THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 2002, *55A* (4), 1211–1240

Expertise, attention, and memory in sensorimotor skill execution: Impact of novel task constraints on dual-task performance and episodic memory

Sian L. Beilock, Sarah A. Wierenga, and Thomas H. Carr

Michigan State University, East Lansing, USA

Two experiments explored the attention and memory processes governing sensorimotor skill. Experiment 1 compared novice and experienced golf putting performance in single-task (putting in isolation) and dual-task conditions (putting while performing an auditory word search task). At specific intervals, participants also produced episodic descriptions of specific putts. Experiment 2 assessed novice performance following training on the same putting task. In Experiment 1, experienced golfers did not differ in putting accuracy from single- to dual-task conditions and, compared to novices, had higher recognition memory for words heard while putting but diminished episodic memories of specific putts. However, when using an s-shaped arbitrarily weighted "funny putter" designed to disrupt the mechanics of skill execution, experienced golfers produced extensive episodic memories of specific putts but showed decreased dual-task putting accuracy and recognition memory for secondary task words. Trained novices produced results intermediate between the untrained novices and experienced golfers. As predicted by current theories of practice-based automaticity, expertise leads to proceduralized control that does not require constant attention. Resources are free to devote to secondary task demands, yet episodic memory for primary task performance is impoverished. Novel task constraints (e.g., a funny putter) increase attention to execution, compromising secondary task performance but enhancing memory for skill execution.

Current theories of skill acquisition and automaticity suggest that well-learned skill execution is "automated"—controlled by procedural knowledge that requires little on-line attention and control and operates mainly outside of working memory (Anderson, 1982, 1983, 1993; Fitts & Posner, 1967; Keele & Summers, 1976; Kimble & Perlmuter, 1970; Langer & Imber, 1979; Proctor & Dutta, 1995). Because attention at encoding is known to be an important precursor for the successful explicit retrieval of episodic information from memory (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998), high-

---

Requests for reprints should be sent Sian L. Beilock, Department of Psychology, Michigan State University, Rm. 236 Psychology Research Building, East Lansing, Michigan 48824, USA. Email: beilocks@msu.edu

The authors would like to thank D. Zach Hambrick for his comments on an earlier version of this manuscript.

© 2002 The Experimental Psychology Society

http://www.tandf.co.uk/journals/pp/02724987.html DOI:10.1080/02724980244000170

level performance that is not controlled via the conscious mechanisms of working memory may be largely closed to explicit introspection, retrieval, and report. As a result, attention may be available to devote to secondary task demands if necessary. Novice skill performance on the other hand is thought to be based on declarative knowledge that is held in working memory and attended in a step-by-step fashion (Anderson, 1982, 1983; Fitts & Posner, 1967). Less practiced performance that demands the active memorial maintenance of skill knowledge should require extensive attentional resources for successful implementation. Thus, unlike experts, novices may not have resources available to devote to secondary task demands if the situation requires it. However, because novices must attend to the real-time unfolding of skill processes and procedures in order to ensure successful execution, their memories for specific performance episodes may be more complete than those of highly skilled individuals.

Research across a number of different skill domains has documented the differences in attentional requirements of novice and experienced skill performance predicted by the theories of skill acquisition and automaticity mentioned earlier (see, e.g., Allport, Antonis, & Reynolds, 1972; Leavitt, 1979; Smith & Chamberlin, 1992). Recently, Beilock, Carr, MacMahon, and Starkes (2002) explored the attentional demands involved in a soccer dribbling task at different levels of soccer expertise. Novice and experienced soccer players dribbled a soccer ball through a series of pylons while simultaneously performing a secondary auditory monitoring task. In the monitoring task, individuals listened to a series of words for a specified target word and, upon hearing it, repeated it out loud. Results demonstrated that the secondary auditory task harmed the dribbling performance of the less skilled players, regardless of which foot they dribbled with, yet did not affect experienced soccer players' dominant foot dribbling performance in comparison to single-task dribbling in isolation. However, when using their less practised non-dominant foot, experienced players' dribbling *did* suffer from the secondary auditory task. This pattern suggests that whereas novel or less practised performance may demand extensive attentional resources for successful implementation, such explicit monitoring and control may not be necessary at high levels of skill execution.

Present study

The purpose of the present study was to further test the notion that increasing expertise through practice will create proceduralized performance processes that do not rely on constant attentional scrutiny. Three different comparisons involving skill level, attention, and episodic memory for performance were made in the sensorimotor task of golf putting in an attempt to shed light on the cognitive substrates driving novice and well-learned skill performance.

The first comparison involved the generic knowledge and episodic memories of experienced and novice performers. "Generic" knowledge captures schema-like or prescriptive information about how a skill is typically performed, whereas "episodic" knowledge captures a specific memory, an autobiographical record of a particular performance. If on-line well-learned golf putting is supported by procedural knowledge, as theories of automaticity and skill acquisition would predict, then experienced golfers may well give longer, more detailed generic descriptions of the steps involved in a typical or "generic" putt compared to the accounts given by novices, because experts know more about how their skill ought to be performed. However, experienced golfers should give shorter, less detailed episodic recollections of any particular putt than less skilled golfers. Because proceduralization reduces the need to attend to the specific processes by which skill execution unfolds, experienced golfers' episodic recollections of step-by-step real-time performance should be impoverished. Beilock and Carr (2001) found support for this notion. The present study attempted to replicate this result as a starting point.

The second comparison involved the attentional demands of single- versus dual-task performance. Putting performance in a single-task, isolated environment was compared to performance in a dual-task condition in which individuals performed a series of putts while simultaneously engaging in a secondary auditory word search task involving monitoring words for a specified target, much like the soccer players studied in Beilock et al. (2002). In the search task, individuals monitored a series of words being played from a tape recorder for a specified target word and, upon hearing the target, repeated it out loud. A recognition memory test for a subset of the distractor words heard while putting was administered after the dual-task was complete. Both dual-task putting performance and recognition memory ability were retained as measures of the attentional requirements involved in the golf putting task. If well-learned putting does not require constant on-line attentional control, then the addition of a secondary monitoring task should not harm putting performance in comparison to single-task conditions. Furthermore, because experienced golfers' attentional resources should not be overly taxed by the putting task, they should have attention available to devote to the secondary task. Hence, their target detection performance and their recognition memory for words heard while putting should be similar to those based on an auditory monitoring task performed in isolation as a baseline measure. In contrast, novel skill execution that is constrained by attention-demanding cognitive processes should be impacted quite differently by secondary task demands. The addition of a secondary monitoring task should not only harm novice putting performance, but should also result in poor recognition memory for words heard while putting in comparison to the performance of either of these tasks in isolation—as novices should not be able to devote adequate attention to the monitoring task when simultaneously performing the putting task, and vice versa.

The third comparison added what we call a "funny putter" manipulation. Putting performance and generic versus episodic memory protocols were examined with experienced and novice individuals in single-task and dual-task situations using either a regular putter or an altered "funny putter". The funny putter consisted of a regular putter head attached to an "s"-shaped and arbitrarily weighted putter shaft. The design of the funny putter was intended to require experienced golfers to alter their well-practised putting form in order to compensate for the distorted club, perhaps forcing them to allocate attention to the new skill execution processes. The dissociation proposed by the skill acquisition literature concerning the attentional mechanisms supporting novice and well-learned performance suggests that although highly practised individuals may be better able than novices to allocate a portion of their attention to other stimuli and task demands if the situation requires it, their memories of this performance will be diminished in comparison to less skilled performers. However, if novel task constraints are imposed, requiring experienced performers to alter skill execution processes, they should be forced to attend to task control in a step-by-step fashion in much the same way as individuals in less practised states. As a result, experienced golfers may no longer be able to attend to multiple tasks simultaneously. In the present study, this would result in a decrease in dual-task putting performance or secondary auditory search task target detection and recognition memory. Furthermore, with the addition of novel task constraints, experienced individuals' memories for specific instances of performance should be enhanced, resembling those of less skilled participants, as attention should now be directed back to controlling the step-by-step execution of the primary task at hand. In contrast, novice performers should not be affected by the "funny putter" in the same way as more experienced golfers. Because novices have not yet adapted to putting under normal conditions, performance should not be drastically influenced by an altered putting environment.

In the experiment just described only novice golfers with no previous golf exposure and highly skilled golfers with several years of golf experience were tested. Although contrasting relatively extreme ends of the skill acquisition continuum may speak to differences inherent in novel and well-learned performance processes, this comparison does not illuminate the mechanisms underlying task execution at intermediate stages of skill acquisition, nor does it illuminate the manner in which these structures change as individuals develop well-learned skill responses. Thus, a second experiment was conducted in which we examined the effects of a modest amount of skill training on the memory structures and attentional demands associated with golf putting performance under both single- and dual-task conditions. Awareness of the processes and procedures involved in the intermediate stages of skill acquisition is not only important in gaining a better understanding of experienced skill execution, but is also crucial in determining the most appropriate instructional techniques for enhancing performance at different levels of skill learning. We now turn to Experiment 1 in which we explored novice and experienced golf putting performance across single- and dual-task conditions and under various task constraints.

EXPERIMENT 1

In Experiment 1 novice and experienced golfers performed a series of golf putts on an indoor putting green using either a regular or a "funny putter" under both single-task and dual-task putting conditions. At specific intervals unknown to participants, generic or episodic memory protocols were collected.

Method

Participants

Participants were 84 novice and experienced golfers. Novice participants (n = 42) consisted of introductory psychology students enrolled at Michigan State University with no previous golf experience. Experienced participants (n = 42) were local high school and college students with 2 or more years of high-school varsity golf experience or a Professional Golfers' Association (PGA) handicap less than 8. Individuals were randomly assigned within skill level to either a regular putter or a funny putter condition in a 2 (novice golfer, experienced golfer) × 2 (regular putter, funny putter) experimental design with 21 participants in each group.

Procedure

After giving informed consent and filling out a demographic sheet concerning previous golf experiences, participants were told that the purpose of the study was to examine performance on a number of different cognitive and motor tasks. Individuals first took two blocks of 20 putts followed by a generic memory questionnaire. Next, participants completed a single-task word-monitoring test in which they listened for a target word embedded in a series of auditorally presented words, and upon hearing the target, repeated it out loud. The monitoring task was followed immediately by a short arithmetic task. The purpose of this task was to eliminate recency effects associated with the word list in the monitoring task. A recognition memory test for a subset of the words presented in the single-task word-monitoring condition was then administered. Participants next performed a dual-task putting and word-monitoring task followed by an episodic memory questionnaire. Finally, participants completed a second arithmetic task after which they received another recognition memory test based on a subset of the words presented during the dual-task putting and word-monitoring condition.

