Student name : **Student number :**

Coordination Dynamics: Principles and Clinical Applications Exam 2009-2010

Open book exam
14-12-2009
15:15–18:00h
FG2

Please write on each paper your name and student number (to receive the first 10 of in total 100 points). The exam consists of a combination of 22 true/false questions for which 33 points can be earned (12 good answers: 3 points, 13 good answers: 6 points, …, 22 good answers: 33 points) and several open questions, for which 57 points can be earned. Concise answers for open questions are highly appreciated. Note that erroneous passages in a lengthy answer may have consequences in that they can lead to diminution of points you received for correct parts in the lengthy answer.

Good luck!

€0.65

Student name : **Student number :**

Question 1

Kelso and Engstrøm defined coordination dynamics as a set of context-dependent laws and rules that describe, explain, and predict how patterns of coordination form, adapt, persist, and change in natural systems (Kelso & Engstrøm, 2008, page 90). In their book, "The complementary nature", the notion of complementarity played a central role. List three complementary pairs that are fundamental to the coordination dynamics approach and motivate your choice in your own words in maximally 4 lines per pair **[15 points]**.

Many answers possible, most outstanding answers are micro~macro, homogeneity~heterogeneity and information~(intrinsic)dynamics. Motivate the crux of the complementary pair for coordination dynamics.

Question 2

The coordination dynamics approach focuses on the stability properties of a wide variety of behavioral coordinative patterns. There are several tools to assess the stability of the system under study.

a) In the last lecture, the relative effectiveness of visual (projected stepping stones) and acoustic (metronome beats) cues to modify gait was discussed. The attractiveness of visual and acoustic cues for gait synchronization was assessed by means of two paradigms: 1) rhythm perturbations and 2) intentional switching. After a perturbation, the synchronization between gait and cues was restored more rapidly in visual cueing conditions. In switching trials, synchronization with the new, phase-shifted cues was achieved faster when switching from acoustic to visual cues than vice versa. These results imply that gait was attracted more strongly to the visual than to the acoustic cues.

true */ false* **[1]**

b) Describe –using tools and methods of coordination dynamics– a third way to compare the relative effectiveness of acoustic and visual cues in inducing gait modifications. What would you expect given the abovementioned observations? **[4 points]**.

By means of assessing the magnitude of the fluctuations in the order parameter, i.e., the relative phase variability between footfalls and cues. In line with abovementioned results, greater relative phase variability is expected for the acoustic pacing condition.

€0.65

Student name : **Student number :**

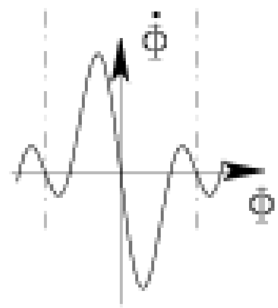
Question 3

In human movement sciences, coordination dynamics is often associated with the HKB model for rhythmic bimanual coordination. This model captures stability characteristics of rhythmic isofrequency coordination of two coupled oscillating fingers, hands or forearms. The HKB model can be represented by $V(\Phi) = -y\cos(2\Phi) - z\cos(\Phi)$, in which Φ represents the relative phase between the coupled oscillators.

a) René Thom studied and classified phenomena characterized by sudden shifts in behavior arising from small changes in circumstances, analyzing how the qualitative nature of equation solutions depends on the parameters that appear in the equation. According to Thom's 'magnificent 7' catalogue, $V(\Phi)$ with $y > 0$ and $z > 0$ is an example of a potential function with a cusp geometry.

true* / *false **[2]**

b) The figure on the right captures the order parameter dynamics for $y / z > 0.25$. How many fixed points can be identified in this figure? **[3 points]**



7: count the zero crossings

c) The number of stable fixed points in this figure exceeds the number of unstable fixed points.

true* / *false **[3]**

d) Give the equation, corresponding to abovementioned $V(\Phi)$, capturing the rate of change of the order parameter **[3 points].**

Φdot = -2*y*sin(2Φ) - *z*sin(Φ)

e) The magnitude of fluctuations in the order parameter around $\Phi = 180^o$ is greater for $y = 5$ and $z = 8$ than for $y = 3$ and $z = 8$

true* / *false **[4]**

f) What is critical slowing down and when does it occur for abovementioned $V(\Phi)$ around $\Phi = 0^o$? **[5 points]**.

