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Decision-Making and Reported Thought Processes Among Expert, Intermediate, and Novice Poker Players

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DECISION-MAKING AND REPORTED THOUGHT PROCESSES AMONG EXPERT, INTERMEDIATE, AND NOVICE POKER PLAYERS

By

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To the St. Germain Family

Glen, Karen, Sean, and Katie

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ABSTRACT

The experimental design utilized in this study tested the decision-making and reported cue utilization among poker players. Forty-five participants, 15 in each group, comprised expert, intermediate, and novice poker players. Participants completed the Computer Poker Simulation Task (CPST), comprised of 60 hands of the No-Limit Texas Hold 'Em. During the CPST, participants engaged in a think-aloud protocol in which they literally "thought out loud" throughout the hand. The 60 hands were broken into six separate conditions, two time conditions nested within three style conditions. All hole cards for the participant and computer players, and all community cards, i.e. the flop, turn, and river, were identical across players.

The DM performance measures of Expected Value (EV) and profit were subjected to Repeated Measures ANOVAs (RM-ANOVA). The think-aloud protocol was coded to determine if there were skill-level differences in reported cue utilization, using chi square analysis.

RM-ANOVAs revealed several significant ($p < .05$) effects for the DM performance variables; not all in line with the stated hypotheses. Expert players and intermediate players performed significantly better than novice players on the performance measures of EV and profit. Expert players displayed better EV scores than intermediate players, but this effect only tended towards significance.

Experts displayed higher EV scores than novices at all stages of play. In addition, expert players outperformed intermediate players at the pre-flop and flop stages. Also, intermediate player's EV scores were higher than novice player's EV scores on the turn. Intermediates scores were higher than novices on the river, but this difference was not significant.

All skill-level groups displayed higher EV and profit scores in the timed condition. Novices displayed a large difference in EV scores between the non-timed and timed conditions, while expert and intermediate players displayed only small differences. Experts and novices exhibited large differences in profit scores between the timed and non-timed conditions, with novices displaying the greatest difference. Intermediates displayed moderate differences in profit scores, but these differences were modest in comparison to novices and experts.

In the non-timed condition, expert players displayed higher EV scores than novice players at all stages of play, other than the flop. Intermediate players' EV scores were higher than novice players' EV scores on the turn and river. In the timed condition, expert players

outperformed novice players in EV scores on the pre-flop, flop, and turn stages. Expert players also displayed higher EV scores than intermediate players on the pre-flop and flop stages.

To examine differences in EV scores between the time and non-timed conditions for each skill group by stage of play, effect sizes were calculated. Experts displayed larger EV scores in the timed condition in the flop and turn stages but performed better on the river stage in the non-timed condition. Intermediates displayed higher EV scores in the flop and turn stages in the timed condition. In the turn and river stages, novices displayed a large difference in EV scores between the timed and non-timed conditions, in favor of the timed condition.

Considering the think-aloud protocol, expert players reported processing more thoughts than intermediate players, who reported processing more thoughts than novice players. 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.

Overall, expert and intermediate poker players outperformed novice players in DM performance. This difference was largest at later stages of the hand. This can be attributed to greater attendance to the most relevant stimuli, which has the best chance of triggering a correct response (Alain, 1991), and enables prediction of later events allowing subsequent behavior to be planned (Eccles et al., 2002). Experienced players outperformed novices in all styles conditions, which infers that the ability of experts to make better decisions is useful against any opponent style. In the timed condition, contrary to research in other areas, the novices displayed the greatest increase in DM performance. Experts have been found to activate higher-level complex strategies when they had to plan several actions (Poplu et al., 2003). In the non-timed condition, experts and intermediates were given the time required to engage in more complex DM strategies and evaluative DM processes. However, in the timed condition, the initial heuristically-based decisions may have been distorted, and due to time constraints evaluative processes could not occur.

INTRODUCTION

Poker has become a very popular game with over 80 million people in the United States alone reporting playing the game at least once a month (Story, 2006). Millions of dollars are won and lost every year in casinos and private home games, and some professionals play poker throughout the calendar year. The extent of the popularity of poker can also be seen in the bid to make poker an Olympic event in London in 2012, as it meets the requirements of being played in at least 75 countries and four continents (Hubbard, 2005). One poker author has mused that "years ago, the player with the most courage and best intuition prospered. Those things are still important, but the scientific age has come to poker" (Brunson, 2003). However, little research has been devoted to areas that could increase poker performance and most of the studies have focused on the pathology of compulsive gambling. With the increased number of people who play poker as a career (Brunson, 2003), empirical research is required to better understand the differences between high-level and low-level poker players. One area of particular interest is the subject of decision-making (DM).

Functional DM processes are one requirement of successful poker play. 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). This statement echoes the sentiments of scholarly research on the DM processes of athletes. Experts have been found to display superior DM skills, especially in terms of knowledge base and procedures (McPherson, 1994). These processes allow experts to more quickly and accurately solve problems (Ripoll, 1991) and anticipate the actions of opponents (Ericsson, 1996). 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). However, this relationship has yet to be studied in the arena of poker.

The next chapter includes an overview of the rules of poker (specifically Texas Hold 'Em), as well as a review of the requirements of overall poker performance, particularly the variables, which are relevant for poker DM processes. Next, the DM literature is reviewed and is followed by a review of expert and novice differences in DM. Throughout the literature review, implications for poker performance are discussed and elaborated. Based on the theoretical conceptualization, working hypotheses were derived and presented at the end of the next chapter. The second chapter consists of a research methodology designed for testing these hypotheses.

The third chapter presents the results of the study. The final chapter is comprised of a discussion of the results, study limitations, and possible future research.

CHAPTER 1
LITERATURE REVIEW

Poker Rules and Requirements

Poker is a complex game. There are countless variations, which present different challenges and require assorted strategies. Of the variations, "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, which is the largest poker tournament in the world.

Doyle Brunson, considered one of the best poker players in the world (Munchkin, 2003) described a hand of Texas Hold 'Em as follows:

> Each player is dealt two cards. There is a round of betting. Then three cards are dealt face up. This is the "flop" and all 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. In all, each player holds two cards known only to him and five face up cards shared with his opponents. The best five-card combination of the seven cards constitutes each individual's hand (Brunson, 2003, p. 54-55).

Each hand is played with a standard deck of cards, which consists of 52 cards, with four suits (clubs, diamonds, hearts, and spades) and 13 values per suit (2, 3, 4, 5, 6, 7, 8, 9, 10, jack, queen, king, and ace; Sagristano, Trope, & Liberman, 2002). The winning hand is based upon which set of cards has the most value. The strength of card combinations are based on the odds of obtaining the combination (three of a kind is less common than a pair and is therefore more valuable) and the value of the individual cards (a '2' valued the lowest and an 'ace' valued the highest).

There are many variables involved in successful poker performance, which include many psychological and strategic variables (Brunson, 1978). Many books and magazine articles have focused on these areas, but for the purpose of this dissertation, the focus is on the necessary components of the DM process for poker players. A conceptual scheme of these components is shown on the following page (Figure 1). This conceptual scheme is based on the poker literature review further refined after a pilot study of Poker DM (St. Germain, 2009).

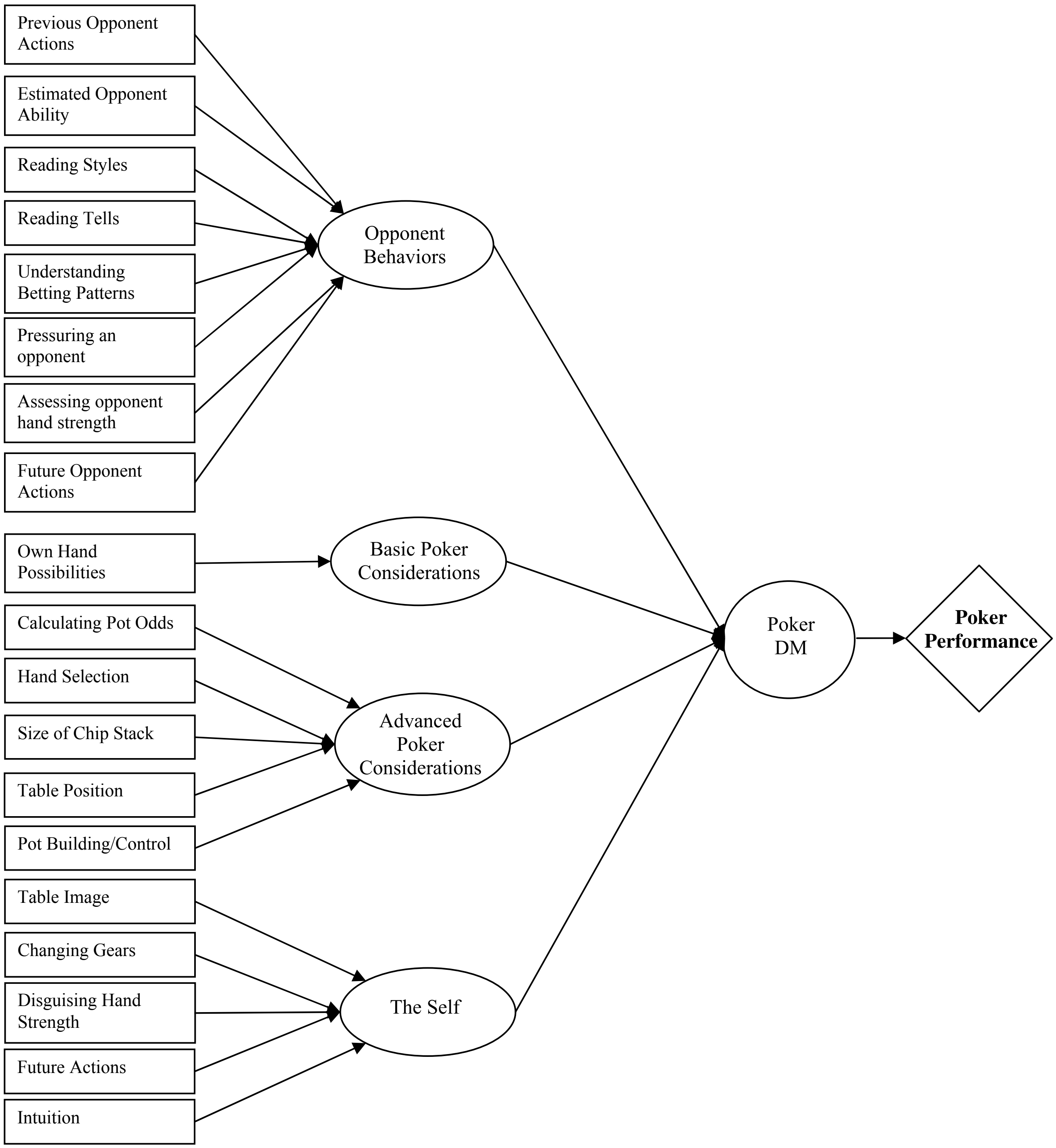


Figure 1. Poker DM Conceptual Scheme

Components of the Poker DM Conceptual Scheme

There are four main DM components that comprise this conceptual scheme: Opponent Behaviors, Basic Poker Considerations, Advanced Poker Considerations, and The Self. Each of the components has sub-components, which are described shortly. All of these components and sub-components may be involved in a decision that is made while playing a particular hand of poker and are moderated by the variable of poker playing experience. In theory, correct DM should be related to successful poker performance.

Component I: Opponent Behaviors. The first component of the conceptual scheme, Opponent Behaviors, is comprised of eight items: Previous Opponent Actions, Estimated Opponent Ability, Reading Styles, Reading Tells, Understanding Betting Patterns, Pressuring an Opponent, Assessing Opponent Hand Strength, and Future Opponent Actions. The component of Opponent Behaviors is of particular importance to poker authors who advise players to play not just their cards, but also their people (Brunson, 2003). The first sub-component is Previous Opponent Actions. For many opponents, the best way to predict future behaviors is to pay attention to how they play (Fox & Harker, 2006). From a collection of previous behaviors, players may get a better idea of how a particular opponent plays, which should aid in anticipating his or her actions and subsequent DM.

Estimated Opponent Ability is another important part of the DM process in poker. In Doyle Brunson's *Super System* (1978), several pages of the book were focused on the separate strategies that should be utilized when playing against high-level and low-level players. In summary, he argues that against low-level players, the obvious play should be made. However, Brunson cautioned that one must mix up his or her play in order to succeed against a high-level player. This means that, at times, a player needs to make the obvious play but also must alternate plays at other times in order to confuse the high-level opponent. Therefore, estimating the ability level of an opponent should be considered in the DM processes of successful poker plays.

There are additional components to consider in an opponent: *tells,* opponent mannerisms that give an indication to the strength of his or her hand, and an opponent's style, or general approach to the game (Brunson, 1978). According to poker literature (Brunson, 1978; Feeney, 2000; Fox & Harker, 2006), it is vital for poker players to determine an opponent's style and adjusting play accordingly. There are two main continua that can be used to determine an opponent's style: Passive/Aggressive and Loose/Tight (Schoonmaker, 2000). *Passive* opponents are known mainly for checking an unopened pot (e.g., a pot that no one has bet or raised the big blind), calling opponent bets, and will rarely raise (increasing the amount of money required for a player to stay in a hand). *Aggressive* players, on the other hand, are known to bet into unopened pots, raise regularly, and re-raise often. Loose players are known to play a variety of cards, while tight players tend to play hands of high value. Where an opponent sits on these two continua is vital to the success of DM in poker (Schoonmaker, 2000). In addition, players must adjust to the different styles of all of their opponents, which requires constant adaptation of play and depends on which players are in the hand.

Being able to read tells is another useful tool of the successful poker player. A tell is a habitual mannerism of a player in a particular situation that gives an indication of the strength of an opponent's hand (Brunson, 1978). The spotting of tells is discussed in many books and is the main focus of *Caro's Book of Poker Tells* (2003). The intricacy of reading tells is beyond the scope of this dissertation. However, it is important to note as a general rule, if an opponent acts strong, s/he probably has a weak hand and vice versa (Caro, 2003). The assessment of tells is much less important in poker played online, as players cannot actually see one another.

Understanding the betting patterns of an opponent is also useful when appraising what cards s/he may have. The amount of the bet, in relation to the pot, and the timing of an opponent's bet can provide further insight into the strength of his or her hand.

Pressuring an opponent keeps the opponent off guard and allows a player to control the hand. Brunson (1978) recommends that players should keep "hammering away" at their opponents. According to Brunson, this causes the opponent(s) to become afraid of playing back (betting or raising) at the original raiser. This allows the raiser to pick up many pots, some in which the original raiser will have the worst hand.

As poker is a game of incomplete information, assessing hand strength is important in poker DM. By investing in an early raise to gain information on the strength of the opponents' hands, players can save themselves more money in later stages of the hands (Sklansky, 1980). They can then evaluate the merits of their own hand to the perceived strength of the opponent's hand.

Players should take possible future opponent actions into account when making a decision. A call of a raise on the flop may be considered a good call if the opponent does not bet on the turn or river. However, the same call could be considered a bad call if a player assumes the opponent will bet on the turn and river.

Component II: Basic Poker Considerations. The second component of the Poker DM Conceptual Scheme, *Basic Poker Considerations*, contains one sub-component: Own Hand Strength. Understanding the strength of one's hand is the basic skill of a poker player. Unless a player understands the rules and the value of the cards, successful DM may not be possible. Furthermore, Own Hand Strength is one aspect of Hold 'Em that requires no special qualities, but it gives players much trouble. It is the simple matter of reading the board and relating it to one's hand correctly (Brunson, 1978). Therefore, if a player misreads or does not fully understand the complexity of a flop, turn, or river in Texas Hold 'Em, an incorrect decision could easily be made.

Component III: Advanced Poker Considerations. The third component of the Poker DM Conceptual Scheme, *Advanced Poker Considerations*, contains five sub-components: Calculating Pot Odds, Hand Selection, Size of Chip Stack, Table Position, and Pot Building/Control.

Pot odds are a consideration that must be taken into account when making a poker-related decision. There are some situations in which a player may determine that s/he currently have the worst hand, but making a call would be the correct decision based upon the size of the pot and the odds of a card coming that would make his or her hand a winner. Consider the following situation: A Texas Hold 'Em pot contains $80 before the flop. After a flop, which contains the Ace of spades, 9 of spades, and 2 of hearts, Player A bets $10. Player B holds the King and 8 of spades. In this scenario, Player B has approximately 4 to 1 odds of "catching" another spade on the turn to complete his or her flush (given that no other players have folded a spade). Even if he or she thinks that Player A has a better hand, Player B would be justified to call (match the bet in order to stay in the hand) in this situation because he or she is receiving 9 to 1 odds (risking $10 to win $90). Even though the odds are against catching the spade, if the player made this call, over time, he or she would show a profit.

Another aspect of Texas Hold 'Em is *hand selection*. Many books (Fox & Harker, 2006; Warren, 2003; amongst others) have stressed the importance of refraining from playing too many hands. This is important, mathematically speaking, because the better hand pre-flop tends to be the better hand post-flop, after the turn, and after the river (Warren, 2003). Therefore, playing premium hands will tend to result in winning more money. This seems to be of particular importance to novice players who can be regularly outplayed after the flop by more experienced players (Fox & Harker, 2006).

