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Life-span Age Trends in Laterality[1]

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Laterality of hand, foot, eye, and ear was measured in a sample of 1964 subjects, ranging in age from 8 to 100 years. Age trends were found, with hand, foot, and eye preference becoming more right-sided and ear preference becoming more left-sided with increasing age. Sex differences emerged in foot, eye, and ear preference but these did not systematically interact with the age variable. Several causal mechanisms are proposed but none can fully explain either the direction or the magnitude of the observed age changes. Thus, these data are most consistent with the view that the study of sidedness in humans should proceed with a consideration of a complex of underlying factors and individual difference variables.

Key Words: Laterality, Sex differences, Age differences, Life-span, Handedness

DESPITE the fact that the human body appears to be bilaterally symmetrical, there are distinct asymmetries in how the paired limbs and sensory organs are used. The most obvious dimension of laterality is hand preference. Approximately 90% of all humans consistently use the right hand in coordinations where only one hand can be used (such as writing or throwing a ball). There is an analogous dimension of foot preference. Thus most individuals prefer to kick a ball with the right foot. Less obvious asymmetries in lateral preference are found for the eyes and ears. These are displayed in such tasks as sighting down a telescope or pressing an ear against a clock to hear its faint ticking. As in laterality of the limbs, there is a consistent tendency to prefer the sense organ on the right side in such coordinations (Clark, 1957; Porac & Coren, 1979).

Lateral preference behaviors have engendered scientific interest for centuries. The fact that these coordinations, especially handedness, show a strong right-sided, or dextral, bias in one of the aspects of the problem that has caused considerable debate and theoretical controversy (Annett, 1973; Collins, 1977; Corballis & Morgan, 1978; Levy, 1977; Morgan & Corballis, 1978). Some researchers have used this fact to argue that sidedness has a physiological or even a genetic basis and is linked to asymmetries in brain development and neural control. Other investigators have maintained that the preponderance of right-sidedness within populations indicates an environmental influence related to the evolution of tool use or cultural patterns towards confirmity to the majority (Blau, 1946; Collins, 1977; Dawson, 1977; Hildreth, 1949). It is in the context of this controversy that the study of age-related changes in lateral preference behaviors assumes some importance. For instance, the absence of any age trends would be difficult to explain if one felt that lateral preference behaviors were primarily based upon the cumulative effect of environmental pressures.

There have been a number of attempts to assess age trends in handedness. These studies generally report that individuals become more right-handed with increasing chronological age (Fleminger et al., 1977; Hildreth, 1949). The lateralities of foot, eye, and ear have not been systematically studied in this way, which is unfortunate, since investigations of the changes in other aspects of laterality can also contribute to our understanding of human sidedness and, perhaps, help to resolve some of the current theoretical controversy. Life-span trends for foot and eye, as well as for hand preference, are suggested when one surveys

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the existing literature on the topic of laterality. Many investigators have studied lateral preference in samples of different ages. By tabulating the incidence of right-sidedness reported in a number of these studies, one can crudely assess the possibility of age trends. The results of such a tabulation are shown in Table 1 which summarizes the data from 113 studies published during the past 90 years. The criterion for inclusion in this survey was the use of a preference measure to assess handedness, footedness, or eyedness (unfortunately, there are too few studies of ear preference to make meaningful age comparisons). The data in Table 1 suggest age trends for hand, eye, and foot preference. The pattern is similar in each instance with adults seeming to be more dextral than children. These data are only suggestive of life-span trends. Each of the studies surveyed used different measures of lateral preference, and the age groupings vary and are unevenly spaced. However, the suggestion that there are age trends in lateral preference over the life span does warrant further systematic study. The present report attempts to assess changes in hand, eye, foot, and ear preference over the age range from 8 to 100 years.

METHOD

Subjects. — The sample consisted of 1964 subjects, ranging in age from 8 to 100 years. All were middle class Caucasians residing in urban areas of the U.S.A. and Canada. Subjects were contacted through the assistance of educational institutions, recreation associations, and associations for retired persons. Only non-institutionalized individuals with full use of both hands, feet, eyes, and ears were included in the sample. Since sex differences in the measurement of handedness and eyedness have been reported (Bryden, 1977; Porac & Coren, 1975), care was taken to ensure an approximately equal proportion of males and females, especially in the most senior age groups where sex differences in mortality rates could lead to an over-representation of females in this portion of the sample. The final representation of sex within each age group was 43% male in the 8 to 15 year range, 59% in the 16 to 25, 58% in the 26 to 35, 51% in the 36 to 45, 52% in the 46 to 55, 41% in the 56 to 65, 52% in the 66 to 75 and 54% in the 76 to 100 year group.