Following a perturbation on the order parameter, the time to return to the initial order parameter value (relaxation time) goes to infinity. Critical slowing down occurs when y / z is 0.25 and $\Phi = 180^o$; then the slope around $\Phi = 180^o$ in the order parameter dynamics graph is about zero, representing that after a small perturbation to let say $\Phi = 190^o$ there is no –or an infinitesimally small– driving force back to $\Phi = 180^o$. Hence, relaxation time goes to infinity. Critical slowing down does never occur for abovementioned $V(\Phi)$ around $\Phi = 0^o$

g) The HKB model can explain phase transitions.

true / <u>false</u> **[5]**

€0.65

Student name : **Student number :**

Question 4

In Lecture 6 and in the laboratory in the Rehabilitation Centre Amsterdam, Lex van Delden introduced the ULTRA-stroke randomized controlled trial. In this study, one group of stroke patients receives bilateral arm training with rhythmic acoustic cues. In a related study on stroke patients, Malcolm et al. (2009; Lecture 6) published the effects of a 2-week intensive reaching training program using rhythmic acoustic cues on clinical scores and reaching kinematics.

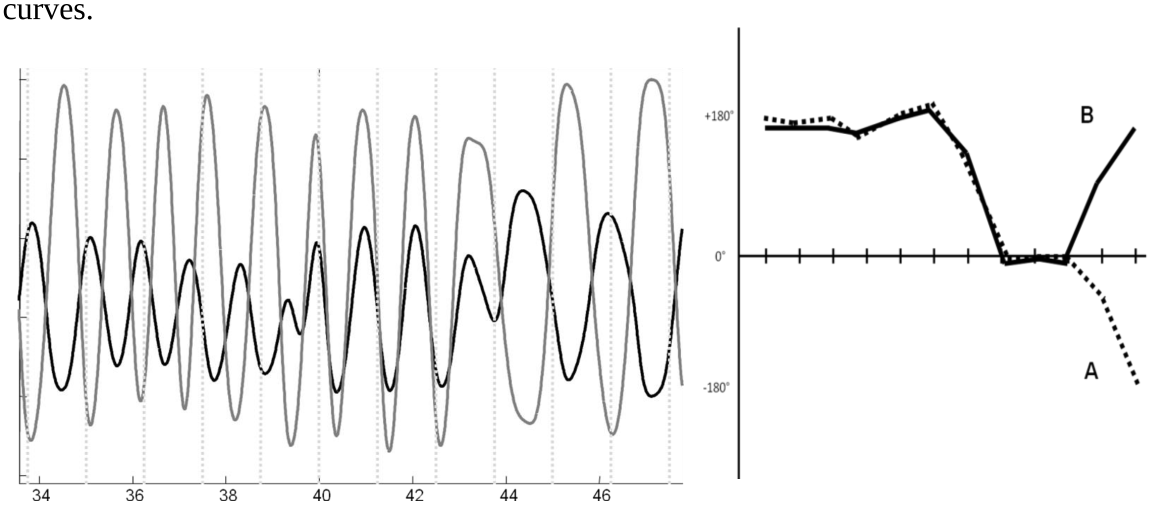
a) Holism ~ reductionism is complementary pair. Relative to the study of Malcolm et al. (2009), the ULTRA stroke trial adopts a holistic approach.

true / false **[6]**

b) The experimental procedures in ULTRA stroke are aimed at dissecting the neural interactions underwriting coordination, such as phase entrainment, error correction, and integrated timing. These three sources of neural interactions roughly relate to different levels of processing in the central nervous system. The highest level is associated with phase entrainment through motor afference.

true / false **[7]**

Wrist oscillation data of stroke patients during active bimanual movements can take various forms. The flexion-extension movements of the paretic arm are often smaller in amplitude, which is also the case for the patient data depicted in the panel on the left. The patient was instructed to coordinate wrist oscillations in an antiphase manner in time with a metronome (vertical dotted lines). Peak flexion is represented by local minima in the curves.