All participants took part in identical experimental conditions presented in the same order. A fixed order was utilized in order to obtain baseline performance measures of single-task putting and recognition memory prior to the dual-task putting and word-monitoring condition. In the present study, the fact that single-task conditions preceded dual-task performance actually works against our hypothesis that novices and experienced golfers performing under novel task constraints (i.e., the funny putter experienced golfers) will show performance decrements under dual-task conditions, whereas experienced golfers performing under normal task demands (i.e., the regular putter experienced golfers) will not. That is, providing participants with single-task putting practice prior to the dual-task condition afforded these individuals the opportunity to practise and improve skill performance. Under the power law of practice, the two novice groups and the experienced golfers using the novel, funny putter should improve at a faster rate than the experienced golfers putting under relatively normal conditions—as the former groups have had less exposure to the novel parameters of the task at hand. Thus, implementation of the single-task conditions prior to dual-task performance should serve to narrow the gap in dual-task performance across experimental groups, decreasing the likelihood of finding differences in dual-task performance that are dependent on skill level or type of putter utilized.

Single-task putting. Participants were informed that they would be completing a golf putting task. The object of this task was to putt a golf ball as accurately as possible from nine locations on a carpeted indoor putting green (3 m × 3.7 m) that were 1.2 m, 1.4 m, or 1.5 m away from a target, marked by a square of red tape, on which the ball was supposed to stop. All participants followed the same random alternation of putting from the nine different locations. A standard golf putter and golf ball were supplied for those participants who took part in the regular putter condition, and the "funny putter" and a standard golf ball were supplied for those participants in the funny putter condition.

Participants were set up at the first putting spot. They were asked whether they preferred to putt right-handed or left-handed and were given the appropriate putter. The experimenter informed participants that they would be putting from nine locations on the green. Participants' attention was then directed to a tiny light set up next to each putting spot. Participants were informed that the lights were hooked up to a switch board controlled by the experimenter. Participants were told that before every putt, a light would illuminate beside the location from which they were to take their next putt. Participants took two blocks of 20 putts, with a short break following each block of putts. Participants then filled out a generic memory questionnaire eliciting a description of the steps involved in a "typical" golf putt (Appendix A).

Single-task word monitoring. Following completion of the generic memory protocol, participants were informed that they would be listening to a series of words spoken from a tape recorder. Every time participants heard the target word, "Dean", they were to repeat it out loud. Words were 60 one-syllable common concrete nouns presented at a rate of 1 word/3 s, with the target word occurring randomly once every 12 s for a total of 20 presentations. Next, individuals were told that they would be performing another cognitive task. A sequence of 20 random digits (1–9) was presented on a tape recorder at a 2-s rate. Participants were instructed to add 3 to each number and to respond orally.

Recognition Memory Test 1. Participants were given a list of 60 words and informed that about half of the words on the list were from the tape-recorded list that they had heard previously, and about half were not. Participants were instructed to put a check mark next to each word that they recognized hearing from the word list.

Dual-task putting and word monitoring. Participants were again set up at the first putting spot. Individuals were informed that they would be completing the same putting task that they had participated in during the single-task putting condition. However, individuals were also told that they would be simultaneously listening to a series of words while putting. Every time they heard the target word, "Thorn", they were to repeat it out loud. Participants were reminded to putt as accurately as possible. Individuals completed one block of 20 putts while monitoring for the target word. Words were one-syllable common concrete nouns presented at a rate of 1 word/3 s until the individual completed the putting task. Target words occurred randomly, averaging once every 12 s. Immediately following the last putt, the tape recorder was turned off, and participants filled out an episodic memory questionnaire designed to access their episodic recollection of the last putt that they had just taken (Appendix A). Next, individuals were told that they would be performing another cognitive task. Participants completed the same number task that they had performed after the single-task word-monitoring condition.

Recognition Memory Test 2. Participants were given a list of 60 words and informed that about half of the words on the list were on the tape-recorded list that they had heard while putting, and about half were not. Participants were instructed to put a check mark next to each word that they recognized hearing while putting. Individuals were then thanked for their time and fully debriefed.

Results

Putting performance

Accuracy of putting was measured by the distance in cm away from the centre of the target that the ball stopped after each putt. The mean distance from the target of the first 20 putts was used as a measure of pre-test putting performance. The first 20 putts were included in order to give both the novice and the experienced golfers exposure to our somewhat novel putting task of having to land the ball on a target rather than in a hole. The mean distance from the target of the second 20 putts was used as a measure of single-task putting. The mean distance from the target of the 20 putts in the dual-task putting condition was used as a measure of dual-task putting skill (Figure 1).

A 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) × 2 (single-task putting, dual-task putting) analysis of variance (ANOVA) revealed a significant Expertise × Putter × Condition interaction, $F(1, 80) = 6.35$, $p < .01$, $MSE = 10.77$, as well as a significant main effect of experience, $F(1, 80) = 125.09$, $p < .01$, $MSE = 49.59$, and condition, $F(1, 80) = 17.36$, $p < .01$, $MSE = 10.77$. Paired-sample t-tests performed as post hoc tests revealed that the regular putter novice group (NR), $t(20) = 3.01$, $p < .01$, the funny putter novice group (NF), $t(20) = 2.24$, $p < .04$, and the funny putter experienced group (EF), $t(20) = 5.1$, $p < .01$, performed significantly worse in the dual-task putting condition than in the single-task putting condition. In contrast, the regular putter experienced group (ER) actually improved from single- to dual-task conditions, although this difference was not significant, $t(20) = 1.67$, $p < .11$.

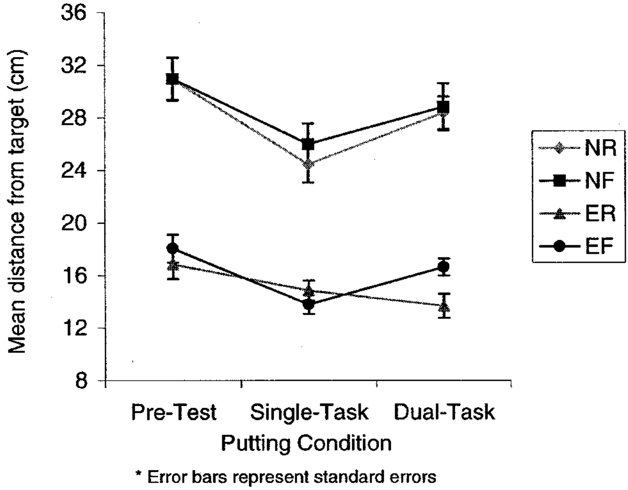

Figure 1. Mean distance (cm) from the target that the ball stopped after each putt in the pre-test, single-task, and dual-task conditions for each group. See Table 1 caption for group names.

As can be seen from Figure 1, experienced golfers, regardless of type of putter, outperformed novices during both the single- and dual-task putting conditions. Additionally, novice golfers using the funny putter did not significantly differ from regular putter novices during either the single-task, $t(40) = 0.73, p > .47$, or the dual-task conditions, $t(40) = 0.21, p > .83$. This result is not surprising considering that novices were not experienced with either type of putter prior to the experiment. In addition, this result indicates that the funny putter was not inherently more difficult to use.

Experienced golfers using the funny putter performed at a similar level to that of regular putter experienced golfers during the single-task condition, $t(40) = 1.0, p > .31$. However, funny putter experienced golfers were significantly less accurate than regular putter experienced golfers during the dual-task putting condition, $t(40) = 2.64, p < .01$. It is interesting to note that the novel constraints of the funny putter led to negative performance consequences only for experienced golfers in the dual-task condition. This finding suggests that although experienced golfers were able to adjust to the demands of the funny putter under conditions that did not stress attentional resources (i.e., single-task putting), the addition of a secondary task overly strained attentional capacity. In fact, several of the experienced golfers mentioned adjusting to the "offset weight" of the putter or having to "hold the putter tightly" in order to compensate for "the misshapen club" in their episodic protocols, suggesting that these individuals were able to identify and adapt to the irregular putter constraints. The role of the funny putter in prompting experienced golfers to explicitly attend to their putting performance is further demonstrated in the generic and episodic memory data described in the protocol analysis section later.

Thus, whereas the two novice groups and the experienced golfers using the funny putter declined in putting accuracy from the single-task to the dual-task condition, the regular putter experienced golfers did not. From this pattern of data it could be concluded that well-learned skill execution does not mandate constant on-line attention and control. As a result, experienced golfers' putting performance under normal task constraints (i.e., the regular putter) is not harmed by the addition of secondary task demands. However, it is possible that the regular putter experienced golfers' dual-task performance did not decline in comparison to single-task conditions because these individuals were not allocating a significant amount of attention to the secondary word-monitoring task. If so, this should be reflected in poor recognition memory for words heard while putting. As described later in the recognition memory analysis, this does not appear to be the case.

Nonetheless, in order to further guard against the possibility that changes in putting performance from the single-task to the dual-task conditions were due to a trade-off in attentional allocation with the secondary auditory monitoring task, a 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) × 2 (single-task putting, dual-task putting) ANOVA was performed with the difference between Recognition Memory Test 1 and Test 2 performance used as a covariate. If putting under dual-task conditions is the result of a trade-off with secondary monitoring task performance, then covarying out the difference in performance between the baseline single-task recognition memory test (Test 1) and the recognition memory test for words heard while putting (Test 2) should lead to a non-significant Expertise × Putter × Putting Condition interaction, as attention to the secondary auditory monitoring task, rather than type of putter used or level of expertise, would be influencing differences in putting performance across the single- and dual-task putting conditions. Even when using Recognition Memory Test 1 and Test 2 performance differences as a covariate, a significant Expertise × Putter × Condition interaction was found, $F(1, 79) = 5.5$, $p < .02$, $MSE = 10.90$. Thus, differences in putting performance from the single-task to dual-task conditions do not appear to be the result of a trade-off with secondary task performance.