The size of the chip stack is another variable in the DM process of poker players. In general, the more chips a player has on a table, the more power he or she has. This allows the player with the bigger chip stack to make bets that force other players to wager all of their chips. This move subsequently puts more pressure on the opponent, while the player with the big stack is only wagering a portion (albeit, at times, a large portion) of his or her chips. Doyle Brunson (1978) mentioned that he does not like to play in a game of Texas Hold 'Em unless he can buy-in (initial amount of money purchased for play in a particular poker game) for more than or equal to the biggest chip stack.

Table position (where a player is on a hand in relation to the deal) is vital to every hand of Texas Hold 'Em. Brunson (1978) suggested that, if a player had position (is the last to act on a hand) all night, they could beat the game and win a lot of money even if they weren't the best player at the table. This is due to the fact that a player with position has some amount of information on every player when he or she is forced to make a decision. In this instance, all the players in the hand have made some indication of the strength of their hand by checking, betting, raising, re-raising, or folding before the player in position has to make any indication on the strength of his or her hand. Furthermore, this scenario requires each player to adapt their play to their position of every hand.

The final sub-component of Advanced Poker Considerations is pot building/control. According to Joey Hawthorne in *Super System* (1978), most poker players are continually looking for a reason to get more money into a pot, termed "pot building." Another aspect of controlling the size of the pot is termed "pot control." A player can keep the size of the pot down by betting, and subsequently controlling the size of the bet, rather than calling an opponent's bet (Kim, 2008). The desire to build or control the pot varies on the strength of a player's hand and the skill-level of his or her opponents.

Component IV: The Self. The fourth component of the Poker DM Conceptual Scheme relates to the individual poker player and contains the sub-components of *Table Image*, *Changing Gears*, *Disguising Hand Strength, Future Actions,* and *Intuition*. Table Image is related to the continua of poker style of Aggressive/Passive and Loose/Tight described in Component I. In this component, however, the player is the focus rather than the opponent. In order to make correct decisions, a player must understand how the rest of the table views him or her in relation to the two style continua (Schoonmaker, 2000). If a player plans to bluff, he or she must first appear to be a tight player (Brunson, 1978). Furthermore, if a player has a loose/aggressive image, he or she must realize that other players will call their bets more often because opponents may guess that he or she is bluffing. To counteract the effects of opponents adapting their play to one's table image, he or she can often *change gears.*

Changing Gears is defined as adapting one's play in order to confuse the opponents. Poker is a dynamic game because one may face an identical situation twice against the same opponent, handle it two different ways, and be right both times (Brunson, 1978). By adjusting one's play, it forces the opponent to adjust on the fly, which, may result in incorrect decisions on their part. In fact, Brunson (2003) stated that one of the biggest secrets a true professional player possesses is his ability to adapt (change gears) from game to game and hand to hand.

Disguising one's hand is an important tool in a poker player's toolbox. Brunson (1978) recommended a style of poker that is very deceiving, which in turn may befuddle the opponent. Any time the opponent is in a confusing situation, the deceiving player has a decided advantage. In addition, according to Sklansky's Fundamental Theorem of Poker (1980), any time an opponent plays differently than he or she would if all cards were exposed, s/he loses. Therefore, if a player has successfully disguised his or her hand, it is more likely that an opponent will violate the Fundamental Theorem of Poker.

When making a decision in poker, a player also takes into account his or her possible future actions. For example, Sklansky (1980) discussed making a bet in position when a player has a straight or flush draw. The purpose of this move, in some cases, is to encourage the opponents to check after the turn, which will allow the original better to check if s/he misses his or her draw, in essence, getting a "free card". In addition, other poker authors (Fox & Harker, 2006) mentioned calling a bet on the flop, even without a good hand, with intentions of betting or raising on the turn or river if a particular card comes up on the board (i.e., a card that completes a flush draw) in order to win the pot.

Intuition is another aspect of the self in poker DM. When a poker decision is so close that a player cannot use scientific poker knowledge to resolve it, many professionals generally go with their feelings (Brunson, 2003). This is mainly due to the fact that many professionals assume this "feeling" is actually a rapid analysis of conscious and sub-conscious processes

(Brunson, 1978). This assumption concurs with the psychological literature. When high levels of skill are acquired through practice, expert decision-makers often perform better when they trust their intuitive judgments, as opposed to detailed analysis (Gigerenzer & Goldstein, 1996; Klein, 2003).

Scientific DM Literature

Decision-making (DM) is the process in which an individual selects one action from an assortment of possible actions within a specific situation (Tenenbaum, 2004). The making of decisions, including those made in poker, is often difficult because of uncertainty and conflict (Shafir, Simonson, & Tversky, 1997). DM processes become more difficult with more alternatives, multiple contingencies, and multiple conflicting dimensions of value (Payne, Bettman, & Johnson, 1997). Many theories have been postulated and researched. However, there is no single, universally endorsed theoretical framework that researchers use to organize and guide their efforts in studying DM (Goldstein & Hogarth, 1997). A complete review of the entire catalogue of DM theory is beyond the scope of this literature review, but a thorough overview of DM theory and sport-specific DM theory is put forth in this chapter. Expert and novice differences are illustrated and implications for DM in poker are discussed throughout the review of scientific literature.

Utility Theory

Utility Theory, one of the first approaches to studying DM was developed in the domain of economics. The seminal work by von Neumann and Morgenstern's *Theory of Games and Economic Behavior* (1944), included a discussion on the concept of *utility*. According to Utility Theory, decision-makers attempt to maximize subjective expected value (Tenenbaum, 2004; Over, 2004). In other words, the option that will be chosen is the one that best helps an individual achieve his or her goals and does the most good (Baron, 1996; Baron, 2004). One application of this approach accounted for some gambling behaviors, including some seen in poker, in which unknown parameters necessitated a probabilistic estimation of expected value (Tenenbaum, 2004).

Maximization of expected utility requires a person to process all relevant, problem-specific information and to trade off values and beliefs (Payne et al., 1997). Despite the appeal of Utility Theory, these types of models were largely unsuccessful due to a lack of ecological validity (Tenenbaum, 2004). March (1994) observed that decision-makers do not take into account all consequences for their actions, focusing on some aspects and not others. Instead of having a complete set of preferences, decision-makers have incomplete and inconsistent goals, not all of which are taken into consideration at the same time. In addition, in situations with time pressure, decision-makers may be not given the amount of time necessary to take all problem specific information into account.

Expected-utility theory deals with decisions under uncertainty, cases in which outcomes are broken down into parts that correspond to outcomes in different states of the world (Baron, 2004). According to this theory, the overall utility of an option is the utility averaged across various possible states, with the outcomes weighted according to the probability of the states (Baron, 2004). The expected utility of an option is computed by multiplying the utility of each outcome by its probability and then summing across all possible outcomes. This is similar to the concept of expected value in poker. If the expected utility/expected value is more than $0, it is considered to have a positive expected value and is generally considered a good play. If the expected utility/expected value is less than $0, it is considered to have a negative expected value and is generally considered a poor play. The greater the expected value, the better the play. In judgments under uncertainty, some information must be ignored; the art is distinguishing between relevant and irrelevant stimuli (Gigerenzer, 2004). This is especially important in poker, as some actions are designed to fool an opponent while other actions provide insight into the strength of an opponent's hand.

Early utility models imply that choices can be modeled as always favoring the alternative with the highest expected utility (Goldstein & Hogarth, 1997). However, many individuals consider more items than expected value in making a decision, and these additional components must be taken into account (Tenenbaum, 2004). In particular, individuals make decisions based on beliefs or desires (Over, 2004). For example, some poker players may make calls or raises in situations in which they normally would not if they are angry or want to "get back" at one particular player.

Many models of DM, including Utility Theory, adhere to the following premise: good reasoning must adhere to the laws of logic, the calculus of probability, or the maximization of expected utility; if not, there must be a cognitive or motivational problem (Gigenrenzer, 2004). However, these models do not describe how people actually make decisions. In these models, all relevant information is assumed to be available with sufficient time to process all information.

Herbert Simon (1955) argued that the utility theory is beyond the scope of an individual's cognitive capacity and introduced Bounded Rationality (Goldstein & Hogarth, 1997). Bounded rationality tries to answer the question: how do humans behave under conditions in which time and knowledge is limited (Gigerenzer, 2004)? The term "bounded" can refer to the constraints in the environment, such as information costs, and to constraints in the mind, such as limited memory (Todd, 2001). Simon (1995) suggested that individuals use heuristics to achieve bounded rationality and will choose the first alternative to achieve a minimum criterion as opposed to choosing the optimal choice after accounting for all factors, which is termed "satisficing" (Goldstein & Hogarth, 1997; Over, 2004). Along these lines, Slovic (1975) has found that, when faced with equally attractive options, individuals will choose the alternative that is superior on the most important dimension. This phenomenon has been seen in the domains of choosing between college applicants, auto tires, baseball players, and routes to work (Slovic, 1975).

Heuristics and Biases

Normative models must be understood in terms of their role in looking for biases, understanding these biases in terms of descriptive models, and developing prescriptive models (Baron, 1985). Researchers in the early 1970s reported that extensive exposure, experience, and skill-level are associated with task-specific capabilities that enable a decision-maker to utilize techniques to integrate information beyond cognitive constraints (Tenenbaum, 2004).

In some cases, it may not be beneficial to take all possible cues and outcomes into consideration during the DM process due to high cognitive overhead (Over, 2004). In instances such as these, individuals can make better decisions by relying on heuristics (Gigenrenzer, 2004). Heuristics can be efficient because they are applied relatively effortlessly and with reasonable levels of reliability (Over, 2004). The use of heuristics, as opposed to taking all cues into account, can be justified because it helps an individual complete two goals: a final decision that is productive for the individual and making this decision without expending too much time and energy (Over, 2004).

The research approach known as heuristics and biases, started by Tversky and Kahneman (1974), has been highly influential in shaping the field of judgment and DM (Keren & Teigen, 2004). A number of heuristics are utilized in order to quickly assess the environment and make decisions. One important simplification of DM, proposed by Simon (1955), is to stop the searching for other options once a satisfactory solution, albeit possibly not optimal, is found.

However, almost any heuristic is bound to fail under some conditions (Kahneman, 2000; Keren & Teigen, 2004). Even if this is a rare occurrence for a particular heuristic, it could prevent an individual from reaching an important goal (Over, 2004). The importance of this goal can range from minor importance, such as losing a hand of poker, to vital importance, such as staying alive. In general, these heuristics are useful but at times lead to systematic errors (Tversky, 1969; Tversky & Kahneman, 1974). Judgments are considered to be mediated by a heuristic when an individual assesses a target attribute of an object by utilizing a related heuristic attribute that comes to mind easily (Kahneman & Frederick, 2002). Current views (Kahneman & Frederick, 2002) seem to suggest that mechanisms underlying heuristics are automatic and do not operate under an individual's awareness. People hardly ever make a conscious decision about which heuristic to use, but they quickly and unconsciously tend to adapt heuristics to changing environments, providing there is feedback (Payne, Bettman, & Johnson, 1993).

Several authors have questioned the ecological validity and logical soundness of the heuristics and biases approach (Cohen, 1981; Gigerenzer 1991, 1996), and even the originators of this approach have changed their perspective and suggested new interpretations (Kahneman & Frederick, 2002). When high levels of skill are acquired through practice, expert decision-makers often perform better when they trust their intuitive judgments, as opposed to detailed analysis (Gigerenzer & Goldstein, 1996; Klein, 2003).

The Information-Processing Approach

From the mid-twentieth century on, the information-processing approach has been a theoretical framework for a vast array of research in DM (Payne & Bettman, 2004). One of the hallmarks of the information-processing approach is using trace methods to trace DM. This is in contrast to the traditional focus in normative models (utility theory, etc.) in which the focus is on what decisions are made instead of how they are made (Payne & Bettman, 2004). The task-contingent nature of DM means that people routinely violate the principles of descriptive, procedural, and context invariance traditionally assumed by economic models (Payne & Bettman, 2004).

A core idea of the information-processing approach is that conscious attention is the limited resource for decision-makers (Simon, 1978). Therefore, decision-makers are highly selective about what information is attended to and how it is used (Payne & Bettman, 2004). In addition, deliberation, or processing information, is a costly cognitive activity (Conlisk, 1996).

Individuals react to the discrepancy between information processing demands and information processing capacity in DM by selectively processing a subset of the available information and/or selectively applying that information to processes that are easier to perform (Payne et al., 1997). Furthermore, people may be unaware that their attention has been focused on certain aspects of the environment and has influenced their DM processes (Payne & Bettman, 2004). The more an individual attends to only relevant stimuli in the environment and ignores irrelevant information influences the chances of coming up with a good decision (Johnson & Payne, 1985). This is especially important in poker, as some opponent actions are deceptive while others are revealing.

Strategies for solving decision problems are acquired through experience and training (Payne & Bettman, 2004). A critical assumption of the information-processing approach to DM is that an individual possesses a "toolbox" of heuristic strategies for solving problems (Payne et al., 1993). According to Brunswik (1952), in the face of uncertainty, the perceptual system adapts to its environment, learning the intercorrelations among environmental cues and capitalizing on these intercorrelations to allow some cues to substitute for and/or predict another (Goldstein & Hogarth, 1997).The heuristic selection process for information-processing means that errors can occur, and such errors in judgment tend to be systematic and predictable (Payne & Bettman, 2004). Overall, research in this area suggests that if a decision-maker wishes to achieve both a reasonably high level of accuracy and low effort (by using heuristics), he or she must use a "toolbox" of heuristic strategies, with selection contingent upon situational demands.

Two-System Model

While there is evidence that the mind operates content-specific heuristics, in domain specific models, sometimes the mind over-rides these heuristics with content-independent, formal rules (Over, 2004).Those who are persuaded by this evidence have proposed two-system theories of the mind (Sloman, 1996; Stanovich & West, 2000).

Stanovich and West (2000) developed a two-system cognitive model (Figure 2). In the model, intuition is represented by *System 1* and reasoning by *System 2. System 1* is fast, automatic, difficult to control or modify, and often emotionally charged in process. However, content is not only based upon the current stimulation in the DM process. Conceptual representations, based upon previous experience, the present situation, and future ramifications, are quickly taken into account and create a general impression of the environment. The processes of *System 1* are nearly totally hidden from consciousness, and the output is unaffected by higher-level cognition (Over, 2004). *System 2* is slow, flexible, deliberately controlled, and constantly monitored. Much like *System 1*, conceptual representations, the present situation and future ramifications are taken into account. However, due to the slow, serial nature of this system, the initial impressions of *System 1* and other information are evaluated before a judgment is made. Finally, a judgment is deemed intuitive if it directly reflects the impression created by *System 1* and is left unmodified by *System 2*.

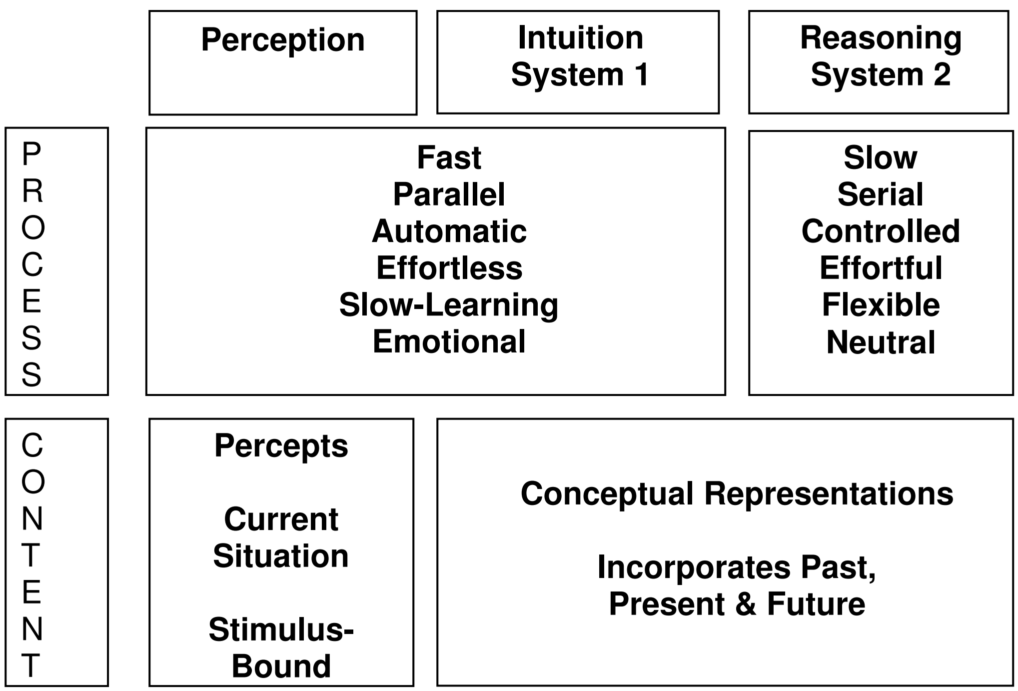


Figure 2. Processes and Content in the Two-System Cognitive Model (from Kahneman, D. (2003). A perspective on judgment and choice. *American Psychologist,* 9, 698.)

