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Especial Skills: Their Emergence With Massive Amounts of Practice

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Differing viewpoints concerning the specificity and generality of motor skill representations in memory were compared by contrasting versions of a skill having either extensive or minimal specific practice. In Experiments 1 and 2, skilled basketball players more accurately performed set shots at the foul line than would be predicted on the basis of the performance at the nearby locations, suggesting considerable specificity at this distance. This effect was replicated even when the lines on the court were obscured (in Experiment 2). However, the effect was absent when jump shots were executed in Experiment 3. The authors argue that massive levels of practice at 1 particular member of a class of actions produce specific effects that allow this skill to stand out from the other members of the class, giving it the status of an *especial* skill. Various theoretical views are proposed to account for the development of these skills.

Keywords: motor learning, schema theory, practice specificity

One of the oldest and most common findings in learning and memory research concerns *specificity* effects: Performance in test conditions is most likely to be optimized when the conditions under which the information or skills were practiced are identical to those in the test. This line of thinking was promoted early on in Thorndike's theory of "identical elements" (Thorndike, 1913; Thorndike & Woodworth, 1901), which claimed that performance in transfer is a function of the number of elements that are identical to those in the conditions of learning. This viewpoint received support during the middle of the 20th century when considerable work in the transfer of skills was being conducted (see Cormier & Hagman, 1987, and Schmidt & Young, 1987, for reviews); here, the general finding was that transfer was small unless the skills were essentially identical to one another. Additionally, findings of specificity emerged later in the century in experiments on "context-dependent memory" (Davies & Thomson, 1988; Smith & Vela, 2001), in which the context of the practice and test conditions was the focus. So-called state-dependent learning was a similar notion, based on the learner's internal states (e.g., drug effects) during practice and test conditions (e.g., Eich, Weingartner, Stillman, & Gillen, 1975).

The study of motor skill specificity effects emerged in experiments in which participants learned a task during practice and then performed the task under similar or changed conditions in transfer. In one line of investigation (e.g., Newell, Shapiro, & Carlton, 1979; Proteau, Marteniuk, & Lévesque, 1992; Reeve & Cone, 1980; Tremblay & Proteau, 1998), vision of the task and/or moving limb was either available or not available in practice. Performance was usually most effective when the transfer conditions matched those conditions that had been available during the practice trials. In a different line of research, practice on "parts" of a rapid task did not transfer appreciably to performance of the "same" parts when they were embedded in a larger skill (Lersten, 1968), probably because the part was altered when it was dissected from the larger skill.

The foregoing research suggests that motor skills are represented in memory in a highly specialized way—one that provides for optimization either when the skills required for performance are identical to the learned skills or, at least, when they are performed under the same conditions as those experienced in learning. However, such a viewpoint contrasts sharply with evidence that motor control is highly flexible and nonspecific. For example, although handwriting is a skill learned almost entirely with just one effector system—the fingers of the dominant hand, with the elbow and the shoulder mainly fixed—Merton (1972) has shown that a person's blackboard-sized signature (when reduced in

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size photographically) is nearly identical to that person's usual signature, even though the effector system has changed (shoulder and elbow movements, with the fingers largely fixed). Also, writing skill can be expressed reliably by other effectors, such as by the nondominant limb or with a pencil held with the teeth or foot (Lashley, 1942; see also Bernstein, 1947; Merton, 1972; Raibert, 1977). This, plus other lines of evidence, has fueled the argument that motor skills are not stored as effector-specific memories but rather as abstract representations that can be instantiated quite faithfully through use of a wide range of effectors and, of course, conditions of testing. An important theoretical stance was taken by Bernstein (1967, 1996), who suggested that the flexible organization of the system's many degrees of freedom represents the hallmark of skilled motor behavior.

Schema theory (Schmidt, 1975, 2003) formalized the generality of motor skill representations in detail and provided a number of testable hypotheses. Schema theory suggested that motor skills were represented by two structures stored in memory. The first structure, called the *generalized motor program* (GMP), supported a class of movements (e.g., overarm throwing) by storing invariant features, such as the order by which the individual parts of the movement unfolded during action, as well as their relative timing and relative force. A separate structure, called the *recall schema*, was responsible for supplying the parameters that were needed to scale the GMP's output to the specific environmental demands and conditions. According to the theory, each practice attempt at throwing different distances produces information that is abstracted and used to update the accuracy and reliability of the schema. The schema comes to represent the relationship between (a) the parameters of the GMP that were used on each attempt and (b) the outcome (e.g., distance thrown) that was produced in the environment on that attempt. In this way, the schema is not a collection of specific memories but rather a rule that expresses the relationship among variables. In this sense, schema theory provides at least one way to conceptualize the generalizability of motor control.

Although experimental findings exist that support both specificity and generality of motor skills, such evidence has emerged from very different experimental conditions and paradigms, making direct comparisons difficult. Are there particular learning conditions that produce highly specific products of practice, whereas other conditions produce more generalized products? One possible example might be a situation in which a particular member of a class of actions—because it has a special status in society—receives an inordinate amount of practice. One example might be overarm throwing; baseball pitchers have very high levels of practice at a 60.5-ft distance (the regulation pitching distance in baseball), so this particular set of conditions might yield a very specific skill, perhaps separable in some way from overarm throwing in general.

