Journal of Applied Research in Memory and Cognition 1 (2012) 34–40

Contents lists available at SciVerse ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

Roles of domain knowledge and working memory capacity in components of skill in Texas Hold'Em poker

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ARTICLE INFO

Article history:
Received 5 September 2011
Received in revised form
18 November 2011
Accepted 18 November 2011
Available online 30 November 2011

Keywords:
Expertise
Individual differences
Working memory capacity

ABSTRACT

Domain knowledge is a powerful predictor of success in many complex tasks, but do general cognitive abilities also play a role? To investigate this question, we had 155 participants representing a wide range of poker experience and skill complete tests of poker knowledge, working memory capacity (WMC), and two components of skill in Texas Hold'Em poker: the ability to remember hands and the ability to evaluate hands. Not surprisingly, poker knowledge positively predicted performance in all of the Hold'Em tasks. However, WMC added significantly to the prediction, and there was no evidence for interactions between poker knowledge and WMC. That is, WMC was as important as a predictor of performance at high levels of poker knowledge as at low levels, suggesting that domain knowledge may not always enable circumvention of WMC in domain-relevant tasks.

The origins of expert performance have been of interest to scientists for over a century (e.g., Galton, 1869). The debate is often characterized as nature vs. nurture—which is to say talent vs. practice. However, few would dismiss a central role of the latter. For example, it seems highly unlikely that a person could win the World Series of Poker or become a Grandmaster in chess without extensive practice. And, in fact, estimates of *deliberate practice*, reflecting cumulative engagement in training activities designed to improve performance in a domain (Ericsson, Krampe, & Tesch-Römer, 1993), correlate positively with performance in a variety of domains, including music (Krampe & Ericsson, 1996), sports (Hodges, Kerr, Starkes, Weir, & Nananidou, 2004), and games such as chess (Charness, Tuffiash, Krampe, Reingold, & Vasyukova, 2005) and Scrabble (Tuffiash, Roring, & Ericsson, 2007).

The role of general cognitive abilities in skilled performance is less clear. An idea that has been discussed by a number of theorists is that basic abilities play an important role in performance initially, but become less important as domain-specific knowledge and skills are acquired. Extending Fitts and Posner's (1967) and Anderson's (1982) models of skill acquisition to individual differences, Ackerman (1988) proposed that general cognitive ability (*g*) positively predicts complex task performance early in training, when it still necessary to hold in mind declarative knowledge about how to execute the skill, but for tasks with consistent information processing demands becomes less important as training continues and knowledge is proceduralized. Similarly, Ericsson and Charness (1994) argued that "The effects of extended deliberate practice are more far-reaching than is commonly believed. Performers can acquire skills that circumvent basic limits on working memory capacity and sequential processing" (p. 725).

This idea, which we have termed the *circumvention-of-limits hypothesis* (Hambrick & Meinz, 2011), is appealing because it implies that basic abilities and capacities—which are known to be influenced by genetic factors (e.g., Plomin & Rende, 1991)—do not limit the ultimate level of performance a person can attain in a domain. Instead, although basic abilities may contribute to individual differences in skill among novices, their role decreases as knowledge increases, with abilities ultimately unimportant to skilled performance among experts. Statistically, the circumvention-of-limits hypothesis is reflected by a Knowledge × Ability interaction, with general abilities important to skilled performance at low, but not high levels of knowledge. An interaction of this form was found by Sohn and Doane (2003); the effect of working memory capacity (WMC) on a piloting situational awareness task was reduced among individuals who easily recalled piloting-relevant information. Similarly, Ruthsatz, Detterman, Griscom, and Cirullo (2008) found a positive correlation between reasoning ability and musical skill among high school band students, but not among conservatory musicians.

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2211-3681/$ – see front matter
doi:10.1016/j.jarmac.2011.11.001

There is some evidence, however, that this hypothesis does not always hold true: *g* has both indirect effects on job performance, through job knowledge, and direct effects, above and beyond job knowledge, even in highly experienced workers (Schmidt & Hunter, 2004). Furthermore, Kahneman and colleagues found that measures of selective attention predicted fighter pilot proficiency (Gopher & Kahneman, 1971) and accident rates in highly skilled bus drivers (Kahneman, Ben-Ishai, & Lotan, 1973). In a similar vein, Grabner, Stern, and Neubauer (2007) found that general cognitive abilities predicted chess skill, even after taking deliberate practice into account, and Robbins et al. (1996) found that a secondary task (random letter generation) designed to tax working memory impaired performance in a chess move task, even in highly skilled players. Finally, we found that *working memory capacity* (WMC), reflecting the ability to maintain task-relevant information in a highly active state (Engle, 2002), positively predicted performance in a piano sight-reading task, above and beyond the very large contribution of deliberate practice (Meinz & Hambrick, 2010).

