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Decision-making and thought processes among poker players

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This study was aimed at delineating decision-making and thought processing among poker players who vary in skill-level. Forty-five participants, 15 in each group, comprised expert, intermediate, and novice poker players. They completed the Computer Poker Simulation Task (CPST) which comprised of 60 hands of No-Limit Texas Hold 'Em. During the CPST, they were asked to 'think out loud' throughout the hand. The 60 hands were broken down into two time conditions (e.g., 15 seconds and no time restriction). Findings indicated that expert and intermediate players outperformed novice players in decision-making (DM) performance. This difference was largest at later stages of the hand. Expert players reported processing more thoughts than intermediate players and novice players. Additionally, experts and intermediates reported attending to situational-relevant cues while novices focused on basic poker considerations and irrelevant cues. Contrary to research in other areas, the novice players displayed the greatest increase in DM performance during the limited time condition. The uniqueness and constraints of poker are used to explain and elaborate on the study's findings.

Keywords: expertise; poker; decision-making; thought processing

Experts in many areas (e.g., chess, sport, etc) have been found to display superior decision-making (DM) skills; especially in terms of knowledge base and procedures (McPherson, 1994). A greater knowledge base enables the performer to more quickly and accurately solve problems (Ripoll, 1991). Furthermore, skilled performers have been found to develop more flexible and detailed mental representations than less skilled performers, thus enabling enhanced anticipation and rapid adaptation to changes in the environment (Williams & Ward, 2007). In addition, experts, within their domain of expertise, are better suited to respond to novel situations because they are much better at developing new and effective strategies (Klein, 1998). While expertise has been studied in a variety of arenas, little to no research has focused on expertise in the game of poker. Due to the prevalence of poker, and the increased number of people who play poker as a career (Brunson, 2003), it is an intriguing area for research. The aim of this study was to delineate the DM processes among expert, intermediate, and novice poker players.

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Skill level differences in DM

In domains other than poker, expert performers were found to rapidly recognize and interpret complex patterns within a set of information in order to assess a situation more quickly and accurately than non-expert performers (Dreyfus, 1997). Furthermore, in situations involving the ability to recognize an opponent's actions, or recognize the solution to a given problem, experts were more accurate and rapid in problem-solving than novices (Ripoll, Kerlinzin, Stein, & Reine, 1995). Skilled soccer players were more attuned to the relative motion between players, and the higher order relational information conveyed by such motion than their non-skilled counterparts (Williams, Hodges, North, & Barton, 2006). The ability to recognize patterns was one of the strongest predictors of anticipatory skill (Williams & Davids, 1995). Perceptual–cognitive skills are also required for securing successful moves in the game of poker. For example, Fox and Harker (2006) claimed that novice players regularly are outplayed in later stages of a poker hand by more experienced players. In the early stages where little information is available, high-level and low-level players may display similar estimations of the strength of an opponent's hand. Later in the hand there is much more information available and high-level players display greater accuracy in predicting the strength of an opponent's hand. This advantage is attributed to attending to the most relevant stimuli, which in turn, trigger the appropriate response selection (Alain, 1991).

In addition to the skill-level differences in knowledge base, attention strategies, and pattern recognition, expert and novice differences in DM may be partially explained by the speed of information processing. According to hypothetical thinking theory (HTT), people consider a single mental model at one time (e.g., the *singularity principle*), focus on the model that is most relevant (e.g., the *relevance principle*), are evaluated with reference to current goals, and are accepted if satisfactory (e.g., the *satisfying principle*) (Evans, 2007). Given time to conduct deductive reasoning processes, experts are more likely to reject unsatisfactory models (Evans, 2007). In many instances, however, a complete search and evaluation of the environment is limited due to time constraints and opponent activity (Eccles, Walsh, & Ingledew, 2002). For the expert, DM is likely automatic and utilizes heuristics (McMorris & Graydon, 1996), which are based on a well-organized, domain-specific knowledge structure (Williams, 2000). For example, Klein (1998) found that expert fire-fighters rarely choose among options when working under pressure, as only one option comes to mind; the notion being that expert can more quickly assess environmental cues and make proper decisions. We expect to observe similar DM differences between poker players of varying skill-levels exposed to time pressure.

The ability to correctly alter actions in response to an opponent is believed to be a skill that develops with practice and experience, and is seen more often in expert performers (Tenenbaum, 2003). Expertise entails intuitive-based reasoning and supplants analytical based reasoning (Reyna, 2004). For these reasons, experts are better suited to respond to novel situations, as they are much better at developing new and effective strategies needed for performing skillfully (Klein, 1998). This general concept should also apply to poker players. Thus, we expect experienced poker players to engage in more thought processes and focus more of their attention on situational-relevant cues than non-experienced players.