Furthermore, *System 2* must also monitor the quality of both systems (Gilbert, 2002). However, this monitoring is very lax and at many times allows intuitive judgments to be expressed (Kahneman & Frederick, 2002). According to Kahneman (2003), people rarely intensely concentrate during the DM process, and are often satisfied with expressing the decision that easily comes to mind, regardless of accuracy. Editing processes have been proposed as an important component of the DM process (Goldstein & Einhorn, 1987; Kahneman & Tversky, 1979). While Goldstein and Einhorn (1987) and Kahneman and Tversky (1979) argued that editing processes come first and then the simplified alternatives are evaluated, Payne and colleagues (1997) stated that the editing occurs throughout the DM process whenever an individual notices something in the environment that can be utilized to aid in DM. However, almost nothing is known about the editing process (Payne et al., 1997).

Therefore, according to Kahneman and Tversky (1982), errors of intuitive judgment involve failures of both systems: *System 1*, which generates the error, and *System 2*, which fails to detect and correct the error. An intuitive judgment will be corrected when *System 2* identifies bias. However, unless one has the knowledge required to identify the bias, *System 2* will not engage in the required corrective mechanisms. Therefore, experts should have a *System 2* that is more capable in identifying and correcting errors.

Naturalistic DM

According to the Naturalistic DM approach, individuals use rational and irrational processes, as well as personal values, morals, motivation, and emotion, when engaging in the DM process (Tenenbaum, 2004). From the naturalistic perspective, the DM process consists of defining a problem, seeking possible solutions, and choosing a solution (Tenenbaum, 2004). Naturalistic DM researchers set out to examine expertise in natural settings, instead of in the laboratory (Phillip, Klein, & Sieck, 2004). The goal is to study players performing tasks under conditions that are typical for one's workplace, which in poker would be at a poker table or in front of a computer. The outcome of rational DM depends on the choices of one's opponents and one's self (Plowman, 1995). This occurs many times in one poker hand, as the environment is altered after turn of a card and every decision that is made by players in a hand.

Contemporary naturalistic model focus on how people make decisions, as opposed to how they should make decisions (Tenenbaum, 2004). Naturalistic DM researchers are interested in domains that require high-stakes, time-pressured DM under conditions of uncertainty and competing goals (Phillips et al., 2004). In this instance, the domain of poker would seem to be a nearly perfect area for naturalistic DM research. These models consider the actual conditions in which decisions are made and have replaced, in large part, the mostly mechanical models previously described (Tenenbaum, 2004).

The Recognition Primed (RPD) Model

According to the RPD model, in naturalistic settings, experts rely on an extensive knowledge base to make judgments about a situation, and subsequently, how to act (Phillips et al., 2004). This model is based on observations of fire-fighting DM, in which the expert fire-fighters reported they never made decisions. Past experiences in similar situations control the DM process (Tenenbaum, 2004). In the RPD model, skilled decision-makers made sense of a situation by recognizing it as prototypical situations that they have experienced and stored in their long-term memory (Phillips et al., 2004). If the situation is familiar, the decision is intuitive and automatic. In a situation that is ambiguous or unfamiliar, the decision-makers must actively work at generating an accurate assessment of the situation. In some of these situations, once the decision-maker assesses the situation, the desired course of action becomes obvious. However, in situations in which the choice of action is not obvious, expert decision-makers envision a possible course of action and then utilize mental simulations to assess the plausibility of this choice. According to the interview data of fire-fighting DM, decisions were made; however, they were perceived by the expert fire-fighters to be just actions as other options were not compared.

Expert decision-makers, according to the RPD model, seek a course of action that is workable, but not necessarily the best or optimal decision (Phillips et al., 2004). From a practical perspective, the critical implication of the RPD model is that expertise leads to a broader and more refined set of heuristics that promote exceptional performance in specific task domains (Phillips et al., 2004).

In domains ranging from fire-fighting to system design and military command, research indicates that experts, in natural settings, use a recognition primed strategy to make decisions (Phillips et al., 2004). Observational and interview data suggest that 80-90% of difficult decisions are made in this way (Klein, 1998). However, extensive research is needed to further test, refine, and possibly reject the hypotheses of the RPD model.

Expert Skill Acquisition

Multiple theories account for the process of a performer beginning as a novice and improving his or her performance to becoming an expert. Fitts (1964) considered the process of skill acquisition to fall into three stages of development. In the first stage, the *cognitive stage*, initial encoding of a skill forms into an entity sufficient for the learner to generate a desired behavior. In the second stage, the *associative stage*, errors in the initial understanding of the skill are eliminated. The third stage, the *autonomous stage*, is characterized by continued improvement in the performance of a skill.

Anderson (1982) presented another model, which provides an explanation of the stages observed by Fitts (1964). In the first stage of Anderson's conceptual model (1982), the *declarative stage*, the learner receives instructions and information about a particular skill. In this stage, verbal mediation is frequently observed, as the required knowledge must be kept in working memory in order to be utilized in the completion of the skill. In the second stage, *knowledge compilation*, through practice, knowledge of the skill is converted from the declarative to the procedural form. In the procedural form, the skill can be performed without other interpretive procedures, such as verbal mediation. In the third stage, the *procedural stage*, the skill is further refined and is characterized by a gradual speed-up of the process of completing the skill.

Ericsson and Kintsch (1995) proposed that acquired memory skills enable individuals to utilize long-term memory (LTM) as an extension of short-term working memory (STWM) in domains in which the individual has achieved a sufficient level of practice and training. This extension is termed Long-Term Working Memory (LTWM). With domain specific practice, LTM can create domain-specific retrieval structures that can be used to enhance storage and maintain items in a more accessible state (Ericsson & Kintsch, 2005). When expertise is attained, relevant information is fed forward to LTM, and faster and better responses are selected (Tenenbaum, 2003).

According to Glaser (1996), during the process of achieving expertise, some changes occur: (1) variable performance becomes consistent, accurate, and efficient; (2) individual acts are integrated into overall strategies; (3) with perceptual learning, a focus on isolated variables is replaced to perceptions of complex patterns; (4) increase in self-reliance; and (5) ability to form new strategies as needed.

Expert DM in Sport

In sport, the DM process depends largely on the environmental conditions and rules in which an individual operates (Tenenbaum, 2004). Sport-related DM has been studied extensively over the last couple of decades (Tenenbaum, 2003), with a large portion of the research focusing on the cognitive aspects of the DM process. In most sports, an athlete must complete an extensive DM process in order to decide on a course of action. This finding in sport may also be applicable to the area of poker.

Tenenbaum (2003) set forth a generic DM process that all athletes must complete. First, an athlete must decide what stimuli to attend to. For poker players, one's cards, opponents, and the community cards comprise only a few of the cues in the environment. Also, one must decide what cues in the environment are relevant and which are not. This allows the player to anticipate what may happen next. In poker, this would include attending to opponent's behaviors and mannerisms, which aids in anticipating the moves of an opponent.

Then, according to Tenebaum's (2003) model, the athlete must make a decision based upon the present relevant information, relying on his/her knowledge base. With an increased knowledge base, long-term working memory allows experts to process information, and make a decision with high certainty (Ericsson & Kintsch, 1995). This may be observed in poker as experts may have previously been in situations affording insight into the how to play the current hand. Before executing the action, a player must decide how to execute the action and keep possible alternatives in mind. In Texas Hold 'Em, this would involve deciding whether to portray strength or weakness in order to get the desired response from the opponent(s). Finally, an athlete reviews feedback from the environment to determine DM appropriateness. This occurs in poker at the conclusion of the hand when cards are turned over and a winner is determined. It provides the required feedback for the poker player. Throughout this process, experts are more proficient decision-makers. These differences are outlined and discussed in the following paragraphs.

Expert and Non-Expert DM

When considering experts, individuals who have achieved exceptional skill in one particular domain are used as the point of reference (Phillips et al., 2004). Researchers, in some instances, rely on peer-nominations by professionals in the same domain (Ericsson, 2006) for determining which individuals are experts. Research on expertise is largely founded on the idea that experts have achieved a rare level of proficiency in a domain that non-experts never quite reach (Phillips et al., 2004).

Not all researchers, however, have reported great differences in DM accuracy between experts and non-experts. Koehler, Brenner, and Griffin (2002) showed that experts in a variety of domains were poorly calibrated for assessing probabilities. Trained clinicians and graduate students were more accurate than novices in using the MMPI to judge personality disorders, and students performed better and better with every year of training (Camerer & Johnson, 1997). While training has been shown to have an effect on accuracy, experience does not (Camerer & Johnson, 1997). In judging personality disorders, clinicians do no better than advanced graduate students. Libby and Frederick (1989) found that experience improved the accuracy of auditors' explanation of audit errors only slightly. Kundel and LaFollette (1972) reported that novices and first year medical students were unable to detect lesions from radiographs of abnormal lungs, but fourth-year students were as good as full-time radiologists. The conclusion from these studies of expert judgment in the clinical and medical domains is that experts are little to no more accurate than trained novices (Camerer & Johnson, 1997).

Expert and Novice Differences in Mental Representations

A majority of scientists researching DM have indicated that there is a significant difference between experts and novices. While engaging in DM, experts have a more active search pattern than novices, as subsets of variable are considered in each decision and in different sequences (Camerer & Johnson, 1997). Different search strategies have been found in the domains of financial analysis (Johnson, 1988), auditors (Bedard & Mock, 1989), graduate admissions (Johnson, 1980), and physicians (Johnson, Hassebrock, Duran, & Moller, 1982).

Athletes can utilize automatic and voluntary strategies for signal detection in the sport environment. Furthermore, as expertise develops, an athlete may easily shift between the two strategies, which allow the athlete to more accurately assess the dynamic environment (Nougier, Stein, & Bonnel, 1991). This is due to the fact that experts attend to the most relevant stimuli, which has the best chance of triggering a correct response (Alain, 1991). Evidence of this phenomenon has been shown in a study of volleyball players (Castiello & Umilta, 1992). In this study, players shifted their attention faster than non-players to valid cues but not to invalid cues. This advantage enables experts to efficiently assess essential cues, which aids in the DM process. This can be observed in poker: expert players may only attend to tells that pertain to the strength of an opponent's hand, while a novice player may attend to another mannerism, which may have no relevance to the poker hand.

Information processing is less costly for experts than for novices (Camerer & Johnson, 1997), as experts can perceive large and meaningful patterns of information in the environment (Ericsson & Smith, 1991). Expert waiters (Ericsson & Chase, 1981) and chess players (Chase &

Simon, 1973) have exceptional memory skills, which allow more efficient encoding of task specific information. Because DM is a skill, one's ability improves with practice (Klein & Weick, 2000).

To determine how athletes encode, store, and retrieve meaningful information, many researchers have looked for recall differences among experts and non-experts. The seminal work in this area was carried out in chess (de Groot, 1965; Simon & Chase, 1973). Differences between skill-level groups have been shown to be significant in structured situations but not in random ones. These results have been replicated in the sports of basketball (Allard, Graham, & Paarsalu, 1980), volleyball (Allard & Starkes, 1980), snooker (Abernethy, Neal & Koning, 1994), dance (Starkes, Deakin, Lindley, & Crisp, 1987), gymnastics (Ille & Cadopi, 1999), figure skating (Deakin & Allard, 1991), football (Garland & Barry, 1991), and soccer (Williams & Davids, 1995). The ability of experts to process and store much more task-specific information than their novice counterparts appear to be the cause of these findings.

In order for information processing to be efficient in the sport context, two systems must be working in tandem: a perceptual system and the long-term working memory system (Tenenbaum, 2003). The ability to detect patterns in the sport environment accounts for a large portion of DM differences between varying levels of skill (Abernethy, 1987; Gobet, 1993, Gobet cited in Poplu, Baratgin, Mavromatix & Ripoll, 2003). Several studies (for a review, see Tenenbaum & Bar-Eli, 1993) indicate that players attend to similar cues but experts display superior forecasting ability in regards to predicting the flight of a ball. These differences have been found in the sports of tennis (Jones & Miles, 1978), badminton (Abernethy & Russell, 1987), soccer (Williams & Burwitz, 1993), and ice hockey (Salmela & Fiorito, 1979).

Pattern recognition is another area in which long-term working memory allows high-level players to perform better than low-level players. In a study of soccer players, skilled players were found to be 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). This ability to recognize patterns has been suggested to be one of the strongest predictors of anticipatory skill (Williams & Davids, 1995). These findings may also be relevant in poker, as high-level players may be better able to recognize betting patterns, or other patterns of play, than low-level players. This may allow the high-level player to better estimate the strength of an opponent's hand and subsequently make a better decision.

Expert and Novice Differences in Anticipation

Exceptional experts are more accurate in DM than well-trained individuals (Camerer & Johnson, 1997). In a study by Goldberg (1959) involving organic brain damage diagnoses, a well known expert was right 83% of the time, while other clinical psychologists earning a Ph.D only got 65% correct. Chi, Feltovich, and Glaser (1980) found that expert physicists were better able to judge the difficulty of a physics problem and, in a follow-up study, Chi Feltovich, and Glaser (1981) noted that the problem features on which subjects judged difficult varied between experts and non-experts.

Experts can rapidly recognize and interpret complex patterns in a set of information in order to assess a situation more quickly and accurately than non-experts (Chase, 1983; Dreyfus, 1997). 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, Kerlirzin, Stein & Reine, 1995). Experts acquire habits that allow them to process more information through processes such as chunking and more intuitive problem solving strategies (Hogarth, 2001).

This difference between expert and novice in levels of processing has been seen in a multitude of domains. Experts in physics showed a deeper understanding of a problem, whereas novices responded in terms of superficial characteristics (Anzai, 1991). Experts have a broader and deeper knowledge base than journeymen and novices (Phillips et al., 2004), which enable the experts to better describe, explain, and predict actions in the environment (Rouse & Morris, 1986). De Groot (1965), in his study of chess players, developed the idea of *progressive deepening* to describe how players decided on their next move. Skilled players identified a small rather than broad set of possible moves. The skilled players would then simulate their opponents counter moves and their own subsequent reaction. In a study of battle commanders, Serfaty, MacMillan, Entin, and Entin (1997) found several examples of high-expertise commanders viewing situations differently than less-expert commanders. For example, high-expertise subjects were able to consider the effects of sequencing and timing of event, as well as the effects of terrain and distances in the battlefield. Experts were found to undertake greater depth of processing than novices in a study of shot planning in snooker (Abernethy et al., 1994). Experts planned (on average) six shots in advance, while novices only planned four shots ahead.

The advantage of expert DM is perceptual in nature. Ripoll and colleagues (1995) suggested expertise in boxers has more to do with detecting pertinent cues than with speed of response. Eccles, Walsh, and Ingledew (2002) observed that experts and novice orienteers used two different types of heuristics in route planning. Experts tended to start from the end and work backward, while novices did the opposite. This finding suggests that experts and novices use different planning strategies, which correspond with McPherson's (2000) results with tennis players. The key notion is that, based upon past experience, athletes develop intuitive expectations that can be confirmed or disconfirmed (Hogarth, 2001).

In DM processes, information is fed forward to the brain neural system and enhances the DM processes of expert athletes (Tenenbaum, 2003). The extended knowledge base of the expert provides a retrieval route for applying previous knowledge to the current situation (Ericsson & Kintsch, 1995). In a study by Tenenbaum, Tehan, Stewart, and Christensen (1999), the effect of experience on memory of a floor routine was examined. In this study, the older and more experienced gymnasts performed better than their younger counterparts in the recall of the floor routine. In this situation, the older gymnasts utilized well-organized, domain-specific knowledge structures in order to retrieve the required information during the DM process. This ability is consistent with the notion that they were able to access the long-term memory of the floor routine while engaging in DM. Therefore, when expertise is attained, more relevant information is fed forward to long-term memory and better responses are made (Tenenbaum, 2003).

Expert and novice differences also appear in planning and anticipation, which, in turn, affects DM. Expert decisions are considered knowledge-driven, while novice decisions are considered search-driven (Eccles et al., 2002). The knowledge-driven strategies of experts reduce the demand of processing by allowing experts to anticipate their actions (Ericsson, 1996). Because of this extensive knowledge, experts can adopt a selective set of strategies based on deep and abstract aspects of the problem (Chi, Glaser, & Rees, 1982). This allows the expert to attend to meaningful cues in the environment, which enables prediction of later events, and subsequent behavior can be planned (Eccles et al., 2002). Novice problem representations are less complex and rely on surface aspects of the problem (Chi et al., 1982). As a result, novices are less able to plan and anticipate, which in most cases, results in a decrement in performance.

In later stages of anticipation, experts have been found to be more confident in the final location of the ball than novices or intermediates (Abernethy et al., 1994; Tenenbaum & Bar-Eli, 1995). In this case, it is clear that experts have a superior knowledge of ball location, which is accompanied by high self-efficacy and results in superior response selection (Tenenbaum, 2003). One could predict similar results in the poker environment; for example, in the pre-flop stage where little information is available, high-level and low-level players may display similar estimations of the strength of an opponent's hand. However, later in the hand (after the flop, turn, or river stages) there is much more information available and high-level players should display greater accuracy in predicting the strength of an opponent's hand.