Secondary word-monitoring task performance

Target word identification. Each instance in which individuals failed to identify a target word was recorded. Target word identification failure did not significantly differ across groups for either the single-task auditory monitoring, $F(3, 80) = 0.73$, $p > .5$, $MSE = 0.06$, or the dual-task auditory monitoring condition, $F(3, 80) = 1.13$, $p > .3$, $MSE = 0.18$. Failure to identify target words was more prevalent in the dual-task monitoring condition than in the single-task condition, $F(1, 83) = 5.25$, $p < .03$, $MSE = 0.11$. Overall, however, target word identification failure occurred relatively infrequently across both the single-task ($M = 0.04$ errors, $SD = 0.24$) and dual-task conditions ($M = 0.15$ errors, $SD = 0.42$).

Recognition memory. Performance on Recognition Memory Test 1 and Test 2 was assessed using the discrimination indices A', d', % correct, and hits minus false alarms (Pollack & Norman, 1964). These measures did not differ significantly in the conclusions they reached. A' was thus retained as the primary measure of recognition memory performance in the present study. A' is a nonparametric measure of discrimination that, unlike d', can be calculated without adjustment of any scores, even when the observed hit or correct-rejection rate is 1.0 (see Macmillan & Creelman, 1991; Snodgrass & Corwin, 1988).

The measure A' is calculated by $A' = 0.5 + (H - F)(1 + H - F)/[4H(1 - F)]$ when performance is above chance, $H > F$, where H is a hit and F is a false alarm, and by $A' = 0.5 + (f - H)(1 + F - H)/[4F(1 - H)]$ when performance is below chance, $H < F$. A response was considered a hit (H) if a participant correctly identified a word that had been previously presented in the word list. A response was considered a false alarm (F) if a participant identified a new word as having been presented previously. Table 1 presents hit and false alarm rates for Recognition Memory Test 1 and Test 2.

In Recognition Memory Test 1, participants were presented with a list of 60 words (30 words from the single-task word-monitoring condition, and 30 words that they had not been previously exposed to in the present experiment) and instructed to put a check mark next to each word that they recognized hearing during the single-task word-monitoring condition. Individuals were informed that about half of the words on the memory test were contained in the word list that they had heard previously, and about half were new words that were not contained in the single-task word-monitoring list.

In Recognition Memory Test 2, participants were again presented with a list of 60 words and instructed to identify the words that they recognized hearing during the dual-task putting and word-monitoring condition. As in Test 1, participants were instructed that about half of the words on the memory test were contained in the word list that they had heard while putting, and about half were not. However, the number of words on Recognition Memory Test 2 that participants had been exposed to while putting was dependent on the actual time spent performing the putting skill. Upon completion of the putting task the word list was turned off, and the experimenter noted the last word played. Thus, participants were not always presented with all 30 words on the monitoring list that were included in Recognition Memory Test 2. In order to compensate for this occurrence, any word contained in the memory test that had not been presented while putting was scored as a new word (i.e., a check mark by a participant indicating that the word had been played on the word-monitoring list was considered a false alarm). Due to the fact that prior to both the single- and dual-task recognition memory tests, individuals were informed that approximately half of the words on the test had been presented previously, a lower number of previously presented words in the dual-task condition presents the possibility of a confound in response bias with single- versus dual-task memory tests. However, the mean percentage of previously presented words (i.e., the number of possible hits) was relatively similar across

TABLE 1
Hit and false alarm rates for Recognition Memory Tests 1 and 2 in Experiments 1 and 2

		Test 1				*Test 2*			
		Hits		*False alarms*		*Hits*		*False alarms*	
Experiment	*Group*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1	NR	42.70	3.19	17.94	2.58	32.18	4.06	23.80	3.12
	NF	48.25	3.44	20.32	3.33	31.40	3.98	22.60	3.69
	ER	41.11	3.73	17.46	3.19	31.77	3.54	15.04	2.70
	EF	44.44	3.27	16.98	3.23	26.43	4.20	19.94	4.01
2	TR	44.60	2.96	16.19	2.47	35.01	3.35	17.11	2.73

Note: Hit and false alarm rates in percentages. NR = regular putter novice group; NF = funny putter novice group; ER = regular putter experienced group; EF = funny putter experienced group; TR = trained novice group.

recognition memory tests: 50% (30 words) in the single-task condition and 44% (26.2 words) in the dual-task condition.[1]

A 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) × 2 (Memory Test 1, Memory Test 2) ANOVA revealed a significant Expertise × Putter × Test interaction, $F(1, 80) = 5.56, p < .02, MSE = 9.47 \times 10^3$. A 2 (experienced golfer, novice golfer) × (funny putter, regular putter) ANOVA on Recognition Memory Test 1 produced no significant main effect of experience, $F < 1$, or putter, $F(1, 80) = 1.11, p > .30, MSE = 7.7 \times 10^3$, and no Experience × Putter interaction, $F < 1$. In terms of Memory Test 2, a similar ANOVA produced a significant Experience × Putter interaction, $F(1, 80) = 4.86, p < .03, MSE = 0.02$. As can be seen from Figure 2, in Recognition Memory Test 2, the experienced golfers using the regular putter performed at a higher level than the regular and funny putter novice groups, $t(40) = 2.74, p < .01$ and $t(40) = 2.36, p < .03$, respectively, and the funny putter experienced golfers, $t(40) = 2.95, p < .01$. The two novice groups and the funny putter experienced golfers did not differ in Recognition Memory Test 2 performance, ps > .6, respectively.

Additionally, both regular and funny putter novices' recognition memory performance significantly decreased from Memory Test 1 to Test 2, $t(20) = 4.1, p < .01$, and $t(20) =$

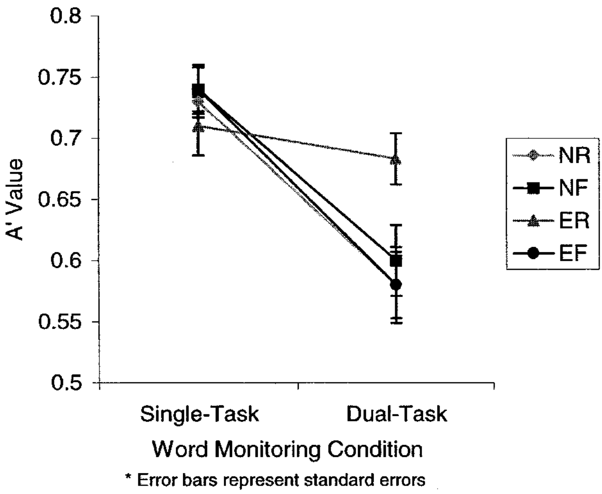

Figure 2. Mean A' value for the single-task and dual-task recognition memory tests for each group.

[1]If instructions that about half of the words had been presented previously introduced a response bias in the dual-task condition, then this should be evident in a greater percentage of false alarms (i.e., the identification of a new word as having been previously presented) on the dual-task recognition memory test than on the single-task test. However, a paired-sample t test showed a non-significant difference in the percentage of false alarms between the single- and dual-task conditions, $t(83) = 1.66, p = .10$. Additionally, in order to further assess and guard against the possibility of differential response bias influencing our results due to variation in the number of previously presented words in the single-task word-monitoring test in comparison to the dual-task test, percentage of previously presented words in Memory Test 2 was used as a covariate in the analyses intended to assess single- and dual-task recognition memory differences. Adding percentage of previously presented words as a covariate did not alter the results of these analyses in any way.

4.96, $p < .01$, respectively. The funny putter experienced golfers' memory performance also significantly declined from Memory Test 1 to Test 2, $t(20) = 5.31, p < .01$. In contrast, the regular putter experienced golfers' Recognition Memory Test 1 performance did not significantly differ from Memory Test 2 performance, $t(20) = 1.15, p > .27$. The effect size estimate for this statistic is $d = .27$ (Dunlap, Cortina, Vaslow, & Burke, 1996). This is a fairly small effect. In order to detect an effect of this magnitude, with power = .80, we would need over 175 participants in the regular putter experienced group (Cohen, 1988). Thus, there does not appear to be a substantial difference in the regular putter experts' Recognition Memory Test 1 and Test 2 performance. These results accord quite precisely with the predictions derived from theories of skill acquisition and automaticity.

It should be noted that Recognition Memory Test 1 and Test 2 were based on different word lists, thus creating the possibility that one list was inherently more difficult than the other. All words were one-syllable common concrete nouns randomly assigned to either Test 1 or Test 2. Thus, there does not seem to be any obvious reason to suspect that these word lists were of different difficulty levels. Nonetheless, the possibility still remains that one word list was consistently more difficult than the other. If this were the case, however, then a main effect of recognition memory test performance should appear, rather than the Memory Test × Expertise × Putter interaction that did in fact occur, as all participants should perform significantly worse on the memory test based on the more difficult word list.

Additionally, there was a longer delay between the dual-task word-monitoring condition and Recognition Memory Test 2 than between the single-task word-monitoring condition and Recognition Memory Test 1. This delay was due to the administration of the episodic memory protocol immediately following the dual-task putting and word-monitoring condition and may possibly have affected Recognition Memory Test 2 performance by creating a more difficult measure of recognition memory. The interval between the single-task word-monitoring condition and Recognition Memory Test 1 was about 40 s. This was a filled retention interval consisting of an arithmetic task in which participants were presented with 20 single-digit numbers at a 2-s rate and were required to add 3 to each number and respond orally. The delay between the dual-task word-monitoring condition and Recognition Memory Test 2 consisted of the episodic protocol and the same arithmetic filler task. Thus the filled retention interval prior to both recognition memory tests was 40 s or longer. It is not likely then that word list information for either recognition test was stored in short-term memory, as it has been suggested that filled-interval short-term storage is likely not to exceed 30 s (for a review, see Cowan, 1988). If the word lists were being held in long-term memory, the temporal differences between word list presentation and test for Recognition Memory Test 1 and Test 2 should not have a significant impact on performance. Furthermore, the Memory Test × Experience × Putter interaction further supports the notion that Recognition Memory Test 2 was not inherently more difficult than Test 1. From these various checks we conclude that memory performance legitimately reflects an interpretable impact of differences in skill and performance environment.