To address this question, we sought a way to examine a class of tasks in which one member of the class had received far more practice than the others. This would allow an evaluation of the performance of this particular variant relative to other variants that had received much less practice. Views that emphasize generality (e.g., schema theory) are essentially silent about any specific advantages afforded to the member of the class receiving extra practice and focus more on the benefits from this one variant for the entire class. In contrast, specificity views would predict the emergence of a distinguished memory representation for that particular variant within the class.

A problem we faced in studying this question is that, in using unpracticed laboratory tasks and naive participants, it is difficult to create a situation in which there is sufficient practice so that differences between the highly practiced variant and other members of the class of skills could be seen in the data. Consequently, in the present research, we adopted a different approach in which we used a naturalistic task for which such a condition—with very high experience at one version and minimal experience at the others—is already met. We assumed that the *set shot* in basketball (typically performed as a one-handed shot in which the feet do not leave the floor) represents a general class of skills for which one particular member, the *free throw*, has a unique status because of its role in the game of basketball. Experienced basketball players have accumulated massive amounts of practice (certainly many thousands of practice attempts) specifically at 15 ft (i.e., the foul line) yet only minimal practice attempts at any of the other distances. (Set shots are not typically practiced from spots other than the foul line because in a game they can be easily blocked by an opponent; defenders are not allowed to block a foul shot, however. Also, free throws are taken only from the foul line.) We examined the possibility that a general memory representation existed for the control of the entire class of set shots (here, examined at distances that ranged from 9 ft to 21 ft from the basket) but that performance at the foul line (15 ft) would be distinguished among the others in the class. Three experiments addressing this general issue are described here.

Experiment 1

Studies of manual aiming, dating as long ago as Woodworth (1899) and most frequently associated with the work of Fitts (1954), have found a close relationship between force production and error. Schmidt, Zelaznik, and Frank (1978) pointed out that as the distance to the target increases, an individual must generate increased levels of force, which produces increased levels of variability in force output, resulting in a linear increase in the endpoint variability of the aimed movement (Schmidt, Zelaznik, Hawkins, Frank, & Quinn, 1979; see also Abrams, Meyer, & Kornblum, 1989; Patla, Frank, Allard, & Thomas, 1985). For an aiming task such as basketball shooting, both theory and common experience predict that a critical performance variable is the distance of the shooter to the basket.

In the present study, skilled players were asked to produce set shots at 9, 11, 13, 15, 17, 19, and 21 ft (2.74, 3.35, 3.96, 4.57, 5.18, 5.79, and 6.40 m) from the basket.[1] On the basis of force–variability principles, a decline in success rate was predicted as a function of the distance of the shot. The predictions regarding the existence of a skill with particular specific properties at 15 ft (the foul line) must, therefore, be considered relative to performance expected from other adjacent members of the class. Through use of a regression line established from the data generated at distances of 9, 11, 13, 17, 19, and 21 ft, the appropriate comparison for

[1] Because of common use of English imperial distances in the sport of basketball (e.g., the foul line is at 15 ft), we provide metric equivalences where appropriate but continue to refer to shooting distances in feet.

performance at the foul line (15 ft) is the level predicted by the regressed interpolation. If specific effects result from high levels of practice at 15 ft, then the actual level of performance at the foul line should be significantly greater than the level predicted from the regression equation. This distinguished level of performance could occur even though the performance levels at the other distances would conform closely to the regression line.

Method

Participants. Eight male college student-athletes between 18 and 22 years of age volunteered to participate. They were all members of the California State University, Long Beach, basketball program, which competes in Division I of the National Collegiate Athletic Association. Participants represented all positions on the team (guard, forward, and center), and each had more than 12 years of experience in basketball shooting. None was informed about the purpose of the experiment.

Materials and environment. Basketball set shots were performed by all participants with their preferred limb. The action required a coordinated shooting motion involving the upper and lower limbs, with the feet maintaining contact with the floor at all times. The task was to propel an official leather basketball (Rawlings National Collegiate Athletic Association) toward a regulation basketball rim, mounted 10 ft (3.05 m) above the floor of a standard basketball court. Shots were taken from seven locations positioned in a straight line from the backboard, toward the center of the court. Each location was measured from the front edge of the rim, at intervals of 2 ft (0.61 m) beginning from the shortest distance of 9 ft. Each location was marked and labeled using a 2- × 10-in. (5.0- × 25.4-cm) strip of masking tape. Participants were asked to position their feet as closely as possible to, but not on, the tape when taking the shot.

