity to anticipate the actual outcome (or to anticipate as the outcome the most threatening criterion option). However, participants generated significantly fewer total options under time constraint (M = 1.70, SD = 0.53) than under no time constraint (M = 1.93, SD = 0.60); $t(20) = -2.259$, $p = 0.035$. The number of task-relevant or task-irrelevant options generated across time constraint conditions did not significantly differ.

During response trials, no significant differences were observed between time constraint conditions in the ability to select the best option. As in prediction, participants generated signifcantly fewer total options under time constraint (M = 1.72, SD = 0.55) compared to no time constraint (M = 2.0, SD = 0.51); $t(20) = -2.764$, $p = 0.012$. However, unlike prediction trials, during response trials participants generated significantly reduced the number of task-irrelevant options under time constraint (M = 0.90, SD = 0.41) compared to when not under time constraint (M = 1.21, SD = 0.46), $t(20) = -2.879$, $p = 0.009$. Time constraint did not significantly affect the number of task-relevant options generated during response trials.

Correlations during prediction. During prediction trials with time constraint, there was a trend towards both the total number of options generated and the number of task-relevant options generated being positively correlated with anticipation accuracy ($r = 0.35$, $p = 0.12$; $r = 0.40$, $p = 0.07$, respectively). The correlation between number of task-relevant options generated and anticipating the most threatening criterion option as the outcome also approached significance, ($r = 0.36$, $p = 0.10$). The number of task-irrelevant options generated was not related to any measures of performance.

During prediction trials with no time constraint, the total number of options generated was not related to anticipation accuracy. There was a trend towards the number of task-relevant options generated being positively correlated with anticipation accuracy when not under time constraint ($r = 0.30$, $p = 0.19$). However, the number of task-relevant options generated was significantly and positively correlated with the ability to generate the most threatening criterion option ($r = 0.60$, $p < 0.01$), accurately rate that option as most concerning ($r = 0.59$, $p < 0.01$), and to anticipate the most threatening criterion option as the outcome ($r = 0.45$, $p < 0.05$). The generation of task-irrelevant options was significantly and negatively correlated with the ability to generate the most threatening option ($r = -0.48$, $p < 0.05$), accurately rate the most threatening option ($r = -0.49$, $p < 0.05$), and anticipate the most threatening option as the outcome ($r = -0.43$, $p < 0.05$).

Correlations during response. During response trials with time constraint, the number of task-relevant options generated was positively correlated with the ability to select the criterion best option as their intended course of action ($r = 0.63$, $p < 0.01$). Both the total number of options generated and the number of task-relevant options generated were also positively correlated with the ability to *generate* the best option ($r = 0.50$, $p < 0.05$; $r = 0.72$, $p < 0.001$, respectively). The generation of task-irrelevant options was not related to any measures of performance.

During response trials without time constraint, the number of *task-relevant* options generated was not correlated with selection of the criterion best option as their intended course. However, there was a trend towards this variable being postively correlated with the ability to *generate* the criterion best option ($r = 0.36$, $p = 0.10$). In addition, there was a non-significant trend toward both the total number of options generated and the total number of irrelevant options generated being negatively related to the ability to *rate* the criterion best option as best approached significance ($r = -0.36$, $p = 0.11$; $r = -0.37$, $p = 0.10$, respectively).

DISCUSSION

As time pressure increased, participants generated significantly fewer options during both prediction and response trials, as would be expected by current models of skilled option generation. During prediction trials, the data suggests that both types of information—task-relevant and -irrelevant options—were reduced equally. However, the correlation data provide some additional insight in this regard. In accordance with Ward et al. (2012), when under time constraint the generation of task-relevant options approached being significantly and positively related to anticipatory performance (i.e., anticipation of actual outcome and most threatening option as the outcome)—rather than negatively correlated with the total number of options as predicted by TTF. When the time constraints were removed, the strength of these correlations increased, reaching statistical significance. These data support the assertions of LTWM theory. Moreover, the provision of additional time to access the encoded representation of the situation permitted a more accurate retrieval of relevant information. These data have implications for training prediction skills: Given more time to access the encoded representation, trainees are more likely to retrieve task-relevant information more reliably. Ultimately, the goal would be to develop exercises that shift the trainee toward reliable generation of task-relevant information under increasing amounts of time pressure.

During response trials, the data suggest that the reduction in time available to process information when under time constraint resulted in the selective reduction of the amount of task-irrelevant information being generated. While this information reduction strategy appears highly consistent with the TTF heuristic—i.e., by stopping the generation of additional lower quality options—the correlation data suggest that a TTF strategy was employed only during decision making without time constraint. The observed trend was toward a negative relationship between the *total* number of options generated and generating the criterion best option (but not accurately rating or selecting the best). Counter to our expectations and the TTF prediction, when under time constraint, the number of task-relevant options generated was significantly and positively correlated with all measures of decision quality (i.e., generating the criterion best option, accurately rating the criterion best option as best, and selecting the criterion best option as their intended course of action). These data also have implications for training decision skills: If permitted more time to deliberate over their encoding of the situation, participants are less likely to generate and select the best option. Accordingly, the training goal would be to develop exercises that improve more rapid and intuitive decision making without necessarily reducing that intuition to a single option—because the number of task-relevant options generated was positively (rather than negatively) correlated with decision quality when under time constraint.

In addition to providing novel results to the field by exploring the effects of time constraint on decision making during both prediction and response, our results offer an explanation of the seemingly contradictory findings in previous research. When under no time constraint, the LTWM and TTF hypotheses provide potential mechanisms that would explain prediction and response behaviors, respectively. However, when put under time constraint, contrary to our expectations, participants shifted to a LTWM strategy during response, rather than vice versa.

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