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DO LEFT-HANDED COMPETITORS HAVE AN INNATE SUPERIORITY IN SPORTS? [1]

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Summary.—This study assessed handedness distributions among (a) sporting competitors ($n = 1,112$) and nonsporting university students ($n = 1,112$), (b) sporting competitors engaging in interactive ($n = 576$) and in noninteractive sports ($n = 536$), and (c) sporting competitors engaging in direct interactive ($n = 219$) and indirect interactive ($n = 357$) sports. Chi-squared showed that there were statistically significant differences in proportions of left-handed persons in (a) sporting competitors and nonsporting university students, (b) sporting competitors engaging in interactive and noninteractive sports, (c) sporting competitors engaging in interactive sports and nonsporting university students, and (d) sporting competitors engaging in direct interactive and indirect interactive sports. It appears that left-handers are more common among those who engage in competitive manual activities. This superiority of the left-handers may be fully explained by a consideration of tactical or strategic factors associated with handedness during sporting interactions. The results with important implications for the measurement and evaluation of handedness are discussed in the light of the current findings on laterality.

Handedness is a universal, uniform, and unique characteristic of all humans (Corballis, 1983; Toth, 1985; Bradshaw, 1991; Marchant, McGrew, & Eibl-Eibesfield, 1995). Only in primates do individuals have a consistently preferred and more skillful hand for manual actions (Walker, 1980; Bradshaw, 1988, 1989). Such laterality of hand use reflects asymmetry of cerebral structure, and the evolution of handedness is likely linked to the cerebral representation of language and particularly of speech (Annett, 1985; Corballis, 1989). Handedness seems to be heritable (Annett, 1967, 1985; Levy & Nagylaki, 1972; McManus, 1991), although the relative importance of genetic and cultural inheritance is still unsettled (Yeo & Gangestad, 1993; Laland, Kumm, Van Horn, & Feldman, 1995). Approximately 90% of humans exhibit a right-hand preference for object manipulation (Annett, 1972; Connolly & Bishop, 1992; Gilbert & Wysocki, 1992). Archeological evidence suggests that this percentage has apparently remained stable during historic times (Coren & Porac, 1977; Keeley, 1977; Foley, 1987; Corballis, 1989).

Many hypotheses have been advanced to explain the dominance of right-handedness in humans. For instance, the environmental hypotheses as-

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sume that the ultimate cause of right-handedness is (a) the development of language in the left cerebral hemisphere (Annett, 1972, 1985; Levy & Nagylaki, 1972), (b) a rapid motor sequence in the left cerebral hemisphere for throwing ability during hunting (Calvin, 1982), (c) a postural asymmetry during feeding as observed in prosimians (MacNeilage, Studdert-Kennedy, & Lindblom, 1987; MacNeilage, 1993), (d) a preferred left side for infant cradling, freeing the other hand for other purposes (Hopkins, Bard, Jones, & Bales, 1993), (e) a specialization of hands in tool behavior (Susman, 1988) and a competition for neural space (Frost, 1980), (f) an unidentified *nurtural* (rather than natural) selection process in favor of the right hand (Porac & Coren, 1981; Ashton, 1982), or (g) an inability of the left-handers to handle the dextral pressures in the environment (Coren, 1989, 1993).

The genetic hypotheses suggest that right-handedness is a result of (a) a right-dominant or left-recessive gene (Ramaley, 1913; Annett, 1964), or (b) a cortical trade-off in abilities, with better verbal and poorer spatial skill in left handers (Levy, 1974, 1976).