Expert and Novice Differences under Time Constraints

Expert and novice differences may be partially explained by the speed of processing. For the expert player, DM is likely automatic and utilizes heuristics (McMorris & Graydon, 1996), which is based on a well-organized, domain-specific knowledge structure (Williams, 2000). Therefore, the intuitive impressions are considered correct, and the expert can put forth more cognition towards completing the physical task. For the novice, a different cognitive process takes place, which requires increased cognitive activity (McMorris & Graydon, 1996). In this instance, there is an increased reliance on reasoning, which may limit the amount of cognition available for the completion of the physical task.

In many cases, a complete search and evaluation of the environment is not possible due to time restraints and opponent activity (Eccles et al., 2002). Therefore, in order to get a relative assessment of the situation, heuristics must be used. In this case, the heuristics used by experts are more accurate because the situation is better represented by their more extensive knowledge base (Chi et al., 1982). Klein (1998) found that expert fire-fighters rarely need to choose between options when working under pressure, as only one option comes to mind. Furthermore, Klein found that expert fire-fighters were able to look at a burning building and know what was happening. For example, they could tell from the look and location of smoke and flames how the fire was burning and where it was probably located.

Professional handball players have been found to make better decisions when they have less time (Johnson & Raab, 2003). This is similar to Klein's findings pertaining to fire-fighters. Accordingly, confirmation suggests one set of actions, while disconfirmation suggests another set of actions. The expert can more quickly assess the environmental cues and make the proper decision. These findings suggest that experts and novices are different not only in the technical skill-level but also in the perceptual skill-level.

Expert and Novice Differences in Adaptation

Hinton (1990) found that people are capable of taking frequently repeated sequential steps and transforming the steps into one intuitive sequence. Expertise develops intuitive-based reasoning and supplants analytical based reasoning (Reyna, 2004). For these reasons, experts, within their domain of expertise, are better suited to respond to novel situations, as they are much better at developing new and effective strategies (Klein, 1998).

Experts seem to represent a problem at a deeper level than novices, who are decidedly superficial in their mental representations (Glaser & Chi, 1988). Skilled performers develop more flexible and detailed representations than less skilled performers, which allow them to adapt rapidly to changes in the environment (Williams & Ward, 2007). Serfaty and colleagues (1997) found clear expert-novice differences in quality, level of detail, and flexibility of the courses of action generated.

The DM process is largely dependent on factors that are external to the athlete (Tenenbaum, 2003). Therefore, an athlete must constantly adapt one's responses in order to counter an opponent's actions. This is of particular importance in poker, as multiple styles and strategies are employed by opponents, and players must simultaneously adapt to each set of styles and strategies. This 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). In fact, Brunson (2003) states that one of the biggest secrets a true professional player possesses is his ability to adapt from game to game and hand to hand.

Hypotheses

Expert DM consists of the integration of visual-attention mechanisms, anticipatory mechanisms, and the interface of the information from these mechanisms with an extensive knowledge which allow efficient processing, response selection, and response alteration (Tenenbaum, 2003). Research in the sport arena has supported the above assertion, but no research has shown this relationship in the world of poker. The literature reviewed support in stating the following six hypotheses:

(1) Expert players would make better poker decisions than intermediate and novice players, and intermediate players will make better poker decisions than novice players, shown by higher scores on DM performance measures across all trials.

(2) Expert players would make better poker decisions at later stages of the hand than intermediate and novice players, and intermediate players will make better decisions at later stages of the hand than novice players, shown by greater improvement (or lesser decrement) in DM performance measures.

(3) Expert players would make better poker decisions in hands involving players of varying styles than intermediate and novice players, and intermediate players will make better decisions in hands involving players of varying styles than novice players, shown by greater improvement (or lesser decrement) in DM performance measures.

(4) Expert players would make better poker decisions in hands involving time pressure than intermediate and novice players, and intermediate players will make better decisions in hands involving time pressure than novice players, shown by greater improvement (or lesser decrement) in DM performance measures.

(5) Expert players would report processing more thoughts when making a decision than intermediate and novice players, and intermediate players will report processing more thoughts when making a decision than novice players.

(6) Expert players would report processing a higher percentage of situational-relevant thoughts than intermediate and novice players, while intermediate and novice players will report processing a higher percentage of irrelevant thoughts. Intermediate players will report processing a higher percentage of situational-relevant thoughts, while novice players will report processing a higher percentage of irrelevant thoughts.

CHAPTER 2
METHOD

Participants

Forty-five participants, 15 in each group, comprised expert, intermediate, and novice poker players. The expert players were recruited from the population of professional poker players. It has been noted that ten years is a sufficient amount of time to achieve expertise in a given domain (Hayes, 1985). However, experience does not necessarily bring expertise. Therefore, researchers rely on peer-nominations by professionals in the same domain (Ericsson, 2006); poker in this case. The experts included a World Poker Tour player of the year, multiple World Series of Poker bracelet winners, and multiple World Series of Poker Main Event champions and averaged 13 years and 39,200 hours of poker-playing experience. The intermediate players were recruited from the population of players who report that they play poker at least once every other week and averaged 7.1 years and 1,990 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, purposeful sampling was employed.

Computer Poker Simulation Task (CPST)

Players competed in 60 hands of Texas Hold ‘Em against nine computer players possessing varying poker-playing styles, depending on the condition. The 60 hands were broken into six separate conditions, two time conditions nested within three style conditions, of 10 hands per condition. The three style conditions consisted of the following: (1) Normal, (2) Loose-Passive, and (3) Tight-Aggressive. The Normal condition is similar to a regular poker game in that all the computer players possessed individual styles. In the Loose-Passive condition, all the computer players were loose and passive. In the Tight-Aggressive condition, all the computer players were tight and aggressive. A tight player will generally call, raise, or re-raise with only very strong hands, while a loose player generally will call, raise, or re-raise with any type of hand. A passive player is known mainly for calling, even with a great hand, or folding and raising only on rare occasions. An aggressive player is known mainly for raising and re-raising often, while rarely calling with any type of hand.

Within each style condition, two time conditions were used, no time limit (A) and time limited (B). 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. For example, Participant 1 completed the conditions in the following order: 1A, 1B, 2A, 2B, 3A, 3B. Participant 2 completed the conditions in the following order: 3A, 2B, 3B, 1A, 1B, 2A, etc. A breakdown of the conditions is shown in Figure 3.

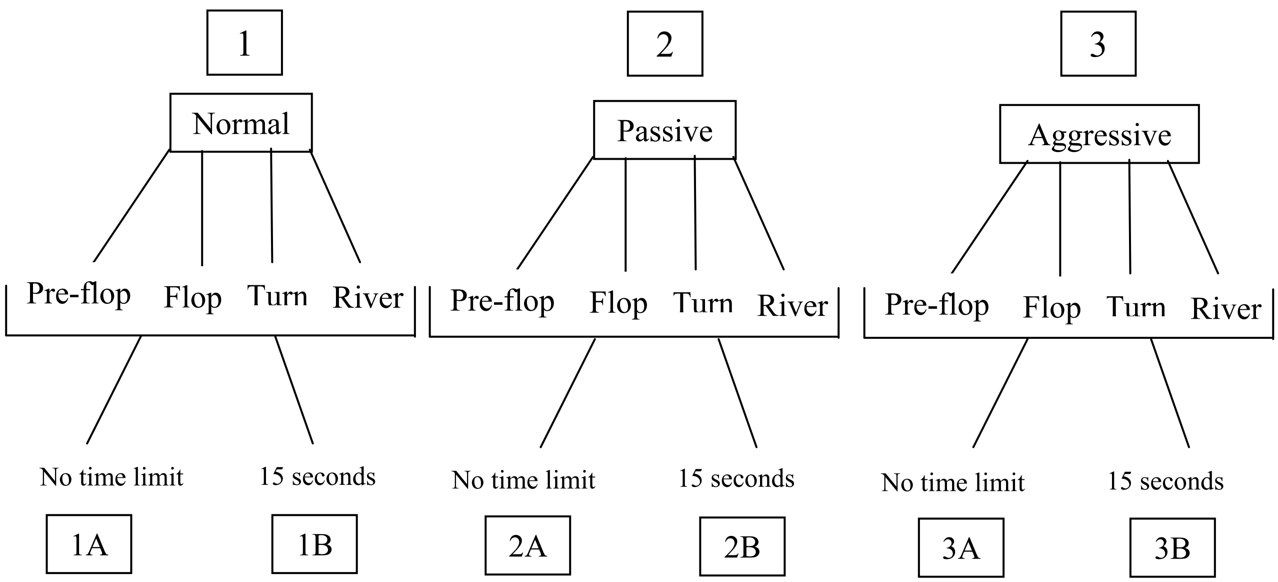


Figure 3. Computer Poker Simulation Task Conditions

Poker hands were similar in appearance and interface to online poker programs such as "Full Tilt Poker" or "PokerStars." Computer programs provide methodological advantages in measuring DM behavior (Andersson, 2004a). Two of these advantages are as follows: (a) decision behavior can be reliably and accurately measured (Biggs, Rosman & Sergenian, 1993), and (b) complex and interactive environments can be implemented (Brehmer, 1999).

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 players adjusted their play accordingly. This process was completed for all 60 hands. All hole cards for the participant and computer players and all community cards (the flop, turn, and river) were identical across players. All player actions and computer actions were recorded for each hand.

Instrumentation

Informed Consent (Appendix A). An informed consent form was used to gain written permission from the expert, intermediate, and novice poker players in terms of their participation in the study. The form described the study's purpose, benefits, and minimal risks. In addition, the informed consent form outlined the player's right to withdraw from the experiment at any time, to ask questions of the researcher, and to assure anonymity.

Poker Experience Questionnaire (PEQ; Appendix B). Players completed a short questionnaire which included questions concerning how many years they have played poker and their estimated number of poker-playing hours.

Performance measures. Two performance measures were used to assess players' performance. How much money a player wins or loses was used as one performance measure. This is a real-life measure of performance. Over 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 & Ankenman, 2006). For example, if one were to bet $10 on a flip of a coin, the expected value would be $0 as:

(Probability to win)(Value of outcome) + (Probability to lose)(value of outcome)

(50%)($10) + (50%)(-$10) = $5 + (-$5) = $0

EV can be calculated for every poker decision, given the amount of money that can be won, the amount of money that can be lost, and the probability of winning the pot. EV scores can be positive or negative, with positive scores indicating better (more profitable) decisions.

Think-Aloud Protocol

At the theoretical level, the blending of naturalistic and laboratory-based research can generate a variety of lawful relationships (Phillips et al., 2004). Decision researchers within the information-processing framework often complement an analysis of DM with the results of "process-tracing," such as verbal reports of processing during the task (Svenson, 1996). Verbal reports, when elicited with care, are a valuable and thoroughly reliable source of information about cognitive processes (Ericsson & Simon, 1980). Furthermore, the collection of verbal reports may provide an informative approach given a player's need to integrate knowledge and perceptual processing to make effective and correct decisions (Williams & Ward, 2007).

The essence of the verbal protocol is to ask the participant to give continuous verbal reports while performing some task (Payne & Bettman, 2004), playing a hand of Texas Hold 'Em poker in this case. Think-aloud statements are invaluable, as they give insight into the decision process that is not available from another source (Raynard & Williamson, 2004). Prior to completing the CPST, all players were read the think-aloud instructions (Appendix D) and practiced the protocol while engaging in a mental multiplication task. Players engaged in a think-aloud protocol during each hand. The think-aloud protocol was treated as a record of the participant's ongoing DM process, as the information verbalized will be some portion of the information currently being attended to (Ericsson & Simon, 1980).

Procedure

Expert poker players were recruited from the population of professional poker players; intermediate poker players were recruited from the population of poker players who play regularly; and novice players were recruited from the population of people who play poker occasionally. The goals and purposes of the study were introduced and followed by a request that the individual would participate in the study.

At the beginning of the study, participants were asked to read and sign the informed consent form. Participants then completed the Poker Experience Questionnaire (PEQ). At the completion of the PEQ, the instructions for the Computer Poker Simulation Task (CPST), including the directions of the think-aloud protocol, were read. The participant then completed a practice think-aloud protocol in 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 in which they literally "thought out loud" while deciding their choices pre-flop and on the flop, turn, and river. After the CPST, participants completed a manipulation check (Appendix E). 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 three-way Repeated Measures ANOVA (RM-ANOVA), using one BS factor, skill-level (expert, intermediate, or novice), and three WS factors: style (normal, loose and passive, or tight and aggressive), stage of play (pre-flop, flop, turn, and river), and time (no time limit or 15 seconds). The WS factors of stage of play and time were nested within playing style. See Figure 3 in the Computer Poker Simulation Task section for a review of the study's design.

The DM performance measure of profit was subjected to a two-way RM-ANOVA, using skill-level as a BS factor and playing style and time as two WS factors. The WS factor of time was nested within playing style.

Qualitative Analysis. For the encoding of the think-aloud protocol, each statement was separated into a corresponding segment. If monologue were completely grammatical, a segment would essentially be a clause or a sentence (Ericsson & Simon, 1993). A rigorous 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 (Willis, 2005). These categories should be relevant to the processing and problem-solving of the situation (Willis, 2005). For this reason, the Poker DM Conceptual Scheme 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 expert, five intermediate, and five novice) independently. The coding of the two raters was compared, and the percentage of agreement between them was used as a measure of reliability (Ericsson & Simon, 1993). To determine if there were skill-level differences in reported thought processing, a Chi Square test was utilized.

CHAPTER 3

RESULTS

Descriptive statistics were obtained for all performance variables including skewness and kurtosis, to check any possible deviations from normality assumptions. Means, standard deviations, and normality coefficients for performance variables are shown in Table 1.

Table 1

Descriptive statistics of performance variables (i.e., Expected Value and profit)

Variable	n	Mean	SD	Skewness	Kurtosis
Expected Value					
Pre-Flop					
Normal - Non-timed	45	14.58	3.79	1.55	4.57
Normal - Timed	45	-0.75	4.65	-4.76	27.25
L & P - Non-timed	45	-8.16	7.46	-0.95	-0.4
L & P - Timed	45	5.44	3.49	1.88	5.43
T & A - Non-timed	45	7.86	3.62	0.29	-1.26
T & A - Timed	45	5.95	4.25	0.07	-0.02
Flop					
Normal - Non-timed	45	66.85	35.85	1.82	4.87
Normal - Timed	45	-6.19	54.65	-2.02	5.26
L & P - Non-timed	45	5.38	24.53	-0.45	-0.19
L & P - Timed	45	33.82	15.18	0.53	0
T & A - Non-timed	45	-4.23	57.3	-2.02	5.26
T & A - Timed	45	112.4	77.63	2.52	8.67
Turn					
Normal - Non-timed	45	154.25	119.51	1.32	2.16
Normal - Timed	45	5.66	189.55	-0.3	3.02
L & P - Non-timed	45	-91.77	133.8	-1.59	4.21
L & P - Timed	45	91.54	97.22	1.85	4.37
T & A - Non-timed	45	26.65	188.14	-0.62	4.71
T & A - Timed	45	287.3	157.82	1.25	4.61

Table 1 (cont.)
Descriptive statistics of performance variables (i.e., Expected Value and profit)

Variable		n	Mean	SD	Skewness	Kurtosis
River						
	Normal - Non-timed	45	-32.95	204.63	0.76	4.77
	Normal - Timed	45	22.11	228.14	-0.06	2.59
	L & P - Non-timed	45	40.19	176.01	0.74	1.78
	L & P - Timed	45	124.75	88.57	0.96	1.1
	T & A - Non-timed	45	139.46	364.46	1.85	5.74
	T & A - Non-timed	45	47.42	282.68	0.36	0.91
Profit						
	Normal - Non-timed	45	-28.93	508.48	-0.68	-0.36
	Normal - Timed	45	-240.33	538.17	0.05	-0.43
	L & P - Non-timed	45	-456.38	641.92	-0.31	-0.93
	L & P - Timed	45	211.02	408.57	0.50	0.74
	T & A - Non-timed	45	-66.00	584.63	-0.17	0.49
	T & A - Timed	45	892.51	447.33	-0.94	2.79

L & P = Loose & Passive
T & A = Tight & Aggressive

The descriptive statistics for performance variables indicated that many variables produced distributions outside the accepted range of skewness and kurtosis (> |2.00|). Since sphericity cannot be assumed, the Greenhouse-Geisser correction was utilized in the RM-ANOVA tests.

EV Scores: RM-ANOVA

EV scores were subjected to a three-way RM-ANOVA using one BS factor, skill-level (expert, intermediate, or novice), and three WS factors: style (normal, Loose-Passive, or Tight-Aggressive), stage of play (pre-flop, flop, turn, and river), and time (no time limit or 15 seconds). The WS factors of stage of play and time were nested within playing style. Results of the RM-ANOVA are shown in Table 2.

