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RESEARCH ARTICLE

Especial Skills in Experienced Archers

Mahdi Nabavinik[1], Ali Abaszadeh[2], Mehrab Mehranmanesh[3], David A. Rosenbaum[4]
[1]Motor Behavior Department, Ferdowsi University of Mashhad, Iran. [2]Motor Behavior Department, Islamic Azad University, Tehran Branch, Iran. [3]Motor Behavior Department, Shahid Chamran University of Ahvaz, Iran. [4]Penn State to Department of Psychology, University of California, Riverside.

ABSTRACT. Especial skills are skills that are distinctive by virtue of massive practice within the narrow contexts in which they are expressed. In the first demonstration of especial skills, Keetch, Schmidt, Lee, and Young (2005) showed that experienced basketball players are better at shooting baskets from the foul line, where they had massive amounts of practice, than would expected from their success at other locations closer to or farther from the basket. Similar results were obtained for baseball throwing. The authors asked whether especial skills hold in archery, a sport requiring less movement. If the emergence of especial skills depends on large-scale movement, one would expect archery to escape so-called especialism. But if the emergence of especial skills reflects a more general tendency for highly specific learning, experienced archers should show especial skills. The authors obtained evidence consistent with the latter prediction. The expert archers did much better at their most highly practiced distance than would be expected by looking at the overall function relating shooting score to distance. We offer a mathematical model to account for this result. The findings attest to the generality of the especial skills phenomenon.

Keywords: archery, especial skills

One of the oldest questions in the study of learning concerns the specificity of what is learned. If learners learn only what they experience, they will be unable to generalize, but if they fail to learn especially well what they have been most exposed to, they will fail to show special expertise. Some combination of generalized and specific learning is optimal. How specific or general is the learning in any given task?

In a remarkable demonstration of specificity of learning, Keetch, Schmidt, Lee, and Young (2005) asked experienced basketball players to shoot baskets from the foul line, where the players had had much more practice than from other locations along the line joining the middle of the basket to the middle of the foul line. Keetch et al. found that the farther the shooters were from the basket, the worse they did. However, one data point stuck out in the graph showing the probability of sinking the basket to shooting distance: At the foul-line distance, the success rate shot up. Players were markedly better at that distance than would be expected based on distance only. The players had, evidently, formed a special or, to use the term of Keetch et al., “especial” skill.

A natural question about the especial-skills demonstration of Keetch et al. (2005) is whether it was somehow unique to this team of researchers or to basketball shooting. Other studies have shown that the phenomenon of exceptional performance for highly practiced skills extends to other throwing tasks. Nabavinik, Taheri, and Moghaddam (2011) obtained the same kind of result in another test of basketball shooting, showing that the result of Keetch et al. was not unique for that team of scientists. Others have found evidence for especial skills in other activities, including wheelchair-bound basketball shooting (Fay, Breslin, Czyż, & Pizlo, 2013) and baseball throwing (Simons et al., 2009). Finally, returning to basketball players, Nabavinik et al. (2011) showed that most highly practiced (favorite) locations, rather than only most highly practiced distances, show especial benefits.

The present investigation was prompted by the observation that quite a bit of motion is required in the skills where especial skills were found. Basketball shooting and baseball throwing involve swings of the arms and other body parts. It is possible that these activities are prone to the formation of especial skills because the activities rely on large-scale movements (ones often called gross motor skills). Over the various distances and locations from which basketball and baseball throws are launched, many control parameters must be varied, so it is possible that the motor system becomes highly sensitive to the control parameters associated with performance at particular sites because the generalization gradients extend to many dimensions of the control-parameter hyperspace. According to this hypothesis, especial skills arise for gross motor skills but will not necessarily appear for fine motor skills such as those involved in slightly moving the hands and fingers to release arrows in archery. Our desire to test this possibility was the motivation for this study, as was our desire to test the alternative hypothesis that especial skills are not just tied to gross motor skills but extend to fine motor skills as well.

