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Manual Laterality and Hitting Performance in Major League Baseball

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Asymmetrical hand function was examined in the context of expert sports performance: hitting in professional baseball. An archival study was conducted to examine the batting performance of all Major League Baseball players from 1871 to 1992, focusing on those who batted left (n = 1,059) to neutralize the game asymmetry. Among them, left-handers (n = 421) were more likely to hit with power and to strike out than right-handers (n = 638). One possible account, based on the idea of hand dominance and an analogy to tennis, is that batting left involves a double-handed forehand for left-handers and a weaker and more reliable double-handed backhand for right-handers. The results are also interpretable in the light of Y. Guiard's (1987) kinematic chain model of a between-hands asymmetrical division of labor, which provides a detailed account of why left batting is optimal for left-handers.

In this research we examined the relationship between performance and asymmetrical hand function in a population of highly skilled individuals: people who have played in Major League Baseball. Although our work does reveal some interesting insights about the understanding of the game of baseball, our primary goal was to contribute, in a basic research perspective, to the study of functional asymmetry in the performance of bimanual movements.

Research on manual asymmetries has focused on hand preference and hand performance asymmetry, the two major aspects of human handedness (for recent reviews, see Elliott & Roy, 1996). *Hand preference* can be assessed in the context of unimanual activities such as throwing a dart. By recording the proportion of right- and left-hand preferences in standardized questionnaires, a global estimate of a person's manual lateralization is obtained and it becomes possible to classify him or her on a continuum ranging from extremely right-handed (RH) to extremely left-handed (LH). Questionnaire studies have shown that human individuals tend to exhibit a consistency of hand preference across a variety of unimanual acts of everyday life, although a number of puzzles remain, particularly within the LH minority (Gilbert & Wisocki, 1992; Peters & Servos, 1989).

Hand-performance asymmetry, the other aspect of handedness, is assessed experimentally by testing people on unimanual motor tests and comparing the scores obtained with the left and right hands. Much research has been aimed at understanding the relationship between hand preference and hand superiority as an attempt to characterize handedness in general, an enterprise that turned out to be unexpectedly difficult (Peters, 1994; Peters & Murphy, 1992).

However, handedness as operationalized in research with hand-preference questionnaires and unimanual tests is just one aspect of human manual lateralization. As emphasized by Guiard (1987), the vast majority of human manual activities involve both hands with each playing a different, specialized role. For example, in dealing cards, one hand manipulates the pack while the other hand passes out the cards. In the specific case of baseball, players generally manifest a preference for adopting one of two postures for hitting. To bat "right," the hitter stands with the left shoulder toward the pitcher, grasping the extremity of the bat handle with the left hand and placing the right hand just above the left. To bat "left," the hitter stands with the right shoulder toward the pitcher and grasps the extremity of the bat handle with the right hand. Choosing to bat right or left is important for a number of reasons, and, in this article, we focus on how this choice constrains the two hands to act in functionally different ways. Because both hands are essential for hitting a baseball, we do not refer to this choice as a hand preference but as a *lateral preference* (Guiard, 1987).

A lateral preference for an asymmetrical bimanual action can usually be predicted from hand preference. For example, to play the guitar, a person known to exhibit right-hand

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preference for unimanual action is likely to prepare the chords with the left hand and to pluck or strum the strings with the right. Guiard and Ferrand (1996) have recently shown that about 80% of RH humans prefer to hold bimanual hitting implements like a sledgehammer, a bludgeon, or a pickax with the left, nonpreferred hand placed at the end of the handle and the right, preferred hand placed more peripherally. Adopting the convention that rotation direction is judged in the horizontal plane as viewed from above, this grip is associated with a counterclockwise swing of the implement.

There are, however, instances in which lateral preference for the two-handed manipulation of a hitting implement cannot be straightforwardly predicted from hand preference. For example, only about one third of RH ice hockey players choose to hold the stick with the right hand placed closest to the blade and to hit counterclockwise; the remaining two thirds adopt the reverse grip and hit clockwise (Grondin, Trottier, & Houle, 1994). Hitting in baseball is another intriguing instance of hand preference being a mediocre predictor of lateral preference. Our analysis shows that a substantial percentage of RH baseball players choose to bat left (i.e., in the direction opposite that which would be expected on the basis of their handedness).