Measurement of lateral preference. — Lateral preference was measured by means of a 13-term behaviorally-validated self-report battery. There were four questions concerning hand use and three questions each for the assessment of foot, eye, and ear preference. Individuals were permitted a choice of three possible responses to each question, "right," "left," or "both." The questions used appear

Table 1. Age Trends in Hand, Foot and Eye Preference Based upon a Survey of 113 Published Studies.

Type of Preference	Approximate Age Range Studied	No. of Studies Reviewed	% Right-Sided Behavior Mean	S.D.
Hand	Infant	3	79.9	14.1
	Pre-School	4	82.6	9.4
	Elementary School	24	92.7	4.5
	High School/College	15	90.0	4.7
	Adult	20	92.3	3.4
Foot	Infant	—	—	—
	Pre-School	—	—	—
	Elementary School	6	84.6	12.8
	High School/College	4	64.7	15.1
	Adult	3	90.5	7.1
Eye	Infant	1	62.0	—
	Pre-School	3	60.5	7.0
	Elementary School	18	65.6	6.5
	High School/College	9	69.6	4.3
	Adult	15	71.0	6.7

Note: Some studies are represented under 2 or 3 categories. Thus the number of distinct contributions to the table is 113.

in other published reports and each of them has been validated against actual performance measures in three separate studies (Coren & Porac 1978; Coren et al., 1979; Raczkowski et al., 1974). They have an average concordance rate of 90% with direct behaivoral measures of hand, foot, eye, and ear performance (Coren et al., 1979).

RESULTS

The data were scored in two ways. The first involved a numerical tabulation of the self-report responses for each index of laterality, assigning a +1 for each response of "right," a −1 for each response of "left," and a 0 for each response of "both." The algebraic sum of all of the responses for each index gave the respondent's score. Thus the composite score incorporates both the direction and the consistency of laterality, with higher numbers indicating greater dextrality. In the second procedure, individuals were dichotomously classified with sums greater than 0 scored as right-sided. Thus, individuals with no clear left or right preference (respondents with a 0 score constituted less than 1% of the sample) were classified with the left group. For both types of scoring, the age range was subdivided into 10-year blocks except for the youngest (8 to 15 years) and the oldest (76 to 100 years) age group. The combination of the oldest age categories was done to insure that no age grouping contained fewer than 50 individuals.

Analysis of age trends. The results derived from the dichotomous scoring procedure are shown in Fig. 1 which plots the mean percentage of right-sidedness as a function of age for each of the four indices of laterality. Dextrality is the norm regardless of age on any one of the four dimensions of lateral preference. This is consistent with the reports summarized in Table 1. However, the proportion of the sample classified as right-handed, right-footed, or right-eyed increases with chronological age. Conversely, the percentage of the sample classified as right-eared decreases with age, although dextrality still predominates even in the oldest age group. Table 2 contains the mean score for each age group on the four

Table 2. Mean Lateral Preference Scores for Each Index and Age Group.[a]

Age (Years)	N	Hand	Foot	Eye	Ear
8- 15	282	2.68 (2.37)	1.67 (1.73)	1.15 (2.37	1.00 (2.16)
16-25	396	2.94 (2.08)	1.59 (1.57)	1.17 (2.22)	0.69 (2.11)
26-35	392	2.89 (2.35)	1.60 (1.82)	1.36 (2.27)	0.63 (2.35)
36-45	243	3.03 (2.20)	1.75 (1.66)	1.74 (2.03)	0.22 (2.40)
46-55	317	3.33 (1.70)	2.05 (1.38)	1.51 (2.20)	0.41 (2.39)
56-65	189	3.35 (1.52)	2.11 (1.42)	1.27 (2.31)	0.44 (2.41)
66-75	84	3.30 (1.42)	2.06 (1.41)	1.26 (2.20)	0.30 (2.20)
76-100	61	3.78 (0.70)	2.22 (1.28)	1.70 (2.05)	0.93 (2.51)
Combined	1964	3.03 (2.07)	1.78 (1.62)	1.35 (2.24)	0.58 (2.30)
Maximum Right Score		4	3	3	3
Maximum Left Score		−4	−3	−3	−3

Note: [a]Standard deviations are shown in parentheses.