The pathological hypotheses claim that left handedness is caused by (a) an atypical torque, i.e., twisted, appearance of the brain in left-handers (Galaburda, LeMay, Kemper, & Geschwind, 1978; Habib, 1989), (b) an oxygen deficiency at birth (perinatal hypoxia or 'birth stress') which produces a dysfunction in the contralateral motor pathways of the 'more susceptible' left cerebral hemisphere (Bakan, Dibb, & Reed, 1973; Bakan, 1987; Schwartz, 1988), (c) other 'birth stressors', such as RH incompatibility between mother and fetus, prolonged labor, premature birth, multiple births, breech delivery, and low birth weight (Coren & Porac, 1980; Coren, Searleman, & Porac, 1982; van Strien, Bouma, & Bakker, 1987), (d) an atypical maturational pattern of the right cerebral hemisphere which involved a gradual shift toward left-handedness (Corballis, 1983; Porac, Coren, & Duncan, 1989; Coren & Halpern, 1991), (e) high prenatal testosterone (or progesterone) which affect the neural development of the brain, specifically by slowing the rate of growth within the left cerebral hemisphere (Geschwind, 1984; Geschwind & Galaburda, 1987; McManus & Bryden, 1991), or (f) the development of a more subtle and less abnormally exaggerated alinormal syndrome in which left-handedness is but one of several possible behavioral deviations that occur in combination (Coren & Searleman, 1985, 1987).

None of these hypotheses, however, succeeded in making *a priori* predictions of the existence and persistence of left-handers as a stable fraction of the population.

In the last two decades, a number of studies of handedness have focused attention on sport populations (Porac & Coren, 1981; McLean & Ciurczak, 1982; Azemar, Ripoll, Simonet, & Stein, 1983; Annett, 1985; Bisiacchi, Ripoll, Stein, Simonet, & Azemar, 1985; Wood & Aggleton, 1989; Aggleton & Wood, 1990; Raymond, Pontier, Dufour, & Moller, 1996). Globally, their findings suggest that there is an unusually high proportion of left-handers among top level sportsmen and sportswomen. Several hypotheses have been proposed to explain this imbalance of handedness distribution among sporting individuals.

Bisiacchi, *et al.* (1985) proposed that left-handers have a central motor advantage in motor tasks. This advantage depends on some higher lateralized processes, e.g., spatial orientation and attention, cued recall, in the right cerebral hemisphere which controls the left hand. Azemar, *et al.* (1983), Annett (1985), and Nass and Gazzaniga (1987) claimed that left-handers have an intrinsic advantage over right-handers due to superior spatiomotor skills and that the relatively high proportion of left-handed sporting individuals reflects this innate superiority. Geschwind and Galaburda (1987) assumed that left-handers have higher overall skill on those tasks which require the use of both hands due to a higher rate of bilateral representation of axial motor control. Their assumption, which is consistent with a number of previous theoretical accounts (e.g., Hecaen & Sauguet, 1971; Hardyck & Petrinovich, 1977; McLean & Ciurzak, 1982), postulates that left-handers are less lateralized than right-handers. This lack of lateralization in left-handers may, in some manner, contribute to the motor function of the nondominant hand, thereby enhancing a dexterity that clearly requires the coordination of both hands.

In contrast, Wood and Aggleton (1989) and Aggleton and Wood (1990) argued that the superiority of the left-handers in many sports reflects the nature of the sport and not an innate neurological advantage. Although they did not rule out a left-handed advantage linked to spatial skills, they emphasized that a variable excess of left-handed individuals in sport is present only in such sports where left-handers have clear strategic advantages, e.g., cricket and tennis.

Finally, Raymond, *et al.* (1996) stressed the point that lateralization itself is not responsible for the increase in frequency of left-handers in a sport population. They proposed an evolutionary hypothesis, namely, the 'fighting hypothesis', to explain the existence and persistence of left-handedness in humans and, consequently, in sporting individuals. Raymond, *et al.*, speculated that left-handers have an advantage when they engage in combat. This is because left-handed individuals usually interact with right-handers who are more numerous and are, therefore, more accustomed to encountering other right-handers. Thus, when a fight or aggressive interaction occurs between a right- and a left-hander, the left-hander has a tactical or strategic advantage, given being in a relatively familiar situation. During evolution this advantage may offset the disadvantages of left-handedness associated with various developmental disorders (e.g., Annett & Kilshaw, 1984; Batheja & McManus, 1985; Satz & Soper, 1986; Bishop, 1990; Devenny & Silverman, 1990; Di Nuovo & Buono, 1997; Grouios, Sakadami, Poderi, & Alevriadou, in press) and reduced fitness components (e.g., Coren & Porac, 1977; Coren & Searleman, 1987; Coren, 1989, 1993; Coren & Halpern, 1991; Aggleton, Kentridge, & Neave, 1993; Fudin, Renninger, & Hirshon, 1994), often enough to ensure that left-handers survived and passed their handedness on to their children through genetic processes.