Procedure. The experiment began after the participants read and signed the ethics consent and listened to a standardized set of instructions. A total of 175 shots was performed on each of 2 consecutive days of testing (25 shots per distance per day), for a total of 350 shots (50 shots per distance). The shots were taken with 5-s rest intervals between trials, with a predetermined quasi-random order such that no more than 2 shots were taken at the same distance on consecutive trials. No emphasis was placed on the performance of any particular distance, and all participants were encouraged to perform each trial, regardless of distance, with the same level of effort and desire to score the shot.

Each trial began with the verbal announcement of the target distance (in feet), at which time the participant moved to the appropriate location before being handed the basketball. The participant then shot the basketball without any preshot routine (e.g., without dribbling the ball). The intertrial interval began when the ball returned to the floor after the shot. Performance on the trial (successful or unsuccessful) was recorded by an experimenter during the intertrial interval while another experimenter retrieved the ball. Participants were able to watch the ball flight and could determine goal success from the visual feedback.

Results and Discussion

The data were collapsed over the 50 shots at each of the shooting distances; the resulting means for each participant were used for further analyses. For each participant, the mean scores at the 9-, 11-, 13-, 17-, 19-, and 21-ft distances were used to compute a linear regression equation, which accounted for 85.5% of the variance in the data, on average. These individual regression equations were then used to predict each participant's performance at the 15-ft distance. The resulting set of predicted data was then compared with the participants' actual data from the 15-ft distance in a one-tailed, directional, paired-samples *t* test (we used a directional test because the hypotheses predicted either no difference or a specific directional difference).

The results are illustrated in Figure 1. On the basis of the individual regression equations, the across-subjects mean predicted percentage of success at the foul line was 72%. The participants' actual performance was 80.8%. This difference was statistically significant, with $t(7) = 4.87$, $p < .05$, indicating that the data generated by the regression equations systematically underestimated the participants' actual performances at the foul line.

The results of this study support the emergence of a specific advantage for one highly practiced member of a class of basketball set shots. The free throw performances of expert basketball players were roughly equivalent to their set shot performances at the 9–11-ft distance and were significantly more accurate than free throw performances that were predicted by regression analyses. These findings suggest that years of specific practice at the foul line produced a skill that has a specific motor-control advantage at that particular distance and that provides little or no detectable advantage for any other distance, regardless of its proximity to the foul line (at least there was no advantage for any of the other distances examined in this experiment). These findings are not predicted by generality views such as schema theory (Schmidt, 1975), which holds that nothing specific is learned about shooting at any one of the particular distances.

We next sought to investigate what might be some of the dimensions of this specificity effect. That is, which variables associated with the practice at the 15-ft position are represented in the specific memory for that skill? An extreme view might hold that every aspect of the context becomes part of the skill. A more likely possibility, we suspect, is that several features of the 15-ft context are represented, but not all of them. A basketball court has standard lines on the floor (the foul key in particular) that provide

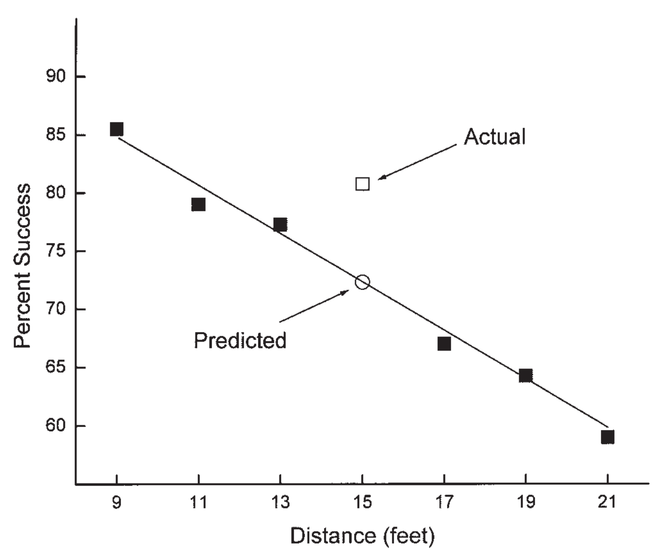

Figure 1. Set shot performance (% success) as a function of the distance from the basket in Experiment 1. The filled squares represent the actual performance at the non-foul-line distances, the unfilled square represents the actual performance at the foul line (15 ft), and the unfilled circle represents the predicted success at the foul line (15 ft) on the basis of individual regression analyses using the nonfoul line distances.

visual landmarks that could be used to stabilize free throw performance. Are these lines, and the visual information provided by them, critical in influencing performance of this particular skill and the specific advantages seen in the present experiment? It is certainly possible that they are, as the role of (seemingly) incidental cues in the establishment of memories, and the degrading effect if they are changed at test, is well documented in the literature (e.g., Smith & Vela, 2001).

A related set of findings has also been demonstrated for motor skills. For example, Wright and Shea (1991) found that actions learned in the context of specific, yet presumably incidental, visual cues were performed much more poorly when these incidental cues were no longer available at test compared with when they were available (see also Magnuson, Wright, & Verwey, 2004). In a different line of research, the often discussed "home-field advantage" in amateur and professional sports has been linked, in part, to an increased familiarity of the visual environment due to increased number of previous exposures available to the home team (Courneya & Carron, 1992). We conducted Experiment 2 to assess the impact of the visual cues provided by the lines on the court as well as to replicate the present results in a separate group of individuals.