Poker principles and rules

Poker is a complex game with countless variations. Describing all of the game's complexities is beyond the scope of this paper, but the basic goal is win more money than an opponent(s) by having a stronger hand, ranked according to a hierarchy, or getting them to fold (basically to submit) by convincing an opponent(s) that one's hand is stronger. According to Miller, Sklansky, and Malmuth (2004), successful poker playing necessitates DM that results in the greatest probability to make a profit. This is clearly postulated in Sklansky's fundamental theorem of poker (1980), where he states that any time a player makes decisions differently than s/he would if all cards were exposed, s/he loses; any time a player makes decisions the same than s/he would if all cards were exposed, s/he gains.

According to Brunson (2003), the greatest asset a true professional player possesses is his ability to adapt from game to game and hand to hand as multiple strategies are employed by opponents, and players must simultaneously adapt to each set of strategies. As poker is a game of incomplete information, its skill are based upon the ability of a player to accurately assess his/her opponents(s) hand, and adjust his/her play in a way that results in the greatest profit (for further elaboration on the role of skill in poker see Dedonno & Detterman [2008]).

Of the variations of poker, 'No Limit Texas Hold 'Em' is one of the most played (if not *the* most played), and decides the winner of the Main Event of the World Series of Poker, the largest live poker tournament in the world. For this reason, No Limit Texas Hold 'Em is used in this research. A hand of Texas Hold 'Em plays out as follows: in all, each player holds two cards known only to him/her ('hole cards'), and five face up cards ('community cards') shared with his/her opponents. Each player is dealt two cards (termed 'pre-flop'), and there is a round of betting. In a round of betting a player can 'check' (e.g., put no money in the pot [the money that can be won on the hand], but stays in the hand – this can only be done if no player has bet in the betting round), 'bet' (e.g., put money into the pot which forces opponents to put the same amount of money into the pot to stay in the hand), 'raise' (e.g., putting more money in the pot following an opponent bet, forcing an opponent to match that amount), 'call' (e.g., match the bet or raise and stay in the hand in an attempt to win the pot), or 'fold' (e.g., leave the hand, but put no more money in the pot). Then three cards are dealt face up. This is the 'flop' where all face up cards are shared by all players. There is another round of betting, another card is dealt up (the 'turn'), another betting round, a final card (the 'river'), and then the last round of betting. The winner of the hand is then determined in one of two ways. In one scenario, a player bets and is not called by an opponent(s) (i.e., all the other opponents fold), and that player wins the pot. In the other scenario, the players remaining in hand after the last betting round turn their hole cards face up and the player with the most valuable hand wins the pot.

The purpose of this study was to delineate skill-level differences in poker DM performance and thought processing. To determine if differences in DM across skill levels existed, a computer poker simulation task was utilized. Two time conditions were incorporated in order to assess skill-level differences in DM under varying levels of time pressure. To assess differences in thought processing, each participant thought out loud while completing the computer poker simulation. It was hypothesized that experts would outperform intermediates and novices in poker DM, and would focus on more situational-relevant cues while intermediates would outperform novices in these variables.

Method

Participants

Forty-five participants, 15 in each group, comprised expert, intermediate, and novice poker players. Researchers rely on peer-nominations by professionals in the same domain (Ericsson, 2006) for determining which individuals are experts. The expert players were recruited from the population of poker players that were nominated as experts by their professional peers. They averaged 13 years of play, and 39,200 hours of poker-playing experience. The intermediate players were recruited from the population of players who reported that they play poker at least once every other week and averaged 7.1 years and 1990 hours of poker-playing experience. The novice players were recruited from the non-poker playing population and averaged 2.4 years and 23.9 hours of poker-playing experience. Given these parameters, a purposeful sampling was employed.

Computer poker simulation task (CPST) and conditions

Computer programs provide methodological advantages in measuring DM behavior (Andersson, 2004). Two of these advantages are: (a) DM behavior can be reliably and accurately measured (Biggs, Rosman, & Sergenian, 1993), and (b) complex and interactive environments can be implemented (Brehmer, 1999). For this study, players competed in 60 hands of Texas Hold 'Em against nine computer opponents in every hand possessing varying poker-playing strategies. Poker hands were similar in appearance and interface to online poker programs such as 'Full Tilt Poker' or 'PokerStars'. Each player started each hand with $1000 in chips with the small blind (small forced bet to induce action in a poker hand) being $5 and the big blind (larger forced bet) was $10.