The purpose of the present study was twofold. To investigate the handedness distributions among (a) sporting competitors and nonsporting university students, (b) sporting competitors engaging in interactive and noninteractive sports, and (c) sporting competitors engaging in direct interactive and indirect interactive sports. The null hypotheses were that no differences in the percentage of left-handedness should exist between any of these groups.

Method

Subjects

One thousand one hundred and twelve highly skilled sporting competitors, 578 men and 534 women, and 1,187 nonsporting undergraduate university students, 623 men and 564 women, participated. The sporting competitors averaged 19.3 yr. of age ($SD=2.5$) and had 5.8 yr. of sporting experience ($SD=1.4$). They were recruited from a population of class A (very good) athletes in northern Greece. Then, they were sorted into two categories, competitors in 'interactive sports' in which two or more opponents are involved (basketball, boxing, fencing, football, handball, judo, karate, table tennis, tennis, and volleyball), and competitors in 'noninteractive sports' (cycle racing, discus throwing, diving, gymnastics, rifle shooting, rowing, running events, skiing, swimming, and weight lifting) in which no direct opponent could clearly be identified. Competitors in 'interactive sports' were further classified as competitors in direct interactive sports, regarding the distance between the opponents during the interaction or confrontation (boxing, fencing, judo, and karate) and as competitors in indirect interactive sports (basketball, football, handball, table tennis, tennis, and volleyball). The nonsporting university students averaged 20.1 yr. of age ($SD=1.7$) and were registered for social sciences, economics, and law in the Aristotelian University of Thessaloniki. All subjects were naive as to the purpose of the study and were volunteers who participated with informed consent.

Handedness Determination

Handedness was assessed with the Briggs and Nebes' (1975) 12-item Handedness Inventory, a revision of Annett's hand preference questionnaire (1967) which takes into account the fact that for many left-handed and ambidextrous persons, lateral preferences are not easily dichotomized (Briggs &

Nebes, 1975). The 5-point scale measuring strength of laterality for each item, i.e., always left, usually left, no preference, usually right, always right, was added to make this inventory more sensitive to ambidexterity than Annett's earlier questionnaire.

The Handedness Inventory was administered to all subjects in a session of approximately 5 minutes. Each subject was tested individually in a quiet room by an adult experimenter. The Handedness Inventory ascertained handedness by asking each subject about choice of side in performing 12 one-hand activities and other acts, including choice of hand for writing a letter legibly, throwing a ball to a target, holding scissors to cut a paper, hammering a nail into wood, etc.

A handedness score was obtained by assigning two points to always responses, one point to usually, and none to no preference. Scoring left preferences as negative and right preferences as positive gave a range of scores from −24 for the most left-handed to +24 for the most right-handed. The authors, following Briggs and Nebes' (1975) scoring method, called subjects who received scores of 9 to 24 right-handed, those with scores between −9 and 8 were called ambidextrous or mixed-handed, and scores from −9 to −24 indicated left-handers.

Results and Discussion

The classification of the subjects and the sporting competitors based on their handedness assessment is presented in Tables 1 and 2, respectively.