The fact that batting preference in baseball is often inconsistent with hand preference must, at least in part, result from the inherent asymmetry of the game. Not only are players who bat left (BL) closer to the immediate goal of first base than those who bat right (BR), but, after swinging the bat, they are also likely to be appropriately headed in the direction of this base. Moreover, an axiom of baseball holds that it is easier to adopt the hitting posture (i.e., BL or BR) that is opposite to the hand being used by the pitcher to throw the ball, with the hitter in a better position to perceive the release of the ball. Finally, the basic curve ball from a RH pitcher tails away from a BR hitter, perhaps ending up out of reach, whereas the same pitch curves toward a BL player. Therefore, given that most pitchers are RH, there seem to be several converging reasons to believe that the asymmetrical environment of baseball induces players to bat left. Although this is consistent with the existence of a notable proportion of RH players batting left in baseball (as opposed, e.g., to golf), what remains to be understood is why most RH players bat right, a fact likely to implicate manual lateralization.

In the present study we capitalized on the fact that there are many LH and RH players who bat left. The movements of these two categories of players—who, as hitters, perform the same act—differ if manual lateralization is taken into account. To bat left, RH players place their preferred hand at the end of the handle, whereas it is their nonpreferred hand that LH players place at this position. By focusing on the BL players, we can minimize the influence of the inherent asymmetries in baseball.

There are published data on the implications of motoric asymmetries for skilled performance in baseball. In particular, eye dominance has been suggested to interact with hand dominance in determining batting performance (Adams, 1965; Bahill & LaRitz, 1984; Portal & Romano, 1988). Portal and Romano (1988) reported that players with an uncrossed eye–hand dominance pattern (e.g., left-hand and left-eye dominant) performed worse than those with a crossed pattern or no ocular dominance (but see Adams, 1965, for an opposite suggestion). Unfortunately, our archival records do not report eye dominance. What they do provide is a rich database that allowed us to investigate possible interactions between hand preference for throwing and lateral preference for hitting.

Method

A CD database titled *Total Baseball* (Thorn & Palmer, 1993) was used to obtain all frequencies, performance statistics, and anthropometric measurements. This database includes all individuals who have played in Major League Baseball since its inception in 1871. The batting statistics in the players' records section of the disk was the source of our data. We did not include pitchers in our sample given their notorious inability to hit, at least in the modern era.

The distribution of players in the six categories that resulted from the crossing of our two lateralization factors, hand preference for throwing (throw left or right) and lateral preferences for hitting (BL, BR, and switch-hitters), is presented in Table 1. The table shows separately the distribution for all players of the database (n = 7,196) and for those identified as having made at least 502 plate appearances over their careers (n = 3,355), the most reliable subset on which we base our main statistical analyses.

We chose to use the throwing hand as an indicator of handedness. No single indicator of hand preference is a perfect predictor of overall handedness, and ball throwing is no exception. For example, Gilbert and Wisocki (1992) reported that about 3% of people who throw right write left, but almost 20% of people who throw left write right. Nonetheless, throwing hand remains one of the best known indicators of overall handedness in hand-preference questionnaires (Peters, 1996). Indeed, in the classic study by Annett (1970), throwing hand was selected as one of the six primary items for the assessment of handedness in view of the high correlation this item had with all the other items in her large-scope hand-preference questionnaires. For clarity, we treat players who throw with the left and right hand as LHs and RHs, respectively.

Results

Distribution of Throwing and Batting Preferences

Several interesting facts stand out in Table 1 concerning throwing and batting choice. First, note that the overall incidence of left-handedness in our total sample of 7,196 players is 13.5% (13.7% in the 502+ group), a figure similar to modern estimates for North American adults (Gilbert & Wisocki, 1992). Recall, however, that our sample extends more than a century. Because the incidence of patent left-handedness is known to have increased monotonically throughout this century (Levy, 1976), our data would suggest an overrepresentation of left-handedness among professional baseball players, in support of the view that baseball favors LH batters.