The 60 hands were broken into two time conditions (A and B) of 30 hands per condition. In the no time limit condition, players had as much time as necessary to make a decision. In the time-limited condition, players had 15 seconds to make a decision. The order of the conditions was randomized.

The most important feature of the CPST was that all hands for every player in the study were exactly the same. All hole cards for the participant and computer opponents, starting stack sizes (the amount of money each players each player has to play each hand) for each hand for the participant and computer opponents, community cards (the flop, turn, and river) were identical across players. Additionally, the computer opponents reacted in same way, given the actions of the participant. For example, if two participants made the same decisions in a hand – the computer players responded in exactly the same way, resulting in the hand playing out in identical fashions.

All player actions and computer actions were recorded for each hand. Participants were required to make a decision to fold, check, call, or raise at all stages of a hand (pre-flop, flop, turn, and river) on each hand, and the computer opponents adjusted their play accordingly. This process was completed for all 60 hands.

Performance measures

Two performance measures were used to assess players' performance. How much money a player wins or loses was used as one real-life performance measure. Over

tens of thousands of hands, the element of luck is nearly equal amongst all players, and therefore profit/loss is a fairly reliable and valid measure of performance. In this study, however, there were a small number of hands. For this reason, an additional measure of performance, which does not involve luck, was utilized. Expected value (EV) is the value of each outcome multiplied by its probability, and then summed together (Chen and Ankenman, 2006). For example, if one were to bet \$10 at 1:1 odds on a flip of a coin, the expected value would be \$0 as:

$$(\textit{Probability to win})\,(\textit{Value of outcome}) + (\textit{Probability to lose})\,(\textit{value of outcome})$$
$$(50\%)(\$10) + (50\%)(-\$10) = \$5 + (-\$5) = \$0$$

EV can only be estimated by a player in a hand, given that poker is a game of incomplete information. The goal of a poker player is to maximize their EV by guessing their opponent(s) holdings and acting accordingly, along the lines of the fundamental theorem of poker (Sklansky, 1980), described earlier. EV scores can be positive or negative, with positive scores indicating better (more profitable) decisions. In this study, EV was calculated for every poker decision in this study, given the amount of money that can be won, the amount of money that can be lost, and the probability of winning the pot given opponents' holdings, since all participant and opponent hole cards and subsequent opponent actions were known to the researchers (via post hoc simulations). For example, a bluff (making a bet when the chances of winning are slim, if an opponent were to call) can be a play with positive EV, if the opponent player were to fold, or negative EV, if the opponent were to call.

Think-aloud protocol

Verbal reports were collected to understand how players integrated knowledge and perceptual processing to make decisions (Williams & Ward, 2007). The essence of the verbal protocol is to ask the participant to give continuous verbal reports while performing a task (Payne & Bettman, 2004). For this study, participants engaged in a think-loud protocol during each hand of Texas Hold 'Em poker played. The think-aloud protocol was treated as a record of the participant's ongoing DM process, as the information verbalized represents a portion of the information currently being attended to (Ericsson & Simon, 1980).

Procedure

Participants were asked to read and sign the informed consent form. An experimenter read the instructions for the computer poker simulation task (CPST), including the directions of the think-aloud protocol. Each participant then completed a practice think-aloud protocol during which s/he engaged in a mental multiplication task. The participant then completed the 60 hands of the CPST. During the CPST, participants were asked to engage in a think-aloud protocol while deciding their choices pre-flop and on the flop, turn, and river. After the CPST, participants completed manipulation check questions. At the completion of the CPST, participants were thanked for their participation and dismissed.

Statistical analyses

Quantitative analysis

The DM performance measure of EV scores was subjected to a mixed three-way repeated measures ANOVA (RM-ANOVA), using one between subjects (BS) factor, skill-level (expert, intermediate, or novice), and two within-subjects (WS) factors: stage of play (pre-flop, flop, turn, and river), and time (no time limit or 15 seconds). The DM performance measure of profit was subjected to a two-way RM-ANOVA, using skill-level as a BS factor and time as a WS factor. Differences of means are shown in standardized unit called effect size (*ES*), which are determined by *ES = (Mi – Mj)/SDp*, where *Mi* and *Mj* are the respective means of two groups and *SDp* is the pooled standard deviation of the two groups.