Experiment 2

This study was conducted at a different university and used skilled women rather than men as participants, a smaller ball than that used in Experiment 1 (but standard for women), and five distances rather than seven. The critical conditions of Experiment 1 were replicated here. In addition, this experiment included an equal number of trials in which all of the set shots were taken in an altered visual context. In the altered context, the entire shooting area of the floor was covered with a tarp that effectively eliminated any of the incidental visual cues from the court surface that may have influenced performance in Experiment 1.

Method

Participants. Eight female college student-athletes between 18 and 23 years of age served as paid volunteers in this experiment. They were all members of the McMaster University basketball program, which competes in the league of Canadian Intercollegiate Sports. Similar to the situation in Experiment 1, the athletes represented all positions on the team, and each had more than 10 years of experience in basketball shooting. None was informed about the purpose of the experiment. Participants gave informed consent prior to participation in the study in accordance with the guidelines established by the McMaster University Research Ethics Board and were paid $25Cdn (approximately $20 U.S. dollars) for their participation.

Materials and environment. The materials and environment were similar to those in Experiment 1, with the following exceptions. For one half of the trials, the part of the court used for the experiment was covered with a tarp material (Covermaster, Inc., floor covering). The athletes shot a Spalding 28.5 TF-1000 zk microfiber composite basketball, which is standard for women's competition. Set shots were performed from five target locations positioned in a straight line directly away from the basket (9, 12, 15, 18, and 21 ft). However, 12 markings were placed on the floor (and tarp) at intervals of 1.5 ft, starting at the 6-ft location. The reason for 12 markings instead of just for the five shooting distances was to make the target locations on the floor less obvious to the participants in the covered-floor condition (explained below). Each of the 12 locations was designated with a letter (from A to L), with target distances being C, E, G, I, and K. An even number of marked locations was used; the absence of a middle location was expected to reduce the impression that any one of them coincided with the foul line. Each session was recorded using a Panasonic PV-DV400-K digital camera and then digitized on a Dell Inspiron 5100 laptop computer using Microsoft Windows Movie Maker, Version 5.1.

Procedure. The players participated in two sessions, separated by about 24 hr. In one session ("uncovered floor"), the participants could see the normal basketball lines on the floor (e.g., key, 3-point zone). In the other session ("covered floor"), the entire half court used for the experiment was covered with the tarp.

All participants performed 30 shots at each distance in each session (150 shots per day). In total, 300 set shots were performed, half with the floor uncovered and half with the floor covered. The floor-covering variable was counterbalanced, such that 4 participants performed in an uncovered/covered order and the other 4 in the reverse order. Shots at each location were performed in blocks; 6 shots were performed at each distance before participants were moved to the next location on a verbal signal by an experimenter. The order of target distances was counterbalanced such that a complete repetition of the five distances was completed in each set of five blocks of trials (30 trials per set) before another repetition was started. A Williams square design (Williams, 1949) was used for counterbalancing such that by the end of the second session, each location had been preceded and followed by every other target location twice. Participants were told to perform each shot at their own pace; however, a second experimenter controlled the overall flow between shots by handing over each basketball after about a 5-s interval. A third experimenter retrieved the basketballs and returned them to the second experimenter. Rest intervals were offered after every 60 shots.

Data analysis. Video analysis of the performance data facilitated later use of a 4-point scoring system, rather than the 2-point system used in Experiment 1. Three points were awarded for a successful, clean shot that resulted in minimal disruption in the downward trajectory of the ball's descent (a "swish," in basketball terms). Two points were awarded for a successful shot that resulted from the ball's having hit and bounced off the top of the rim at least once before falling in. One point was awarded for an unsuccessful shot that resulted from the ball's having bounced off the top of the rim at least once before falling away. Zero points were awarded for an unsuccessful shot that hit the bottom half of the rim and fell away or that missed completely. Similar coding systems have been shown to be reliable in previous basketball shooting studies (Hardy & Parfitt, 1991; Wallace & Hagler, 1979); it was adopted here to increase the sensitivity of the scoring system. Two experimenters independently coded 2 participants to test the interrater reliability of this coding system. Analysis revealed a correlation coefficient of .96, suggesting that the coding system was reliable. Thus, the primary investigator coded the remaining participants alone. Performance scores were converted to a percentage score: [(total points)/(3 × number of shots taken)] × 100.

Similar to Experiment 1, individual linear regressions were determined for each condition on the basis of the four non-foul-line distances (9, 12, 18, and 21 ft). These regression equations were then used to generate predicted values at the foul line. The predicted data were compared with the actual data through use of a 2 (visual condition: uncovered vs. covered) × 2 (score: predicted vs. actual) repeated measures analysis of variance (ANOVA). The effect of trial position within a block of trials was also examined using a 6 (trial position) × 2 (covered vs. uncovered) × 5 (shooting distance) repeated measures ANOVA.