Finally, participants may have suspected that they would receive a recognition memory test for a subset of the words presented in the dual-task putting and auditory monitoring condition. If Recognition Memory Test 2 was not a surprise, then individuals may have increased attention to the monitoring task and in turn decreased attention to the putting task, in the dual-task condition. This should not only result in a decrement in putting accuracy, but an increase in recognition memory ability in comparison to single-task performance on either task. However, as can be seen from Figure 2, Recognition Memory Test 2 performance significantly decreased in comparison to Test 1 for all groups except the regular putter experienced golfers. Even if participants were aware of the fact that they might be asked to later remember words presented while putting, only the regular putter experienced golfers were able to allocate the necessary attentional resources to do so. The differential recognition memory performance of the regular putter experienced golfers in comparison to the other experimental groups also rules out the possibility that proactive interference from the first word list resulted in a reduction in Recognition Memory Test 2 performance. If proactive interference was responsible for Memory Test 2 decrements, then all experimental groups should have shown decreased Test 2 performance. Furthermore, not only did recognition memory suffer under dual-task conditions for both novice groups and the funny putter experienced golfers, but putting accuracy did as well, suggesting that novel task constraints prevented these individuals from sufficiently attending to either the putting or the monitoring task in the dual-task condition.

Generic and episodic memory protocols

Questionnaire responses were analysed quantitatively in terms of the number of golf putting steps included in each type of protocol and qualitatively in terms of the relative frequencies of different categories of steps.

Quantitative analysis. Three expert golfers and the "how to" golf putting book, *Classic Instruction in Golf* (Jones, Davis, Crenshaw, Behar, & Davis, 1998) were employed in establishing a master list of steps involved in a successful golf putt (Appendix B). The statements in each participant's protocol were compared with this master list. If a step given by a participant referred to the same action or biomechanism as a step on the master list, it was counted as one step. For example, the step given by a participant, "I took the putter back", and Step 13 on the expert golfer list, "swing the club straight back", were coded as a match because they both refer to the same action (i.e., "taking a backswing"). Similarly, the step given by a participant, "I kept wrists still", and Step 19 on the list developed by the expert golfers, "wrists should not break during the stroke", were deemed a match because they both refer to the same biomechanism (i.e., "motion of the wrists"). If two steps given by participants both described one step on the list developed by the expert golfers, they were combined and counted as one step. For example, if a participant reported the following two steps: (1) "My hands were on the putter and situated in a grip I liked", and (2) "About 2 inches from the top was my left hand and immediately underneath was my right hand", this was combined to match the step on the list developed by the expert golfers referring to the "grip of the putter". If a step given by a participant did not match a step on the master list, yet did refer to a necessary part of the participant's putting process (e.g., "analyse putt to make corrections if necessary"), it was counted as a step. Because the master list was fairly detailed, "non-match steps" were quite infrequent. Finally, if a step given by a participant did not match a step on the master list and was not part of the putting process itself (e.g., "started sniffling because of the beginnings of what seemed to be a cold"), it was not counted as a step. Such non-process commentary is legitimately part of the autobiographical record. However, it is not part of the specific object of prediction in testing for experts' diminished episodic memory. Furthermore, non-process commentary was quite rare and, if included, would not have altered the results in any way.

The order in which the steps were recorded was not taken into account in determining the number of steps given by participants. Three experimenters independently coded the data. Inter-experimenter reliability was extremely high, $r = .94$.

Figure 3 presents the results. A 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) × 2 (generic protocol, episodic protocol) ANOVA compared the lengths of the generic and episodic protocols produced at each level of expertise. This analysis revealed an interaction of Experience × Putter × Questionnaire, $F(1, 80) = 26.72$, $p < .01$, $MSE = 3.38$. It should be noted that the generic protocol was collected after single-task putting whereas the episodic protocol was administered following dual-task putting. Thus it is possible that the differential putting environments preceding the generic and episodic questionnaires led to differences in putting protocol generation, rather than expertise level or the type of putter utilized. The protocol data presented in this study are the third replication of these results, however. In two different experiments, in which both the generic and episodic protocols were collected following identical single-task putting conditions, Beilock and Carr (2001) found a similar pattern of results to those observed here.

A 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) ANOVA on the generic protocol produced a main effect of expertise, $F(1, 80) = 25.09$, $p < .01$, $MSE = 6.17$, with the experienced performers giving longer generic protocols than the novices, no main effect of putter, and no Experience × Putter interaction, Fs < 1, respectively. A similar ANOVA on the episodic questionnaire produced an Experience × Putter interaction, $F(1, 80) = 6.76$, $p < .01$, $MSE = 7.9$. Independent sample t tests revealed that although the two novice groups did not differ in terms of the number of steps given in their episodic protocols, $t(40) = 0.12$, $p > .91$, the funny putter experienced golfers gave significantly more steps in their episodic protocol than did the regular putter experienced golfers, $t(40) = 3.58$, $p < .01$. Additionally, both novice groups and the funny putter experienced group gave significantly more

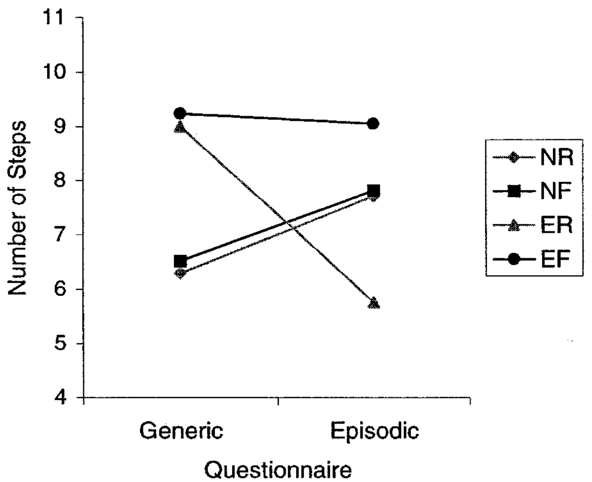

Figure 3. Mean number of steps for the generic and episodic questionnaires for each group.

steps than did the regular putter experienced golfers in the episodic questionnaire, $ps < .05$, respectively.

Direct comparisons of the number of generic versus episodic steps within each group showed that both the regular and funny putter novices gave significantly more steps in their episodic than in their generic protocols, $t(20) = 2.43, p < .03$, and $t(20) = 2.98, p < .01$, respectively. The experienced golfers using the funny putter gave an equivalent number of steps in their generic and episodic protocols, $t(20) = 0.34, p > .74$. In contrast, the experienced golfers using the regular putter gave significantly fewer steps in their episodic than in their generic protocols, $t(20) = 4.9, p < .01$. Furthermore, as can be seen from Figure 3, the experienced golfers using the funny putter gave longer generic and episodic putting descriptions than any other group. We take this to mean that increased attention to the novel constraints of the funny putter prompted these golfers to allocate more attention to skill execution processes, enhancing generic descriptions and leaving explicit episodic memory traces of performance.

Qualitative analysis: Types of step. The qualitative analysis divided steps into three categories (see Table 2). Assessment or planning referred to deciding how to take a particular putt and what properties the putt ought to have. Examples are "I looked to see how far from the target I was", "there is little or no break in the putt", "look at the contour of the green", and "mentally create a line of sight" (from the ball to the hole or target). Mechanics or execution referred to the components of the mechanical act that implements the putt. Examples are "grip the putter", "take the putter back", and "follow through as far as putter was taken back", all of which deal with the effectors and the kinesthetic movements of the effectors required to implement a putt. Ball destinations or outcomes referred to where the ball stopped or landed and hence to degree of success. A 2 (experienced golfer, novice golfer) × 2 (regular putter, funny putter) × 2 (generic protocol, episodic protocol) ANOVA was conducted on the number of steps given in each of these three categories.

The analysis of assessment produced a significant interaction of expertise and type of protocol, $F(1, 80) = 15.55, p < .01, MSE = 1.08$, which is displayed in Panel A of Figure 4, along with a non-significant interaction of Expertise × Protocol × Putter, $F < 1$. A one-way ANOVA on the generic protocol with putter collapsed within skill level produced a main effect of experience, $F(1, 82) = 13.81, p < .01, MSE = 2.24$. Assessment steps appeared more often in the generic descriptions of experienced golfers, regardless of putter type, than anywhere else. In the episodic protocol, a one-way ANOVA with putter collapsed within skill level illustrated no significant difference between novice and experienced golfers' assessment steps, $F < 1$.

Paired sample t tests further revealed that the regular and funny putter experienced golfers gave significantly more assessment steps in their generic descriptions than in their episodic recollections, $t(20) = 4.46, p < .01$, and $t(20) = 3.7, p < .01$, respectively. In contrast, the regular and funny putter novices did not differ in terms of the number of assessment steps given in the generic and episodic protocols, $t(20) = 1.14, p > .27$, and $t(20) = 0.57, p > .58$, respectively. Thus, assessment steps decreased in number from the generic to episodic protocol for the two experienced groups, regardless of type of putter used, whereas the two novice groups did not differ in terms of generic and episodic protocol assessment steps.

Turning to mechanics, this analysis produced an interaction of Experience × Protocol × Putter, $F(1, 80) = 6.42, p < .01, MSE = 3.92$, as can be seen in Panel B of Figure 4. A 2

TABLE 2
Assessment, mechanics, and destination descriptions for the generic and episodic questionnaires in Experiments 1 and 2

		Generic questionnaire								*Episodic questionnaire*							
		Assess steps		*Mechanic steps*		*Destin steps*		*Total steps*		*Assess steps*		*Mechanic steps*		*Destin steps*		*Total steps*	
Experiment	*Group*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1	NR	1.95	0.32	4.33	0.49	0.00	0.00	6.29	0.50	1.57	0.27	5.71	0.65	0.43	0.13	7.71	0.63
	NF	1.76	0.18	4.76	0.40	0.00	0.00	6.52	0.34	1.67	0.20	5.86	0.61	0.29	0.14	7.81	0.52
	ER	2.81	0.36	6.19	0.76	0.00	0.00	9.00	0.68	1.14	0.19	4.00	0.73	0.62	0.19	5.76	0.67
	EF	3.33	0.41	5.91	0.54	0.00	0.00	9.24	0.59	2.00	0.32	6.52	0.66	0.52	0.18	9.05	0.63
2	TR	2.00	0.37	5.14	0.50	0.00	0.00	7.14	0.50	1.52	0.34	4.67	0.53	0.38	0.15	6.57	0.55

Note: Assess = assessment; Mechanic = mechanics; Destin = destination. NR = regular putter novice group; NF = funny putter novice group; ER = regular putter experienced group; EF = funny putter experienced group; TR = trained novice group.