1. Present study

The purpose of this study was to further investigate the involvement of WMC in skilled performance. WMC is typically assessed with complex span tasks, which include interleaved processing and storage components. For example, in operation span, the participant's task is to solve arithmetic equations while remembering a word following each equation for later recall. Complex span measures correlate strongly with each other (Kane et al., 2004), suggesting that WMC is highly general, and with success in a wide range of complex tasks, including abstract reasoning, language comprehension, problem solving, and complex learning, to name a few (see Engle & Kane, 2004, for a review). There is also evidence that individual differences in WMC are stable across time (Unsworth, Heitz, Schrock, & Engle, 2005) and are influenced by genetic factors, with heritability estimates typically around 50% (e.g., Kremen et al., 2007; Polderman et al., 2006).

The domain we chose for this study was the card game Texas Hold'Em. A variant of poker, a game of Hold'Em consists of four deals or hands: the pre-flop in which each player is dealt two cards face-down, and then three deals in which community cards are dealt face-up: the flop (three cards), the turn or fourth street (one card), and finally the river or fifth street (one card). A round of betting follows each hand, and the winner is the player who by the end of the game has accumulated all of the chips (Hellmuth, 2003). Unsworth and Engle (2007) *dual-component theory* of WMC is useful for thinking about the underpinnings of skill in this game. According to this theory, individual differences in WMC reflect the efficiency of maintaining information in primary memory (i.e., a short-term store) through the continued allocation of attention to the information, or when the severely limited capacity of this component is exceeded, the efficiency of using cues to search for and retrieve information in secondary memory (i.e., a long-term store). And consistent with this theory, Unsworth, Spillers, and Brewer (2010) found that a primary memory factor, based on recency effects in a free recall task (i.e., recall of list-final items), and a secondary memory factor, based on primacy effects in the same free recall task (i.e., recall of list-initial items), made independent contributions to the prediction of WMC.

At low levels of skill, performance differences in Hold'Em are presumably influenced by some mixture of these general processes (i.e., active maintenance and controlled search). For example, to effectively "read" an opponent's playing style—one key to success in Hold'Em—the player must keep track of the action in a game. That is, the player must attend to opponents' actions on a given hand, and then search for and retrieve this information on subsequent hands to make inferences about what cards they are holding. For instance, if an opponent is observed to infrequently make an initial bet, this is a signal that this opponent is a "tight" player—one who only plays hands with a high likelihood of winning. Furthermore, in order to evaluate the strength of a hand in making a decision about how much to bid—another key to success in Hold'Em—the player must attend to and integrate multiple pieces of information, including the community cards shown, the number of chips in the pot, and the presumed hands of the opponents (Hellmuth, 2003).

However, the more critical question is whether WMC contributes to performance differences in Hold'Em at high levels of knowledge. That is, consistent with the circumvention-of-limits hypothesis, does WMC become less important as a predictor of performance differences as Hold'Em experience and knowledge accumulate? To answer this question, we had participants representing a wide range of declarative knowledge about poker and WMC complete tasks to assess the two components of Hold'Em skill just described—the ability to keep track of and remember actions in a Hold'Em game and the ability to evaluate hands. We then performed regression and path analyses to test for main and interactive effects of WMC and poker knowledge on performance in these tasks.

2. Method

2.1. Participants

Before the materials were administered, we screened participants to ensure a minimal level of poker knowledge. The screening test included 10 four-alternative, multiple-choice items about poker, including questions about the order of hands and basic poker terminology. Participants were required to answer at least 7 of 10 questions correctly in order to continue in the study—we expected this criterion would guarantee at least novice status in poker. The final sample consisted of 155 undergraduate students,[1] who participated in exchange for credit in their Introductory Psychology course.

The sample was predominantly male (59.8%) and young (age: M = 20.0 years, range = 18–29), and included participants from a wide range of Hold'Em experience.[2] For example, participants reported playing online Hold'Em poker between 0 and 3600 min per month, playing face-to-face poker between 0 and 3000 min per month, watching Hold'Em on television 0–2400 min per month, and reading about Hold'Em 0–240 min per month.

2.2. Materials and procedure

The study took place in a single session of approximately 2.5 h, and we tested participants in small groups (<20 participants). After participants completed the poker screening and demographic questionnaire, we administered the materials in the following fixed order:

2.2.1. Poker knowledge

We developed two paper-and-pencil tests of poker knowledge. In the first, participants answered 40 multiple-choice questions about poker terminology, such as terms used for different cards, hands, plays, and players. In the second, participants answered 21 multiple-choice questions about the rules of Hold'Em. These tests were timed (13 and 7 min, respectively), and for each test,

[1] Two participants' data were excluded because of missing data on key variables (WMC, poker knowledge).

[2] Due to an experimenter error, gender and age data were collected for only 110 participants.