Qualitative analysis

For the encoding of the think-aloud protocol, each statement was separated into a corresponding segment. One technique to analyze think-aloud protocols is to apply a formal coding scheme in which segments of the protocol can be examined and assigned coding categories which should be relevant to the processing and problem-solving of the situation (Willis, 2005). For this reason, the Poker DM Conceptual Scheme, based on the poker literature review further refined after a pilot study of Poker DM (St. Germain, 2009), was utilized to code the segments of the think-aloud protocol. The principal investigator initially coded the think-aloud protocol. A second researcher, trained by the PI and familiar with poker, coded 15 of the scripts (five experts, five intermediates, and five novices) independently. Inter-rater reliability fell within acceptable ranges (r = .82 - .91). To determine if there were skill-level differences in reported thought processing, a Chi Square test was utilized.

Results

The descriptive statistics for performance variables indicated that some variables produced distributions outside the accepted range of skewness and kurtosis (> |2.00|). To account for normality violation, the Greenhouse-Geisser correction was utilized in the RM-ANOVA tests.

Performance measure: expected value (EV)

The analysis revealed a significant skill level effect on EV, GG = .62, F (2,42) = 12.69, $p < .001$, $\eta 2$ = .38. This effect is illustrated in Figure 1.

Expert players (M = 64.95, SD = 26.95) and intermediate players (M = 47.90, SD = 21.05) performed significantly ($p < .001$) better than novice players (M = 18.90, SD = 27.42) *(ES* = 1.06; *ES* = 0.67, respectively). Expert players displayed better EV scores than intermediate players, but this effect only trended towards significance (p = .07, ES = 0.39). The analysis also revealed a significant skill-level by stage of play interaction effect, GG = .87, F (3.3.44) = 3.21, p = .02, η^2 = .13, which is presented in Figure 2.

Experts displayed significantly ($p < .05$) higher EV scores than novices at all stages of play (Pre-Flop: p = .003, ES = .75; Flop: p = .03, ES = 0.58; Turn: $p <$ .001, ES = 1.14; and River: p = .04, ES = 0.49). Effect size between experts and novices was greatest at the turn stage. It should be noted that in the pre-flop stages,

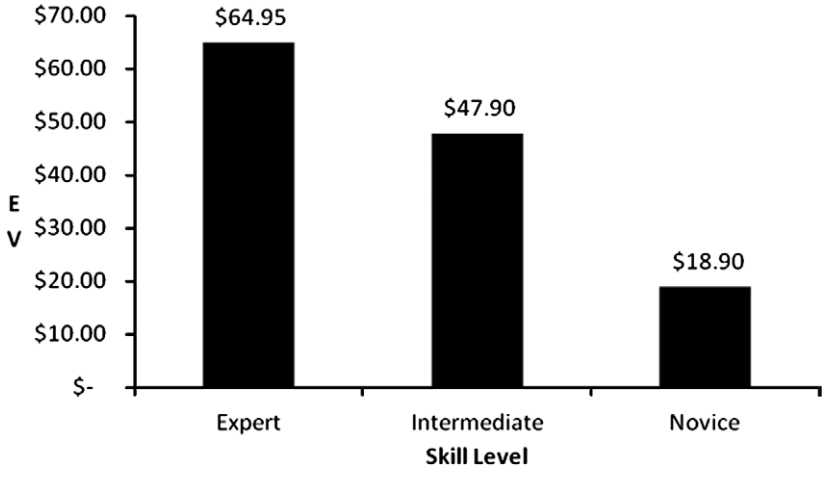

Figure 1. Mean EV scores by skill-level.

the standard deviations are very small, thus inflating the ES estimates despite the small mean differences. In addition, expert players significantly ($p < .05$) outperformed intermediate players at the pre-flop and flop stages (Pre-Flop: $p = .02$, $ES = .44$; Flop: $p = .02$, $ES = 0.47$). Also, intermediate player's EV scores were significantly ($p < .001$) higher than novice player's EV scores on the turn ($p = .001$, $ES = 0.88$).

The interaction of skill-level by time interaction effect only tended towards significance ($p =. 09$). All skill-level groups displayed higher EV scores in the timed condition. Novices displayed a large difference in EV scores between the non-timed and timed conditions ($ES = 0.91$). Expert ($ES = 0.26$) and intermediate players ($ES = 0.27$) displayed only small differences in EV scores between the non-timed and timed conditions.

