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Sensori-Motor Lateral Preferences of Amateur Motorsport Drivers

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Abstract: Vision-related aspects of motorsport activity have been little reported. We consider here oculo-visual influence upon hand and foot action for the kart racing driver as investigated through an assessment of patterns of sensori-motor lateral preference. Functional lateral preferences for eye, hand and foot were determined by a self-administered questionnaire, initially amongst a population of kart racing drivers (N = 60, 90% males, aged 10-52 years) and subsequently for a matched control group of optometric patients. Further comparative laterality data were located in a published study of healthy male subjects in the general population (N = 2,756, 94% aged 8-55 years). For each modality the kart drivers recorded no statistically significant difference in degree of right preference compared to either the matched control group or the larger general population; 70% were right-eyed, 85% right-footed and 90% right-handed. Lateral congruency of sensori-motor combinations was statistically similar in motorsport and non-participating individuals, being only slightly more ipsilateral than chance would predict. Patterns of lateral association between the sighting eye and the preferred upper/lower limbs of kart drivers were no different to those recorded for a non-motorsport population. This outcome is considered in the context of the physical restrictions imposed on the driver by the race equipment and the specific motion dynamics of competitive kart racing.

Key words: Foot preference, functional laterality, hand preference, motorsport, sighting dominance

INTRODUCTION

Behavioural lateral preferences: Despite the appearance of anatomical symmetry about a vertical axis, the human species manifests functional asymmetries of the bilateral sense organs and limbs. A predominantly right-sided preference bias is demonstrated. Adults are more dextral than children, but overall approximately 70% of individuals are right-eyed, around 80% right-footed and nearly 90% right-handed (Porac and Coren, 1981).

Specific lateral preferences do not exist in isolation. The association between 2 or more modalities gives context to a behavioural bias; this includes a consideration of the extent of uncrossed versus crossed laterality of the combined modalities. Total (right-plus left-sided) congruency estimates for paired modalities have been quoted as follows: eye-foot 70%, eye-hand 74% and hand-foot 84% (Porac and Coren, 1981).

The lateral preference manifested for single or combined modalities by an individual might possibly predispose that individual to enhanced success in a particular work or leisure activity. In addition, some persons might be sufficiently flexible such that they can learn or adopt alternative strategies to achieve success in a given field or discipline.

In the sporting arena ocular dominance, particularly in combination with hand preference, has attracted interest (Robison *et al*., 1997). The distribution of preferred lateralities in sports participants has been shown in certain instances to differ from values obtained for the general population (Porac and Coren, 1981; Pointer, 2006) and also vary between sports type. For example, rifle marksmen exhibit a higher incidence of uncrossed hand-eye association (72.4%: Jones *et al*., 1996) compared to baseball players (53.6%: Classé *et al*., 1996).

The majority of sports vision research seems to have been directed towards investigations of track and field athletes. The specific assessment of motorsport participants seems to have attracted little study. Interactions between eye, hand and foot preferences in the motorsport driver might be complex, given the intrinsic speed and frequently extreme motion dynamics of motor racing.

Some vision-related data have recently become available from a self-administered questionnaire circulated to kart drivers at a UK motor race circuit (Pointer, 2005). Despite a modest sample size, a preliminary comparative assessment of patterns of sensori-motor lateral preference in motorsport drivers versus non-participating control subjects is reported here.

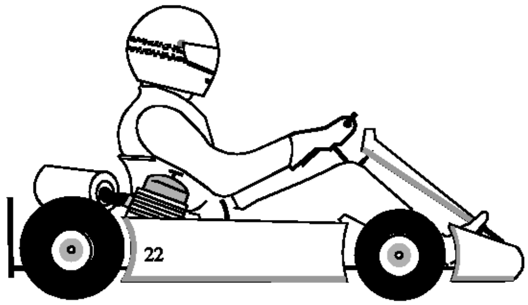

Fig. 1: Outline drawing of a kart and driver, in right profile

UK motorsport: Motorsport is one of the few sports to specify a mandatory minimum vision standard of participants. In the UK most branches of the sport at professional and amateur level are the responsibility of the Motor Sports Association (MSA), Slough, an autonomous division of the Royal Automobile Club (RAC), London.