Method

Participants

Ten classically trained archers (eight men and two women), 20–27 years old (M age = 22.00 years, SD = 2.40 years) participated. They had at least four years of experience in archery. All the archers were or had been

Corresponding address: David A. Rosenbaum, Department of Psychology University of California, Riverside 900 University AvenueRiverside, CA 92521 (814) 571-1891. e-mail: david.rosenbaum@ucr.edu

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FIGURE 1. An archer preparing to release an arrow with a recurve bow. Image reprinted from Wikimedia.

members of the Iranian national team and were members of the Kermanshah provincial team, which does indoor shooting exclusively. The archers in this study reported that they spent at least 90% of their archery practice time practicing the 18-m shot. All of the archers said they had practiced regularly for at least 1 hr/day on average in the year preceding testing. All had normal or corrected-to-normal vision and were otherwise healthy.

Materials and Design

The materials were consistent with the World Archery Federation (WAF) Rule Book (World Archery, n.d.). The archers used a recurve bow (Figure 1) and shot arrows from seven locations marked on the ground, at 15, 16, 17, 18, 19, 20, and 21 m from a standard archery target, 1.22 m in diameter whose center was 1.3 m above the ground, as per standard archery rules. The archers used their personal bows. The target showed three colored circles with scores associated with the circles, as shown in Figure 2. According to WAF rules, there are no differences between men's and women's bows and targets, and that was the case here.

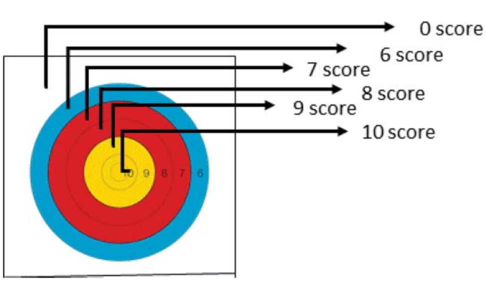

FIGURE 2. Target and associated scores.

Procedure

Before starting the experiment, the players filled out consent forms and were given instructions about the general research methods, minus the hypothesis and predictions. The archers then took nine shots from each of the seven locations in a random order per subject. Each subject was given the chance to rest for up to 5 min between each set of shorts per location and then to go to the next location based on the design. The scores were recorded by the experimenter and ranged from 0 (missed the target) up to 10 (bull's-eye). There was no other feedback except for the visual feedback each participant got about his or her shots.

Results

The normality of the distribution of the data was confirmed by the Shapiro-Wilk test ($df = 63$, $p > .25$). We then used linear regression analysis to calculate the predicted value of all seven locations (Table 1). We calculated individual-subject linear regressions to predict performance based on the distance from the target. The linear fit level approached the standard level of .05, $F(1, 5) = 7.784$, $p < .076$, with an R^2 of .609. According to the linear regression, scores decreased by 0.397 for each meter of distance.

The foregoing analysis does not test for especial skill; that is, it does not test for a significant departure of any given point from the best-fitting linear regression line. To test for such departures, we compared the predicted scores with the actual scores in all seven locations using the independent sample t test. There was a significant difference for the actual and predicted scores at the 18-m distance, $t(16) = 11.005$, $p < .0001$, and there were also significant differences for the actual and predicted scores at the 15-m distance, $t(16) = -3.623$, $p < .001$, and at the 16-m distance, $t(16) = -2.433$, $p < .01$. Table 1 shows the full set of results. Subsequent analysis confirmed that the three differences reported above were still significant when the Bonferroni correction procedure was used.

Figure 3 shows the result of a further analysis. Here, we built on the findings reported above, noting two critical results: (a) the 18-m point was significantly different from the value predicted by the best-fitting linear function, but (b) so were two other points, the ones at 15 and 16 m (see Table 1). We reasoned that if the underlying curve relating score to distance were nonlinear rather than linear (as tested previously), then some of the differences between the observed and predicted values might actually be due to the fact that a curvilinear function rather than a linear function provides a better account of the relation between score and distance, in which case some of the differences, potentially ascribable to an especial-skills effect, might disappear. Our aim, then, was to provide as stringent a test as possible of an especial skills effect.