TABLE 1
Classification of Subjects by Assessment of Handedness

Group	Sporting Competitors		Nonsporting University Students	
	n	% Left-handers	*n*	% Left-handers
Total	165	14.8	108	9.1
Men	92	15.9	63	10.1
Women	73	13.7	45	8.0

Chi-squared statistics showed that there were statistically significant differences in the proportions of left-handed (a) sporting competitors and nonsporting university students in the total sample ($\chi_1^2 = 18.07$, $p < .001$) as well as in men ($\chi^2 = 8.99$, $p < .005$) and women ($\chi^2 = 9.26$, $p < .005$); (b) sporting competitors engaging in interactive and noninteractive sports in the total sample ($\chi^2 = 21.6$, $p < .001$) as well as in men ($\chi^2 = 11.4$, $p < .001$) and women ($\chi^2 = 10.2$, $p < .001$); (c) sporting competitors engaging in interactive sports and nonsporting university students in the total sample ($\chi^2 = 39.1$, $p < .001$) as well as in men ($\chi^2 = 20.7$, $p < .001$) and women ($\chi^2 = 19.4$, $p < .005$); and (d) sporting competitors engaging in direct interactive and indirect interac-

TABLE 2

CLASSIFICATION OF SPORTING COMPETITORS BASED ON THEIR HANDEDNESS ASSESSMENT

Sport	Total Sample			Left-handers					
	N	Men	Women	*n*	%	Men		Women	
		n	*n*			*n*	%	*n*	%
Direct Interactive Sports									
Basketball	62	34	28	10	16.1	6	17.7	4	14.3
Boxing	46	26	20	10	21.7	6	23.1	4	20.0
Fencing	61	28	33	23	37.7	12	42.9	11	33.3
Football	70	41	29	10	14.3	6	14.6	4	13.8
Handball	59	27	32	10	17.0	5	18.5	5	15.6
Judo	48	27	21	10	20.8	6	22.2	4	19.0
Karate	64	36	28	12	18.8	7	19.4	5	17.9
Indirect Interactive Sports									
Table tennis	52	27	25	9	17.3	5	18.5	4	16.0
Tennis	52	22	30	9	17.3	4	18.2	5	16.6
Volleyball	62	28	34	10	16.1	5	17.9	5	14.7
Total	576	296	280	113	19.6	62	21.0	51	18.4
Noninteractive Sports									
Cycle racing	73	44	29	7	9.6	5	11.4	2	6.9
Discus throwing	49	27	24	5	10.2	3	11.1	2	8.3
Diving	58	33	25	5	8.6	3	9.1	2	8.0
Gymnastics	57	28	29	6	10.5	3	10.7	3	10.4
Rifle shooting	45	21	24	4	8.9	2	9.5	2	8.3
Rowing	43	22	21	4	9.3	2	9.1	2	9.5
Running events	55	28	27	5	9.1	3	10.7	2	7.4
Skiing	50	27	23	5	10.0	3	11.1	2	8.7
Swimming	59	27	32	6	10.2	3	11.1	3	9.4
Weight lifting	45	25	20	5	11.1	3	12.0	2	10.0
Total	536	282	254	52	9.7	30	10.6	22	8.7

tive sports in the total sample ($\chi^2 = 17.7$, $p < .001$) as well as in men ($\chi^2 = 10.2$, $p < .005$) (Table 3).

The results of this study showed that the sporting competitors exhibited statistically significant high rates of left-handedness in relation to nonsporting university students in the total sample ($\chi^2 = 18.07$, $p < .005$) as well as in men ($\chi^2 = 8.99$, $p < .005$) and women ($\chi^2 = 9.26$, $p < .005$). This finding lends credibility to several earlier reports (Porac & Coren, 1981; McLean & Ciurczak, 1982; Azemar, *et al.*, 1983; Annett, 1985; Bisiacchi, *et al.*, 1985; Wood & Aggleton, 1989; Aggleton & Wood, 1990; Raymond, *et al.*, 1996) who have suggested an unusually high proportion of left-handers among sporting individuals.