Results and Discussion

The performance scores at the distances surrounding the foul line produced regression equations with multiple correlation squared (R^2) values that accounted for an average of 85% of the variance in the uncovered-floor condition and an average of 88% of the variance in the covered-floor condition. Regression analyses of the uncovered-floor condition generated a mean predicted score percentage of 68.4% success at the foul line. The actual score was 74.9%. Regression analysis of the covered-floor condition revealed a mean predicted score of 66.9% for the foul line distance, compared with the actual percentage of 76.7%. The ANOVA revealed a main effect of the actual versus predicted scores, with $F(1, 7) = 5.73$, $p < .05$. There was no significant main effect for visual condition, $F(1, 7) = 0.01$, or for the Score × Visual Condition interaction, $F(1, 7) = 1.34$, both $ps > .25$. The means for all of the distances are shown in the left side of Figure 2.

The analysis of the position of a shot within a block of trials yielded just two significant main effects—for distance from the basket, $F(4, 28) = 28.80$, $p < .001$, and for the trial position, $F(5, 35) = 4.18$, $p < .001$. As can be seen in the data in the left side of Figure 3, performance became more accurate over repeated trials at the same distance within a block but most dramatically from the first to the second shot taken at a new distance. The only significant differences found in the post hoc tests were between Trial Position 1 and Trial Positions 2–6.

These results both replicate and extend the findings from Experiment 1. The replicated findings again provide support for the existence of specific effects of practice at the foul line within the general class of set shots. It is interesting to note that the floor-covering variable produced no reliable effects; there was no detrimental effect on overall performance when these incidental cues were covered. This suggests that the lines on the standard court were not a part of this specific representation. Also, covering the floor cues had no impact on the emergence of the free throw as a skill that stood out from performance at the other distances. The absence of any differential effect of the floor covering suggests that skilled players probably use direct visual information about the distance between their current location and the location of the basketball rim as the primary (and perhaps sole) source of perceptual input for movement preparation.

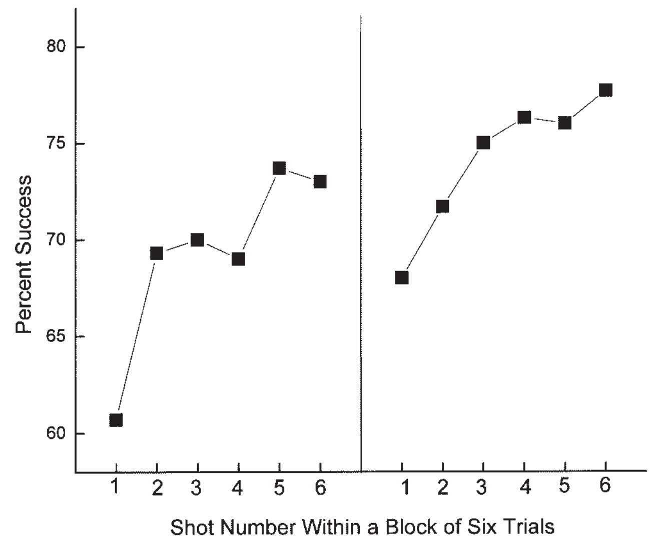

Figure 3. Shooting performance (% success) as a function of the position of the shot within a block of six trials at the same distance. The data represented in the left side of the figure are from Experiment 2 (set shots), and the data represented in the right side of the figure are from Experiment 3 (jump shots).

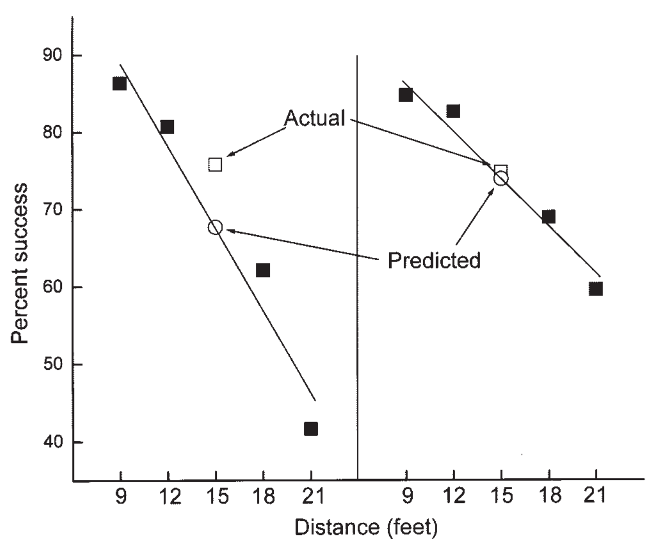

Figure 2. Shooting performance (% success) as a function of the distance from the basket in Experiments 2 and 3. The filled squares represent the actual performance at the non-foul-line distances, the unfilled square represents the actual performance at the foul line (15 ft), and the unfilled circle represents the predicted success at the foul line (15 ft) on the basis of individual regression analyses using the nonfoul line distances. The data represented in the left side of the figure are from Experiment 2 (set shots), and the data represented in the right side of the figure are from Experiment 3 (jump shots).