More than 90% of LH players batted exclusively from the

Table 1
Batting Preferences for Left- and Right-Handed Throwers in the History of Major League Baseball

Throwing preference	Bat left *n*	Bat left %	Bat right *n*	Bat right %	Switch-hitters *n*	Switch-hitters %	All *n*
			All hitters				
Left							
n	881	90.7	51	5.3	39	4.0	971
%	40.4		1.1		7.7		13.5
Right							
n	1,298	20.9	4,460	71.6	467	7.5	6,225
%	59.6		98.9		92.3		86.5
All							
n	2,179	30.3	4,511	62.7	506	7.0	7,196
			502+ at bats				
Left							
n	421	91.7	18	3.9	20	4.4	459
%	39.8		0.9		7.4		13.7
Right							
n	638	22.0	2,009	69.4	249	8.6	2,896
%	60.2		99.1		92.6		86.3
All							
n	1,059	31.6	2,027	60.4	269	8.0	3,355

Note. Pitchers are excluded. Percentages beneath and to the right of numbers (*n*) are relative to the column and row totals, respectively.

left. Interestingly, only about 70% of RH players batted exclusively from the right, a difference likely to reflect the above-mentioned asymmetry of the game, $\chi^2(1, N = 7{,}196) = 991, p < .0001$. Also, almost 60% of the players who batted exclusively from the left threw with the right hand, again an indication of the attractiveness of the BL option. In the critical performance comparisons that follow, our focus is on the LH versus RH contrast within the BL group, keeping in mind that throwing hand was the criterion used for handedness classification.

Baseball Performance Statistics

Six dependent variables that measure performance for each of the six groups, computed for all players and divided by the number of appearances at bat, are shown in Table 2.

Table 2
Performance Statistics as Functions of Batting and Throwing Preferences Over the History of Major League Baseball

Statistic	Throwing preference	Bat left	Bat right	Switch-hitters
Batting average[a]	Left	.281	.276	.268
	Right	.276	.263	.263
Slugging average[a]	Left	.411	.382	.368
	Right	.396	.378	.360
Home runs[b]	Left	1.99	1.30	1.04
	Right	1.77	1.73	1.24
Bases on balls[b]	Left	10.39	8.21	11.06
	Right	10.56	8.79	10.12
Strikeouts[b]	Left	10.44	7.99	10.55
	Right	9.53	11.10	11.41
Stolen bases[b]	Left	2.42	4.55	4.15
	Right	2.27	2.11	3.50
At bats	Left	1,288,664	55,447	47,133
	Right	1,943,722	5,669,744	747,423
	All throwers	3,232,386	5,725,191	794,556

[a]Baseball units. [b]Percentage of at bats.

These six variables were batting average (the number of hits, i.e., the sum of singles, doubles, triples, and home runs divided by the total number of at bats), home runs, bases on balls (walks), strikeouts, slugging average, and stolen bases. Slugging average is a commonly used index of power in baseball, based on the number of bases the batter reaches on average per at bat. It is calculated as the number of singles (i.e., the batter reaches one base after a hit), plus two times the number of doubles (i.e., the batter reaches two bases), plus three times the number of triples (i.e., the batter reaches three bases), plus four times the number of home runs (i.e., the batter reaches all four bases) divided by the number of at bats. For example, a player hitting two singles, one double, and one home run in 20 at bats would have a batting average of .200 (4 divided by 20) and a slugging average of .400 (2 + 2 + 0 + 4 divided by 20).

The overall picture reported in Table 2 reveals better hitting performance for LH than RH players as well as for BL than BR players. Dramatic confirmation that BL was associated with higher success is provided by the fact that 54 of the 111 hitters in the MLB Hall of Fame hit left (excluding switch-hitters), a proportion significantly different from chance given the distributions of Table 1, $\chi^2(1, N = 111) = 13.07, p < .001$.

For our performance analyses, we restricted the sample to individuals who had made a total of at least 502 plate appearances over their careers. This is the criterion adopted by the Major Leagues for an individual to be considered for the best hitter title for a single season.[1] In this individual analysis, there were 2,207 BR players and 1,059 BL players. As only 18 of the BR players were reported to throw with their left hand, we decided to ignore the BR group for the LH versus RH comparison. Statistics are reported in Figure 1 for the three remaining groups (2,009 BR–LH players, 638 BL–RH players, and 421 BL–LH players).