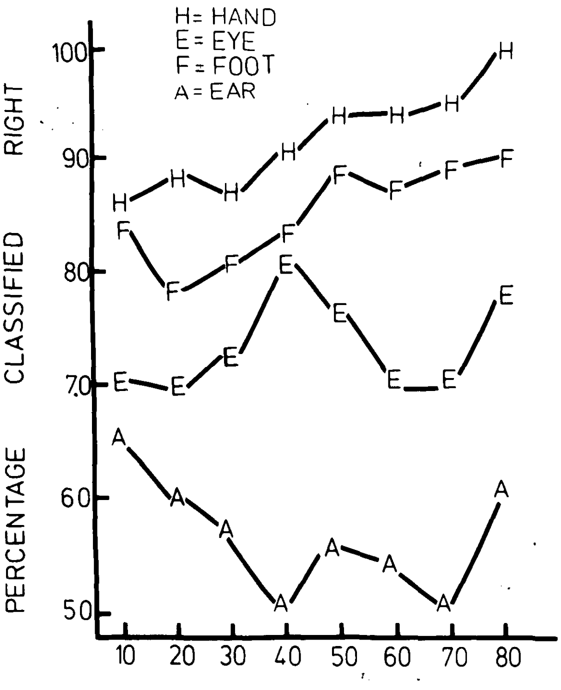

Fig. 1. The percentage of the sample classified as right-sided as a function of chronological age, for hand, foot, eye, and ear preference.

indices of preference; it also clearly shows a systematic shift in lateral preference scores as a function of age.

Previous evidence has suggested that the indices of laterality are correlated within individuals (Porac & Coren, 1979). The obtained correlations for the present sample are shown in Table 3. Since all are significant ($p < .001$), MANOVA analyses were conducted to assess the nature and significance of these apparent age trends. A two-way MANOVA (age by sex) revealed a significant effect of age across the four indices of lateral preference, Wilkes Lambda (4, 7, 1948) = .949, $F = 3.67, p < .001$. However, the overall significance of the MANOVA does not specify the nature of the existing group differences. Since there were no significant age by sex interactions, data were collapsed across sex and a profile analysis was conducted. It indicated that the obtained age trends were not parallel, Maximum root = .031, df = 3, 1.5, 976, $p < .0001$, suggesting that the different laterality indices show different age trends. To decompose these effects, individual analyses were conducted on all four forms of lateral preference.

The effect of age was significant for all four preference indices in the succeeding univariate analyses, with $F(7,1956) = 3.93, p < .001$, for handedness; $F(7,1956) = 4.80, p < .0001$, for footedness; $F(7,1956) = 2.16, p < .05$, for eyedness; and $F(7,1956) = 3.05, p < .01$, for earedness. In addition, all of the tests for a linear trend reached significance: $F(1,1956) = 23.86$, $p < .0001$, for handedness; $F(1,1956) = 25.50$, $p < .0001$, for footedness; $F(1,1956) = 11.26$, $p < .001$, for earedness; and $F(1,1956) = 4.11$, $p < .05$, for eyedness (this last being the weakest trend of the four). Ear preference also showed a significant quadratic component, $F(1,1956) = 6.37, p < .05$. None of the higher-order trend analyses was significant for the other three indices. Thus, one may summarize these results as showing relatively linear age trends for laterality of limbs and sense organs. Hand, foot, and eye preference become more right-sided with increasing age while ear preference shifts towards the left side in a somewhat non-linear fashion with the greatest change in the first four decades of life, after which an asymmptotic level is reached.

One can attempt to quantify the rate at which lateral preference changes by computing best-fitting linear regressions for the data in Fig. 1. The slopes of the regression lines will then approximate the rate of change with age for each preference type. These dextral shifts are 0.19% per year for handedness, 0.15% per year for footedness, and 0.07% for eyedness. For earedness, the shift is toward the left, at a rate of about 0.07% per year; however, if one considers only the first 40 years, the leftward shift occurs at a rate of 0.45% a year. While these age changes in lateral preference may not seem very large, they accumulate into a substantial change over the lifespan. Thus, for example, there are 14.5% more right-handers in the oldest as opposed to the youngest age group.