The MSA issues Kart Competition Licences (National and International racing grades) to applicants paying a fee and completing an annual self-declaration as to their medical fitness to participate in motorsport competitions.

Normal binocular vision is required with full visual fields, normal stereo and colour vision and a (corrected) visual acuity of 6/9 or better in each eye (a cut-off value informed no doubt by the value of $6/9^{-2}$ deduced by Drasdo and Haggerty (1981) for drivers on public roads in Britain).

UK kart racing and equipment: Kart drivers, largely on account of their exposed driving position and the fact that no restraining harness or safety belt is worn, are required to wear full body protective clothing (homologated racing suit, gloves and boots). Head protection is provided by a specialised karting whole-head shell helmet with a horizontal viewing aperture covered by a transparent visor. Observe the low seating position, with the driver supported around the hips and from the lower back to under the upper thigh by the slightly rear-tilted bucket seat. Note the flexed position of the arms with the hands gripping the steering wheel in a fixed position; similarly note the bend of each knee such that flexure of the ankle joint is sufficient to depress the accelerator pedal (right foot) or the brake (left foot). Image derived courtesy of UK Karting (Fig. 1).

Kart equipment specifications vary depending upon racing class and homologation. All vehicles comprise a semi-rigid tubular steel chassis and a carbon fibre bucket seat: ground clearance is a few centimetres. Direct drive to the rear axle is provided by a 2- or 4-stroke petrol engine revving to 15,000 rpm or greater. The four wheel-hubs are mounted with pneumatic tyres. Two foot-pedals are located at the front of the kart: On the right (from the driver's perspective) is the accelerator pedal controlling the carburettor and on the left is the brake pedal connected via a hydraulic system to calliper pads around a rear axle-mounted brake disc. Effective driving style entails mastery of left-footed braking and disciplined switching between the 2 pedals as track and racing conditions dictate.

The performance of a chassis and the balance of grip between the front and rear ends of a kart are regulated by the specific geometry and rigidity of the chassis design and by the way that the kart is set-up for the prevailing track conditions. All kart chassis use a system whereby when the steering wheel is turned the front wheels change their relative heights from the ground: The outside tyre is lifted while the inside tyre is lowered. When driving at racing speeds a vertical force is transferred between the rear inside tyre and the front outside tyre, lifting the former off the ground. This is necessary because there is no differential system on the kart's rear axle. Thus, to avoid loss of power and to overcome understeer when running around a track bend, only the outside rear tyre should make contact with the tarmac.

MATERIALS AND METHODS

The vision survey: motorsport drivers: A printed questionnaire was circulated to the 182 entrants at a kart club's monthly race meeting. The numbered questionnaires were to be completed anonymously, with the incentive of entry in a prize draw offered to encourage their return.

The questionnaire canvassed drivers' opinions on aspects of their vision both on and away from the racetrack, including their attitudes to professional eyecare and the wearing of visual corrections. The responses to these enquiries have been analysed elsewhere (Pointer, 2005).

A self-administered visual acuity test was included on the printed questionnaire utilising a reduced-scale version of the high-contrast logMAR design of optometric letter-naming chart (Bailey and Lovie, 1976). When viewed at 60 cm the nine lines of letters spanned the acuity range logMAR +0.50 (top line) to -0.30, equivalent to Snellen 6/19 to 6/3.

A final survey item was the self-determination of eye, hand and foot preference. The administration of an inventory of tests to determine laterality dominance for each modality was not feasible. Instead, a subjective forced-choice protocol was adopted for the survey, permitting "right" or "left" preference selection only. Three techniques were selected which have been shown to be robust and consistent indicators of laterality preference even under conditions of self-administration (Porac and Coren, 1981). Eyedness was established with a version of the 'hole-in-the-card' test (Crider, 1944; Coren and Kaplan, 1973) and subjects were instructed to hold the test sheet with both hands in an attempt to minimise any influence of handedness on the outcome. Handedness was recorded on the basis of the usual writing hand (Annett, 1973). Footedness was registered as that foot which would be used to kick a ball (Coren *et al.*, 1979).