All statistical tests were *t* tests, and the degrees of freedom were adjusted when the Levene's test for equality of variance was significant. An overall comparison of performance between LH and RH players regardless of their lateral preference for hitting (keeping in mind that the effects of throwing hand and batting side cannot be completely disentangled) suggested that LH hitters were superior in all batting categories ($ps < .001$) but two: The two groups did not differ significantly in the frequency of strikeouts, $t(3,215) = 1.40, p = .16$, and in the stolen base category, $t(3,300) = 1.80, p = .07$.

Considering performance as a function of batting side regardless of hand preference, BL players scored better than BR players for all dependent variables ($p < .001$) but one, stolen bases, for which there was no significant difference, $t(2,096) = 1.68, p = .09$. Although not absolutely conclusive, this result is clearly compatible with the hypothesis that batting left is advantageous in baseball. The BR–RH group (which constituted almost all of the RH players) scored the lowest on most measures. They were outperformed by BL–LH players for all the variables shown in Figure 1 except strikeouts, for which there was no significant difference, $t(2,330) = 1.51, p = .13$. With one exception, no significant difference for stolen bases, $t(1,030) = 0.79, p = .43$, they were also outperformed in all respects by BL–RH players.

We now turn to the critical comparison, that between LH and RH players within the BL group. Because the players in these two groups hit from the same side of the plate, any differences between them cannot be attributed to any external factors. The analyses revealed that LH players hit more home runs, $t(1,057) = 2.15, p < .05$, and had a higher slugging average, $t(1,057) = 2.84, p < .01$, than did RH players. Importantly, RH players did not perform more poorly on every possible measure of hitting proficiency: They were actually less likely to strike out, $t(1,009) = 2.05, p < .05$, than LH players. There were no significant differences between LH and RH players in terms of batting average, $t(1,057) = 0.96, p = .34$, bases on balls, $t(1,057) = 0.05, p = .96$, or stolen bases, $t(1,044) = 1.26, p = .21$.

We must consider whether the LH versus RH differences within the BL group might have reflected a self-selection process. Because the BL–RH group might have had an overrepresentation of players who were aware of their limitations in hitting for power and who chose to bat left to adapt to the game asymmetry, we had to examine the anthropometric data to determine whether this group was composed of shorter or lighter players. We first verified that anthropometric measures do predict power hitting by calculating correlations for the total sample. As expected, height bore a significant positive correlation ($p < .01$) with strikeouts ($r = .457$), with home runs ($r = .460$), and with slugging percentage ($r = .285$). The same was true of weight, which was positively correlated with strikeouts ($r = .433$), with home runs ($r = .589$), and with slugging percentage ($r = .421$). We then compared the anthropometric measures for the two BL groups, but we were unable to find any significant differences in terms of their height (LH = 182.27 cm, RH = 181.86 cm), $t(915) = 1.10, p = .27$, or weight (LH = 82.79 kg, RH = 82.44 kg), $t(915) = 0.67, p = .51$. On the other hand, both groups showed the same type of evidence regarding a potential trade-off between hitting for power and strikeouts. The correlation between slugging percentage and strikeouts was weak

[1] Switch-hitters were excluded from our main analysis. A switch-hitter is someone who bats from either side of home plate depending on the pitcher: When facing a right-handed pitcher, the switch-hitter will bat left; when facing a left-handed pitcher, the switch-hitter will bat right. Switch-hitters could provide a potentially interesting within-subjects analysis. We would predict that switch-hitters would hit for more power when adopting a consistent mode (e.g., a right-hander batting right) but would strike out less when adopting an inconsistent mode (e.g., a right-hander batting left). However, this analysis is plagued by at least two problems. First, there are the basic asymmetries of baseball that favor hitting left. Second, switch-hitters are likely to have many more opportunities to bat left given that the majority of pitchers are right-handed. Although our database does not provide separate statistics for switch-hitters as a function of hitting side, we were able to locate these data for the 1996 season on the World Wide Web (www.baseballstats.com). For the 96 right-handed switch-hitters (out of a total of 100), statistics tended to be better when hitting left, but they had almost three times as many at bats batting left than right.