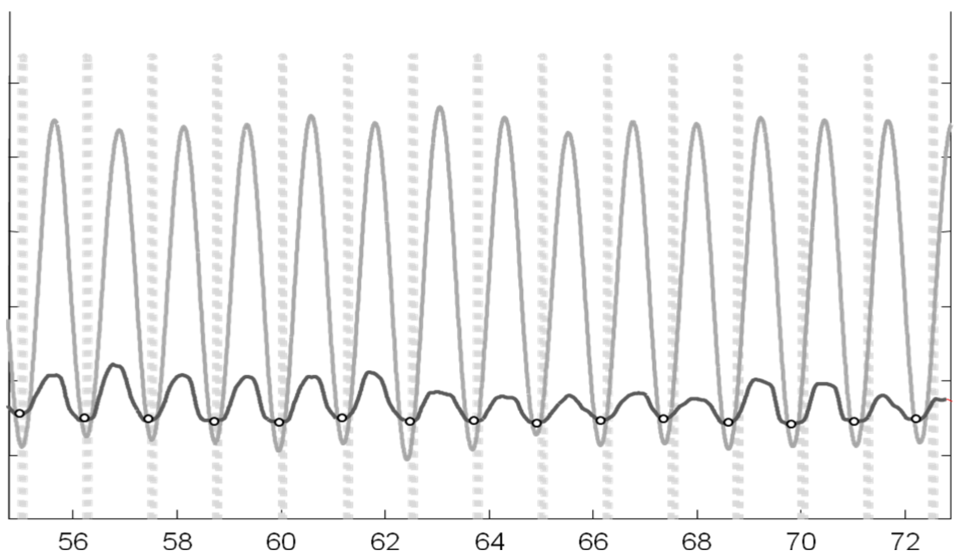


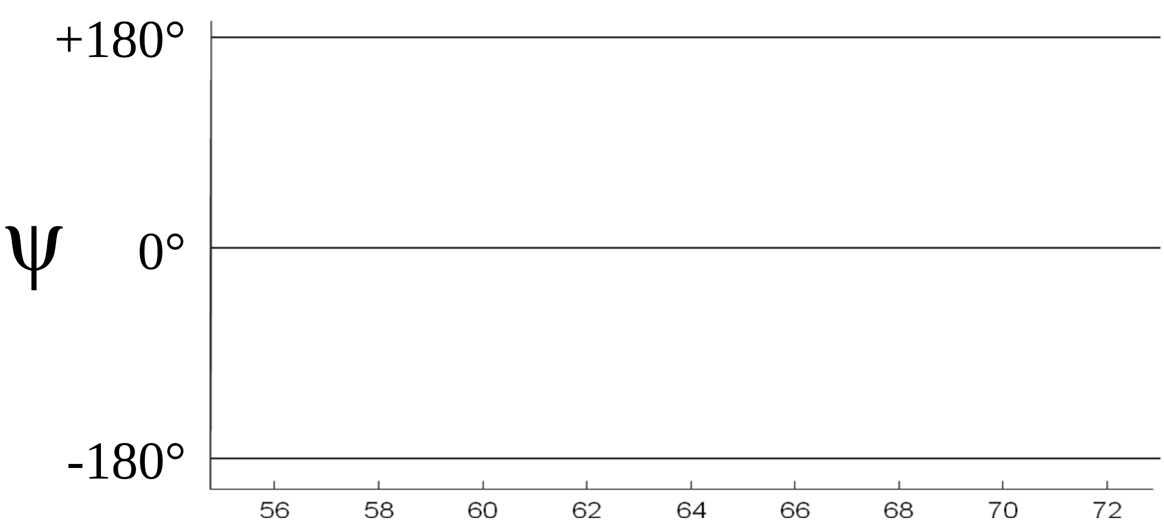
Student name : **Student number :**

c) The panel on the right depicts two hypothetical relative phase time series between moments of peak flexion of paretic and non-paretic hands. Which one does best represent the data presented in the left panel: the dotted line (A) or the solid line (B)? Motivate your answer **[4 points]**.

A: dotted line. The first slip to IP occurs because of an additional peak in the black curve relative to the gray curve. Similarly, the shift back to AP is due to an additional peak in the black relative to the gray curve, and hence, the phase difference between the two curves slipped a full cycle (360 degrees). You can simply check that by counting and comparing the number of cycles (from valley to valley) in the gray and black curves, which differs precisely 1 cycle.

The upper panel of the figure below depicts a trial in which a stroke patient was asked to flex the paretic hand (dark gray line) to the beat of a metronome (vertical dotted lines), while the other hand was moved passively by the motor (bright gray line). Moments of flexion peaks of the paretic arm are marked with the circles.