Table 2
RM-ANOVA results: EV scores

Effect	G-G	F	df	*p*	η^2
A. Skill-level	0.62	12.69	2,42	<.001	0.38
B. Stage of Play	0.67	20.22	1.7,22.7	<.001	0.33
C. Style	0.7	18.15	1.7,34.9	<.001	0.3
D. Time	0.76	13.33	1,42	<.001	0.24
E. A x B	0.87	3.21	3.3,44	0.02	0.13
F. A x C	0.96	0.89	3.4,69.7	0.46	0.04
G. A x D	0.89	2.62	2,42	0.09	0.11
H. B x C	0.82	9.09	2.6,16	<.001	0.18
I. B x D	0.87	6.31	1.8,24	<.001	0.13
J. C x D	0.62	26.13	1.9,39	<.001	0.38
K. A x B x C	0.96	0.84	5.3,32.7	0.53	0.04
L. A x B x D	0.86	3.53	3.6,48	0.01	0.14
M. A x C x D	0.9	2.28	3.8,77.9	0.07	0.1
N. B x C x D	0.67	20.94	2.9,17.9	<.001	0.33
O. A x B x C x D	0.93	1.63	5.8,35.8	0.15	0.07

The effect of skill-level on EV scores was significant ($p < .001$), and is displayed in Figure 4.

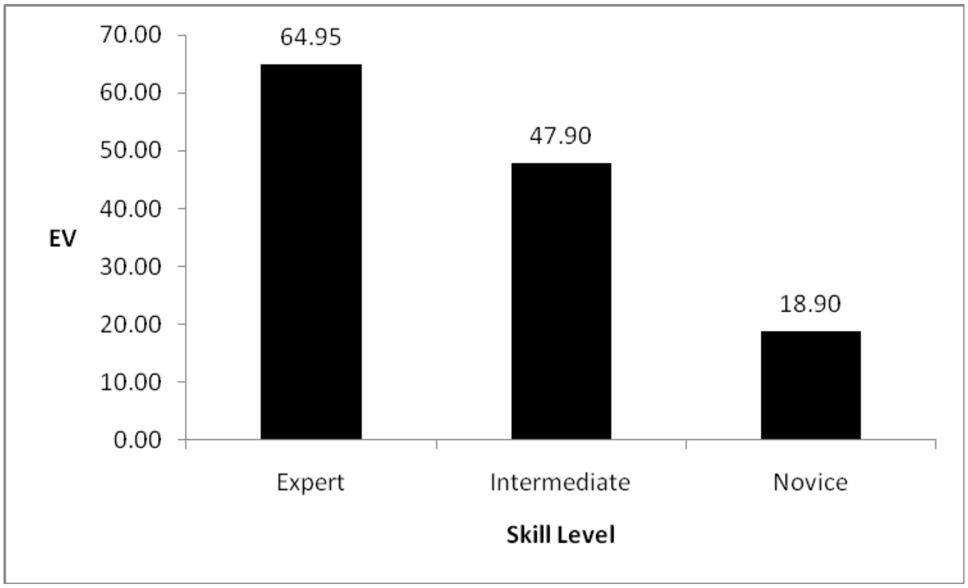


Figure 4. Mean EV Scores by skill-level

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). These results support the first hypothesis.

The significant ($p = .02$) interaction effect of skill-level by stage of play is displayed in Figure 5.

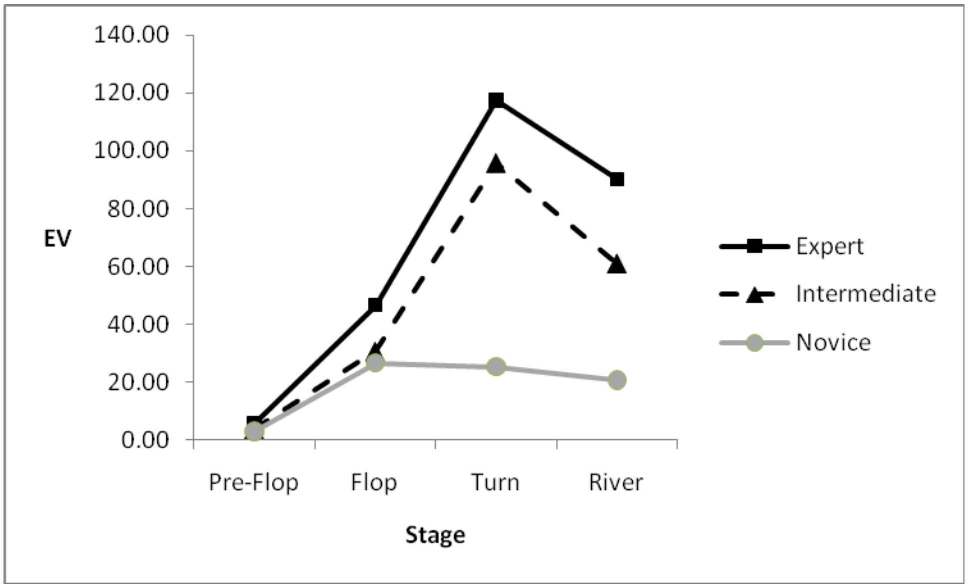


Figure 5. Mean EV scores by skill-level through game stages

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, the standard deviations are very small thus inflating the effect size estimates despite the small mean differences.

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 ($p = .001$, $ES = 0.88$).

Overall, these results provide some support to the second hypothesis postulating that expert and intermediate players make better decisions than novices at later stages of the hand, with experts displaying significantly greater improvement in DM performance, most notably on the turn. While mean differences of intermediate and novices appear to be sizable, the results are only significant on the turn stage.

The interaction effect of skill-level by style was non-significant ($p = .46$), falsifying the third hypothesis assuming skill-level differences depend on the styles of opponent players.

The interaction effect of skill-level by time tended towards significance (p =. 09). All skill-level groups displayed higher EV scores in the timed condition. Effect sizes of differences of mean EV scores between time conditions for each skill-level are displayed in Figure 6.

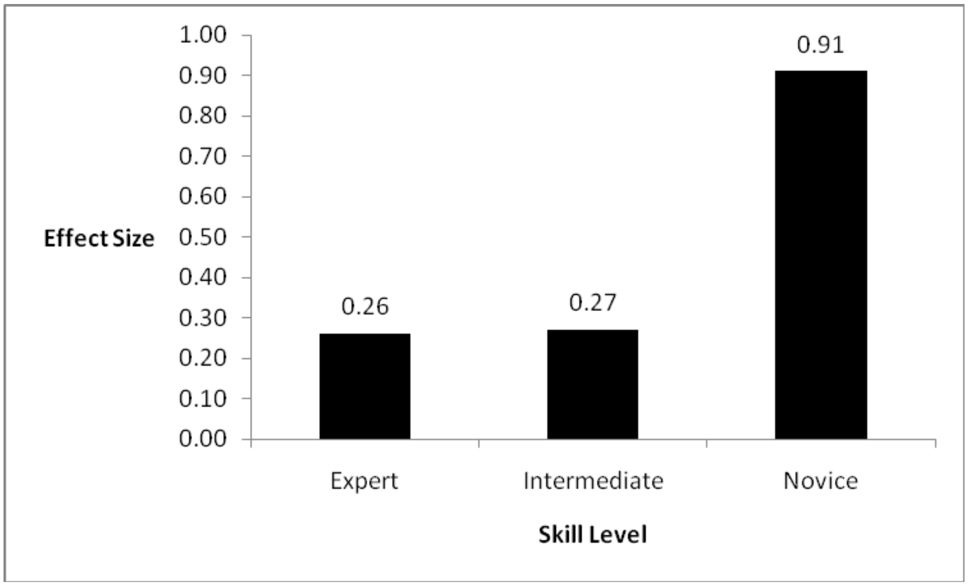


Figure 6. Timed versus Non-timed condition effect sizes by skill-level

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. These results falsify the fourth hypothesis as the interaction of skill-level and time was non-significant and the trend of the relationship is in the opposite direction of what was hypothesized.

The significant interaction effect (p = .01) of skill-level by stage of play by time is displayed in Figure 7.

Non-timed Condition Timed Condition

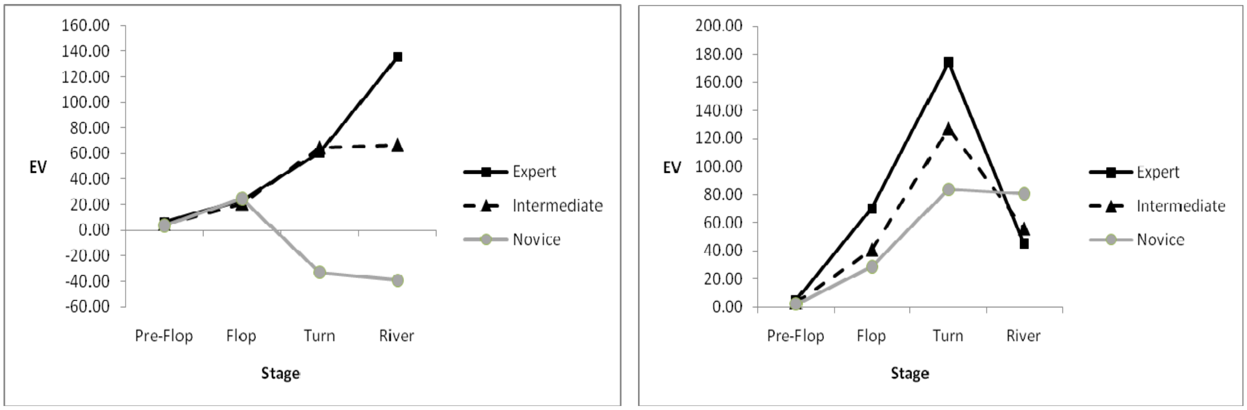


Figure 7. Mean EV scores by skill-level by stage of play for the non-timed and timed conditions

To further elaborate on the findings shown in Figure 7, 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. Effect sizes by stage of play are shown for experts versus novices and intermediates versus novices in Figure 8.

Expert versus Novices Intermediates versus Novices

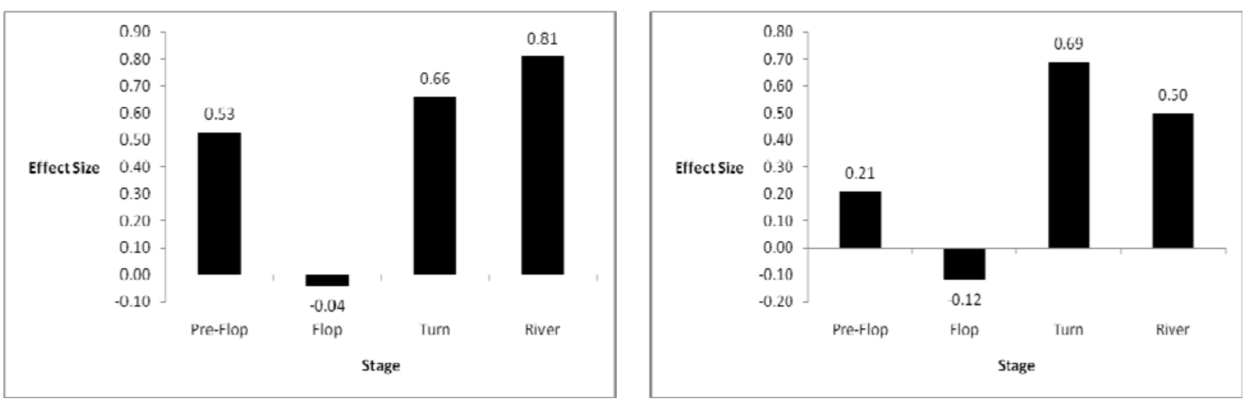


Figure 8. Expert versus novice and intermediate versus novice effect sizes by stage of play for the non-timed condition

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

The results from the non-timed condition provide further support for the first hypothesis, as expert and intermediate players significantly outperformed novice players. In addition, the results support the second hypothesis, as expert and intermediate players displayed significantly higher EV scores in the later stages of play with one exception.

In the timed condition, there were no significant differences in EV scores by stage of play between intermediate and novice players. Effect sizes by stage of play for the timed condition are shown for experts versus novices and experts versus intermediates in Figure 9.

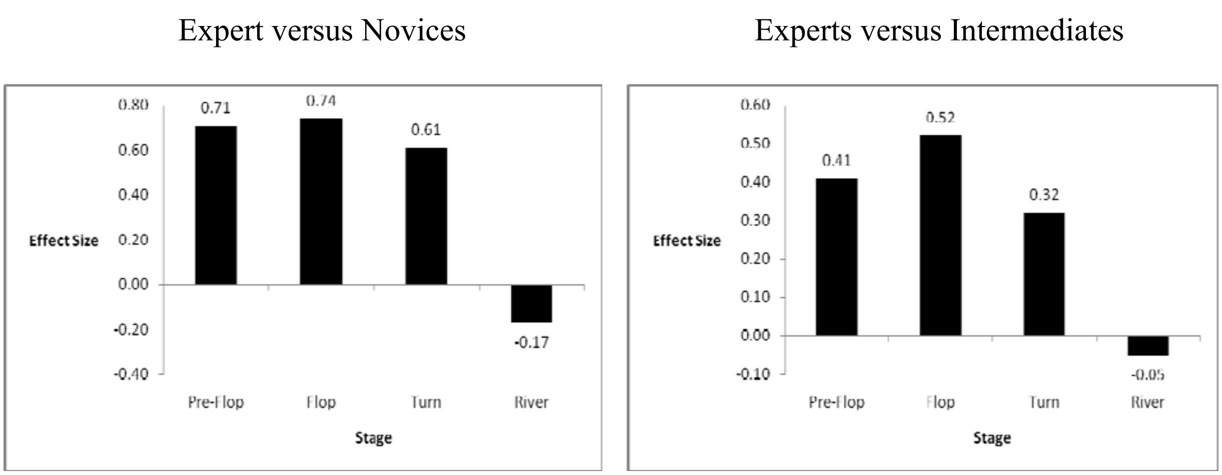


Figure 9. Expert versus novice and expert versus intermediate effect sizes by stage of play for the timed condition

In the timed condition, 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: $p = .02$, $ES = 0.52$). These results further support the first hypothesis, as expert players displayed greater EV scores than intermediate and novice players in the timed condition on the pre-flop, flop, and turn stages, but not on the river.

To examine differences in EV scores between the time and non-timed conditions for each skill group by stage of play, effect sizes were calculated comparing EV scores for each stage of play for one skill-level in the non-timed condition to EV scores for each stage of play for the same skill-level in the timed condition. For example, EV scores for experts in the pre-flop stage in the non-timed condition were compared to EV scores for experts in the timed condition. Effect sizes of mean differences of EV scores by stage of play between time conditions for each skill-level are displayed in Figure 10.

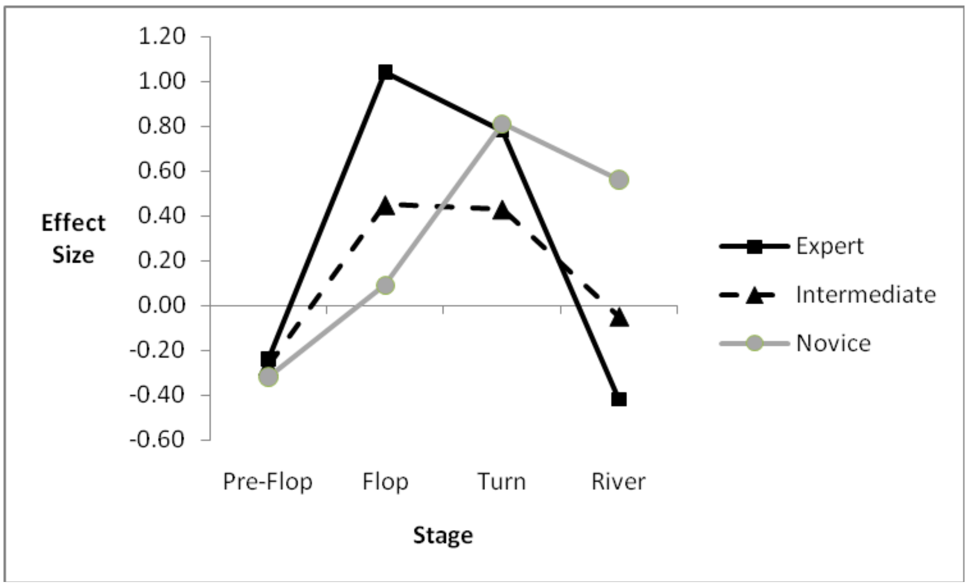


Figure 10. Timed versus non-timed condition effect sizes by skill-level and by stage

In the pre-flop stage, only modest differences between the timed and non-timed condition were found. Experts displayed significantly larger EV scores in the timed condition in the flop and turn stages (*ES* = 1.04 and *ES* = 0.78, respectively), but performed better on the river stage in the non-timed condition (*ES* = 0.42). Intermediates displayed higher EV scores in the flop and turn stages in the timed condition (*ES* = 0.45 and *ES* = 0.43, respectively). In the turn and river stages, novices displayed a large difference in EV scores between the timed and non-timed conditions (*ES* = 0.81 and *ES* = 0.56, respectively), in favor of the timed condition.

These results present further evidence for rejecting the fourth hypothesis as novices displayed higher EV scores in the timed condition versus the non-timed condition in the flop, turn, and river stages.