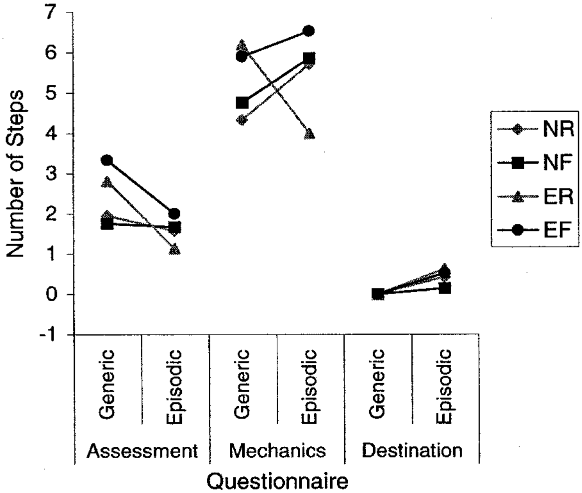

Figure 4. Mean number of steps in the assessment (Panel A), mechanics (Panel B), and destination (Panel C) categories for the generic and episodic questionnaires for each group.

(experienced golfer, novice golfer) × 2 (funny putter, regular putter) ANOVA on the generic protocol produced a significant main effect of experience, $F(1, 80) = 7.06$, $p < .01$, $MSE = 6.69$, with experienced golfers giving more mechanics steps in their generic protocols than novices, no main effect of putter, and no interaction of Experience × Putter, Fs < 1, respectively. In the episodic protocol, a 2 (experienced golfer, novice golfer) × 2 (funny putter, regular putter) ANOVA produced a marginally significant Experience × Putter interaction, $F(1, 80) = 3.23$, $p < .08$, $MSE = 9.23$. As can be seen from Figure 4, the experienced golfers using the funny putter gave more mechanics steps than did any other group, whereas the regular putter experienced golfers gave fewer mechanics steps than did the other three groups. The two novice groups did not differ.

Additionally, both regular and funny putter novices gave significantly more mechanics steps in their episodic recollections than in their generic protocols, $t(20) = 2.42$, $p < .03$, and $t(20) = 2.40$, $p < .03$, respectively. The experienced golfers using the funny putter also gave more mechanics steps in their episodic recollections than in their generic protocols, although this difference was not significant, $t(20) = 0.94$, $p < .36$. In contrast, the regular putter experienced golfers gave significantly fewer mechanics steps in their episodic recollections than in their generic descriptions, $t(20) = 3.03$, $p < .01$.

It is important to note that although both the regular and funny putter experienced golfers gave diminished assessment step descriptions from generic to episodic protocols, this was not the case in terms of mechanical steps. Instead, the funny putter experienced golfers gave somewhat more mechanics steps in their episodic protocol than in their generic description, whereas the regular putter experienced golfers gave significantly less. The altered weight and shape of the funny putter was designed to directly affect the mechanical aspect of the putting task in the present study. The assessment and planning of a putt should not be significantly influenced by putter type. It is not surprising then, that the regular and funny putter experienced golfers did not differ in terms of assessment steps included in their episodic memory protocols, yet did vary in their accounts of the mechanical properties involved in their putting performance.

The analysis of ball destinations produced a main effect of protocol type, $F(1, 80) = 33.21, p < .01, MSE = 0.27$, no main effect of experience, $F(80) = 1.77, p > .19$, or putter, $F < 1$, and no interaction of Protocol × Experience × Putter, $F < 1$. As shown in Panel C of Figure 4, regardless of putter type or expertise, ball destinations were more likely to appear in episodic recollections than in generic protocols.

Discussion

In Experiment 1 three main comparisons were utilized in an attempt to illuminate the cognitive processes governing performance at different levels of skill expertise. First, experienced golfers' generic knowledge of golf putting and episodic recollections of specific putts was compared to the generic knowledge and episodic recollections of novice golfers. Second, novel and well-learned golf putting performance under single-task conditions (i.e., putting in an isolated environment) and dual-task conditions (i.e., putting while simultaneously performing an auditory monitoring task) was assessed. Both dual-task putting performance and recognition memory for words heard while putting were compared to single-task measures given as a baseline. Finally, the effect of the "funny putter" on novice and experienced golf putting performance and generic and episodic memory structures was examined.

Novice golfers, regardless of type of putter used, gave short generic putting descriptions and longer episodic memory recollections. Experienced golfers using the regular putter produced an opposite pattern. Regular putter experienced golfers' generic putting descriptions were longer than novices', reflecting golf expertise. However, regular putter experienced golfers gave shorter episodic recollections than their generic descriptions and also than novices' episodic recollections. This impoverished episodic memory demonstrates what Beilock and Carr (2001) have termed "expertise-induced amnesia". Expertise-induced amnesia centres around the notion that although experts may have extensive generic knowledge regarding how a skill is typically performed that is declaratively accessible during off-line reflection, this knowledge is not used during real-time performance. Instead, on-line performance is controlled by automated procedural knowledge that is substantially closed to explicit introspection, analysis, and report. As a result, episodic memories for the step-by-step processes involved in real-time performance are impoverished.

In contrast to the regular putter experienced golfers, experienced golfers using the "funny putter" did not show this impoverished episodic recollection. These individuals provided the most elaborated generic and episodic protocols, and their episodic recollections were similar in length to their generic descriptions, not shorter as produced by the regular putter experienced golfers. Thus when a proceduralized skill is disrupted by the imposition of novel task demands, "expertise-induced amnesia" disappears. Furthermore, once experts start attending to task performance, their expert knowledge allows them to remember more of what they are attending to than do novices. It should be noted that the episodic memory protocol utilized in the present study reflects recollection of the most recent putt using a free recall procedure. Although this is one measure of episodic recollection, use of other episodic memory measures, such as recognition memory or the temporal order sequencing of different putts, might not necessarily reveal the same pattern of results. This is a question that we would like to address in future research.

In terms of putting performance, both novice groups, as well as the experienced golfers using the "funny putter", showed performance decrements from the single-task to the dual-task putting conditions. In contrast, experienced golfers using the regular putter did not decline in putting accuracy from single- to dual-task conditions. Word recognition performance followed a similar pattern. Both of the novice groups and the experienced golfers using the "funny putter" showed decrements in recognition memory for words heard while putting, in comparison to the single-task word recognition test given as a baseline measure. The experienced golfers using the regular putter, on the other hand, did not show this decrement—exemplifying similar recognition memory ability across both single- and dual-task conditions. Thus, as illustrated by both putting performance and word recognition data, performing in a dual-task environment harmed novices and those experienced golfers using the "funny putter", but did not significantly disrupt putting performance or word recognition ability in experienced golfers putting under normal conditions.

It may be that the dual-task manipulation in the present study did not cause decrements in experienced golfers' putting performance because it was not challenging enough, and that a more attention-demanding secondary task would lead to decrements in the regular putter experienced golfers' putting performance. However, it should be noted that the secondary task used in the present study did cause putting performance decrements in both novice groups and those experienced golfers using the funny putter, thus indicating that this task was somewhat attention demanding. Future research directly manipulating degree of cognitive load and its impact on primary task performance at different levels of expertise will further serve to clarify this issue.

The previous findings suggest that expertise leads to the encoding of task components in a proceduralized form that supports effective real-time performance without the need for constant on-line attentional control. As a result, experienced individuals performing under normal, practised task conditions are better able than novices to allocate a portion of their attention to secondary task demands if the situation requires it—even though under these same normal, practised conditions, experts allocate less attention to their performance and remember fewer of its step-by-step details.

EXPERIMENT 2

In Experiment 1 relatively extreme ends of the skill acquisition continuum (i.e., novice golfers with no previous golf experience and highly skilled golfers with several years of previous golf experience) were utilized in an attempt to compare novel and well-learned skill execution processes. Results suggest that the efficacy of performance, as well as the memory structures associated with this performance, are dependent on level of skill expertise. However, the manner in which the cognitive mechanisms governing performance change as individuals begin to develop well-learned skill repertoires, but before the years of practice that distinguish truly expert performers from novices, is still unclear. This brings us to Experiment 2, in which we attempted to explore the effects of a modest amount of skill training on generic and episodic memory and the attentional demands associated with golf putting performance under both single- and dual-task demanding conditions.

Novice golfers performed 650 practice putts with a regular putter distributed over 3 days of practice on our laboratory putting green. This number of putts was chosen because pilot testing revealed that novice golfers' putting accuracy on our laboratory putting task was similar to the experienced golfers' accuracy after this amount of training. These individuals then participated in the same experimental conditions as those utilized in Experiment 1. In Experiment 2 we were interested in determining whether training novice golfers to a single-task putting accuracy level similar to that of the experienced golfers tested in Experiment 1 would afford these trained novices the same types of knowledge structures and attentional requirements associated with high-level skill execution. That is, we were interested in determining whether trained novices would possess similar generic and episodic memory representations and would demonstrate comparable putting performance under both single- and dual-task conditions to that of the experienced golfers putting under normal circumstances (i.e., regular putter experienced golfers) in Experiment 1.

Although golf putting is a complex task in which considerable time and effort is required to become an expert performer, the possibility of obtaining a high level of putting accuracy as a result of training in the present study seemed feasible because our laboratory putting task was devoid of many of the variables that make real-world putting so difficult (e.g., changing environmental conditions, rolling terrain). However, it remained to be seen whether or not the development of a high-level single-task putting skill would transfer to dual-task, demanding conditions, and whether trained novices' memory structures would resemble those of more experienced golfers under normal putting conditions.

Method

Participants

Participants ($N = 21$) were undergraduate students with no golf experience enrolled in an introductory psychology class at Michigan State University.

Procedure

Participants were informed that the purpose of the study was to examine how individuals acquire a golf putting skill over several days of practice. Participants practised the same putting task as that in Experiment 1 over 3 days using only a regular golf putter. On Days 1 and 2, participants took three blocks of 100 practice putts each with a short break after each block of putts. On Day 3, individuals took another 50 practice putts (for a 3-day total of 650 practice putts) and were given a short break. Participants then completed exactly the same experimental procedure as that used in Experiment 1.