Control material: Comparative control data from non-motorsport participants were derived from two sources. Firstly, a group of optometric patients matched for age and gender against those kart drivers who returned a completed questionnaire were administered a truncated version of the motorsport survey. Visual acuity and laterality preference data generated by this postal survey were thus directly comparable to the material obtained from the motorsport drivers.

A second general (North American) population-based summary of sensori-motor preference was located in the publication of Porac and Coren (1981). Given the substantial male bias in the population of kart drivers (comprising 96% of the entrants at the race meeting surveyed here), the male-only lateral preference data (N = 2,756, age range 8-100 years) were extracted from Porac and Coren (1981) for comparative purposes.

Statistical analysis: All statistical analyses were undertaken using STATISTICA/Mac software (v4.1) (StatSoft Inc., Tulsa, OK74104, USA). Initial application of the Kolmogorov-Smirnov test indicated that the logMAR visual acuity data of kart drivers and control subjects were normally distributed ($p>0.1$). Consequently, the parametric t-test was used for comparative assessment of the acuity material. The age distributions of both populations were positively skewed ($p<0.009$), so the non-parametric Mann-Whitney U test was applied to these data. The Chi-Squared (χ^2) test was employed to evaluate the relationship between the various numerical frequency distributions of the lateral preference data.

RESULTS

Motorsport versus control subjects: Sixty of the 182-motorsport questionnaires were returned. Formal (Zieman *et al.*, 1993) and anecdotal (Ariel, 1994) published evidence suggests that this 33% response rate is on a par with that of other sports vision-related survey returns.

All racing classes attending the event were represented in the completed questionnaires, encompassing cadet, junior and senior drivers. The mean age of respondents was 19.9 ±9.6 years, min-max range 10.8-52.2 (median = 17.1) years. Ninety percent of the returned questionnaires were from male drivers. Exactly 50% of respondents were aged over 17 years and these individuals all held a UK (full or provisional) road driving licence.

The group mean binocular visual acuity was -0.08±0.08 logMAR. This equates to Snellen 6/5.0 (95% Confidence Limits (CL), 6/3.5 to 6/7.2), a level within the minimum visual standard specified by the MSA. Eighty five percent of kart drivers wore no visual correction when racing, 10% wore (soft) contact lenses and 5% spectacles.

The mean age of the matched control group of optometric patients (N = 60; 90% males) was 21.3±10.6 years, min-max range 10.5-52.2 (median = 17.2) years, an age distribution closely coincident ($p = 0.05$) with that of the kart drivers. Fifty percent of these matched control subjects were aged over 17 years and held a UK road driving licence.

The mean binocular acuity of the control group was -0.06±0.08 logMAR. This equates to Snellen 6/5.2 (95% CL, 6/3.6 to 6/7.5, an acuity distribution virtually identical ($p = 0.08$) to that of the motorsport participants).

Comparable age and acuity summary statistics for the larger general population of male subjects (N = 2,756) are not available (Porac and Coren, 1981), aside from a deduction that 94% of these male subjects were aged between 8-55 years (the approximate age span of the kart drivers and the matched control group).

Lateral preferences: The distribution of the lateral preference data across the three modalities of eye, hand and foot is summarised in Table 1.

The right eye was the preferred sighting eye in 71.7% (N = 43 of 60) of this predominantly male group of kart drivers; 68.3% (N = 41 of 60) of the matched control group were similarly right-eyed. Both of these values are closely coincident (no statistically significant difference, $p = 0.8$ and 0.4, respectively) with the figure of 72.9% (N = 2,009 of 2,756) estimated by Porac and Coren (1981) for right-eyedness in the general male population (excluding cases of ambi-eyedness).

The overall incidence of manual (writing) dextrality in the motorsport drivers was 86.7% (N = 52); the proportion was 88.3% (N = 53) in the control subjects. Again, neither

Table 1: Numerical distribution of subjects across the three modalities of sighting eye, preferred hand and foot. 1A: Kart drivers, 1B: Matched control subjects (each sample N = 60, 90% males)

	Right hand		Left hand		
	Right foot	Left foot	Right foot	Left foot	Total
1A.					
Right eye	34	4	3	2	43
Left eye	14	0	0	3	17
Total	48	4	3	5	60
1B.					
Right eye	37	1	1	2	41
Left eye	14	1	1	3	19
Total	51	2	2	5	60

of these values is statistically significantly different (p = 0.9 and 0.7, respectively) to the value of 86.5% (N = 2,384) determined for right-handedness in males (omitting cases of ambidextrality) in the general population (Porac and Coren, 1981).