Student name : **Student number :**

d) One of the three neural interactions can be clearly seen in this figure. Which one? Motivate your answer in maximally 4 lines **[3 points].**

Phase entrainment: as can be seen, in this segment a phase shift is introduced between the motor and the metronome. Although instructed to synchronize paretic peak flexion with the metronome beat, paretic peak flexion is synchronized with peak flexion of the passively moved non-paretic hand, a signature of phase entrainment through motor afference.

e) The discrete relative phase ψ between time onsets of metronome beats ($t_{metronome}$) and moments of peak flexion ($t_{flexion}$) can be determined by:

$$\psi = 360° * ((t_{flexion} - t_{metronome}) / \mathrm{IBI}),$$

in which IBI is the interbeat interval. Sketch ψ, so-defined, in the lower panel for the 15 flexion peaks indicated in the upper panel **[4 points].**

After the phase shift, peak flexion is timed ahead of the metronome. By definition of the relative phase provided in the question, this should be sketched as a relative phase around zero in the beginning of the trial and then progressively more negative relative phase values after the shift.

€0.65

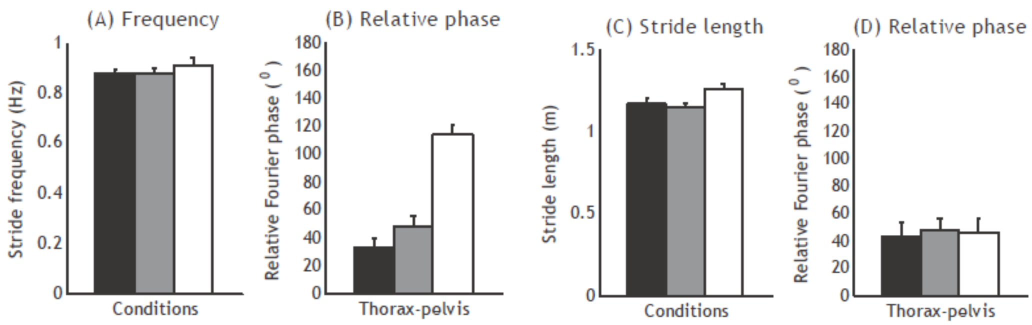
Student name : **Student number :**

Question 5

Pelvis-thorax coordination changes with increments in walking speed. At a slow speed, pelvis and thorax rotate along (in-phase coordination) whereas at a fast speed the pelvis and thorax rotate in opposite directions (antiphase coordination).

a) Changes in walking velocity (v in m/s) are due to changes in stride length (l in m) and stride frequency (Hz) according to $v = l * f$.

true ***/ false*** **[8]**



The figure above depicts the relative contribution of stride length and stride frequency to pelvis-thorax coordination at slow (dark-gray columns), intermediate (bright-gray columns), and fast (white columns) treadmill walking velocities.

b) In panel A, stride frequency was kept constant. Hence, stride length was larger for slow than fast treadmill walking velocities.

true / false **[9]**

c) In panel C, stride length was kept constant. Hence, stride frequency was larger for slow than fast treadmill walking velocities.

true / false **[10]**

d) The figure indicates that the increase in pelvis-thorax relative phase with increasing walking velocities depends more on stride .... than on stride .... Motivate your answer **[5 points]**.

The figure indicates that the increase in pelvis-thorax relative phase with increasing walking velocities depends more on stride length than on stride frequency, as relative phase increases only with increasing walking velocities due to increments in stride length (i.e., fixed stride frequency; panels A and B) and not with increasing walking velocities due to increments in stride frequency (i.e., fixed stride length; panels C, D).

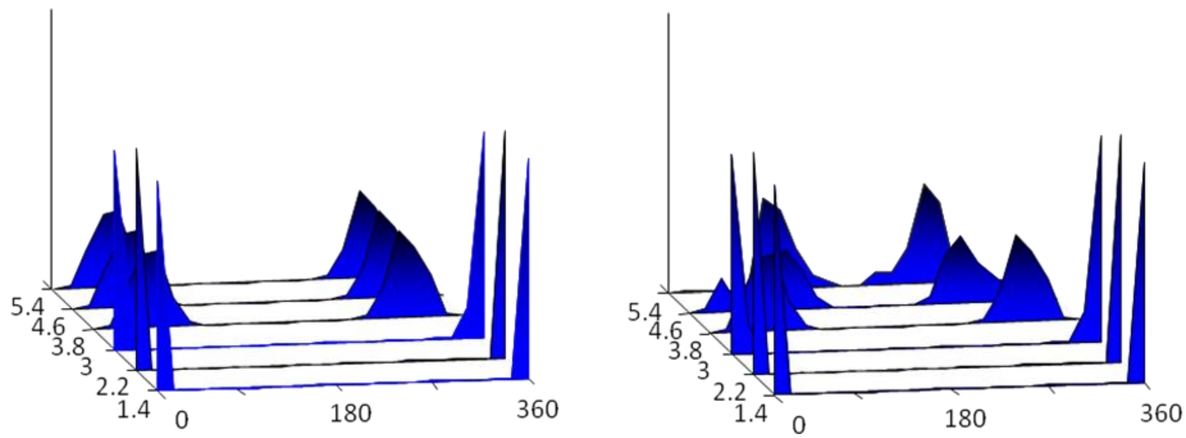
€0.65

Student name : **Student number :**

Wu and colleagues (2008) studied the coordination of horizontal trunk rotations in pregnant women with and without **P**regnancy-related **P**elvic girdle **P**ain.