Further Findings pertaining to EV scores

The significant ($p < .001$) interaction effect of stage of play by style is displayed in Figure 11.

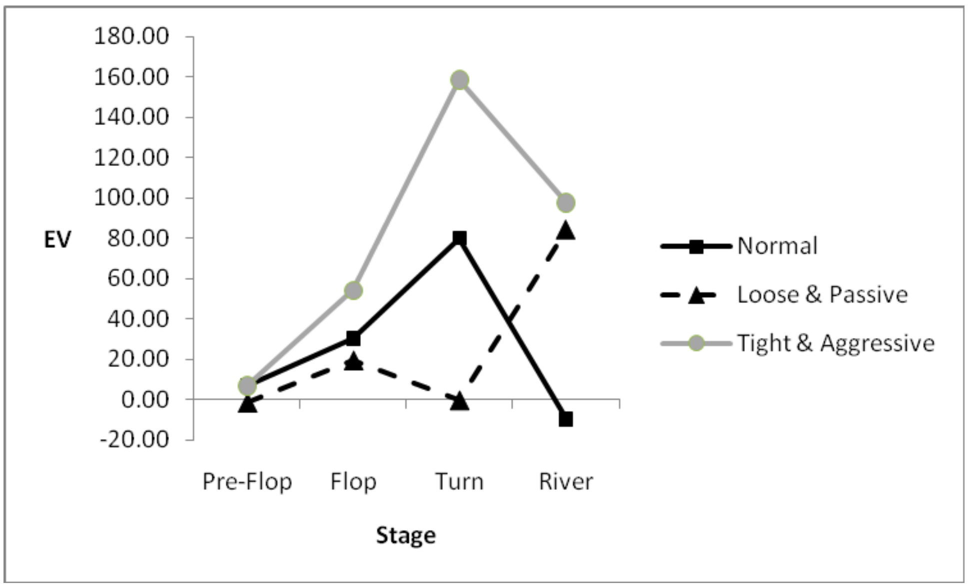


Figure 11. Mean EV scores by stage of play by style

Players in the Tight-Aggressive condition displayed significantly higher EV scores than players in the Loose-Passive condition at all stages of play, except the river (Pre-Flop: *ES* = 2.69; Flop: *ES* = 1.08; Turn: *ES* = 1.41).

Players in the Tight-Aggressive condition outperformed players in the Normal condition at the flop, turn, and river stages (Flop: *ES* = 0.74; Turn: *ES* = 0.88; River: *ES* = 0.72). Also, players' in the Normal condition EV scores were significantly higher than players' in the Loose-Passive condition EV scores at the pre-flop and turn stages (Pre-Flop: *ES* = 2.69; Turn: *ES* = 0.90). However, players in the Loose-Passive condition displayed significantly greater EV scores than players in the Normal condition at the river stage (*ES* = 0.63).

The significant ($p < .001$) interaction effect of stage of play by time is displayed in Figure 12.

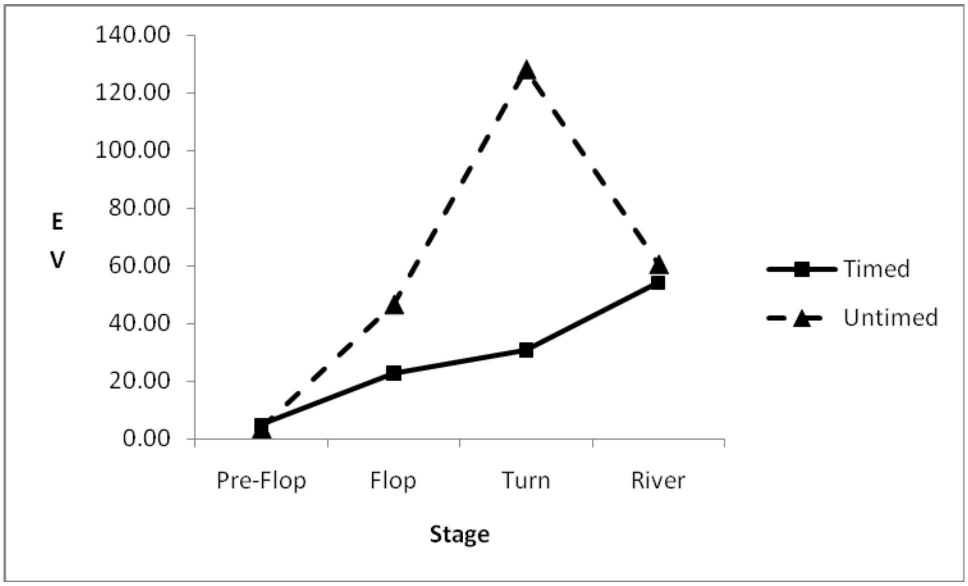


Figure 12. Mean EV scores by stage of play by time

Players in the Non-timed condition outperformed players in the Timed condition at the pre-flop stage (*ES* = 0.48). However, players in the Timed condition displayed significantly greater EV scores than players in the Non-timed condition at the flop and turn stages (Flop: *ES* = 0.69 and Turn *ES* = 1.17, respectively).

The significant ($p < .001$) interaction effect of style by time is displayed in Figure 13, which compares players' EV scores in one style for one time condition to players' EV scores in the same style for the other time condition.

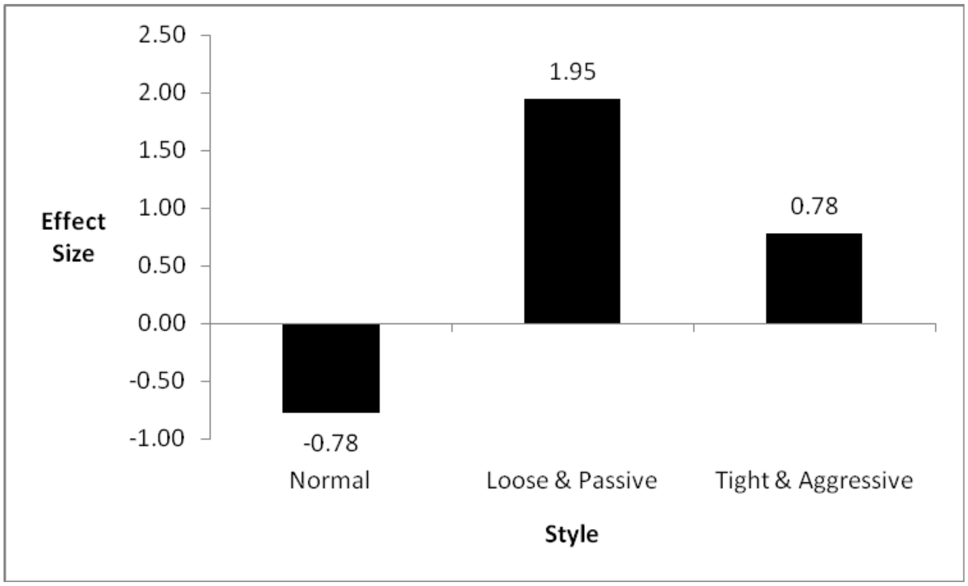
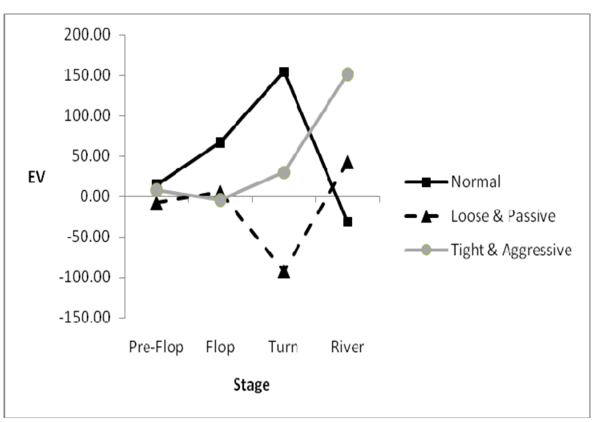


Figure 13. Timed versus Non-timed condition effect sizes by style

Players in the Normal condition displayed significantly higher EV scores in the Non-timed condition (*ES* = 0.78). Conversely, players in the Loose-Passive and Tight-Aggressive conditions displayed significantly higher EV scores in the Timed condition (*ES* = 1.95 and *ES* = 0.78, respectively).

The significant interaction effect (p = .01) of style by stage of play by time is displayed in Figure 14.

Non-timed Condition



Timed Condition

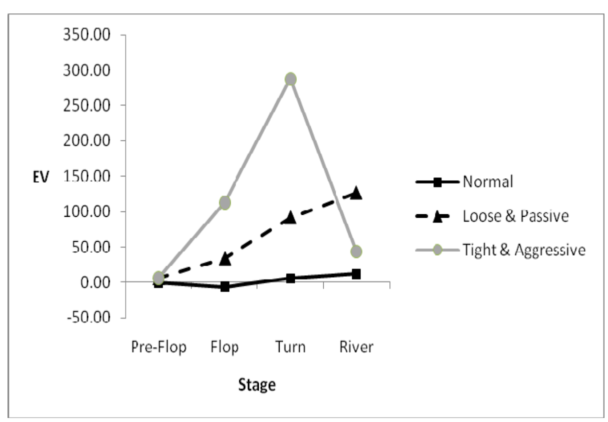


Figure 14. Mean EV scores by style by stage of play for the non-timed and timed conditions

In the non-timed condition, effect sizes are large. Players in the Normal condition displayed significantly higher EV scores than players in the Loose-Passive condition at all stages of play, except the river (Pre-Flop: *ES* = 4.74; Flop: *ES* = 1.60; Turn: *ES* = 1.80, River: *ES* = -0.40). Players' in the Normal condition EV scores were significantly higher than players' in the Tight-Passive EV scores at the pre-flop, flop, and turn stages (Pre-Flop: *ES* = 1.40; Flop: *ES* = 1.84; Turn: *ES* = 0.91). However, players in the Tight-Aggressive significantly outperformed players in the Normal condition on the river (*ES* = 0.81). Players in the Tight-Aggressive condition outperformed players in the Loose-Passive condition at the pre-flop, turn, and river stages (Pre-Flop: ES = 3.34; Turn: *ES* = 0.89; River: *ES* = 0.49)

In the timed condition, effect sizes are large. Players in the Tight-Aggressive condition significantly outperformed players in the Normal condition on the pre-flop, flop, and turn stages (Pre-Flop: *ES* = 1.70; Flop: *ES* = 2.57; Turn: *ES* = 2.02). Players in the Tight-Aggressive condition displayed significantly greater EV scores than players in the Loose-Passive condition on the flop, turn stage (Flop: *ES* = 1.70; Turn: *ES* = 1.41). However, the players in the Loose-Passive condition significantly outperformed the players in the Tight-Aggressive condition on the river (ES = 0.44). Players' in the Loose-Passive condition EV scores were significantly higher than players' in the Normal condition EV scores at all stages (Pre-Flop: *ES* = 1.57; Flop: *ES* = 0.87; Turn: *ES* = 1.00; River: *ES* = 0.60)

Profit: RM-ANOVA

Profit scores were subjected to a two-way RM-ANOVA using skill-level (expert, intermediate, or novice) as a BS factor, and style (normal, Loose-Passive, or Tight-aggressive), and time (no time limit or 15 seconds) as two WS factors. The WS factor of time was nested within playing style. Results of the RM-ANOVA are shown in Table 3.

Table 3
RM-ANOVA results for Profit

Effect	G-G	F	df	p	η^2
A. Skill-level	0.59	14.71	2,42	<.001	0.41
B. Style	0.54	35.86	1.9,39	<.001	0.46
C. Time	0.4	63.61	1,42	<.001	0.6
D. A x B	0.97	0.41	3.9,80	0.79	0.02
E. A x C	0.82	4.62	2,42	0.02	0.18
F. B x C	0.58	30.7	1.9,39	<.001	0.42
G. A x B x C	0.93	0.74	3.9,80	0.57	0.03

The effect of skill-level on profit was significant ($p < .001$), and is displayed in Figure 15.

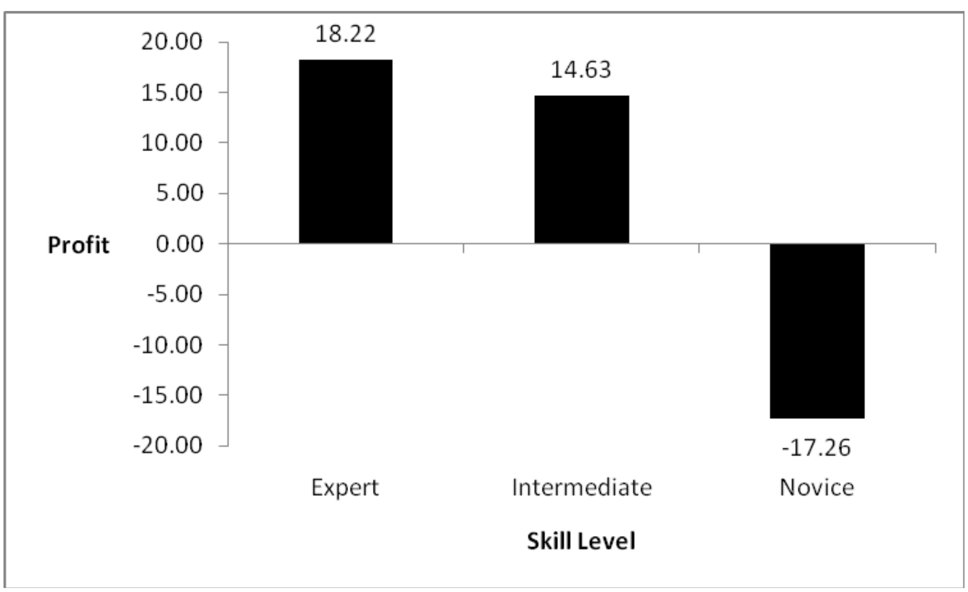


Figure 15. Mean Profit by skill-level

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). These results present further evidence for supporting the first hypothesis assuming experts and intermediates will outperform novices across all trials.

The interaction effect of skill-level by style was non-significant (p = .79), further falsifying the third hypothesis assuming skill-level differences depend on the styles of opponent players.

The interaction effect of skill-level by time was significance (p =. 02). All skill-level groups displayed higher profit scores in the timed condition. Effect sizes of differences of mean profit scores between time conditions for each skill-level are displayed in Figure 16.

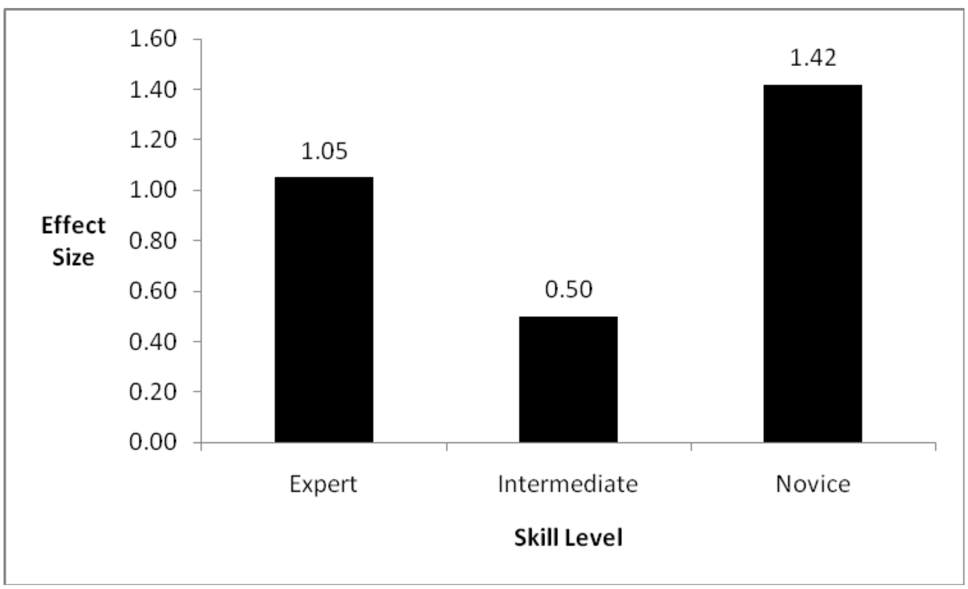


Figure 16. Timed versus Non-timed condition effect sizes by skill-level

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. 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. These results falsify the fourth hypothesis, as novice players improved more than expert and intermediate players between the timed and non-timed conditions.

Further Findings pertaining to profit scores

The significant ($p < .001$) interaction effect of style by time is displayed in Figure 17.