Performance on the first trial at a new distance was far less accurate than at any subsequent trial at that distance (i.e., within the immediate block of six trials). This finding is reminiscent of a *warm-up decrement* effect—a motor retention loss that received considerable attention over many years of study (Adams, 1952; Anshel & Wrisberg, 1993; Nacson & Schmidt, 1971; Schmidt & Nacson, 1971; Schmidt & Wrisberg, 1971; Wrisberg & Anshel, 1993; see Adams, 1961, for a review). For the purpose of the present investigation, it is interesting to note that the first trial position was as detrimental to performance at the foul line distance as it was to performance at any of the other distances; that is, neither the Position × Distance interaction, $F(20, 140) < 1$, nor the Position × Distance × Floor Covering interaction, $F(20, 140) < 1$, was significant. Thus, the trial position effect was a general one—performance from the foul line was no more immune to this trial position effect than was performance at any other distance.

Experiment 3

The set shot is a particular action that is normally executed at the foul line, as a free throw, with no defenders directly in front of the shooter to interfere with the shot. In contrast, the jump shot is typically taken during active play at many different locations on the court, from widely varying angles and distances to the basket. In this action, the player's feet leave the floor so that the shot can be taken at an increased elevation relative to a defender. Unlike the set shot, the jump shot is typically practiced with considerable variability in location (distance and angle to the basket), which is quite different than the constant distance and angle strategy that is typical of set shot (free throw) practice. Therefore, we predicted that no distinguished level of performance at the foul line would occur within the general skill of jump shots.

Method

Participants. The same varsity athletes who participated in Experiment 2 also participated in the present experiment.

Procedure. All trials for this experiment were conducted after the completion of the set shots for Experiment 2, on the same 2 days of testing. The equipment and testing area were identical to those in Experiment 2. In the present experiment, all participants performed the basketball jump shots with their dominant limb. The task involved a coordinated upper and lower limb shooting motion, during which the players' feet always left the ground. Participants were also instructed to take a single step into the jump shot, in a manner that was consistent with their typical practice performance. The goal of each participant was again to score as many shots as possible.

The experimental procedure was identical to that used in Experiment 2, with the exception that individuals now performed jump shots instead of set shots. The jump shots for the covered and uncovered courts were performed on separate days, as in Experiment 2.

Data analyses. All data collection and analysis procedures were the same as those in Experiment 2, using the 4-point scoring system. Two experimenters independently coded 2 participants, which resulted in a correlation coefficient of .98; therefore, the remaining participants were coded by only one experimenter. ANOVA models were the same as those in Experiment 2.

Results and Discussion

The jump shot scores at the distances surrounding the foul line produced regression equations with multiple correlation squared (R^2) values that accounted for an average of 82% of the variance in the uncovered-floor condition and an average of 79% of the variance in the covered-floor condition. These findings are again consistent with force–variability predictions, with a linear increase in error (or linear decrease in success) as the distance from the target increased, as seen in the right side of Figure 2.

Regression analyses of the uncovered-floor condition generated a mean predicted score of 74.5% success at the foul line. The actual mean score was 75.4%. Regression analyses of the covered-floor condition revealed a mean predicted score of 73.2% for the foul line distance, compared with the actual percentage of 74.2%. The ANOVA revealed that neither the main effect for shot (predicted vs. actual) nor the main effect for floor covering was significant, with both $Fs(1, 7) < 1$. The interaction also was not significant, $F(1, 7) < 1$. The means are also presented in the right side of Figure 2. The absence of a performance advantage at the foul line, contrary to the findings in Experiment 2, supports the contention that the foul line jump shot did not possess the specific products of practice as seen in the set shot data.

Similar to Experiment 2, the analysis of the trial position data yielded just two significant main effects, for distance from the basket, $F(4, 28) = 35.01$, $p < .001$, and for the trial position of the shot within a block of six trials, $F(5, 35) = 5.48$, $p < .001$. The means are shown in the right side of Figure 3. Again, the most poorly performed trial was the first shot from the new distance. Unlike the finding in Experiment 2, however, not only was the first trial different from the rest, but shots at Trial Position 2 were performed significantly more inaccurately than shots at Trial Positions 4, 5, and 6. This finding suggests that the jump shot required one more shot than the set shot to overcome the deficit from switching to this position from one of the other spots on the court.

Note that the present results do not rule out the possibility that specific advantages might exist for some particular jump shot distance and/or direction among the class of jump shot skills—only that the 15-ft position was not one of them. Experienced, high-level basketball players often seem to have favorite spots on the court from which they feel extraordinarily confident. It is likely that this confidence has grown from many trials of practice at this spot, proportionally more so than at other positions on the court. The possibility that a performer's self-selected spot might have specific advantages remains an interesting question for further research.