The right foot was the preferred kicking foot in 85.0% (N = 51) of the kart drivers; 88.3% (N = 53) of the control subjects were similarly right footed. Neither of these proportions is significantly greater (p = 0.14 and 0.06, respectively) than the value of 76.7% (N = 2,114) quoted for right-footedness in males (discounting ambipedal cases) in the general population (Porac and Coren, 1981).

Inter-modality relationships: The partitioning of the data for karters and controls in Table 1 across upper and lower limb preference based on sighting dominance facilitates an assessment of whether this inter-group uniformity extends to inter-modality comparisons.

There was revealed a greater tendency for dextral kart drivers to have a right rather than a left sighting preference: 63.3% (N = 38) showed this right ipsilaterality. This eye-hand congruency was absent in sinistral drivers, these individuals being more likely to show right rather than left sighting preference: only 5.0% (N = 3) showed left ipsilaterality. Thus, overall 68.3% (N = 41) of this predominantly male group of kart drivers displayed uncrossed eye-hand association. For the matched control group of non-motorsport drivers 63.3% (N = 38) showed right ipsilaterality and 6.7% (N = 4) left ipsilaterality; *ie*, a total of 70.0% (N = 42) eye-hand congruency. The near-identical values (p = 0.8) for combined (right plus left) eye-hand congruency in motorsport and control subjects are both, in turn, closely coincident (no statistically significant difference: p = 0.2 and 0.3, respectively) with the value of 75.4% (N = 2,078) obtained for the general male population (Porac and Coren, 1981).

Similarly, there was a greater tendency for right-footed kart drivers to be ipsilateral (61.7%: N = 37) rather than contralateral (N = 14) for sighting preference. As reported for left-handers, left-footed drivers were more likely to show right rather than left sighting preference; only 5.0% (N = 3) showed left ipsilaterality. Consequently, overall 66.7% (N = 40) of the motorsport drivers displayed uncrossed eye-foot association. In the control group, 63.3% (N = 38) showed right eye-foot ipsilaterality and 6.7% (N = 4) showed left ipsilaterality, giving a total of 70.0% (N = 42) eye-foot congruency. These similar (p = 0.7) overall values for combined eye-foot ipsilaterality in motorsport versus control subjects are each closely coincident (no statistically significant difference: p = 0.6 and 0.9, respectively) with a value of 69.7% (N = 1.921) quoted by Porac and Coren (1981: *ibid*) for the general male population.

Given that the majority (≥85%) of the kart drivers were right dominant in hand or foot preference, it is not surprising that 80.0% (N = 48) of dextral motorsport drivers showed an ipsilateral foot preference. Furthermore, in contrast to the two previous (eye-limb) modality associations, a greater proportion (8.3%: N = 5) of the sinistral drivers showed an ipsilateral motor (foot) preference. Thus overall 88.3% (N = 53) of kart drivers displayed uncrossed hand-foot association. In the control group, 85.0% (N = 51) showed a right hand-foot ipsilaterality and 8.3% (N = 5) showed left ipsilaterality, providing a total of 93.3% (N = 56) hand-foot congruency. This pair of similar values (p = 0.3) for total (right plus left) hand-foot congruency in motorsport versus control subjects are higher (but not statistically significantly different: p = 0.08 and 0.07, respectively) than the value of 79.4% (N = 2,188) estimated by Porac and Coren (1981) for the general population.

Finally, the incidence of total (eye-hand-foot) lateral congruency was 61.7% (N = 34 right-sided plus N = 3 left-sided on all three modalities) for kart drivers and 66.7% (N = 37 right-sided plus N = 3 left-sided) for control subjects; these proportions are not statistically significantly different (p = 0.6). Comparative combined data are unfortunately not available for the larger general male population of Porac and Coren (1981).