Results

Putting performance

Accuracy of putting was measured by the distance in cm away from the centre of the target that the ball stopped after each putt. The mean distance from the target of the first 20 practice putts on each of the three days of practice was used as a measure of each day's beginning golf putting skill. The mean distance from the target of the last 20 practice putts on each day was used as a measure of each day's ending golf putting skill. As can be seen from Figure 5, the

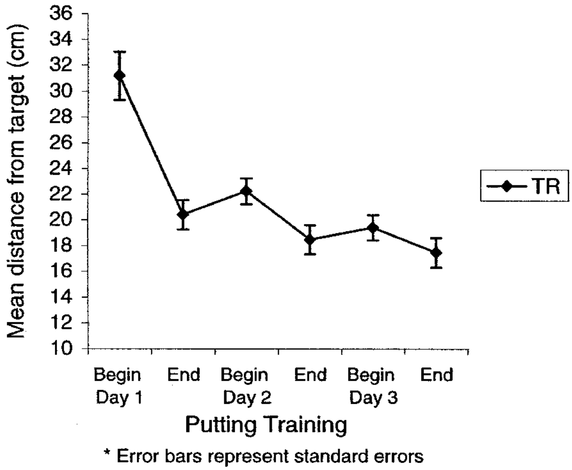

Figure 5. Mean distance (cm) from the target that the ball stopped after each putt for the first 20 and last 20 practice putts over the three days of training for the trained novice group.

trained novices (TR) significantly improved from the beginning of practice on Day 1 to the end of practice on Day 3, $t(20) = 7.54$, $p < .01$.

As in Experiment 1, the mean distance from the target of the first 20 putts in the experimental condition was used as a measure of pre-test putting performance. The mean distance from the target of the second 20 putts in the experimental condition was used as a measure of single-task putting. The mean distance from the target of the 20 putts taken during the dual-task putting condition was used as a measure of dual-task putting skill. To determine how the performance of the trained novices compared to the performance of the untrained novices and experienced golfers of Experiment 1, a 5 (regular putter novices–Experiment 1, funny putter novices–Experiment 1, regular putter experienced–Experiment 1, funny putter experienced–Experiment 1, trained novices–Experiment 2) × 2 (single-task putting, dual-task putting) ANOVA was performed comparing putting performance during the single- and dual-task conditions across Experiments 1 and 2 (see Figure 6). A significant Group × Putting Condition interaction was found, $F(4, 100) = 3.94$, $p < .01$, $MSE = 10.03$.

A one-way ANOVA on the single-task putting condition revealed a significant main effect of group, $F(4, 100) = 28.79$, $p < .01$, $MSE = 24.82$. Post hoc Fisher's LSD tests showed that the trained novices performed at a significantly higher level than did both the regular and the funny putter novice groups from Experiment 1, *p*s < .05, respectively, and did not differ from either the regular or the funny putter experienced groups, $p > .76$ and $p > .32$, respectively. A one-way ANOVA on the dual-task putting condition also revealed a significant main effect of group, $F(4, 100) = 35.37$, $p < .01$, $MSE = 29.63$. Fisher's LSD tests revealed that the trained novices performed significantly better than the two novice groups, *p*s < .05, respectively, but at a lower level than the regular putter experienced group, $p < .03$. There was no significant difference between the performance of the trained novices and the funny putter experienced group, $p > .60$. Finally, the trained novices significantly declined in putting performance from the single- to dual-task conditions, $t(20) = 2.68$, $p < .02$. The decline in the trained novices' putting accuracy mirrors the performance of the funny putter experienced golfers from

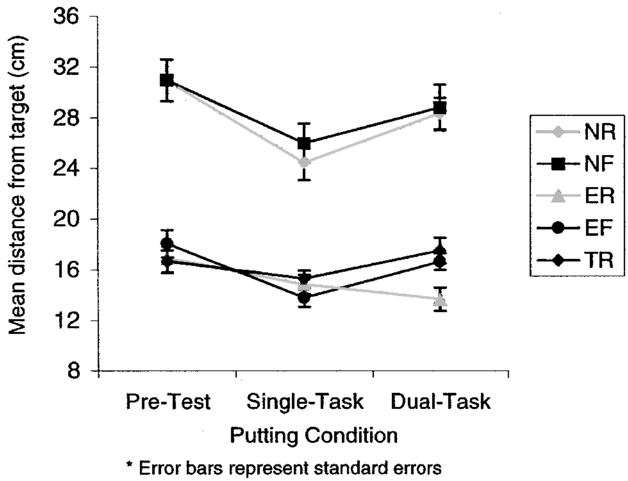

Figure 6. Mean distance (cm) from the target that the ball stopped after each putt in the pre-test, single-task, and dual-task conditions for each group.

Experiment 1. Although the trained novices were able to perform at a similar level to that of the regular putter experienced golfers under single-task conditions, when they were required to perform in a demanding dual-task environment their performance declined. This pattern suggests that the trained novices' putting performance was not automated or proceduralized to the extent necessary to support the addition of secondary task demands.

As in Experiment 1, in order to guard against the possibility that changes in putting performance from the single-task to the dual-task conditions were due to a trade-off in attentional allocation with the secondary auditory monitoring task, a 5 (regular putter novices–Experiment 1, funny putter novices–Experiment 1, regular putter experienced–Experiment 1, funny putter experienced–Experiment 1, trained novices–Experiment 2) × 2 (single-task putting, dual-task putting) ANOVA with the difference between Recognition Memory Test 1 and Test 2 performance used as a covariate was performed. A significant Group × Putting Condition interaction was found, despite using Recognition Memory Test 1 and Test 2 performance differences as a covariate, $F(4, 99) = 3.30$, $p < .02$, $MSE = 10.12$. Thus, differences in putting performance from the single-task to dual-task conditions do not appear to be the result of a trade-off with secondary auditory monitoring task performance.

Secondary word-monitoring task performance

Target word identification. Each instance in which individuals failed to identify a target word was recorded. Failure to identify target words occurred extremely infrequently in the single-task auditory word-monitoring condition (M = 0.05 errors, SD = 0.22) and did not occur in the dual-task auditory word-monitoring condition. Analysis of differences in target word identification errors across the two auditory word-monitoring conditions was not interpretable because of inhomogeneity of variance in the dual-task condition.

Recognition memory. Performance on Recognition Memory Test 1 and Test 2 was measured in the same manner as that in Experiment 1. The discrimination index A' was used to assess the trained novices' Recognition Memory Test 1 and Test 2 performance[2]. Table 1 presents hit and false alarm rates for Recognition Memory Test 1 and Test 2.

A 5 (regular putter novices–Experiment 1, funny putter novices–Experiment 1, regular putter experienced–Experiment 1, funny putter experienced–Experiment 1, trained novices–Experiment 2) × 2 (Memory Test 1, Memory Test 2) ANOVA revealed a significant Group × Test interaction, $F(4, 100) = 4.57$, $p < .01$, $MSE = 8.44 \times 10^3$. A one-way ANOVA on Memory Test 1 revealed no main effect of group, $F < 1$. A one-way ANOVA on Memory Test 2 illustrated a significant main effect of group, $F(4, 100) = 4.63$, $p < .01$, $MSE = 0.01$. Post hoc Fisher's LSD tests demonstrated that the trained novices had significantly better Recognition Memory Test 2 performance than both novice groups and the funny putter experienced golfers from Experiment 1, *p*s < .05, respectively. The trained novices and the regular putter experienced golfers did not differ, $p > .84$. However, as can be seen from Figure 7, there was a significant decline in the trained novices' recognition memory performance from Test 1 to Test 2, $t(20) = 2.63$, $p < .02$. This contrasts with the Experiment 1 experienced golfers' recognition memory, in which there was no significant decrease in performance from the single- to dual-task conditions. Thus, the trained novices do not appear to have developed a golf putting representation that affords them the attention necessary to simultaneously perform both the golf putting and secondary monitoring task without recognition memory decrements for words heard while putting. However, the trained novices did demonstrate superior Recognition Memory Test 2 performance in comparison to both novice groups and the funny putter experienced group from Experiment 1, suggesting that they were able to devote a certain amount of attention to secondary monitoring task performance.

Generic and episodic memory protocols

As in Experiment 1, questionnaire responses were analysed quantitatively in terms of the number of golf putting steps included in each type of protocol, and qualitatively in terms of the relative frequencies of different categories of steps.

Quantitative analysis. Analysis of number of golf putting steps given by participants was performed in the same manner as that in Experiment 1. A 5 (regular putter novices–Experiment 1, funny putter novices–Experiment 1, regular putter experienced–Experiment 1,

[2]As in Experiment 1, instructions prior to both the single- and the dual-task recognition memory tests that approximately half of the words had been presented previously led to the possibility of a confound in response bias with single- versus dual-task memory tests. Including both the trained novices from Experiment 2 and the untrained novices and experienced golfers from Experiment 1, the mean percentage of previously presented words (i.e., the number of possible hits) was relatively similar across recognition memory tests: 50% (30 words) in the single-task condition and 42.3% (25.36 words) in the dual-task condition. Furthermore, a paired-sample t test showed a non-significant difference in the percentage of false alarms between the single- and dual-task conditions, $t(104) = 1.76$, $p > .05$. Finally, percentage of previously presented words was used as a covariate in the analyses intended to assess single- and dual-task recognition memory differences. Adding percentage of previously presented words as a covariate did not alter the results of these analyses in any way.

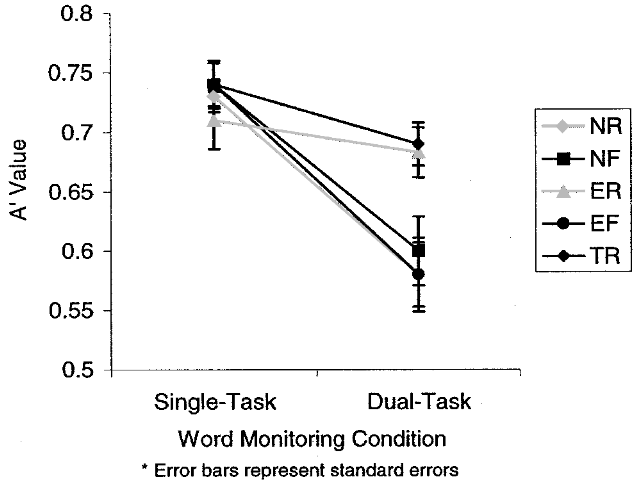

Figure 7. Mean A' value for the single-task and dual-task recognition memory tests for each group.

funny putter experienced–Experiment 1, trained novices–Experiment 2) × 2 (generic protocol, episodic protocol) ANOVA compared the lengths of the generic and episodic protocols for the trained novices in Experiment 2 with those of the novice and experienced golfers in Experiment 1. This analysis revealed an interaction of Group × Questionnaire, $F(4, 100) = 10.40$, $p < .01$, $MSE = 3.6$.