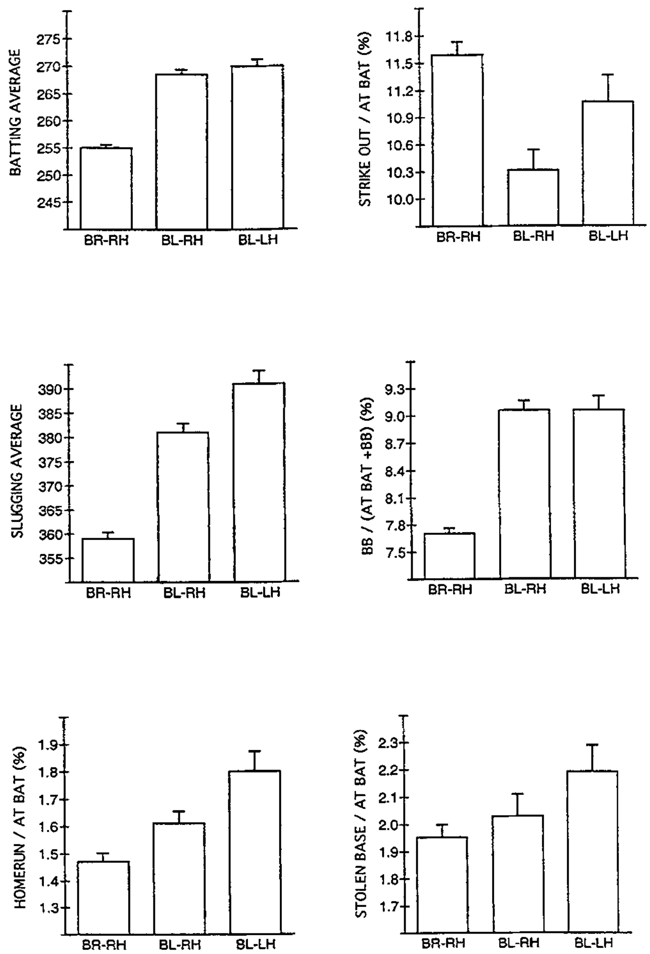

Figure 1. Mean performance score for each dependent variable: batting average, slugging average, home run, strikeouts, base on balls (BB), and stolen bases. In keeping with baseball conventions, units are thousandths for batting and slugging averages. Units are percentages for other dependent variables. Lower scores on strikeouts indicate better performance. BR = bat right; BL = bat left; RH = right-hander; LH = left-hander.

($rs < .12$, $p < .05$), but home runs bore a strong positive correlation with strikeouts ($rs > .5, p < .001$).

Another aspect of the data argues against the view that the BL–RH players were less strong. Stealing bases was negatively correlated with both home runs ($r = -.292, p < .001$) and strikeouts ($r = -.230$, $p < .001$). Had the BL–RH group been composed of weaker hitters for whom the advantage of a shorter distance to first base outweighed the cost of a nonoptimal hitting side, we would have expected this group to be more likely to steal bases than either BR–RH or BL–LH players. This was not supported by the data: As reported earlier, for stolen bases, BL–RH players differed neither from BL–LH players nor from BR–RH players. In summary, from an analysis of both the anthropometric and the stolen base data, we found no evidence that the BL–RH group represented an unusual population in terms of their potential for power hitting.

Discussion

The preceding suggests that the different patterns of performance we found within the BL group between LH and RH players reflect a difference in motor skill rather than in raw physical capability. We now attempt to characterize this difference and to identify directions for further empirical research. We consider two alternative lines of interpretation, one in terms of hand dominance and the other in terms of complementary manual specialization.

Two-Handed Hitting and Hand Dominance

What is the difference between BL–LH and BL–RH players? In biomechanical terms (e.g., Hay, 1985), a forehand is defined as a stroke involving an internal rotation of the shoulder and a forearm pronation, and a backhand is defined as a stroke involving an external rotation of the shoulder and a forearm supination. In a two-handed hitting movement, the hand positioned at the end of the handle is thus involved in a backhand movement, whereas the other hand is involved in a forehand movement. Therefore, focusing on the action of the dominant hand, BL–LH players can be said to perform a *two-handed forehand stroke* and BL–RH players a *two-handed backhand stroke.*