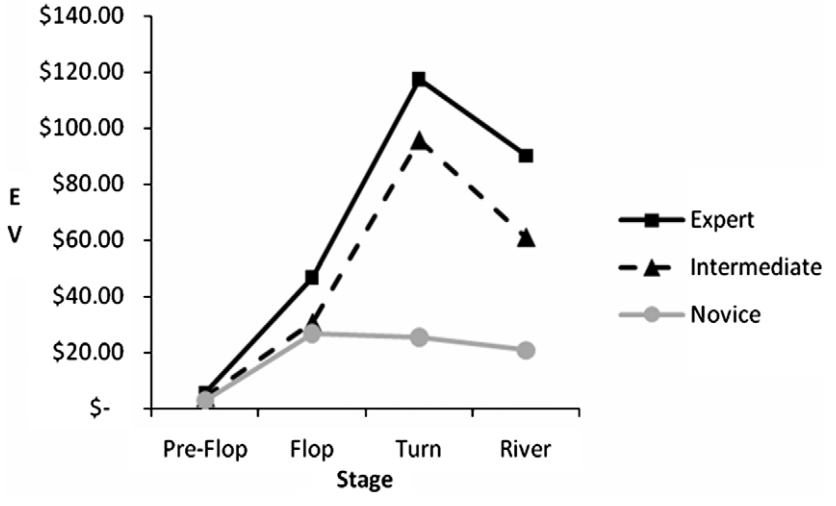

Figure 2. Mean EV scores by skill-level through game stages.

The analysis revealed a significant skill-level by stage of play by time effect, *GG* = .86, $F(3.6.48) = 3.53$, $p = .01$ $\eta 2 = .14$. This interaction is presented in Figure 3.

To further elaborate on the findings shown in Figure 3, effect sizes among the three skill-level players were calculated by stage of play for both the timed and non-timed conditions. For the non-timed condition, there were no significant differences between experts and intermediates in EV scores by stage of play. Expert players displayed significantly ($p < .05$) higher EV scores than novice players at all stages of play, other than the flop (Pre-Flop: $p = .02$, $ES = 0.53$; Flop: $p = .85$, $ES = -.04$; Turn: $p = .006$, $ES = 0.66$; River: $p = .001$, $ES = 0.81$). Effect sizes between experts and novices were slightly greater at later stages of play. Intermediate players' EV scores were significantly ($p < .05$) higher than novice players' EV scores on the turn and river (Turn: $p = .005$, $ES = 0.69$; River:

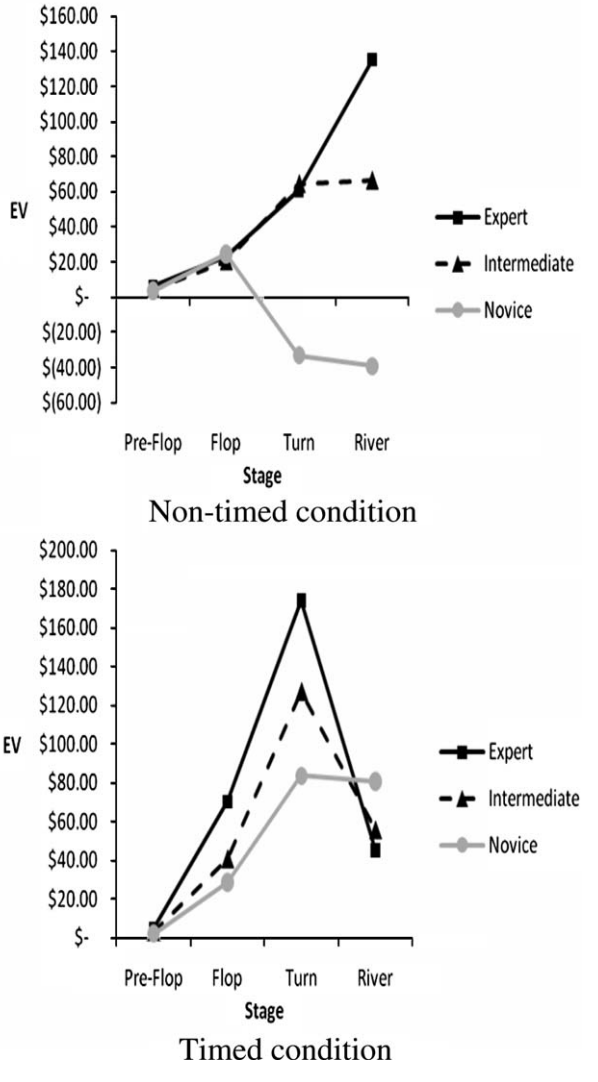

Figure 3. Mean EV scores by skill-level by stage of play for the non-timed and timed conditions.

p = .02, ES = 0.50). Differences between intermediate and novices in the pre-flop and flop stages were non-significant.