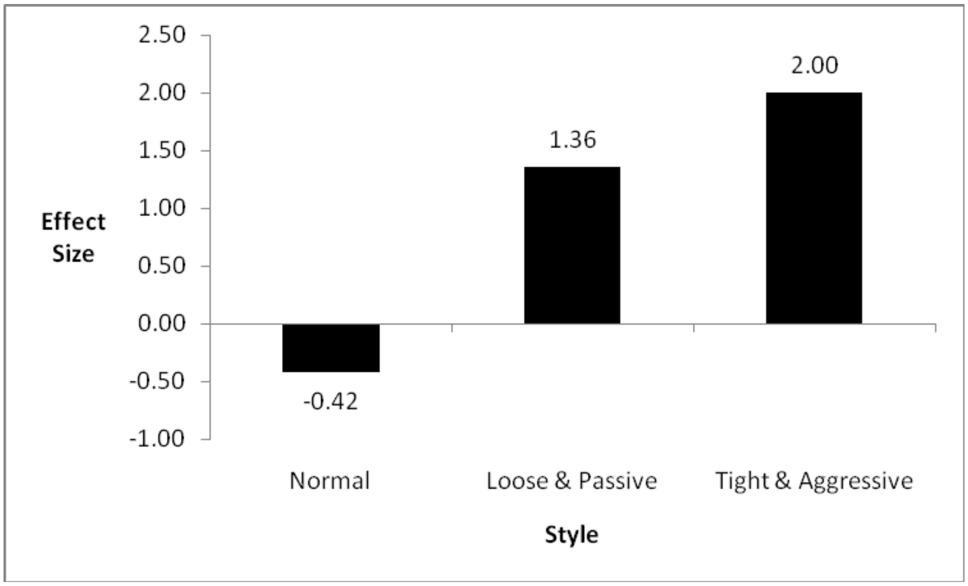


Figure 17. Timed versus Non-timed condition effect sizes by style

Players in the Normal condition made higher profit in the Non-timed condition (*ES* = 0.42). Conversely, players in the Loose-Passive and Tight-Aggressive conditions made significantly higher profit in the Timed condition (*ES* = 1.36 and *ES* = 2.00, respectively).

Qualitative Data

To test the fifth and sixth hypotheses, a think aloud protocol was used, and the total number of thought processes were categorized across all hands for all players. The final coding broke down reported cues in five major categories (sub-categories in parentheses): (1) Opponent Behaviors (previous opponent actions, 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). Codes for reported cues and representative responses of these cues are reported in Table 4.

Table 4
Reported Thought Processing Codes and Representative Responses across Trials

Code	Representative Response
Opponent Behaviors	*These guys are really loose.* *He only seems to bet the river when he has a good hand.*
Basic Poker Considerations	*I have Aces!* *Let's see, that gives me a flush draw*
Advanced Poker Considerations	*I won't play that hand, not even on the button.* *That gives me 6-1 to call.*
Self	*The strength of my hand is concealed.* *If he goes all-in, I'll call.*
Other	*I just want to see a flop.* *I have a feeling that an eight is coming.*

A Chi Square (χ^2) test was performed to test group differences in the number of thoughts processed within the five categories. Table 5 displays the reported thought process distribution in expert, intermediate, and novice players within each of the five categories, and the $\chi2$ test results. Inter-rater reliability fell within acceptable ranges (r = .82 - .91).

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

χ^2 (df = 8; K= 6,924; N = 45) = 2,163.91, $p < .001$

Cue 1 = Opponent Behaviors
Cue 2 = Basic Poker Considerations
Cue 3 = Advanced Poker Considerations
Cue 4 = Self
Cue 5 = Other

Overall, expert players reported processing more thoughts (3,012) than intermediate players (2,500), who reported processing more thoughts than novice players (1,412). This result supports the fifth hypothesis.

The majority of reported thoughts processed by expert players were of the "Opponent Behavior" (k = 1,132; 37.6%) and "Advanced Poker Considerations" (k = 1,311; 43.5%) nature. Intermediate players reported focusing the majority of their attention on three categories: "Opponent Behaviors" (k = 798; 31.9%), "Basic Poker Considerations" (k = 603; 24.1%), and "Advanced Poker Considerations" (k = 633; 25.3%). The majority of reported thoughts processed by novice players were from the "Basic Poker Considerations" (k = 585; 41.4%) and "Other" (k = 509; 36.0%) categories.

These results indicate that there are significant differences in reported thought processing between expert, intermediate and novice players during the DM process. This supports the sixth hypothesis stating that expert players will report attending to more situational-relevant stimuli than intermediate and novice players, and intermediates will report attending to more situational-relevant stimuli than novices.

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. Reported thought processing at the pre-flop stage is shown in Table 6.

Table 6
Reported thought processing of expert, intermediate, and novice poker players within each thought category at the pre-flop stage

	Cue-Type					
Skill-level	1	2	3	4	5	Total
Expert	276 (24.6%)	128 (11.4%)	662 (59.1%)	48 (4.3%)	6 (0.5%)	1,120 (100%)
Intermediate	208 (21.8%)	149 (15.6%)	407 (42.7%)	55 (5.8%)	135 (14.2%)	954 (100%)
Novice	19 (3.7%)	240 (46.2%)	60 (11.5%)	15 (2.9%)	186 (35.8%)	520 (100%)

χ^2 (df = 8; K= 2,594; N = 45) = 858.04, p < .001

Cue 1 = Opponent Behaviors
Cue 2 = Basic Poker Considerations
Cue 3 = Advanced Poker Considerations
Cue 4 = Self
Cue 5 = Other

In the pre-flop stage, expert players reported mainly thinking "Advanced Poker Considerations" (k = 662; 59.1%). Intermediate players reported focusing the majority of their attention on the category of "Advanced Poker Considerations" (k = 407; 42.7%). Novice players mainly reported thinking about cues from the "Basic Poker Considerations" (k = 240; 46.2%) and "Other" (k = 186; 35.8%) categories.

Reported thought processing for expert, intermediate, and novice poker players at the flop stage is shown in Table 7.

Table 7
Reported thought processing of expert, intermediate, and novice poker players within each thought category at the flop stage

	Cue-Type					
Skill-level	1	2	3	4	5	Total
Expert	299 (35.9%)	92 (11.0%)	363 (43.6%)	72 (8.6%)	7 (0.8%)	833 (100%)
Intermediate	230 (27.7%)	324 (39.1%)	117 (14.1%)	36 (4.3%)	122 (14.7%)	829 (100%)
Novice	56 (14.2%)	169 (43.0%)	28 (7.1%)	14 (3.6%)	126 (32.1%)	393 (100%)

χ^2 (df = 8; K= 2,055; N = 45) = 635.06, $p < .001$

Cue 1 = Opponent Behaviors
Cue 2 = Basic Poker Considerations
Cue 3 = Advanced Poker Considerations
Cue 4 = Self
Cue 5 = Other

In the flop stage, expert players reported mainly thinking about "Opponent Behaviors" (k = 299; 35.9%) and "Advanced Poker Considerations" (k = 363; 43.6%). Intermediate players reported focusing the majority of their attention on the categories of "Opponent Behaviors" (k = 230; 27.7%) and "Basic Poker Considerations" (k = 324; 39.1%). The majority of reported thoughts processed by novice players were from the "Basic Poker Considerations" (k = 169; 43.0%) and "Other" (k = 126; 32.1%) categories.

Expert, intermediate, and novice poker player reported thought processing at the turn stage is shown in Table 8.

Table 8
Reported thought processing of expert, intermediate, and novice poker players within each thought category at the turn stage

	Cue-Type					
Skill-level	1	2	3	4	5	Total
Expert	345 (52.2%)	42 (6.4%)	183 (27.7%)	86 (13.0%)	5 (0.8%)	661 (100%)
Intermediate	223 (50.8%)	82 (18.7%)	57 (13.0%)	38 (8.7%)	39 (8.9%)	439 (100%)
Novice	48 (17.0%)	99 (35.0%)	8 (2.8%)	4 (1.4%)	124 (43.8%)	283 (100%)

χ^2 (df = 8; K= 1,383; N = 45) = 578.42, $p < .001$

Cue 1 = Opponent Behaviors
Cue 2 = Basic Poker Considerations
Cue 3 = Advanced Poker Considerations
Cue 4 = Self
Cue 5 = Other

On the turn, the majority of reported thoughts processed by expert players were from the "Opponent Behaviors" (k = 345; 52.2%) category. Intermediate players reported focusing the majority of their attention on the category of "Opponent Behaviors" (k = 223; 50.8%). Novice players reported mainly thinking about "Basic Poker Considerations" (k = 99; 35.0%) and "Other" (k = 124; 43.8%).

Reported thought processing for expert, intermediate, and novice poker players at the river stage is shown in Table 9.

Table 9

Reported thought processing of expert, intermediate, and novice poker players within each thought category at the river stage

	Cue-Type					
Skill-level	1	2	3	4	5	Total
Expert	212 (52.5%)	20 (5.0%)	103 (25.5%)	58 (14.4%)	11 (2.7%)	404 (100%)
Intermediate	137 (49.3%)	48 (17.3%)	52 (18.7%)	17 (6.1%)	24 (8.6%)	278 (100%)
Novice	59 (27.6%)	75 (35.0%)	7 (3.3%)	0 (0.0%)	73 (34.1%)	214 (100%)

χ^2 (df = 8; K= 896; N = 45) = 293.59, $p < .001$

Cue 1 = Opponent Behaviors
Cue 2 = Basic Poker Considerations
Cue 3 = Advanced Poker Considerations
Cue 4 = Self
Cue 5 = Other

In the river stage, expert players reported mainly thinking about “Opponent Behaviors” (k = 212; 52.5%). Intermediate players reported focusing the majority of their attention on the category of “Opponent Behaviors” (k = 137; 49.37%). The majority of reported thoughts processed by novice players were from three categories: “Opponent Behaviors” (k = 59; 27.6%), “Basic Poker Considerations” (k = 75; 35.0%) and “Other” (k = 73; 34.1%).

At each stage, experts reported processing more thoughts than intermediates and intermediates reported processing more thoughts than novices. This supports the fifth hypothesis.

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. These results support the sixth hypothesis.

While the quantification of thought processes presented in this section reveal significant skill-level differences in the thought processes of poker players, an example of one hand is provided below to bring these differences to life:

The participant is dealt the Ace (clubs) and Ace (diamonds) in fourth position (two spots after the blinds). The blinds are $5 and $10.

Expert: “I have the Aces, so I have to raise. Many times players will check-raise in early position with this hand, giving away the strength of their hand. Make it $30, raise sizing should be pretty much the same [pre-flop, to conceal your hand strength.]”

Intermediate: “Oh, pocket Aces. I’m going to raise it up $25 again. Hopefully my opponents recognize that I raise the same amount each time.

Novice: “Double Aces, feel like I can’t lose, almost. Raise to $20 and see what everyone else does.”

The flop comes out with the eight (spades), seven (hearts), and seven (spades).

Expert: “When they check to you on this board you still have to bet, but it’s not a great flop for Aces. Bet $70 [nearly a pot sized bet], to protect the hand and maybe provide information about his hand.”

Intermediate: “That’s a draw heavy board, so I’m going to bet $70 to see if I can get them to define their hands.”

Novice: "Will is tight and aggressive, which means he may have something. However, I have two pair. Bet $20.

The turn is the four (diamonds).

Expert: "The turn is a relatively good turn. He could have the five-six, but again you can't be concerned about that too much [as you are ahead of most of his range], and you want to be concerned about getting your money in. But, in this spot, you could check or bet. I think betting is a little bit better, so I'll bet $150. But, it's a bad spot."

Intermediate: "The four may hit five-six. I'll bet $80, to see if they raise. That way if I have to fold it, I can get away [from the hand] cheaply."

Novice: "Unless he has a seven, I am ahead [holding the best hand]. I'll bet $40."

The river is the 3 (diamonds).

Expert: "When he calls the turn, you can't give him credit for a seven and everything has bricked off [missed]. Because of that you should check-call to induce a bluff, because he's probably not going to call with anything except an over pair."

Intermediate: "That missed the spade draw. Unless he's slow playing the five-six or a seven, I may have the best hand. So again, I'm going to bet $80."

Novice: "I'm going to play hard ball here [show strength]. Let's go all-in [bet $920]."

CHAPTER 4
DISCUSSION

Significant differences between experts and non-experts in the decision-making (DM) process have been found in previous research. These differences, however, have not been explored in the arena of poker. 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 three styles and two time conditions. An additional purpose was to determine what thought processes were taken into consideration during 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 under timed and non-timed conditions and three styles of opponent players while each player engaged in a think-aloud protocol.

In other domains than poker, experts have been found to display superior DM skills, especially in terms of knowledge base and procedures (McPherson, 1994). 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). This has been attributed to greater attendance to the most relevant stimuli, which has the best chance of triggering a correct response (Alain, 1991), and enables prediction of later events allowing subsequent behavior to be planned (Eccles et al., 2002). For the expert player, DM is likely automatic and utilizes heuristics (McMorris & Graydon, 1996), which are based on a well-organized, domain-specific knowledge structure (Williams, 2000). Therefore, intuitive impressions are considered correct, and the expert can put forth more cognition towards completing the physical task. For the novice, a different cognitive process takes place, which requires increased cognitive activity (McMorris & Graydon, 1996). In this instance, there is an increased reliance on reasoning, which may limit the amount of cognition available for the completion of the physical task.

For these reasons, it was hypothesized that (1) expert poker players would make better decisions than intermediate and novice players, and intermediate players would outperform novices players, and (2) expert players' DM performance would improve at a greater rate (or a decrease at a lesser decrement) than intermediate and novices players' performance at the later stages of a poker hand. In addition, intermediates would outperform novices in the later stages of a poker hand.

Overall, expert and intermediate players had significantly better EV scores than novices. Experts outperformed intermediates but this difference merely tended towards significance. EV can be calculated for every poker decision, given the amount of money that can be won, the amount of money that can be lost, and the probability of winning the pot. EV scores can be positive or negative, with positive scores noting better (more profitable) decisions. In addition, experts and intermediates displayed significantly higher profit scores than novices. This indicates clear skill-level differences supporting the first hypothesis. Sport-related tasks, including poker DM, are unique in nature and encoding relevant information for processing requires task-specific perceptual and attentional resources and mechanisms (Tenenbaum, 2004). When competing, decisions are related to the selection of relevant and elimination of irrelevant cues in the environment (Tenenbaum, 2003). The more a player is aware of the task-specific resources and opponent tendencies, the more he or she can alter their actions versus a particular opponent (Tenenbaum, 2004) before, during, and after hand. This is particularly important in poker, as a player may be up against 8 other players with individual styles and tendencies. With the development of expertise, long-term working memory allows a player to better process information, anticipate the situation, and decide a course of action while keeping other responses on alert in case decision alteration is required (Tenenbaum, 2003).

Considering the qualitative data, experts 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). For example, in one hand, players were dealt a pair of Aces pre-flop. Throughout the hand, experts and intermediates focused on many cues, such as board texture, possible opponent holdings, previous opponent actions, and future actions, to name a few. Novices, on the other hand, focused the majority of their attention on their hand ("Aces!") or mentioned that they "wanted to see what happens" if they called or put in a raise. These differences, in accordance with scientific research, allowed experts and intermediates to better anticipate opponent actions, which resulted in greater DM performance scores.

Expert and intermediate players performed significantly better than novice players on the turn. In addition, expert players significantly outperformed novice players, but intermediates did not significantly differ from novice players in EV scores on the river. At 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. A similar phenomenon was revealed in fast ball game anticipatory capability. In later stages of anticipation, experts have been found to be more confident in the final location of the ball, when more information is available, than novices or intermediates (Abernethy et al., 1994; Tenenbaum & Bar-Eli, 1995). In this case, it is clear that experts have a superior knowledge of ball location, which is accompanied by high self-efficacy, and results in superior response selection (Tenenbaum, 2003). Furthermore, poker authors (Feeney, 2000; Schoonmaker, 2000) have noted that the great players play much better than their counterparts on the turn and river.

Examination of the qualitative data may provide a greater insight into the EV-related differences between expert and novice players. In the pre-flop and flop stages, experts focused the majority of their attention on "Advanced Poker Considerations," but in the turn and river stages, experts reported shifting their attention mainly to "Opponent Behaviors." Novices reported focusing on basic or non-poker cues at all stages. With this information, one could surmise that attending to "Opponent Behaviors" is the most important cue to attend to on the turn and river, as experts performed significantly better on the turn and river while reporting a shift in the majority of their attention to this stimulus category. Increased attention to the current and previous actions of an opponent can provide insight as to what cards the opponent holds. Given this information, poker players can adapt their play to the perceived holdings of their opponent, resulting in better DM.

The results of this study are consistent with the existing research in sport and with anecdotal evidence provided in the poker literature. Overall, novice players' DM performance leveled off after the flop while expert and intermediate players' DM performance increased, with experts displaying greater EV scores. Therefore, the results of this study support the second hypothesis in that experienced poker players showed greater improvement in DM performance as the hand progressed.

In any given hand of poker each opponent has an individual playing style, and players must simultaneously adapt to each of their opponents' styles. For this reason, three style conditions were included in this study to examine skill-level differences in DM performance versus particular opponent styles. Theoretically, a poker table with more opponents with separate distinct styles would require more adaptation by a poker player than a table with players displaying similar styles.