Given that all throwing gestures (with darts, all sorts of balls, discuses, javelins, etc.) are performed with the dominant hand moving in the forehand direction (e.g., Hay, 1985; Jöris, van Muyen, van Ingen Schenau, & Kemper, 1985), one may suspect that the forehand is advantageous relative to the backhand. One clear-cut difference between the two strokes, documented in professional tennis by Déchelette and Guiard (1995), is in terms of *stance,* the way in which players orient themselves to hit. To prepare for a forehand stroke, professionals typically adopt an "open" stance, which means that they keep their two feet on a line nearly parallel to the net (Déchelette & Guiard, 1995, found a modal angle of 15° clockwise for RHs). In contrast, a backhand stroke involves a markedly "closed" stance (the modal angle was 165° counterclockwise for RHs), that is, to hit a backhand the players assume a posture with their backs to the net.

Déchelette and Guiard (1995) argued that an open and a closed stance reflect entirely different global organizations of the hitting movement. With a closed stance, the preparatory backward excursion of the hitting implement terminates on a more or less stable extremum of position—a neutral dynamical equilibrium, with minimal muscular and tendinous tension. In contrast, the backswing from an open stance takes the arm a long way away from initial rest (dynamically speaking, to a repelling region), with a large amount of body twisting. One consequence is that the forward, executory phase of the stroke will involve more bodily *degrees of freedom:* Whereas a backhand stroke essentially consists of an arm movement executed on top of a nearly stationary trunk, a forehand stroke involves a substantial amount of trunk and legs motion in addition to the arm, as is the case in power throwing (Alexander, 1991; Hay, 1985; Jöris et al., 1985). Another consequence is that an open stance results in a global *spring effect:* The elastic potential energy accumulated through body twisting during the backswing will be restituted during the forward phase of the swing (Cavagna, 1977; Kermadec, 1995; Guiard, 1993).

Therefore, both the degrees of freedom and the spring effects are reasons to expect a superiority of the forehand for hitting power, which leads to a possible explanation of the present results. The reason why, in the BL group, left-handers exhibit more power than right-handers is because they swing their bat in the forehand direction, the appropriate direction for power hitting and throwing. In contrast, when batting left, right-handers execute their hitting motion in the backhand direction. If this explanation is correct, BL–RHs face a dilemma. Their first option is to go for an open stance and perform a movement similar to the forehand of a left-hander. However, this will be at the cost of relying predominantly on their left, nondominant arm. Alternatively, they may adopt a more closed stance and perform their swing in a manner consistent with the backhand motion of a right-hander so as to preserve the lead role of their dominant right arm. However, this will be at the cost of thwarting the degrees of freedom and spring effects. Thus, right-handers face a cost when opting to bat left to adapt to the asymmetry of the baseball game.

The forehand versus backhand interpretation leads to testable predictions for future research on laterality effects in baseball hitting. The first—not testable in the present archival study—is a more open stance for BL–LH than BL–RH players. Second, if the accumulation of potential energy in the whole bodily musculature during the backswing phase is the hallmark of a forehand motion, then one can predict in the LH group (a) a shorter swing duration, mainly due to a shorter backswing, and (b) a higher bat velocity at the time of ball impact.

However, the recent evolution of professional tennis suggests one reason to doubt that stance will differentiate BL–LH from BL–RH players. The two-handed backhand technique Bjorn Borg introduced in the late 1970s was characterized by a remarkably closed stance, so much so that he invariably terminated his backhand strokes one-handed. More recently, players using the two-handed backhand have adopted a more open stance. Indeed, many players today use a backhand stance and swing that is reminiscent of a two-handed forehand (Déchelette & Guiard, 1995). This evolution suggests that the degrees of freedom and the spring effects have been gradually overriding hand preference.

A similar evolution may have occurred in baseball among BL–RH players. Modern BL–RH players perhaps more or less completely sacrifice the leadership of their dominant hand and adopt an open stance that is indistinguishable from that of BL–LH players. In such a case, the forehand versus backhand account would still predict a higher peak of bat velocity in BL–LHs than BL–RHs because the rear, left arm—of critical importance in an open-stance, two-handed stroke—has a greater power capability in the former group. However, one would expect the stance of BL–RH players to have evolved from closedness in the past, a prediction testable in principle through a systematic examination of photographic documents on baseball hitting.