Actual versus expected congruency: As indicated in Table 1, the majority of motorsport participants and control subjects were right preferent for each of the three modalities screened by the questionnaire. Consequently, on the grounds of probability a substantial proportion of each group might be expected to show an uncrossed laterality association (congruency) for each possible modality combination. It is therefore important to establish to what degree these obtained congruency values align with chance expectations.

In Table 2, "obtained" (actual) and "theoretical" (calculated) incidence values for all combinations of modality are given for the motorsport and control subject

Table 2: Total lateral congruency values (obtained versus theoretical) for each of three modality pairings and overall. 2A: Kart drivers, 2B: Matched control subjects (each sample N = 60, 90% males; percentages in parentheses)

	Obtained		Theoretical			
	N	(%)	N	(%)	χ^2	P
2A.						
Eye-hand	41	(68.3)	40	(65.9)	0.02	0.89
Eye-foot	40	(66.7)	39	(65.2)	0.02	0.89
Hand-foot	53	(88.3)	45	(75.7)	1.28	0.25
Eye-hand-foot	37	(61.7)	32	(53.4)	0.55	0.45
2B.						
Eye-hand	42	(70.0)	38	(64.1)	0.33	0.56
Eye-foot	42	(70.0)	38	(64.1)	0.33	0.56
Hand-foot	56	(93.3)	48	(79.4)	1.28	0.25
Eye-hand-foot	40	(66.7)	32	(53.7)	1.39	0.24

groups. Each obtained value of total (i.e., right plus left) ipsilaterality is the value taken from Table 1. The theoretical values were calculated based on the observed proportions of right and left laterality in these data, adopting the assumptions and methodology of Porac and Coren (1981).

As Table 2 indicates, for either group, each obtained value is closely coincident with the corresponding theoretical value calculated on the basis of an assumed independence of the three modalities. Only in the case of the hand-foot association did these data suggest a greater (but not statistically significant: $p = 0.25$) degree of actual total ipsilaterality than would be expected by chance.

DISCUSSION

The outcome of this sequence of analyses of inter-modality preferences is one of inter-group uniformity when comparing kart drivers with non-racing control subjects. The pattern and strength of the various sensori-motor laterality relationships documented here are in line with results in the literature. The strongest association was that between hand and foot (i.e., purely motor) preferences, in accord with the outcomes reported upon populations of various ages in the UK (Annett, 1985), North America (Porac *et al.*, 1980) and across Europe (Dargent-Paré *et al.*, 1992). The degree of eye-hand association is in agreement with published studies across several age groups of male subjects (Friedlander, 1971; Gur and Gur, 1977; Hebben *et al.*, 1981; Dargent-Paré *et al.*, 1992; Pointer, 2001).

Interestingly, the eye-foot association appears to have been little explored. Reviews (Peters, 1988) and inter-modality investigations (Dargent-Paré *et al.*, 1992) have instead concentrated on the hand-foot association. This suggests a possible area for future investigation, especially with regard to the high speeds and necessarily fast reactions associated with motorsport driving.

It is the case that the majority of motor circuits race clockwise, with a mixture of right and left turns. Overtaking attempts are likely on either side of a driver. Under these circumstances it is not clear that right sighting-preferent drivers will have any advantage over their left-eyed fellow competitors. The co-ordination of the 2 eyes with good (binocular) visual acuity is probably of greater significance than laterality preference.

Both arms of the kart driver are slightly bent at the elbow (Fig. 1) and the hands remain fixed on the steering wheel at approximately 'ten-to-two' throughout the race, unlike conventional road driving where the wheel is fed through the hands when turning a corner. This rigid arrangement makes for more precise steering when racing and plays a role in supporting the driver's upper body against forces of lateral acceleration when cornering at speed. Given the mix of right and left turns and the fixed handgrip position, it is unlikely that one hand can be regarded as more effective than the other at turning the wheel. In rapid succession one hand and then the other will be pulling/pushing the steering wheel to accomplish a turn or manoeuvre. Any distinction between leading and supporting hand is doubtful. Drivers would almost certainly regard either hand as equally active in turning the steering wheel to left or right as the racing situation demands.