The most important feature of the present study, however, was that the excess of left-handers among sporting competitors applies only to competitors in interactive or confrontational sports, i.e., basketball, boxing, fencing, football, handball, judo, karate, table tennis, tennis, and volleyball, and not to competitors in noninteractive or nonconfrontational sports, i.e., cycle racing, discus throwing, diving, gymnastics, rifle shooting, rowing, running events, skiing, swimming, and weight lifting, in which left-handers occur about as frequently as they do in the nonsporting population of our study.

TABLE 3
PERCENT HANDEDNESS AND COMPARISONS BY χ^2 FOR THE TOTAL SAMPLE, MEN, AND WOMEN

Group	% Left-handed					
	Total		Men		Women	
	%	χ^2	%	χ^2	%	χ^2
Sporting Competitors	14.8		15.9		15.9	
Nonsporting University Students	9.1	18.0†	10.1	8.9*	7.8	9.5*
Sporting Competitors–Interactive Sports	19.6		20.9		18.2	
Sporting Competitors–Noninteractive Sports	9.7	21.6†	10.6	11.4†	8.7	10.2†
Sporting Competitors–Interactive Sports	19.6		20.9		18.2	
Nonsporting University Students	9.1	39.1†	10.1	20.7†	8.0	19.4†
Sporting Competitors–Noninteractive Sports	9.7		10.6		8.7	
Nonsporting University Students	9.1	1.5	10.1	.04	8.0	.11
Sporting Competitors–Direct Interactive Sports	25.1		26.5		23.5	
Sporting Competitors–Indirect Interactive Sports	12.3	17.7†	12.9	10.2*	15.2	3.04

*$p < .005$. †$p < .001$.

Moreover, not only left-handers are over-represented in confrontational sports, but the closer the physical interaction of the opponents such as in boxing, fencing, judo, or karate, the greater the prevalence of left-handers. In basketball, football, handball, table tennis, tennis, and volleyball, for instance, competitors stand some distance apart and do not confront directly. But even in these sports, there are more than the expected number of left-handers. Among female sport competitors, the same pattern is clear, although less pronounced.

These results indicate a surprising distribution of handedness among sporting competitors. There are many reasons to believe that this is not just a question of left-handers having a central motor advantage in motor tasks (Bisiacchi, *et al.*, 1985), an intrinsic advantage over right-handers due to superior spatiomotor skills (Annett, 1985; Nass & Gazzaniga, 1987), or higher overall skill on those tasks which require the use of both hands (Geschwind & Galaburda, 1987).

The generally higher proportion of left-handed competitors in interactive sports but not in noninteractive sports seems to be consistent with Raymond, *et al.*'s (1996) 'fighting hypothesis' which argues that '. . . left-handers have a frequency advantage when they engage in combat' (p. 1268). This superiority of the left-handers may be fully explained by a consideration of tactical or strategic factors associated with handedness during fights or aggressive interactions. For example, left-handers have the benefit of unfamiliarity, and in particular, they are able to hit from unexpected directions and at different angles than the right-handers. This requires right-handers repeatedly to reverse their usual strategies when facing a left-hander, but it also necessitates frequently fielding unfamiliar attacks. Furthermore, when considering a sport where being a left-handed competitor offers no obvious tactical or strategic advantage, e.g., cycle racing, discus throwing, diving, gymnastics, rifle shooting, rowing, running events, skiing, swimming, and weight lifting, no evidence was found for an excess of left-handers.

The greater frequency of left-handed men than women in interactive sports but not in noninteractive sports seems also to agree with the "fighting hypothesis." Aggressive interactions manifest a large, cross-culturally universal sex difference: fights of men-women are far more frequent than other combinations (Daly & Wilson, 1989, 1990).

These results have important implications for the measurement and evaluation of handedness. They strongly suggest that information concerning handedness of weapon holding and manipulation, throwing ability and other fighting abilities, or aggressive behaviors should be collected in addition to information concerning other classical parameters of handedness. These functional measurements of handedness, which are rarely considered, may be pivotal in the accurate evaluation of handedness.

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