One-way ANOVAs on both the generic and episodic questionnaires produced a significant effect of group, $F(4, 100) = 6.77$, $p < .01$, $MSE = 6.00$, and $F(4, 100) = 4.4$, $p < .01$, $MSE = 7.57$, respectively. As can be seen from Figure 8, the trained novices gave a similar number of generic protocol steps to that of the two novice groups (i.e., NR and NF) and fewer generic steps than the two experienced groups (i.e., ER and EF) from Experiment 1. This pattern was confirmed by Fisher's LSD tests revealing no significant differences in generic protocol

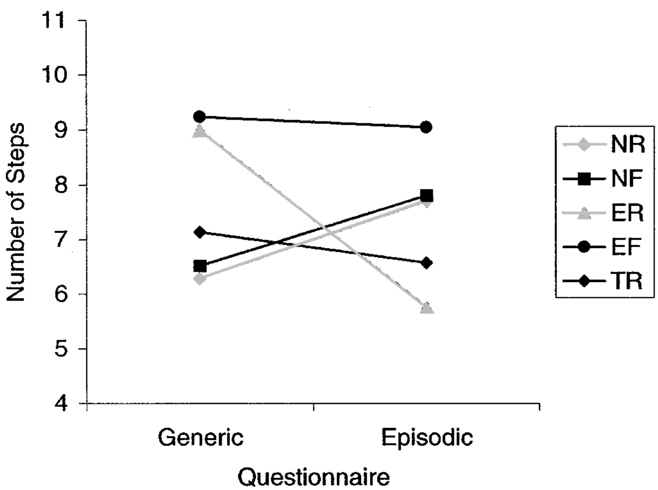

Figure 8. Mean number of steps for the generic and episodic questionnaires for each group.

generation between the trained novice group and the regular and funny putter novice groups, $p > .26$ and $p > .42$, respectively, and a significant difference in generic protocol steps between the trained novices and the regular and funny putter experienced groups, *p*s < .05, respectively. In terms of the episodic questionnaire, the trained novices gave steps that were in between the number given by both novice groups and the regular putter experienced golfers, *p*s > .15, respectively, and significantly fewer steps than the funny putter experienced golfers, $p < .01$. Finally, a paired-sample *t* test revealed that the trained novices gave similar numbers of steps in their generic and episodic protocols, $t(20) = 0.88$, $p > .33$. The effect size estimate for this statistic is $d = .24$ (Dunlap et al., 1996). This is a fairly small effect. In order to detect an effect of this magnitude, with power =.80, we would need about 280 participants in the trained novice group (Cohen, 1988). Thus, there does not appear to be a substantial difference in the number of steps given by the trained novices in their generic and episodic protocols.

It is interesting to note that despite the trained novices' added putting practice, they did not show a significantly greater amount of generic putting knowledge than the novice golfers from Experiment 1. It has been suggested that it takes at least 10 years or 10,000 hours of practice to develop an extensive expert knowledge base in a given skill (Ericsson, Krampe, & Tesch-Romer, 1993). It is not surprising then that the 650 practice putts performed by the trained novices, devoid of any explicit golf putting instruction, did not significantly alter their general golf skill knowledge. Furthermore, similar to the funny putter experienced golfers, the trained novices did not show a significant decrease in the number of putting steps given from the generic to episodic memory protocols. Along with decreases in both putting performance and recognition memory under dual-task conditions, the similarity of the trained novices' generic and episodic protocols suggests that these individuals were still devoting a significant amount of attention to the putting task.

Qualitative analysis: Types of step. The qualitative analysis was performed in the same manner as that in Experiment 1. Steps were divided into three categories (assessment, mechanics, and ball destinations), and a 5 (regular putter novices–Experiment 1, funny putter novices–Experiment 1, regular putter experienced–Experiment 1, funny putter experienced–Experiment 1, trained novices–Experiment 2) × 2 (generic protocol, episodic protocol) ANOVA was conducted on the number of steps given in each of these three categories (see Table 2).

The analysis of assessment steps produced a significant Group × Protocol interaction, $F(4, 100) = 4.50$, $p < .01$, $MSE = 1.06$, which is displayed in Panel A of Figure 9. A one-way ANOVA on the number of assessment steps given in the generic questionnaire illustrated a main effect of group, $F(4, 100) = 3.96$, $p < .01$, $MSE = 2.39$. Fisher's LSD tests revealed that the trained novices produced assessment steps similar to those of the two novice groups, *p*s > .62, respectively, and fewer assessment steps than the regular and funny putter experienced groups from Experiment 1, $p < .1$ and $p < .01$, respectively. A one-way ANOVA on the episodic questionnaire illustrated no main effect of group, $F(4, 100) = 1.28$, $p > .28$, $MSE = 1.56$. Finally, a paired sample *t* test revealed that the trained novices did not significantly differ in terms of the number of assessment steps given in their generic descriptions and episodic recollections, $t(20) = 1.56$, $p > .10$.

Turning to mechanics, this analysis produced a significant interaction of Group × Protocol, $F(4, 100) = 5.32$, $p < .01$, $MSE = 4.18$, as can be seen in Panel B of Figure 9. A one-way

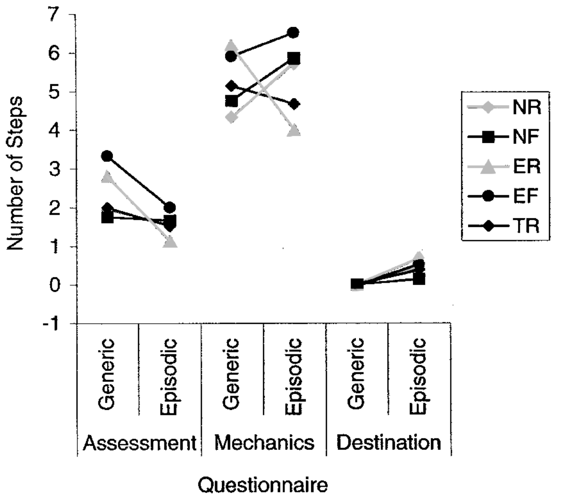

Figure 9. Mean number of steps in the assessment (Panel A), mechanics (Panel B), and destination (Panel C) categories for the generic and episodic questionnaires for each group.

ANOVA on the number of mechanics steps given in the generic protocol illustrated a marginally significant main effect of group, $F(4, 100) = 1.96$, $p < .11$, $MSE = 6.42$, with the trained novices giving mechanics steps that were in between the novice and experienced golfers from Experiment 1, ps > .10, respectively. A one-way ANOVA on the episodic protocol produced a main effect of group, $F(4, 100) = 2.49$, $p < .05$, $MSE = 8.55$, with the trained novices producing mechanics steps that were again in between the two novice groups and the regular putter experienced group, ps > .19, respectively, and significantly different from the funny putter experienced golfers from Experiment 1, $p < .05$. A paired sample t test revealed no significant difference in the number of mechanics steps given by the trained novices in their generic descriptions and episodic recollections, $t(20) = 0.68$, $p > .50$.

Finally, analysis of ball outcomes produced a significant main effect of protocol, $F(4, 100) = 40.02$, $p < .01$, $MSE = 0.27$, no main effect of group, and no Group × Protocol interaction, Fs < 1, respectively. As shown in Panel C of Figure 9, ball destinations were more likely to appear in episodic recollections than in generic protocols.

Discussion

In Experiment 2 novice golfers were trained to a high level of single-task golf putting performance on our laboratory putting task and were then exposed to the same experimental conditions as were the novice and experienced golfers in Experiment 1. The trained novices' putting accuracy was similar to both the Experiment 1 regular and funny putter experienced golfers' performance under single-task conditions. However, analogous to both novice groups and the funny putter experienced golfers from Experiment 1, their performance significantly declined under dual-task conditions. Thus, although the trained novices may have been able to adapt to putting at a high skill level in an isolated single-task environment, their skill representations were not able to support the simultaneous execution of a secondary task without decrements in primary putting performance. It may be that the trained novices were overconfident in their putting ability following training, leading them to believe that they did not need to closely attend to the putting task under dual-task conditions, even though their decrements in dual-task putting performance suggest the opposite. If so, this idea would be consistent with Simon and Bjork's (2001) findings that metacognitive judgements of motor skill learning following a blocked practice regimen are often inflated in comparison to actual skill retention.

There is a well-established notion in the motor-learning literature regarding the importance of skill proficiency assessment across both single- and dual-task attention-demanding situations (see Schmidt & Lee, 1999). Because well-learned sensorimotor skill execution is believed to be based on an automated or proceduralized representation that does not require constant on-line attentional control, the addition of a secondary task should not overly tax primary skill performance. Utilizing single-task performance measures as the sole assessment of task proficiency, then, does not allow for this comparison and thus does not speak to the cognitive representations underlying performance at different skill levels. In the present study, if our only performance measure was single-task putting, then we would not be able to address differences in the cognitive processes governing the performance of the regular and funny putter experienced golfers from Experiment 1 or the trained novices from Experiment 2.

It is interesting to note that although the trained novices' word recognition ability for words heard while putting decreased in comparison to their single-task baseline word recognition measure, they still had significantly higher recognition memory for words heard under dual-task conditions than that of both novice groups and the funny putter experienced golfers from Experiment 1. Thus, the trained novices were able to devote a certain amount of attention to the secondary monitoring task. However, the training that these individuals received only served to automate performance to a certain extent—enough to support partial word monitoring, yet not enough to prevent significant word-monitoring decrements under dual-task conditions.

Finally, in terms of memory protocols, the trained novices in Experiment 2 gave a similar number of steps in their generic and episodic protocols. Their generic knowledge resembled that of the novice golfers from Experiment 1, whereas their episodic protocols were in between those given by the novice and experienced golfers. The trained novices' memory performance contrasts with the episodic memory decrement or "expertise-induced amnesia" shown by the regular putter experienced golfers in Experiment 1 and further supports the notion that extensive practice and explicit instruction are necessary components in the development of a detailed expert skill knowledge base.