In the timed condition, there were no significant differences in EV scores by stage of play between intermediate and novice players. Expert players significantly (p < .05) outperformed novice players in EV scores on the pre-flop, flop, and turn stages (Pre-Flop: p = .003, ES = 0.71; Flop: p = .006, ES = 0.74; Turn: p = .02, ES = 0.61). Expert players also displayed significantly (p < .05) higher EV scores than intermediate players on the pre-flop and flop stages (Pre-Flop: p = .04, ES = 0.41; Flop: p = .02, ES = 0.52).

Performance measure: profit

The analysis revealed a main effect of skill-level on profit, GG = .59, F (2.42) = 14.71, p < .001, $\eta 2$ = .41. This effect is displayed in Figure 4.

Expert (M = 18.22, SD = 19.78) and intermediate players (M = 14.63, SD = 19.09) earned significantly (p < .001) more money than novice players (M = −17.26, SD = 20.26) *(*ES = 1.05 and ES = 0.94, respectively). Furthermore, the skill-level by time effect was significant, GG = .40, F (1,42) = 63.61, p = .001, $\eta 2$ = .60). Novices displayed the largest difference in profit scores between the timed and non-timed conditions (ES = 1.42). Experts (ES = 1.05) also displayed significant differences in profit scores between the timed and non-timed conditions, while intermediates displayed moderate differences in profit scores between the timed and non-timed conditions (ES = 0.50), but these differences were modest in comparison to novices and experts.

Qualitative data

The final coding broke down reported cues in five major categories (example thoughts in parentheses): (1) opponent behaviors (previous opponent actions,

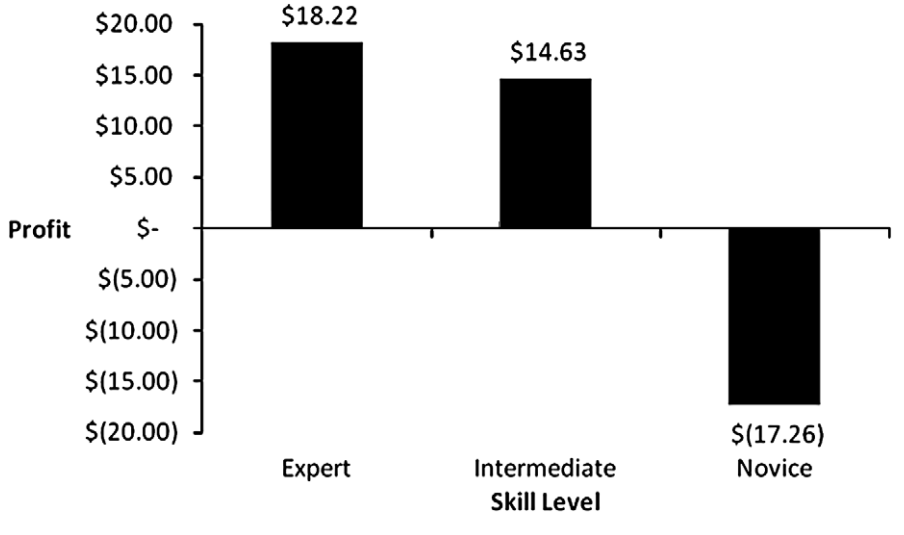

Figure 4. Mean profit by skill-level.

estimated opponent ability, styles, tells, betting patterns, put pressure on/isolate an opponent, assess opponent hand strength, future opponent actions, size of opponent chip stack, and possible opponent hands); (2) basic poker considerations (personal hand possibilities); (3) advanced poker considerations (pot odds, hand selections, size of chip stack, table position, pot building/control, number of opponents in the hand, board texture, value/protection bets); (4) self (table image, changing gears, intuition, disguising hand strength, and future actions); and (5) other (want to play, feeling lucky, not sure, favorite/least favorite hand, angry with one player, scared to raise/bet, and other thoughts unrelated to poker).

A Chi-square (χ^2) test was performed to test group differences in the number of thoughts processed within the five categories. Table 1 displays the reported thought process distribution in expert, intermediate, and novice players within each of the five categories, and the χ^2 test results.

Overall, expert players reported processing more thoughts (3012) than intermediate players (2500), who reported processing more thoughts than novice players (1412). The majority of reported thoughts processed by expert players were of the 'opponent behavior' and 'advanced poker considerations' nature. Intermediate players reported focusing the majority of their attention on three categories: 'opponent behaviors', 'basic poker considerations', and 'advanced poker considerations'. The majority of reported thoughts processed by novice players were from the 'basic poker considerations' and 'other' categories. These results indicate that there are significant differences in reported thought processing between expert, intermediate and novice players during the DM process, χ^2 (df = 8; K= 6,924; N = 45) = 2,163.91, $p < .001$.