To pursue this goal, we fitted a second-order polynomial (quadratic function) to the scores, restricting the fit to all

TABLE 1. Results of *t* Tests and Descriptive Statistics for the Actual and Predicted Performance at the Seven Locations

Distance (m)	Actual score			Predicted score			95% CI for mean difference	*t*	*df*
	M	*SD*	*n*	*M*	*SD*	*n*			
15	8.6296	0.28328	9	9.0225	0.15988	9	[−0.70955, −0.07616]	−3.623***	16
16	8.3580	0.31318	9	8.6252	0.10231	9	[−0.58796, 0.05357]	−2.433**	16
17	8.0988	0.41739	9	8.2280	0.14445	9	[−0.59696, 0.33858]	−0.877	9.89
18	9.3580	0.34146	9	7.8307	0.23823	9	[1.12198, 1.93270]	11.005****	16
19	7.4198	0.36336	9	7.4334	0.34370	9	[−0.50062, 0.47328]	−0.082	16
20	6.6914	0.78916	9	7.0362	0.45277	9	[−1.23059, 0.54100]	−1.137	16
21	6.2593	0.72008	9	6.6389	0.56334	9	[−1.26975, 0.51049]	−1.246	16

**$p < .01$. ***$p < .001$. ****$p < .0001$.

the points other than 18 m, anticipating that the 18-m point would deviate from the best-fitting curve. We also checked that the 15- and 16-m points would be close enough to the best-fitting quadratic curve that their standard error bars would encompass the new quadratically predicted values. Indeed, they did, as shown in Figure 3. The quadratic fit accounted for more variance ($R^2 = .995$) than did a linear fit applied to the same six data points ($R^2 = .950$), although by a *z* test, the difference between the two associated *R* values, .9975 and .9747, approached but did not quite reach the conventional level of significance of .05; the obtained *z* and *p* values were −1.42 and .078 (one-tailed), respectively. Despite the nonsignificance of the better fit of the quadratic function over the linear function, we prefer the quadratic function because, with it, the standard error bars for the 16- and 17-m points encompass their corresponding predicted values, which was not true for the linear fit. We take this to mean that the archers' scores descended at a more rapid rate the farther the archers were from the target. More importantly, with the quadratic fit, just one score has a standard error bar that fails to encompass its corresponding predicted value, the score for 18 m, the distance at which our archers had the most practice.

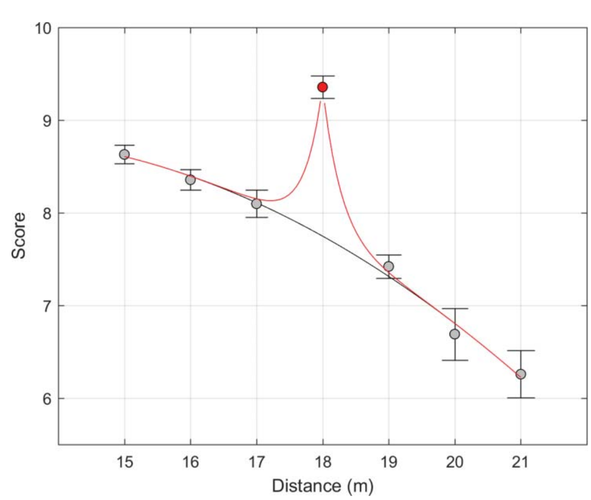

FIGURE 3. Quadratic function (gray curve) fitted to the mean (±1 *SE*) obtained scores at 15, 16, 17, 19, 20, and 21 m (gray points) but not at the most practiced distance of 18 m (red point). The red curve shows the fit of the compound model that incorporates both an effect of distance and of practice.

Discussion

In this study, we asked whether the phenomenon of especial skill holds for archery. We were attracted to archery because holding a bow and releasing an arrow involves little movement compared to shooting a basketball or throwing a baseball—activities where especial skills have been demonstrated before. We thought that if especial skills are restricted to skills that require extensive movement, we would not see them in archery. Contrary to that expectation, however, we obtained strong support for an especial skill effect in archery. The highly experienced archers tested here were particularly proficient at hitting the target when shooting from the distance where they had had the most practice. This outcome suggests that large-scale movement is not a requirement for especial skills. Our results support the generality of the especial skills phenomenon (Breslin et al., 2012; Keetch et al., 2005; Nabavinik et al., 2014).