General Discussion

To summarize, the key result from these experiments, particularly Experiments 1 and 2, is the remarkable degree of specificity as a product of practice. The accuracy at the foul line was significantly greater than that predicted by the performances at the adjacent shot distances, suggesting that something over and above the generalized set shot action was being learned in practice. This specific advantage of practice at the foul line was apparently unrelated to the vision of the markings on the court, as the foul line advantage was not influenced by the presence of a floor covering (in Experiment 2) that obscured the standard court markings. In contrast, the jump shot results of Experiment 3 showed that shooting accuracy at the foul line was predicted well by performances at the adjacent distances; no distinct advantage for the jump shot occurred at the foul line, as had been seen for the set shot in the previous two experiments. With jump shots, none of the positions examined in this experiment should have had considerably more prior practice than any other.

An incidental finding in the present studies was the effect of trial position. The finding is similar in some ways to previous findings of warm-up decrement, as performance after a rest interval shows a temporary loss for a short period after the activity is resumed. The present finding is different, however, in that it is the shift from one distance to another distance that caused the temporary decrement in performance. Because we cannot be certain of the cause for this effect (loss of set, forgetting, interference, etc.), we consider it to be of some theoretical interest for further research. In addition, the effect has practical significance in that many free throws occur in pairs and the second of two free throws is likely to be more successful than the first. A similar interesting finding appeared in data reported a number of years ago by Gilovich, Vallone, and Tversky (1985). In this frequently cited study, Gilovich et al. analyzed some data sets for the presence or absence of so-called hot-hand effects, testing the widespread belief that a basketball player has periods of hot and cold shooting spells. In one analysis, Gilovich et al. reported free throw data for members of the Boston Celtics during the 1980–1981 and 1981–1982 seasons. From the data reported in their Table 3 (p. 305; but not included in their analyses), the Celtics' players were successful on 70.6% of the first of two foul shots and 75.2% of the second foul shots. A dependent t test ($n = 9$) revealed the 4.6% difference in shooting accuracy to be significant at $p < .005$, $t(8) = 3.72$ (see also Wardrop, 1995). Therefore, the incidental finding in our experiment supports data from National Basketball Association game statistics.

High Levels of Practice and Specificity

It is likely that the differences we observed between the predicted and actual foul line performance were due to the extreme levels of practice that these expert performers had experienced at the foul line in set shot training. We cannot be certain, of course, about the number of shots that had been taken over the years from the foul line, but it is safe to say it would number in the range of several thousands to several tens of thousands. In contrast, the amount of practice at any one of the other particular distances would be minimal if one assumes that set shots are normally practiced only at the foul line. Using expert basketball players, in whom such a large discrepancy in practice levels exists for the free throw versus the other distances, was probably a strong factor in allowing us to detect the specific advantages of the foul line. These findings are in contrast to the data by Chamberlin and Magill (1992a, 1992b). They used a class of tasks, with extended practice at one instance and minimal practice at others, with naive subjects in the laboratory. It is possible that the relatively small amount of practice in their study was one of the reasons for the failure to detect specificity effects. In addition, other research has shown that the size of the specificity effects (visual feedback specificity and effector specificity) appears to become larger when the skills are very highly practiced (Park & Shea, 2003; Proteau, Tremblay, & DeJaeger, 1998; Yoshida, Cauraugh, & Chow, 2004; for reviews, see Proteau, 1992, 1995; Shea & Wulf, 2005), which is consistent with our findings here.

Individual-Differences Approaches

Even more generally, it is interesting to note that our evidence is consistent with earlier evidence from an individual-differences approach, which suggested that increasing levels of skill are associated with increased specificity-of-learning effects. Jones (1966), for example, reviewed work showing that, as a function of extended practice, a given task (a) correlates systematically lower with other reference tests of underlying abilities and (b) correlates higher with a factor that is specific to that task. Jones hypothesized that practice was a process of simplification (see Schmidt & Lee, 2005, chap. 13, for a discussion), in that the tasks came to represent increasingly more task-specific (learned) factors and systematically fewer inherited abilities. It is interesting that the earlier individual-differences approach and current experimental approaches have seemingly converged on the same answer but from very different starting points.

In a different way, the specificity of motor skills can be seen in a controversial viewpoint popularized by Franklin Henry in the 1960s. Henry and his many students (e.g., Bachman, 1961, and Lotter, 1960, to name two) discovered that the shared variance between the performance of any two motor tasks was essentially zero, even when those two tasks were seemingly rather similar (e.g., static vs. dynamic balance, speed of reaction vs. speed of movement). This suggested that motor abilities were specific to the task (Henry, 1968), and many of the studies used tasks for which considerable practice was provided, showing that the learned representations (as opposed to fundamental abilities) were also quite specific (see also Fleishman, 1967; Fleishman & Rich, 1963).

Especial Skills

For these specific, highly proficient skills, we propose to use the term *especial*, invoking Webster's meaning as "distinguished among others of the same class" (http://www.webster-dictionary-.org/definition/especial). For the present purposes, we define an especial skill as one that, as a result of massive amounts of practice, has a special status within a generalizable class of motor skills and that is distinguished by its enhanced performance capability relative to the other members of the same class. Our interpretation is that the high levels of practice of this particular variant of the set shot made this version especial in some way. Especial skills stand out from among the remainder of adjacent skills that do not have this status as a result of massive levels of practice.