To further examine the thought processes of poker players, reported thought processing for expert, intermediate, and novice players were inspected at each stage of play. At each stage, experts reported processing more thoughts than intermediates and intermediates reported processing more thoughts than novices. Experts, at each stage, reported focusing their attention on 'opponent behaviors' or 'advanced poker considerations'. Intermediate players reported focusing the majority of their attention on three categories: 'opponent behaviors', 'basic poker considerations', or 'advanced poker considerations'. The majority of reported thoughts processed by novice players were from the 'basic poker considerations' and 'other' categories. 'Opponent behaviors' were a focus of novices on the river.

Table 1. Reported thought processing of expert, intermediate, and novice poker players within each thought category.

Cue-type						
Skill-level	1	2	3	4	5	Total
Expert	1,132	282	1,311	264	23	3,012
	(37.6%)	(9.4%)	(43.5%)	(8.8%)	(0.8%)	(100%)
Intermediate	798	603	633	146	320	2,500
	(31.9%)	(24.1%)	(25.3%)	(5.8%)	(12.8%)	(100%)
Novice	182	585	103	33	509	1,412
	(12.9%)	(41.4%)	(7.3%)	(2.3%)	(36.0%)	(100%)

Notes. χ^2 (df = 8; K= 6,924; N = 45) = 2,163.91, $p < .001$. Cue 1 = opponent behaviours; Cue 2 = basic poker considerations; Cue 3 = advanced poker considerations; Cue 4 = self; Cue 5 = other.

Discussion

The purpose of this study was to delineate DM processes among expert, intermediate, and novice poker players. To examine DM, hands of No-Limit Texas Hold 'Em were examined at each stage of play (pre-flop, flop, turn, and river) under two time conditions. An additional purpose was to describe the thoughts process leading to the DM process, and to examine whether variations exist between expert, intermediate, and novice poker players. The study used essential DM performance measures (expected value [EV] and profit scores) in players who vary in skill-level.

Overall, expert and intermediate players displayed significantly better EV scores than novices. Experts outperformed intermediates, but this difference merely trended towards significance. In addition, expert and intermediate poker players displayed significantly higher profit scores than novices, indicating clear skill-level differences, and supporting findings in areas other than poker (e.g., Serfaty, MacMillan, Entin, & Entin, 1997; Tenenbaum, Tehan, Stewart, & Christensen, 1999). However, what are the underlying features, which make the expert, and to some extent, the intermediate players exhibit superior poker performance over their novice counterparts? The thought process derived from the think aloud protocol shed some light on this aspect. Expert players reported attending to more situational-relevant cues than intermediates, and intermediates reported thinking about more situational-relevant cues than novices. In fact, the vast majority of thoughts reported by novices pertained to their cards or thoughts not pertaining to DM (i.e., luck or curiosity). Similar to previous findings, greater attendance to the most relevant stimuli resulted in the best chance of triggering a correct response (Alain, 1991), enabling the performer to predict later events, and allowing subsequent behavior to be planned (Eccles et al., 2002; Tenenbaum, 2003). The results of this study are consistent with the existing research in sport, and with anecdotal evidence provided in the poker literature. On the turn and river, the most information is available to players, as six cards (on the turn) or seven cards (on the river) have been revealed, and there have been multiple rounds of betting which give insight to the strength of an opponent's hand. Novice players' DM performance leveled off after the flop while expert and intermediate players' DM performance increased, with experts displaying greater EV scores as they perceived large and more meaningful patterns of information in the environment; a findings reported in other domains (Abernethy, Neal, & Koning, 1994; Ericsson & Smith, 1991).

When a player takes longer than usual to make a decision it usually means that his/her choice of action is not clear. Therefore, in order to conceal hand strength/weakness, the ability to make quick decisions is advantageous in the game of poker (Caro, 2003). It was expected that under time pressure experienced poker players would display greater DM performance than novice poker players. In the non-timed condition, experts and intermediates performed significantly better than novices at each playing stage, and this difference increased as the hand progressed. In the timed condition, however, experts and intermediates displayed increasingly greater EV scores from the pre-flop stage to the flop and to the turn. On the river, expert and intermediate players' EV scores took a significant downturn while novice players' EV scores remained stable.

