MOTION PATTERN CONSISTENCY OF THE RIDER-HORSE SYSTEM

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INTRODUCTION: Dressage riding is difficult to judge, because the aesthetic impression created by a performance is very subjective. One of the terms used to describe the quality of dressage riding is harmony; this has not been a measurable criterion up to now. As in many other sports, e.g., gymnastics, innumerable discussions among riders and judges are the result.

In the horse, conformation (Gunn, 1983) and training, innate and learned motion patterns (Persson, 1967), anatomy, and physical condition (Drevemo et al., 1980) affect the locomotion pattern. Experimental studies have demonstrated that animal locomotion is controlled, in part, by a central pattern generator (Collins and Richmond, 1994), which is a network of neurons in the central nervous system capable of producing rhythmic output. If the motion is arhythmic, acceleration and deceleration occur, leading to a waste of energy. A horse that walks, trots or canters at the same frequency and speed over a period of time can be compared to an oscillator driven at its natural frequency, with minimum damping. It is obvious that the locomotory patterns become more complex in ridden horses, as the rider influences the motion of the horse considerably.

In some biological domains such as wildlife populations (Bergerud, 1975) and human locomotion (Hurmuzlu and Basdogan, 1994), complex systems have already been shown to exhibit a steady-state-frequency. The aim of this study was to investigate whether a similar frequency can be found for the rider-horse-system and develop a method of visualizing and quantifying the harmony of the motion of a rider and a horse.

MATERIALS AND METHODS: Twenty riding horses of various breeds aged 4 to 22 years on different training levels were used for this study. All horses were ridden in their usual gear by both a professional rider and a hobby rider. The horses were measured at working trot, with the riders 'sitting' (FEI, 1995).

Spherical markers with a diameter of 7 cm and coated with reflecting foil were attached to the right temporal region of the rider, the rider's right shoulder, elbow, hand, hip, and knee, as well as on the heel and the tip of the right boot. One marker was placed on the median line of the back of the rider in the lumbar area. On the horse, similar markers were placed on the median line of the nasal bone and the frontal bone, two markers were placed on the sacral bone, one on the lateral side of the right carpal joint, on the lateral side of the right tarsal joint, and on both right fetlock joints. Two hemispherical markers with a diameter of 7 cm were placed on the right fore- and hindhoof. Additionally, one marker was placed on the hind end of the median line of the saddle. Placement of the markers was accomplished using textile adhesive tape and/or velcro strips. In order to minimize the unilateral influence on the motion, the same locations were taped (without markers) similarly on the left side of the horse. See Figure 1.

The measurements were carried out while the horse was being ridden down the long side of an indoor riding arena on a 12 m long pressed sand track. Six cameras (sample rate 120 Hz, resolution 240 x 833 points), placed along the right side of the measurement track, traced the markers on horse and rider. For each rider, at least eight trials were recorded with the ExpertVision System of Motion Analysis Corporation (Peham et al., 1998).

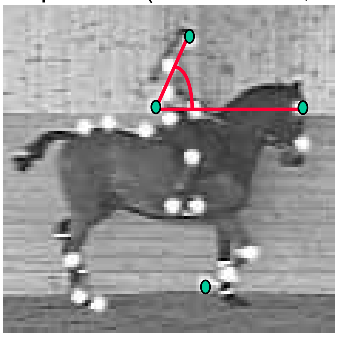

Figure 1: Ridden horse with markers. Used markers are green. The calculated angle is plotted.

At least eight motion cycles of each rider-horse combination were analyzed. For this investigation only the markers on the right forehoof and the frontal bone of the horse, as well as the marker on the head of the rider and on the back of the rider, were used. The three-dimensional coordinates were calculated from the high speed video recordings. The resulting motion tracks were smoothed using a Butterworth lowpass filter. The cutoff frequency was 5 Hz for the motion of the heads, and the back of the rider, and 20 Hz for the motion of the right forehoof.

The data were normalized to 100 % of the length of one motion cycle as indicated by the motion of the marker on the right forehoof. The angle between the linkages of the rider's head to the rider's back and of the rider's back to the horse's head was deduced (see also Figure 1), and angle velocity and angle acceleration were computed. In order to make these different factors comparable, they were set into relation with the maximum of the professional rider's angle, angle velocity and angle acceleration, which were set at 100%. From all three data-sets the trajectories in the phase-space were plotted and the lengths of the resulting vectors (LV) in the phase-space were computed. See Figure 3.

The mean and average deviation of LV of every horse and rider were determined and grouped for each rider. The normal distribution of each group was tested with the Kolmogorov-Smirnov test. The Student test of paired samples and one-way analysis of variance were used to check the differences of the mean of LV and average deviation of LV.

RESULTS:

One example (horse 1) is plotted in Figure 3. The results of our study are shown in Table 1 and Figure 2. The mean of LV of the 2 riders (PR: mean=38%, SD=4.6; HR: mean=40.4%, SD=8) were not significantly different, but there was a significant difference ($p<0.05$) in the average deviation of LV (PR: mean=11.5%, SD=1.4; HR: mean=13%, SD=2.8).