An account of the finding that the BL–RH group strikes out less than the BL–LH group may also be developed by considering tennis. Experts often claim that the forehand, which allows more incisive attacks than the backhand, is also less reliable and that players are often exposed to inflation of their error rates for this particular stroke (Déchelette, 1989). This observation is consistent with a simple speed–accuracy trade-off, in which the batter is more likely to miss the ball when swinging the bat with a greater velocity. Furthermore, assuming that BL–LH and BL–RH players differ for the stance, the control difference we observed is also understandable in view of the greater number of biomechanical degrees of freedom involved in the forehand, which demands a coordination of the arm with the trunk and legs and may, in this sense, be considered more complex than the backhand, which relies almost entirely on within-arms coordination. In summary, the higher probability of a strikeout in BL–LH players represents, according to this account, the mere counterpart of their power superiority resulting from the fact that these players execute forehands rather than backhands.

Two-Handed Hitting and Complementary Manual Specialization

Within the laterality literature, there has been a tendency to assume that most human activities involve a single hand. An implicit corollary of this assumption has been that in bimanual actions, one hand does most of the work. However, this characterization fails when one carefully considers the actions of the two hands in most behaviors involving the use of tools. Guiard (1987) has argued for an alternative approach recognizing complementary specialization of the two hands. Whereas the traditional approach construes left–right asymmetry in terms of one hand being more involved or more skilled than the other, the new approach assumes both hands to be critically involved: The primary concern is then the *logic of partition of labor* between the left and the right, the two hands being assumed to enjoy complementary specializations.

Using the kinematic chain (KC) as a model, Guiard (1987) suggested that in human asymmetric bimanual activities, the left and the right hands cooperate like an arm's proximal and distal components. Guiard derived three general principles from this model: (a) The motion of the preferred hand is organized relative to frames of reference placed under the control of the nonpreferred hand; (b) the contribution of the nonpreferred hand, compared with that of the preferred hand, is macrometric (i.e., characterized by larger amplitudes and longer time periods); and (c) the nonpreferred hand initiates bimanual acts, whereas it is the preferred hand's role to terminate them. Although these three principles are not conceptually independent (e.g., the macroaction precedes the microaction in any hierarchically organized system), they may be treated empirically as separately testable statements. Although the KC model has received its strongest support in the study of human–

computer interaction (e.g., Cutler, Frölich, & Hanrahan, 1997; Hinckley, Pausch, Proffitt, Patten, & Kassell, 1999; Kabbash, Buxton, & Sellen, 1994), it can be applied in a straightforward manner to two-handed hitting.

Consider the double-pendulum model commonly used by students of the golf swing (Cochran & Stobbs, 1968; Jorgensen, 1994; Williams, 1969). This model likens the hitter to a system composed of two rods constrained to rotate in the same inclined plane and linked by an elastic hinge. The central rod usually represents the hitter's arms and the peripheral rod represents the club, but the model may be refined somewhat by taking into account the asymmetrical placement of the hands on the club handle (Cochran & Stobbs, 1968): The hand placed at the handle extremity primarily serves to control the rotation of the central rod, whereas the other, more distal hand is best placed to control the rotation of the peripheral rod about the hinge. As rotating the club about the hinge amounts to rotating it relative to the central rod, the distal hand can be said to act relative to the angular position controlled by the hand placed at the handle extremity.

As predicted by the first principle of the KC model, golfers almost always place their nonpreferred hand at the handle extremity, thus allowing this hand to provide the reference. More generally, this arrangement is observed across a variety of sports that use two-handed hitting implements such as golf, cricket, field hockey, kendo, or croquet as well as in the manipulation of everyday hitting tools (Guiard & Ferrand, 1996). Using a variant of Fitts's (1954) task, Guiard and Ferrand (1996) found that participants were faster and more accurate in manipulating a long-handled, bimanually held hammer when their nonpreferred hand was placed at the handle extremity. Applied to the sport of baseball, this analysis predicts that, for BL players, there should be a performance advantage for LH players over RH players because their posture preserves the preferred to nonpreferred reference principle.