The kart driver's legs, supported under the upper thighs by the bucket seat, maintain a posture such that ankle movement alone is sufficient to depress the accelerator or brake pedals (Fig. 1). For the majority of individuals their preferred (right) foot will be operating the accelerator. In terms of human-machine interaction, the preferred foot is thus performing the action related to the goal of movement, with the other foot providing supportive (braking) action, roles complementary (and possibly subordinate) to visually-guided hand actions. Competitive kart racing relies upon strict pedal control, with either the accelerator or the brake pedal alone being depressed at any one time to avoid the unpredictable consequences of locked rear wheels. Throttle control (right foot) has to be fine-tuned and, for the majority of drivers, left-footed braking is a motorsport skill that has to be finessed by on-track practice. The fact that left limb-preferent individuals can race karts competitively (and drive conventional road cars) further attests to the suggestion that sinistrals display a high degree of adaptive flexibility on hand-foot activities (Peters, 1988).

Specifically within the dynamic environment of driving one might speculate as to the interplay that the driver's lateral preferences might have with the location of the man-machine centre of gravity (Broer and Zernicke, 1979). The typical motorist will respect and adhere to lane position when driving on a winding public road. In contrast, the competitive motorsport driver necessarily corners his vehicle at greater speeds while still maintaining lateral traction (balancing the orthogonal forces of gravity and centripetal acceleration). This particular ability is informed by experience as a race circuit is learned. A "racing line" is identified around track curves and the circuit is driven essentially by memory. Consequently, the apexes of successive curves serve as timing cues to the race driver (Land and Tatler, 2001), whereas the general motorist would use the tangent to each bend in the road as a steering landmark (Land and Lee, 1994; Land and Horwood, 1995).

Motorsport drivers experience heightened forces of lateral acceleration, yet typically only a minimum tilt of a kart driver's head into a corner is observed. Specific physical training might promote development of the neck muscles in order to resist this pull such that the driver's visual reference frame is maintained undistorted (Zikovitz and Harris, 1999). Although, the race driver is interpreting the corner differently to the non-competitive motorist, the sensory input for any driver is predominantly visual (Sivak, 1996). In the specific case of the kart racer, given the exposed driving position, it is possible that auditory feedback arising from engine note or tyre noise might be of additional assistance in adjusting track speed (Matthews and Cousins, 1980).

In order to maintain stability when racing a kart the centre of gravity of the vehicle/driver combination should be as low as possible; typically this point will be located around the driver's midriff. The loaded kart will ideally be set-up such that approximately 60% of the weight will be centred over the rear axle. The supportive bucket seat and the fixed limb positions on the steering wheel and pedals inhibit lateral shift in position of the sedentary kart driver when cornering. This secure driving position minimises head tilt into the corner and inhibits passive head (or body) roll outwards, thereby not only maintaining the appropriate visual reference frame round the corner but also minimising the risk of overturning the vehicle. Consequently, the only significant voluntary displacement of the centre of gravity is in the anterior-posterior direction. It is the case that when entering a corner the grip of the front tyres can be enhanced (especially under wet track conditions) by displacing weight forward from the rear of the loaded kart. This extra grip is temporarily achieved by the driver crouching forward from the waist. When exiting the corner, to improve traction, the driver must then straighten-up against the seat back. But again it is difficult to see a role for (or any advantage arising from) a particular pattern of sensori-motor laterality preference in this regard for competitive kart racing.

CONCLUSION

It must be acknowledged that on account of the sample size this research necessarily represents only a preliminary assessment of the patterns of sensori-motor lateral preference in a specific class of motorsport drivers. Furthermore, no attempt has been made to relate lateral preference to racing performance (e.g., race wins or championship success). To undertake an extended analysis it would be necessary, firstly, to assemble an expanded population of motorsport drivers (ideally including championship-winning and professional race drivers) and secondly, to use test inventories rather than single questions to determine eye and limb lateral preferences.

The conclusion of the present investigation is that patterns of eye and limb lateral preference in kart drivers are no different to those recorded in a closely matched non-motorsport population despite the specific race equipment and the motion dynamics of kart racing.

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