Especial skills seem possible in any number of real-world situations for which the (perhaps arbitrary) importance of one particular member of a class of skills is far greater than all the rest. The free throw among all possible set shot distances is one example, of course, because of the nature of the game of basketball. There is almost certainly nothing that is biologically special about the 15-ft distance, and it is far more likely that the seemingly arbitrary choice of a free throw distance in the rules of basketball was the ultimate basis for these effects. We can think of other examples as well, such as the 60.5-ft throwing distance (relative to other throwing distances) for pitching in baseball (as mentioned earlier), the skills on a 3-m diving board (among all other possible diving-board heights), or perhaps the specialized welding techniques that an assembly worker might gain after years of doing the same task.

Also, we suspect that there are not very many especial skills in one's repertoire. This concept seems limited to those skills that have an ideal pattern that is essentially invariant across different attempts—that is, so-called closed skills. Open skills, in which the environment is unstable and/or unpredictable, would seem not to be amenable to the development of especial skills, and we suspect that massive amounts of practice at this one variant are going to be required. All of this suggests that the average person does not possess very many of these skills. As such, the concept of especial skills does not do much damage to the "storage problem" for motor skills (Schmidt, 1975, 2003), adding only a few additional representations to memory.

Thus, at one level of theorizing, we argue that the general relationship among the distances not at the free throw line is consistent with the schema prediction of generalization. However, at the 15-ft distance, the extended practice has provided a specific advantage over and above the level provided by the generalization mechanism that is not predicted by schema theory. There are various ways that especial skills could develop.

Representation of Especial Skills

How can the existence of these especial skills be considered within the overall theoretical interpretations about skill learning? A number of possibilities exist.

Schema theory. First, the finding of especial skills is not really addressed by schema theory, as the focus there was more on the processes in generalization than on the specific products of practice. In this view, every production of an action (which receives feedback) is used to update the schema-rule. The individual parameters and movement outcomes are not stored directly, and they serve only to update the relationship. Thus, this theory does not provide a way for massive amounts of practice at one instance in a class to have any effect on that instance, as practice should contribute to all members in the class. When a free throw is made, according to this argument, the performer uses the schema for the set shot program and parameterizes it anew for the 15-ft distance. How can the specificity effects from especial skills, and the generality of the schema view, be reconciled?

Especial GMPs. One possibility is that the performer, when faced with practice at a particular member of a class, develops a separate and new GMP for the action that optimizes the action. Having a GMP that must govern an entire class of actions has the benefit that it reduces the number of programs that one must have in order to perform (the so-called storage problem), but at the same time, this GMP will probably be somewhat suboptimal for any one particular member of the class. If so, then extensive practice with feedback at this one member could develop a separate GMP that is used for only this one application. If this occurs, it should be detectable by examining the kinematics (chiefly the relative timing) of the especial skill versus a nearby neighbor in the class; if differences occur, this would be evidence for a separate GMP having been learned.

Parameter specification. Another view is that the massive amount of practice does not produce a new GMP but rather facilitates the assignment of parameters for this one member of the class (only). Thus, the extensive practice with feedback and constant perceptual cues could develop a specialized, perhaps automatic, mechanism for parameter selection. The performer's view of a highly recognizable set of sensory characteristics, unique to the 15-ft distance and in a very stable environment, could recruit a highly consistent and accurate set of parameters. Here, one would expect to see the kinematics of the GMP being indistinguishable for the especial skill versus all of the rest in the class. Note that, strictly, such a view would be inconsistent with schema theory.

A weighting model. A variant of the parameter-specification view just mentioned was suggested by David A. Rosenbaum.[2] Here, the performance of the class members is governed by a schema-rule, but there is an additional component of accuracy that is a function of the proximity of the desired distance to the highly practiced 15-ft distance—a kind of generalization gradient. This view predicts that the effects of the high levels of practice at 15 ft should spread (transfer) most to its nearest neighbors. It is interesting to note that we did not see any evidence of such a spread in our data. Of course, such transfer could be occurring within the 2-ft intervals between the 15-ft skill and its neighbors at 13 and 17 ft. If so, this generalization must have a very steep gradient across distance, with nearly all of the additional effect being reduced markedly if the distance deviated by as much as 2 ft from the 15-ft position. Of course, we have no evidence from our data on this point.

Perhaps all of the aforementioned ideas have some merit in explaining the present results. It appears that our new finding of especial skills, together with the specificity effects that have emerged in the recent literature (discussed above), encourages a somewhat different theoretical approach to motor learning. Such an approach seems to require provisions for the coexistence of motor skill generality and specificity. Further, it seems to require a shift of emphasis toward specificity as a product of the very high levels of practice necessary for the phenomenal level of skill that comes with expertise.

[2] We thank David A. Rosenbaum for suggesting this idea and a way to study it.

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