According to the second principle of the KC model, hitters should prefer to map the relatively macrometric and micrometric component of the bimanual task onto their nonpreferred and preferred hands, respectively. The double-pendulum model makes it clear that the contribution of the distal hand is indeed micrometric compared with the contribution of the hand placed at the extremity of the bat handle. With respect to spatial resolution, the distal hand operates on a much shorter radius of rotation and hence with a much lower gain for the conversion of joint angles into distances at the tip of the implement. With respect to temporal resolution, the action of the distal hand, which involves less inertia, exhibits shorter episodes of motion with steeper variations of angular velocity (Alexander, 1991; Cochran & Stobbs, 1968; Jöris et al., 1985), and hence its time window for action is narrower. Thus, in accord with the KC model, BL–LH baseball players adopt the standard assignment of the hands, with their right, nonpreferred hand in charge of the proximal, macrometric component of the swing and their left, preferred hand in charge of the distal, micrometric component. For the BL–RH players, the hands are assigned the reverse roles.

Finally, the KC model predicts that the contribution of the nonpreferred hand should precede that of the preferred hand. Guiard and Ferrand (1996) observed that the optimal grip for performance with long, bimanually held rods in a variety of tapping tasks required the nonpreferred hand and the preferred hand to take the lead successively during initial target approach and terminal target percussion. However, why should the proximal and the distal hand act in succession in two-handed hitting? Any hitting or throwing movement gives rise to the phenomenon known as the "whip effect" (e.g., Jorgensen, 1994), which is the progressive migration of the momentum from the proximal, high inertia joints to the distal, low inertia joints, leading to a monotonic increase in peaks of angular velocity (e.g., Cochran & Stobbs, 1968; Jöris et al., 1985). In bimanual hitting, if the hand placed at the handle extremity is predominantly involved in the acceleration of the central rod and the distal hand is predominantly involved in the control of the rotation of the implement, then the distal hand must intervene subsequently to the other hand. Therefore, whereas batting left involves a nonpreferred and then preferred sequencing of hand action in BL–LH players, in keeping with the KC model's third principle, the sequence exhibited in BL–RH players is inverse.

In summary, the three principles of the KC model represent three reasons to expect LHs and RHs to prefer to bat left and right, respectively, and to perform better with these preferred options. Concerning the higher probability of strikeouts for BL–LHs than BL–RHs, one is left with the supposition that improvements in the kinematics of the batting movement likely result not only in an increase of the peak velocity of the implement but also in an increase in the probability of a miss.

There is one final hypothesis to consider for the lower strikeout rate for the BL–RH group. As noted earlier, ice hockey stands as an apparent exception to the general arrangement for the placement of the preferred and nonpreferred hands. About two thirds of the players adopt the reverse posture, placing their preferred hand at the handle extremity and the nonpreferred hand more peripherally. Note, however, that the stick serves not only to hit the puck but also to guide it through complex trajectories. Grondin et al. (1994) reported a correlation between lateral preference and playing style that can account for this discrepancy. Using a questionnaire method, they had naive coaches report the grip of their players and rate each player's relative preferences for activities such as controlling the puck, shooting hard, or shooting with accuracy. The results indicated that the players who placed their nonpreferred hand at the handle end, thus adopting the normal grip for hitting, emphasized power, whereas the others emphasized stick handling abilities and accuracy. Perhaps a similar situation applies in baseball with the reverse grip adopted by the BL–RH players leading to an emphasis on controlled hitting. It is interesting to note that some of the metaphors used to describe hitting do not describe a rotational action that conveys power. "To poke a single between the first and second basemen" or "to punch a hit into left field" describe hitting with control rather than power.

Overview and Conclusion

We propose two conceptually different but noncontradictory interpretations of our finding that BL–LH players exhibit more power while being more likely to strike out than BL–RH players: The first is based on the assumption of hand dominance and the other on the assumption of hand specialization. Both represent post hoc accounts, and neither can be conclusive given that our database does not provide any kinematic data. However, we believe the data do provide plausible explanatory mechanisms while also suggesting interesting directions for future empirical research on baseball hitting and, more generally, on the implications of manual specialization in human two-handed hitting.

Of the two accounts outlined earlier, the hand-specialization interpretation seems most promising. If future research fails to support the stance difference predictions derived from the forehand versus backhand hypothesis, it will be hard to salvage the hand-dominance account. The research directions opened by the KC model offer an opportunity to analyze baseball in a manner similar to that which has proved fruitful across a wide range of activities in which humans bimanually manipulate tools.

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