Analysis of sex differences. — Although the variables of sex and age did not interact, the overall MANOVA did reveal a main effect for sex, Wilkes Lambda (4,1, 1948) = .960, $F = 20.41, p < .001$. The nature of these sex differences can be seen in Fig. 2 where the percentage of individuals classified as right-sided on each index of laterality is graphed separately for males and for females. There are no significant sex differences in handed-

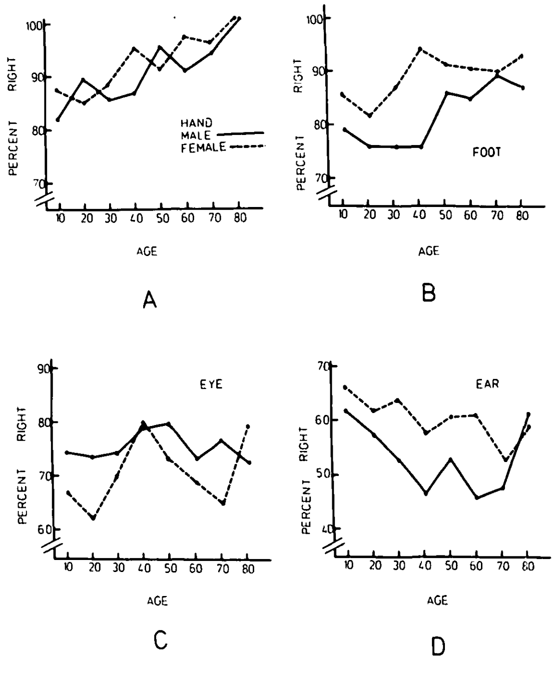

Fig. 2. The percentage of males and females classified as right-sided on each of the four indices of lateral preference.

ness (Fig. 2A), but males are significantly more left-sided than females in footedness (Fig. 2B) and earedness (Fig. 2D). The F values are $F(1,1948) = 51.55, p < .001$, for footedness and $F(1,1948) = 17.34, p < .001$, for earedness. The opposite result was shown by the eye preference responses (Fig. 2C) where females are significantly more left-eyed than males, $F(1,1948) = 6.15, p < .05$.

Discussion

What are the causes of these systematic shifts in right- and left-sidedness in lateral preference? Several hypotheses are possible, both of a developmental and of a nondevelopmental nature. A likely nondevelopmental hypothesis is based upon changing attitudes toward left-handedness over the years. For example, prior to about 1930, both psychologists and educators favored the practice of shifting a child's writing hand from the left to the right side. There was a very strong negative bias toward the use of the left hand for writing during this era (cf. Blau, 1946). However, in succeeding years this attitude changed and, as a result, there are reports that the incidence of left-handed writers has increased (Hildreth, 1949; Levy, 1976). Since the present data represents handedness responses from several generations, it is possible that the 14.5% rise in the incidence of right-handedness reflects the changing pattern of social pressures on the training of the writing hand which might then bias all hand preference behaviors. One way to test this hypothesis is to consider a number of normative studies of adult hand preference that have been conducted over the span of years during which this shift in social pressure has taken place. If overt pressure on the selection of the writing hand plays a role in determining the age trend observed in Fig. 1, the studies conducted earlier in this century should report higher proportions of dextral individuals than those conducted more recently. To evaluate this possibility 34 studies published between 1913 and 1976 were reviewed. Since there have been occasional reports of racial and cultural differences in the incidence of right-handedness (Dawson, 1977; Teng et al., 1976), the review was restricted to studies using western, Caucasian adult samples. Only studies using preference measures (analogous to those employed in the present investigation) were sampled. Fig. 3 shows the scatterplot of the reported percentage of right-handedness as a function of the date of publication of the study. The obtained correlation between these two variables is negative, as predicted by the social pressure hypotheses ($r = .28$); however, it is not statistically significant. In addition, the slope of the observed decrease in the reported incidence of dextrality is .05% which is only one-fourth of the rate of change revealed in the handedness data in Fig. 1. Thus the overt social pressure hypothesis can only account for a small portion of the observed change in handedness. There are no existing hypotheses which suggest that overt social pressure has been applied to foster certain types of foot, eye, and ear preference. Thus it seems even less likely that this hypothesis can account for the age trends obtained.

Two developmental hypotheses seem to be somewhat more successful in explaining the present findings. First, the existence of covert environmental pressures toward right-handedness may be of sufficient magnitude and frequency to gradually strengthen the development of right-sidedness throughout life. Everyday instances of such covert pressures are easy to find, especially for handedness. Left-handers often complain about the right-handed biases which are built into many common mechanisms such as can openers, scissors, or power tools. Rightward biases also exist in a less frequent form for footedness, in the arrangement of foot pedal controls in automobiles and other machinery. Instances of