GENERAL DISCUSSION

"How can you hit and think at the same time?"—Yogi Berra

Berra's words of wisdom imply that a lack of attention to skill execution may be associated with optimal task performance. Though this notion may appear counterintuitive—certainly one must attend to performance in order to perform the most appropriate response in the most accurate and effective way—the findings of the present study suggest that exceptional execution does not heavily depend on step-by-step monitoring and control. High-level performance appears to be governed by proceduralized knowledge that does not require constant attention and, indeed, can be harmed by it. As a result, experienced individuals performing under normal, practised conditions are better able than novices to allocate a portion of their attention to other stimuli and task demands—even though these experts are less able to allocate attention to and remember the step-by-step details of their performance. Conversely, novel performance processes appear to be based on declarative knowledge that is explicitly attended to in real time. As a result, novice performers are not able to adapt to the demands of dual-task environments, showing decrements in both primary and secondary task performance in comparison to performance of either task in an isolated, single-task environment. Due to the fact that novel performance processes are attended to in an on-line fashion, however, episodic recollections of performance are retained.

It has been suggested in the expertise literature that exceptional performance is associated with extensive memory records of skill execution (Ericsson & Lehmann, 1996). At first glance the results of the present study may appear to contrast with the notion that experts retain extremely detailed memories of performance. However, although it has been demonstrated that experts have superior recollections of the stimuli on which they operate (Chase & Simon, 1973; De Groot, 1978) and the outcomes of their actions (Backman & Molander, 1986; McPherson, 2000), to our knowledge it has not been demonstrated that experts possess extensive episodic memories for the steps or processes involved in deriving plans of action or for implementing these actions in real time. In fact, the results of the present study suggest the opposite—that expertise leads to the encoding of skill processes in a proceduralized form that does not require conscious attention and results in less than optimal memories for the skill execution process. For a more extensive discussion of predictions derived from theories of expertise and theories of skill acquisition and automaticity concerning expert performers' memory structures, see Beilock, Wierenga, and Carr (in press).

The present results coincide with research on skill acquisition and automaticity suggesting that the cognitive mechanisms governing task execution are dependent on level of expertise. It should be noted, however, that tasks that become proceduralized with practice and operate largely outside the scope of working memory may utilize attentional resources very differently from skills that rely on the active maintenance of information in memory at all levels of skill learning. High-level sensorimotor skills, such as the golf putting task utilized in the present study, may leave attentional resources available for the processing of extraneous information if necessary. However, regardless of skill expertise, the addition of a capacity-demanding secondary task may detract from complex cognitive skill execution in which information must be continually updated and rehearsed and thus maintained in an active state in working memory.

Although the above-mentioned contrast appears to suggest that well-learned sensorimotor and cognitive skills carry different attentional requirements for successful task execution, a simple cognitive–motor distinction may not accurately reflect the different attentional mechanisms supporting diverse types of skill performance. For example, cognitive tasks that become instance-based with extended practice, such as Zbrodoff and Logan's (1986) alphabet arithmetic skill, may behave more like proceduralized sensorimotor skills than do complex cognitive tasks under secondary task demands at high levels of learning. Highly practised alphabet arithmetic problems are thought to be derived by the stimulus-driven retrieval of past instances of the problem from long-term memory. Because this process is a one-step answer retrieval that circumvents working memory, well-learned alphabet arithmetic performance should leave attentional resources free to devote to secondary task demands if necessary. A simple distinction between cognitive and sensorimotor skills, then, may not accurately reflect the attentional mechanisms governing the performance of various types of tasks at different experience levels. Instead, it may be more appropriate to distinguish between skills that rely heavily on the maintenance of information in working memory during real-time execution and those that do not. We are currently in the process of exploring task-type differences in susceptibility to secondary task demands and performance environment alterations in our laboratory.

REFERENCES

Allport, D.A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single channel hypothesis. *Quarterly Journal of Experimental Psychology*, *24*, 225–235.

Anderson, J.R. (1982). Acquisition of a cognitive skill. *Psychological Review*, *89*, 369–406.

Anderson, J.R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Anderson, J.R. (1993). *Rules of mind*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Backman, L., & Molander, B. (1986). Effects of adult age and level of skill on the ability to cope with high-stress conditions in a precision sport. *Psychology and Aging*, *4*, 334–336.

Beilock, S.L., & Carr, T.H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology: General*, *130*, 701–725.

Beilock, S.L., Carr, T.H., MacMahon, C., & Starkes, J.L. (2002). When paying attention becomes counterproductive: Impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied*, *8*, 6–16.

Beilock, S.L., Wierenga, S.A., & Carr, T.H. (in press). Memory and expertise: What do experienced athletes remember? In J.L. Starkes & K.A. Ericsson (Eds.), *Recent advances in research on sport expertise*. Champaign, IL: Human Kinetics Publishers.

Chase, W.G., & Simon, H.A. (1973). Perception in chess. *Cognitive Psychology*, *4*, 55–81.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York: Lawrence Erlbaum Associates, Inc.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin*, *104*, 163–191.

Craik, F.I.M., Govoni R., Naveh-Benjamin, M., & Anderson, N.D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General*, *125*, 159–180.

De Groot, A. (1978). *Thought and choice in chess.* The Hague: Mouton. (Original work published 1946.)

Dunlap, W.P., Cortina, J.M., Vaslow, J.B., & Burke, M.J. (1996). Meta-analysis of experiments with matched groups or repeated measures designs. *Psychological Methods*, *1*, 170–177.

Ericsson, K.A., Krampe, R.T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406.

Ericsson, K.A., & Lehmann, A.C. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. *Annual Review of Psychology*, *47*, 273–305.

Fitts, P.W., & Posner, M.I. (1967). *Human performance*. Belmont, CA: Brooks/Cole.

Jones, B.T., Davis, M., Crenshaw, B., Behar, T., & Davis, M. (1998). *Classic instruction in golf*. New York: Broadway.

Keele, S.W., & Summers, J.J. (1976). The structure of motor programs. In G.E. Stelmach (Ed.), *Motor control: Issues and trends* (pp. 109–142). New York: Academic Press.

Kimble, G.A., & Perlmuter, L.C. (1970). The problem of volition. *Psychological Review*, *77*, 361–384.

Langer, E., & Imber, G. (1979). When practice makes imperfect: Debilitating effects of overlearning. *Journal of Personality and Social Psychology*, *37*, 2014–2024.

Leavitt, J. (1979) Cognitive demands of skating and stick handling in ice hockey. *Canadian Journal of Applied Sport Sciences*, *4*, 46–55.

Macmillan, N.A., & Creelman, C.D. (1991). *Detection theory: A user's guide*. New York: Cambridge University Press.

McPherson, S.L. (2000). Expert–novice differences in planning strategies during collegiate singles tennis competition. *Journal of Sport and Exercise Psychology*, *22*, 39–62.

Naveh-Benjamin, M., Craik, F.I.M., Guez, J., & Dori, H. (1998). Effects of divided attention on encoding and retrieval processes in human memory: Further support for an asymmetry. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 1091–1104.

Pollack, I., & Norman, D.A. (1964). A nonparametric analysis of recognition experiments. *Psychonomic Science*, *1*, 125–126.

Proctor, R.W., & Dutta, A. (1995). *Skill acquisition and human performance*. Thousand Oaks, CA: Sage Publications.

Schmidt, R.A., & Lee, T.D. (1999). *Motor control and learning*. Champaign, IL: Human Kinetics.

Simon, D.A., & Bjork, R.A. (2001). Metacognition in motor learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 907–912.

Smith, M.D., & Chamberlin, C.J. (1992). Effect of adding cognitively demanding tasks on soccer skill performance. *Perceptual and Motor Skills*, *75*, 955–961.

Snodgrass, J.G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*, 34–50.

Zbrodoff, N.J., & Logan, G.D. (1986). On the autonomy of mental processes: A case of study arithmetic. *Journal of Experimental Psychology: General*, *115*, 118–130.

Original manuscript received 24 July 2001
Accepted revision received 10 December 2001

APPENDIX A

Generic questionnaire
Certain steps are involved in executing a golf putt. Please list as many steps that you can think of, in the right order, which are involved in a typical golf putt:

Episodic questionnaire
Pretend that your friend just walked into the room. Describe the last putt you took, in enough detail so that your friend could duplicate that last putt you just took in detail, doing it just like you did.

Note: Additional explanation was given in order to make it clear that what was being asked for was a "recipe" or "set of instructions" that would allow the putt to be duplicated in all its details by someone who had not seen it. Individuals were told that the friend was not an expert golfer, but someone with an ordinary knowledge of the game. This was done to prevent excessive use of jargon or "in-group" shorthand, in an attempt to equate the need for knowledge that would be assumed by the describers across groups.

APPENDIX B

Steps involved in a typical golf putt

1. Judge the line of the ball.
2. Judge the grain of the turf.
3. Judge the distance and angle to the hole.
4. Image the ball going into the hole.
5. Position the ball somewhere between the centre of your feet. You should be able to look straight down on top of the ball.
6. Align shoulders, hips, knees, and feet parallel and to the left of the target (e.g., image railroad tracks from the ball to the cup—feet outside the tracks, the ball in the middle).
7. Grip—thumbs should be pointed straight down, palms facing each other, a light grip.
8. Posture—stand tall enough so that if you were to practice putting for 30 minutes you would not experience a stiff or sore back.
9. Arms—should hang naturally and be relaxed.
10. Hands—should be relative to ball position. Hands should be slightly in front of the ball.
11. Head position—eyes should be positioned directly over the ball.
12. Weight—distribute weight evenly, about 50–50, or with a little more weight on the left foot.
13. Backswing—swing the club straight back. The distance back that the club goes must equal the through stroke distance.

14. Stroke—the club must accelerate through the ball. Finish with the "face" of the club head pointing directly at the target.
15. Length of the stroke—It is better to err to a shorter more compact stroke rather than a longer stroke.
16. Stroke direction—straight back and straight through.
17. Stroke rhythm—not too fast and not too slow.
18. Keep head and lower body stationary throughout stroke and swing with the arms.
19. Wrists—should not break during the stroke.
20. Arms and shoulders—should do most of the work.
21. Head/trunk/hips/legs—should remain still during the stroke.
22. Watch the ball go into the hole.