The ability to correctly alter actions in response to an opponent(s) is believed to be a skill that develops with practice and experience, and is seen more often in expert performers (Tenenbaum, 2003). In the sport domain, an athlete must possess mental representations of situational components, such as the representation of team structure or the environmental conditions of a specific competition (Tenenbaum et al., 2009). Skilled performers have been found to develop more flexible and detailed mental representations than less skilled performers, which enabled them to adapt rapidly to changes in the environment (Williams & Ward, 2007). In fact, Brunson (2003) stated that one of the biggest secrets a true professional player possesses is his ability to adapt from game to game and hand to hand. For these reasons, it was hypothesized that expert players would make better poker decisions than intermediate and novice players, and intermediates would outperform novices in hands involving players of varying styles. Environmental complexity is manipulated by varying the amount and connectivity of available information (Siemann & Gebhardt, 1996). The normal condition was hypothesized to be a more complex environment, as each computer opponent had an individual style requiring the participant to constantly adapt to the styles of opponents that competed in a particular hand. The loose-passive and tight-aggressive conditions were simpler conditions, as each player at the table possessed the same style requiring, theoretically, less adaptation by the participant.

While expert and intermediate players performed better than novices in each style condition, this advantage was not significantly greater or worse for any particular style condition. Successful DM is, in part, the result of control over the visual system, which allows anticipatory decisions to be made and retrieved from long-term memory and knowledge structures (Tenenbaum & Land, 2009). Experts are better able to utilize their visual systems and mental representations to anticipate and adapt to the environment (Tenenbaum, 2003; Williams & Ward, 2007). This advantage of expertise was present in every style condition. Therefore, the ability of experts to make better decisions due to the reasons described previously in this section are useful against any opponent style. Therefore, the third hypothesis assuming that expert players would make better poker decisions than intermediate and novice players, and intermediates would outperform novices in hands involving players of varying styles could not be verified.

In addition to the opponent style manipulation, this study employed a time pressure condition to examine skill-level differences in poker performance under stress. Scientific evidence reveals that time pressure is a significant impediment to DM (Apter, 1982; Edgell, Roe, & Dodd, 1996; Goodie & Crooks, 2004; Hockey, 1993). In cases such as this, 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. Heuristics used by experts are more accurate because the situation is better represented by their more extensive knowledge base (Chi et al., 1982). In addition, an expert holds alternatives "on alert" which allows relatively effortless DM response alteration, which occurs mainly in complex and time-limited conditions (Tenenbaum, 2004). For these reasons, it was hypothesized that expert players would make better poker decisions than intermediate and novice players, and intermediates would outperform novices in hands involving time pressure.

Expert and intermediate poker players displayed greater EV scores in the timed condition than the non-timed condition, but these differences were not significant. Novice players, however, displayed significantly better EV scores in the timed condition than under the non-timed condition. Also, all players displayed greater profit scores in the timed condition than the non-timed condition, with novices exhibiting the greatest differences. These findings are not aligned with the fourth hypothesis as novice players displayed the greatest improvement in DM performance measures in the timed condition.

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.

While it may appear that experts and novices "choked" on the river, Stanovich and West's (2000) two-system cognitive model may provide a better 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 et al., 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 et al., 1993). In addition, DM is more challenging when the number of stimuli increases (Tenenbaum, 2004), such as in the later stages of a poker hand. In the timed condition, a complete evaluation of the hand was not possible due to time restraints. In order to assess the situation, some kind of heuristics must have been used (Over, 2004). In environments in which cues are misleading, such as poker, heuristic processing may impair performance (Goodie & Crooks, 2004). 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 initial heuristically-based *System 1* decisions may have been incorrect and due to time constraints the *System 2* processes could not occur. Therefore, the DM performance of experts and intermediates dropped to levels more similar to novice performance.

Considering the qualitative data, it can be seen that all players reported attending to less cues in the timed condition than the non-timed condition, seemingly due to the fact that there was less time to process cues in the environment. Novices reported mainly thinking about "Basic Poker Considerations" and "Other." Adding time pressure may not have hindered the novices, as they had less time to process information on the most basic poker consideration (answering the question: What cards do I have?) and thoughts unrelated to the poker DM process. While knowing the cards is necessary to understand the value of a players' hand, cues from the "Other" category provide little to no value to the DM process as these cues are not relevant to making a poker decision. 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. At the culmination of the hand, 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 a near impossibility, which may have resulted in incorrect decisions.

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). Research in the scientific literature has uncovered that experts can perceive large and meaningful patterns of information in the environment (Ericsson & Smith, 1991). In a study of battle commanders, Serfaty, and colleagues (1997) found several examples of higher-expertise commanders seeing situations differently than less-expert commanders. In addition, experts have been found to undertake greater depth of processing than novices in a study of shot planning in snooker (Abernethy et al., 1994). Based on the differences in perception and DM processes found in the literature, it was hypothesized that (1) expert players would perceive and report utilizing more cues in the DM process than intermediate and novice players, and intermediate players would report utilizing more cues than novice players, and (2) expert players would report utilizing a higher percentage of situational-relevant cues than intermediate and novice players, and intermediate players would report utilizing a higher percentage of situational-relevant cues than novices. Conversely, novice players would report utilizing a higher percentage of irrelevant cues than expert and intermediate players, and intermediate players would report utilizing a higher percentage of irrelevant cues than experts.

Results of this study fail to reject the fifth hypothesis. Expert players reported processing a greater number of thoughts than intermediate players, and intermediate players reported processing more thoughts than novices. The DM process is largely dependent on factors that are external to the athlete (Tenenbaum, 2003). This finding may also be applied to poker players. A poker player must constantly adapt their responses in order to counter an opponent's actions. Evidence exists that athletes can utilize automatic and voluntary strategies for signal detection in the sport environment (Tenenbaum, 2003). Once again, the results of studies done in sport may be applicable to poker. 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. However, at this point, there is nothing else a player can do. Therefore, taking in more information throughout a hand, should result in a greater understanding of possible opponent holdings.

The results of this study fail to reject the sixth hypothesis as expert players reported processing a higher percentage of situational-relevant thoughts than intermediate and novice players and intermediate players reported processing a higher percentage of situational-relevant thoughts than novices. Conversely, novice players reported processing a higher percentage of irrelevant thoughts than expert and intermediate players and intermediate players reported processing a higher percentage of irrelevant thoughts than experts. Skill-level differences were significant on all of the major categories of thought processing. Experts attend to meaningful cues in the environment (Eccles et al., 2002), while novice problem representations are less complex, and rely on surface aspects of the problem (Chi et al., 1982). The percentage of expert players' thought processing was significantly greater on situational-relevant thoughts ("Opponent Behaviors", "Advanced Poker Considerations", and "Self") than intermediate players, who reported processing a significantly greater percentage of these thoughts than novices. Novices reported processing a significantly greater percentage of less complex thoughts ("Basic Poker Considerations"), and irrelevant stimuli ("Other") than intermediates, who reported processing a significantly greater percentage of thoughts in these categories than experts.

As expertise develops, an athlete (or a poker player) can more accurately assess the dynamic environment (Nougier et al., 1991). The experts' advantage is due to the ability to attend to the most relevant stimuli, which has the best chance of triggering a correct response (Alain, 1991). Further evidence of this phenomenon has been shown in a study of volleyball players (Castiello & Umilta, 1992). In this study, players shifted their attention faster than non-players to valid cues, but not to invalid cues. The advantage enables experts to efficiently assess essential cues, which aids in the DM process. This can be observed in poker as expert players may only attend to tells or betting patterns that pertain to the strength of an opponent's hand, while a novice player may attend to cues unrelated to poker DM. In this study, expert and intermediate players were found to report thinking about significantly more stimuli that related to "Opponent Behaviors", "Advanced Poker Considerations", and their self ("Self"), while novices reported thinking about significantly more stimuli at the most basic level of poker DM ("Basic Poker Considerations") or cues that were not related to poker ("Other").

Study Limitations & Future Research Directions

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 understand skill-level differences in poker. This is especially true when it comes to adapting play based upon a particular opponent. Expert players may require a larger number of hands to assess and exploit the way a particular opponent plays.

All participants reported that they were motivated to play well and do their best. However, it should be noted that they were not playing for real money. While players may make the same play while playing for real or fake money, this cannot be assumed to be true. Therefore, a similar study should utilize real money to determine the effect of playing for real money versus fake money.

This study utilized the artificial intelligence (AI) of poker software that while sophisticated, may not be the best software for simulating hands of No-Limit Texas Hold 'Em. As computer AI gets more advanced, top of the line software should be used in future research to better differentiate between expert (hypothesized to be stronger players), intermediate (hypothesized to be stronger than novices, but weaker than experts), and novice players (hypothesized to be weaker players).

The Poker DM Conceptual Scheme, developed by St. Germain (2009), needs to be amended for use in future studies. The cues of opponent isolation, size of opponents' chip stack, possible opponent hands, number of opponents in the hand, board texture, and bet sizing were found to be a significant part of the DM process and must be added to the model. This study has provided a springboard for the study of cognitive features associated with poker playing. Further qualitative research, such as in-depth interviews, can be utilized to dig deeper into the thought processes of poker players. Also, process-tracing may be utilized to better understand the order of cue-utilization of poker players.

The surprising results of the time condition should be examined in future studies. Fifteen seconds may not have been enough time for expert and intermediates to process the situational-relevant cues on the river and take advantage of the insight that these cues may provide. A study with a third (intermediate) time condition may provide more insight into the phenomenon of time pressure on poker DM.

The definition of one of the skill-level groups may have been a limitation of this study.

Novice pokers in this study were defined as poker players with limited experience (less than 50 hours) playing poker, but they were not true novices. A study involving true novices may result in greater differences among experienced and novice players.

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 I know of, the other poker forms need to be studied to determine if similar skill-level differences exist. Omaha, Razz, Stud, just to name a few, are additional types of poker with similar, but different rules to No-Limit Texas Hold 'Em. While one could hypothesize that similar skill differences exist, the extent of these differences could differ among games and require further study.

In addition to the different types of poker, the differences in the two major poker venues, online versus live, have yet to be examined empirically. The study detailed in this dissertation consisted of a computer simulation of poker hands akin to online poker sites. It could be hypothesized that similar results would be found in a live setting, but this yet to be studied. Furthermore, it raises the question as to whether being a successful player in online poker results in successful live play and vice versa. Further research must be conducted to determine the main differences (if there are any) in live versus online poker.

Finally, skill-level differences in two commonly discussed topics in the poker literature and media, *tilt* and *tells*, have yet to be explored empirically:

(1) *Tilt* is defined as an adverse impact of emotion on poker play (Feeney, 2000), which results in sub-optimal DM and often the loss of money (Gallant, 2006). According to Gallant (2006), the ability to control tilt is the biggest difference between successful and unsuccessful poker players. While researchers have studied the tilt phenomenon, no scientific study has been completed that examines the role of skill-level in controlling or succumbing to tilt. In addition, qualitative research could be completed to better understand skill-level differences in the tilt experience.

(2) A *tell* is a player's mannerism that gives away the strength of his/her hand (Greenstein, 2005). The importance of picking up tells is portrayed by the media as an important part of poker, perhaps most famously in the movie *Rounders* where the hero of the film, Mike McD, determines the strength of his opponent's (Teddy KGB) hand by the way Teddy eats an Oreo cookie. However, little is known in the scientific community regarding the

importance of tells. In addition, while it has been stated in the poker literature that expert players are better at picking up opponents' tells, this has yet to be tested empirically.

APPENDIX A
INFORMED CONSENT FORM

I freely and voluntarily and without element of force of coercion, consent to be a participant in the research project entitled "Decision-Making and Reported Cue Utilization among Expert, Intermediate, and Novice Poker Players."

The principal investigator, Joey St. Germain, is a doctoral candidate in the Sport Psychology program at Florida State University working under the supervision of his advisor, Dr. Gershon Tenenbaum, and is conducting an experiment on poker decision-making for his dissertation. I understand that the purpose of this exploratory study is to better understand the phenomenon of poker decision-making.

I understand I will be asked to complete a general questionnaire, related to poker playing experience and poker playing style. I understand that I will be asked to participate in simulations of computer hands utilizing Wilson Software's Turbo Texas Hold 'Em. During these simulations, I will think aloud my thoughts which will be audio recorded whilst completing the simulations. The audio recording will be transcribed and coded at a later date. The total time commitment will be approximately 75 minutes in one sitting. I understand that the information obtained in the course of this study will remain confidential, to the extent allowed by law. I understand that all information obtained in the experiments will be kept in a locked cabinet, of which only the researcher, Joey St. Germain, has access. All questionnaires, audio files, and transcriptions will be deleted and destroyed by December 12th, 2012.

I understand that my participation is totally voluntary, and I may stop participation at anytime. All answers will be kept confidential, to the extent allowed by law, and identified by a participant code number. My name will not appear on any of the results, and I understand that if I wish to obtain a copy of the results I will notify the researcher.

I understand that there is very minimal risk involved with this study, which is no more than taking an hour examination for school. I understand I will be providing educational and poker professionals with valuable insights into the decision-making processes in poker. This knowledge can assist them in providing educational assistance to better serve poker players.

I understand that this consent may be withdrawn at anytime without prejudice, penalty, or loss of benefits to which I am otherwise entitled. I have been given the right to ask any questions pertaining to the study and questions, if any, have been answered to my satisfaction.

I understand that I may contact Joey St. Germain, Florida State University, Department of Educational Psychology and Learning Systems-Sport Psychology, jis02c@fsu.edu or (850) 321-1782, for answers to questions about this research or my rights, alternatively I may contact Dr. Gershon Tenenbaum, Department of Educational Psychology and Learning Systems-Sport Psychology, tenenbau@coe.fsu.edu or (850) 644-8791. The Human Subjects Committee can be contacted, (850) 644-8633 or 2010 Levy Ave Bldg B Suite 276, Tallahassee, FL 32310, with any grievances. Results will be sent to me upon request.

I have read and understand this consent form.

______________________________ ____________________
(Participant) (Date)

FSU Human Subjects Committee Approved on 6/15/2009. Void after 6/14/2010. HSC#: 2009.2825

APPENDIX B

POKER EXPERIENCE QUESTIONNAIRE

Please answer the following questions with as much detail as necessary to answer the question fully.

Demographic Information

Participant Code:
____

Estimated Number of Years Playing Poker: ____

Estimated Number of Hours Playing Poker (in lifetime): ______________________________

APPENDIX C

PLAYER PROFILES

Condition 1: Mix Styles

1) Rock: Tight & Passive
2) Dana: Loose & Aggressive
3) Herb: Tight & Aggressive
4) Arlo: Tight & Aggressive / Hoyt: Tight & Passive
5) Will: Tight & Aggressive
6) Myron: Tight & Aggressive
7) Ted: Weak Player & Tight
8) Lana: Tight & Passive
9) Nicole: Loose & Aggressive

Condition 2:

ALL PLAYERS ARE LOOSE & PASSIVE

Condition 3:

ALL PLAYERS ARE TIGHT & AGGRESSIVE

APPENDIX D

COMPUTER POKER SIMULATION TASK INSTRUCTIONAL SET

You will be participating in hands of poker versus computer simulated poker players. Consider these hands as you would as if you were playing in a real-life situation. The computer players will have varying styles. I will inform you of the styles of the computer players. In half of the trials, you will only have 15 seconds to make a decision. While competing in each hand, try to simply talk aloud the thoughts that go through your mind; that is, simply say the thoughts as they occur to you. Very importantly, do not try to explain or describe your thoughts as if we are in conversation; simply say them aloud as if you were alone and do not worry if your verbalizations sound disjointed as you say them. I will only speak to state the name of the hand and the stage of play (pre-flop, flop, turn, and river) or to let you know when you have 5 seconds remaining to make a decision in the timed condition. Let's practice, please think aloud as you multiply 21 times 12.

Your verbalizations will be recorded.

APPENDIX E

MANIPULATION CHECK

Please answer the following two questions in regards to your participation in this study.

1. How motivated have you been to win?

Low Motivation High Motivation

1 2 3 4 5 6 7

2. How motivated have you been to do your best?

Low Motivation High Motivation

1 2 3 4 5 6 7

APPENDIX F

HUMAN SUBJECTS APPROVAL

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 6/15/2009

To: Joseph St. Germain

Address: 4612 Autumn Woods Way
Dept.: EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
DECISION-MAKING AND REPORTED CUE UTILIZATION AMONG EXPERT, INTERMEDIATE, AND NOVICE POKER PLAYERS

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 6/14/2010 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc: Gershon Tenenbaum, Advisor
HSC No. 2009.2825

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BIOGRAPHICAL SKETCH

Joey St. Germain grew up in the small town of Long Prairie, Minnesota. There he attended high school at Long Prairie/Grey Eagle HS and worked at South Side Auto Sales, where made sure the cars he washed were "extra clean." Joey went on to graduate from the University of Minnesota – Duluth in 2002 with a degree in Psychology and a minor in coaching. In the summer of 2002, he moved to Tallahassee to pursue a degree in Sport Psychology at Florida State University. In a little over seven years, Joey completed his master's and doctoral degrees while working full-time for five of those years.

Joey is a huge sports fan and you can usually find rooting for his hometown teams from Minnesota (Vikings, Twins, Timberwolves, and occasionally the Wild) or the Florida State Seminoles. He is convinced that the Vikings will win their first Super Bowl soon.

Joey's true passion is poker, the subject of this dissertation. While he plans to continue researching this subject, his dream is to play full-time. Don't be surprised if you run into him at a poker table near you.