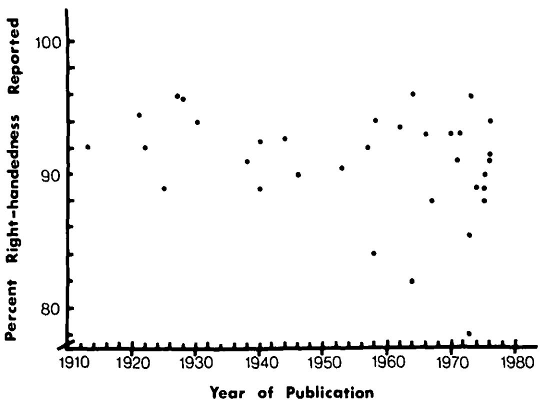

Fig. 3. The percentage of adults classified as right-handed in 34 studies as a function of the date of publication of the report.

such dextral biases may even be found for eyedness in pieces of equipment which require sighting, such as rifles. Everyday experience with a dextral world may enhance right-sided performance, and such factors have been shown to be influential in the determination of hand (paw) preference in animals (Collins, 1975). These covert influences can account for the higher percentages of individuals who can be classified as right-handed, -footed, and -eyed in the older age groups. Integrating the leftward shift in ear preference into this scheme is more difficult. However, one could interpret the ear preference data, not as a *leftward shift* with age, but as a *loss of dextrality* and a regression toward an unbiased population (equal numbers of right-and left-eared individuals) as a function of increasing age. This interpretation is supported by the fact that the age groups from 8 to 35 show proportions of right-eared individuals in numbers which are significantly greater than chance ($z = 4.75, p < .01; z = 3.29, p < .01; z = 2.63, p < .01$, respectively); however, the proportion of right-earedness does not exceed chance levels for the remaining age categories ($z = 0.06; z = 1.63; z = .65; z = .00; z = 1.35$). Perhaps the absence of environmental pressures on right-ear use results in a gradual loss of existing ear preferences with advancing age.

Secondly, it is possible that the present trend represents developmental maturational processes. While most of the available data indicate that neural development and myelination are complete by the end of the second decade of life (Flechsig, 1920), some reports have indicated that myelination in parts of the cortex may be incomplete until the age of 45 or later (Kaes, 1907) and that neural development in the cerebral commissures continues into the third decade (Yakovlev & Lecours, 1967). If laterality is determined by a speech dominant cerebral hemisphere as some investigators maintain (Levy & Reid, 1978), then one might expect to find a single underlying dimension of laterality with the present findings caused by neural maturation. Table 3 presents the Pearson product moment correlation coefficients between the various indices of lateral preference, and all are highly significant ($p < .001$). This fact could be taken as support for the notion that there may be a single underlying dimension of lateral preference primarily determined by one physiological mechanism. However, this hypothesis is weakened when one considers that other measures of lateral asymmetry, such as performance on dichotic listening tasks, do not show consistent age trends (Hynd & Obrzut, 1977; Schulman-Galambos, 1977). In addition, the existence of different trends for the various indices of laterality seems to be most consistent with the hypothesis that more than one physiological mechanism is responsible for manifestations of laterality.

Table 3. Intercorrelations Between the Four Indices of Lateral Preference ($N = 1964$).

	Hand	Eye	Foot	Ear
Hand	—	.308	.538	.213
Eye		—	.262	.221
Foot			—	.330
Ear				—

How can one incorporate the group differences between males and females on foot, ear, and eye preference into this scheme? The most commonly-reported form of sex difference in laterality, the finding that males are more left-handed than females (Bryden, 1977) is not confirmed in this study. However, these data do support the results of Porac and Coren (1975) who found greater degrees of right-eyedness in males. Regardless of the type of hypothesis proposed to explain the age changes, it is clear that males and females display differing degrees of rightward bias on three of the indices of lateral preference and that these differences do not systematically change with age. The existence of group gender differences, in addition to the age trends, supports the notion that the manifestations of human sidedness are the results of complex processes that interact with at least two individual difference variables.

This study is clearly only a first step. Not only have life span changes in lateral preference been virtually ignored, but data on age changes in footedness, eyedness, and earedness are sparse. The present data suggest that lateral preference in limbs and sense organs is not fixed but continues to change across the life span. This is of theoretical import and must be taken into account in any attempt to provide a comprehensive explanation of human laterality. Certainly the notion that patterns of laterality are fixed and immutable beyond childhood is not supported, although the mechanisms which promote the developmental trends observed here are, at present, ambiguous. It is likely that a number of different factors may determine and maintain the complex of behaviors which lead to sidedness, or lateral preference in humans. More direct experimental intervention and analysis of the patterns of interrelationships among the indices of lateral preference will be needed to provide clearer answers.

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