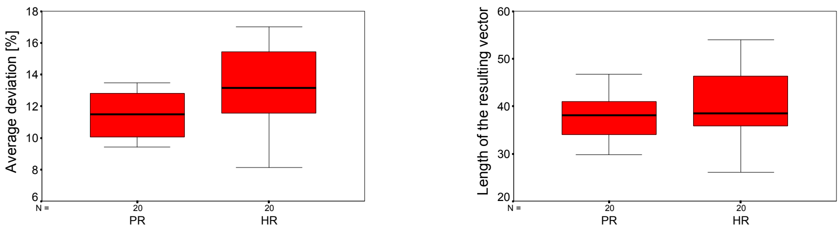

Figure 2: The distributions of the average deviation (left) and the length of the resulting vector (right) are drawn as box-plots. The length of the box equals the

inter-quartile range, 50% of the values lie within. The median is depicted as a bold line. The whiskers reach the last value of the distribution if they are within the range of one inter-quartile.

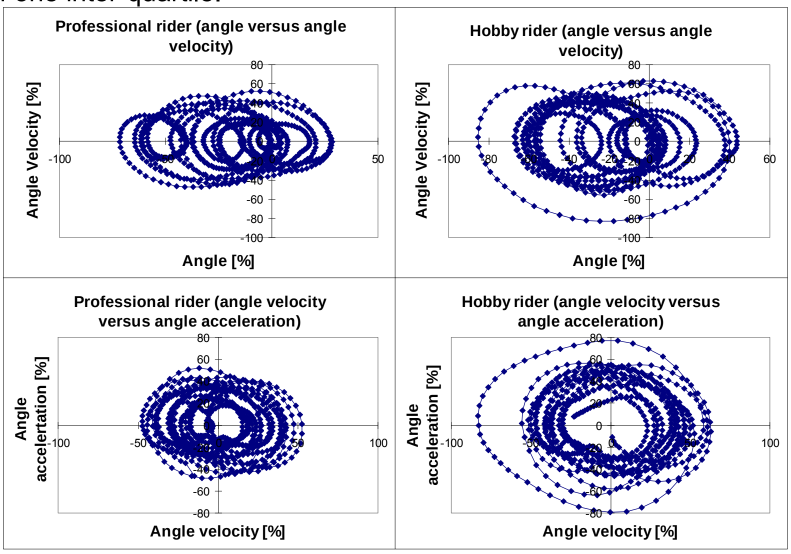

Figure 3: top: plots of phase-plane of angle versus angle-velocity; bottom: orthogonal plane in the phase-space, with angle velocity versus angle acceleration. The area of the phase plane diagram of the professional rider is smaller, because of lower variation.

Table 1: Mean and average deviation (= Av.Dev.) of Length of the resulting Vector (=LV) for the professional rider (=PR) and for the hobby rider (=HR).

Horses	Mean LV PR	Mean LV HR	Av.Dev. LV PR	Av.Dev. LV HR
Horse1	40.89	54.04	13.19	13.93
Horse2	39.10	46.30	11.42	14.00
Horse3	39.66	40.56	13.27	12.40
Horse4	33.75	26.05	10.99	8.12
Horse5	37.21	52.89	10.24	13.61
Horse6	45.72	37.54	10.31	8.65
Horse7	41.10	31.56	13.04	11.79
Horse8	40.63	36.34	13.49	17.02
Horse9	34.40	52.84	12.26	15.15
Horse10	33.13	36.65	12.17	11.99
Horse11	34.10	35.43	9.42	8.69
Horse12	46.70	39.22	11.91	9.74
Horse13	39.37	37.89	11.56	15.90
Horse14	37.11	47.43	13.38	16.84
Horse15	29.77	36.68	9.48	15.28
Horse16	35.99	31.06	12.57	12.09
Horse17	41.86	44.73	11.46	12.73
Horse18	32.38	44.66	9.90	15.61
Horse19	34.09	30.26	9.68	15.84
Horse20	43.45	46.39	9.49	11.34

DISCUSSION: From these results we conclude that a professional rider is able to ride a trotting horse close to its limit cycle. In this system the kinetic energy is minimal, as the velocity changes are minimal, and therefore the system is closest to the ideal steady state. In the phase-plane-diagram this steady state is shown as the limit cycle, which is a closed contour to which all curves tend, independently of their initial conditions (Bajpai et al., 1983). A coupled system such as the rider-horse system works most efficiently in its limit cycle. The hobby rider wastes more energy than the professional rider, as acceleration and deceleration occur more frequently (see Figure 2). Regarding the hobby rider-horse system as an oscillator, this can be compared to driving an ideal oscillator at a frequency that is not its natural frequency. In such a case, the oscillation is damped (Peham et al., 1998). In the other scenario, i.e., the professional rider-horse system, the motion of rider and horse are well suited to each other and this can be compared to an ideal oscillator driven at its natural frequency, which oscillates with minimum damping.
Usually, a change in motion or arhythmic movements can be detected subjectively by a dressage judge, but the depiction in phase-space and the calculation of average deviation of LV have the advantage of objectivity. This study shows that the motion of the professional rider-horse system is more consistent than that of the hobby rider-horse system and that this difference can be measured and quantified. With the presented method the rhythm of the rider-horse system can be evaluated, and this information might prove useful for the training of riders.

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