We have two additional topics of discussion. One concerns another study of especial skills in archery (Czyż & Moss, 2016), which we learned about in the final stages of preparing this report. The other concerns a mathematical model we wish to introduce to account for our data.

Another Study of Archery

Czyż and Moss (2016) asked whether archers show especial skill. Their study differed from ours in that the shooting distances they used were longer than ours. Whereas the longest shooting distance in our study was 21 m, the shortest distance tested by Czyz and Moss was 22 m; the other distances they studied went as high as 90 m.

Czyż and Moss (2016) did not question whether, in general, archers would show especial skills. We wondered about this, however, considering that previous demonstrations of especial skills that we were aware of when we began our investigation all used large-scale throwing movements. As indicated in the introduction, we wondered whether especial skills would also emerge in tasks not involving such movements. Archery was an attractive candidate in this regard because it tends to get a great deal of practice at particular distances, similar to foul-shooting in basketball. But archery involves setting up the body and holding still before releasing the arrow. Our results indicate that especial skills can appear in tasks that use very little movement (archery) as well as large movements (basketball and baseball).

How can we reconcile our results with those of Czyż and Moss (2016)? In the study of Czyż and Moss, especial skills were absent or barely discernible. However, their archers were tested at much longer distances than used here, as noted above, and in one of their experiments their archers had variable rather than constant practice. One possibility is that our result was as strong as it was because our archers had much more practice at one distance (18 m) than at the other distances. The other possibility is that at the much longer distances tested by Czyż and Moss, the difficulty of performance was so great that stochastic noise hid a possible especial-skills effect. We cannot say for sure which of these explanations is more likely to be correct; both could be. According to the mathematical model proposed in the following section, both factors could play an important role in determining the likelihood of especial skills.

A Mathematical Model

Previous discussions of especial skills have relied on qualitative statements about generalized motor programs, recall schemas, and the like to provide reasons for and against the emergence of especial skills in various contexts; see, for example, Czyż and Moss (2016) and Keetch et al. (2005). We are receptive to these models. Indeed, one of us has summarized models of this kind elsewhere (Rosenbaum, 2010, 2017). In the present discussion, we wish to introduce a mathematical expression of these models' main claims, not to question or undermine them in any way, but rather just to pursue a quantitative formula that can succinctly make exact predictions.

The core claims of our mathematically expressed model echo the main idea of current models of especial skills, namely, that while there are overarching challenges to skilled performance as physical difficulty increases (e.g., as shooting distance increases), large amounts of practice at particular sites (e.g., at particular shooting distances) can bestow special benefits.

What are the components of our mathematical model? First, as stated previously, we fitted a quadratic function to the scores, S, for the distances, D. The exact equation, along with its best-fitting coefficients, was

$$S = 2.9 + .93D - .04D^2 \tag{1}$$

We then added a term, P, for practice, to get the compound effect of distance and practice

$$C = S + P \tag{2}$$

where

$$P = \alpha\ \exp(-\beta\,|D - Practiced\_D|) \tag{3}$$

We then added S and P to get an overall measure of performance, C, after setting $Practiced\_D$ to the distance that our archers practiced the most (i.e., 18 m, the task-governed value), and after finding values of α and β that permitted the greatest reduction in the sum of squared deviations between the observed and predicted scores. These turned out to be 1.62 and 3.64, respectively. The goodness of fit was quite good, as seen in Figure 3, with the proportion of variance accounted for being $R^2 = .997$.

According to the model, there was a general effect of distance on the archers' scores, such that scores decreased quadratically as distance increased, and there was an added effect of practice, such that scores decreased exponentially the more the performance distance departed from the most practiced distance. The simplicity of our mathematically expressed model, coupled with the new domain in which especial skill has been shown here, attests to the generality of the especial-skills phenomenon. Our study builds on the others that have been cited here in showing how general factors and specific factors combine in the learning of skills expressed through motor behavior.

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