In situations involving the ability to recognize an opponent's actions or recognize the solution to a given problem, experts have been found to be more accurate and rapid in problem solving than novices (Ripoll et al., 1995). Under stress, a

complete search and evaluation of the environment is not possible due to time restraints and opponent activity (Eccles et al., 2002). Therefore, heuristics must be used. Previous findings indicated that heuristics used by experts are more accurate because the situation is better represented by their more extensive knowledge base while novices rely on more surface aspects of a problem (Chi, Glaser, & Rees, 1982). The results of this study confirm this notion in all stages of play, except the river. This exceptional and unexpected finding deserves further elaboration.

Stanovich and West's (2000) two-system cognitive model may provide an explanation for these findings. In the model, intuition is represented by *System 1* and reasoning by *System 2*. *System 2* must also monitor the quality of both systems (Gilbert, 2002). Experts have been found to activate higher-level complex strategies when they had to plan several actions (Poplu, Baragtin, Mavromatis, & Ripoll, 2003), such as in a poker hand, and complex decision strategies have been found to more likely produce correct decisions (Suedfeld, de Vries, Bluck, Wallbaum, & Schmidt, 1996). Novices, however, may have relied on DM processes demanding less cognitive effort than the complex strategies of the experts and intermediates (cf. Payne, Bettman, & Johnson, 1993). In the non-timed condition, experts and intermediates were given the time required to engage in more complex DM strategies and evaluative *System 2* processes. However, in the timed condition, the *System 2* processes could not occur as a complete evaluation of the hand was not possible due to time restraints. Therefore, the DM performance of experts and intermediates dropped to levels more similar to novice performance.

Additionally, novices reported mainly thinking about 'Basic Poker Considerations' and 'Other.' Adding time pressure may not have hindered the novices' performance, as they had less time to process information on the most basic poker considerations and thoughts unrelated to the poker DM process. Therefore, having less time to focus on these cues may not have a significant effect on novice poker DM. Experts and intermediates reported mainly thinking about 'Advanced Poker Considerations' and 'Opponent Behaviors' with an increased focus on 'Opponent Behaviors' on the turn and river. It can be surmised that at the pre-flop, flop, and turn stages, expert and intermediate poker players were able to focus enough attention on the relevant cues to outperform novices. On the river, however, there were too many cues to take into account in the allotted time, especially in hands where experts and intermediates had tough decisions. During the non-timed condition, when experts and intermediates found themselves in a spot with a tough decision, they tended to think about the whole hand through all four stages of play. In the timed condition, going through the entire hand was nearly impossible, which may have resulted in incorrect decisions. This observation is in line with hypothetical thinking theory. According to the singularity principle, people only consider a single hypothetical possibility at one time (Evans, 2007). Experts, however, are able to choose more optimal decisions because they complete more mental simulations as more information is available later in the poker hand. However, the short time interval allowed for decision-making was too constrained for the experts to take advantage of the additional information that would aid in the DM process. As a result, their responses were similar to that of the intermediates and novices.

As this was the first study to examine skill-level differences in poker DM, it was also important to examine skill-level differences in thought processes. One of the characteristics of advanced poker play is the ability to process multiple pieces of information at one time during a poker hand (Feeney, 2000). Therefore, we

expected that high-level players would take more thought processes into account when making a decision and report thinking about more situational-relevant cues than lower level players. Indeed, expert players reported processing a greater number of thoughts than intermediate players, intermediate players reported processing more thoughts than novices, and skill-level differences were significant on all of the major categories of thought processing. Research in the scientific literature has uncovered that experts can perceive large and meaningful patterns of information in the environment (Ericsson & Smith, 1991). The ability to use signal detection strategies is important in poker, as it is a game of incomplete information. A poker player never truly 'knows' what his/her opponent holds until the opponent's cards are flipped over on the table. Therefore, taking in more information throughout a hand, should result in a greater understanding of possible opponent holdings.

While this study controlled for luck by giving all players the same cards and measuring EV scores, the number of hands may need to be increased in order to better capture skill-level differences in poker. Additionally, players were not playing for real money; while they may play similarly for real or fake money, this cannot be assumed deterministically.

This study has extended the scope of the literature on expertise and provided a springboard for the study of cognitive features associated with poker playing. To further examine the cognitive features of poker playing, additional qualitative research, such as in-depth interviews, can be utilized to dig deeper into the thought processes of poker players. In addition, No-Limit Texas Hold 'Em is but one type of poker. As this is the first study of skill-level differences in poker DM that we know of, the other poker forms need to be studied to determine if similar skill-level differences exist. Furthermore, the differences in the two major poker venues, online versus live, have yet to be examined empirically. Further research must explore the main differences (if there are any) in live versus online poker.

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