e) Depicted below are two histograms of pelvis-thorax relative phase for the various walking velocities (1.4 , 2.2, ..., 5.4 km/h). On average, trunk coordination during gait of pregnant women with PPP is best represented by the histogram depicted on the left.

true* / *false **[11]**



f) Adaptations in the timing of thorax rotations, as observed by Wu and colleagues (2008), are specific for pregnant women with PPP.

true* / *false **[12]**

g) Braune & Fischer (1895-1904) were the first to note that at higher walking velocities the pelvis starts to lengthen the step, a phenomenon known as the pelvic step.

true* / *false **[13]**

Student name : **Student number :**

Question 6

Baratto and colleagues (2002) distinguished global and structural posturographic parameters in the study of postural control, focusing on their reliability and discriminative power. At the end of the comparative analyses, the large set of initial posturographic measures was reduced to just 4 parameters: SP, FB, MP and MD. With regard to SP, Baratto and colleagues (2002) state that "The global parameters in the time domain are about equivalent, and we suggest choosing SP, which is simpler to compute and has a better reliability index.

a) In the laboratory and the subsequent computer practical you determined SP yourself. It was indeed simple to compute, but its value was also prone to at least two data collection parameters and one data processing parameter. List these three parameters **[3 points]**.

1) Sample duration, 2) Sampling frequency, 3) Filter settings

b) Select one of the other reliable and discriminative global time domain parameters used by Baratto et al. (2002), whose value is less susceptible to the choice of the parameters in question. **[3 points]**.

AP or ML (i.e., the SD in AP or ML direction, as also quantified in the laboratory) or SA: the sway area.

c) The number of peaks in the sway density curve depends on the choice of the cut-off frequency to low-pass filter the raw sway density curve. The value of MP depends more on the choice of this cut-off frequency than the value of MD.

true* / *<u>false</u> **[14]**

The studies of Schmit and colleagues (2006) and Roerdink and colleagues (2009a) used other structural parameterization techniques to quantify the dynamic structure of centre-of-pressure (COP) fluctuations, namely, recurrence quantification analyses and sample entropy analyses.

d) Sample entropy is a measure of the regularity of COP fluctuations, with higher values representing more regular COP fluctuations.

true* / *<u>false</u> **[15]**

e) The recurrence plots for S1 and a representative control subject depicted in Figure 2 of Schmit et al. (2006) differ mainly in terms of % determinism.

<u>true</u>* / *false **[16]**

Student name : **Student number :**

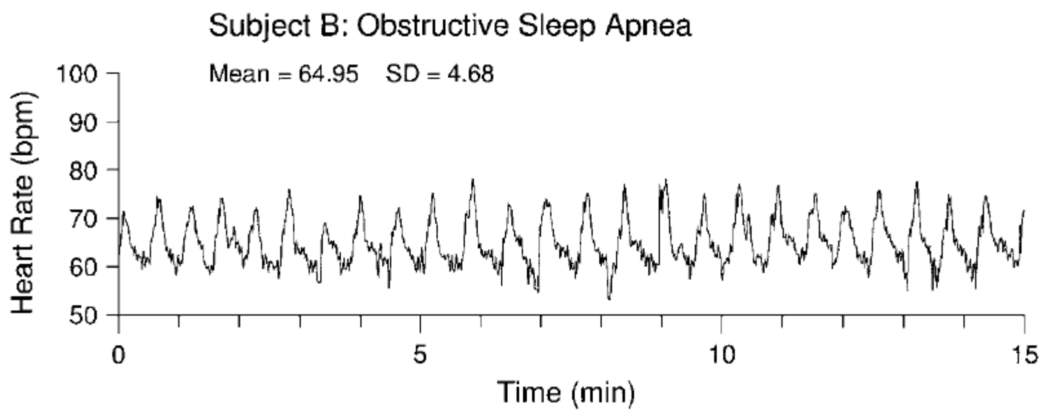
Question 7

Nonlinear dynamical systems are composed of multiple interacting components. The resultant behavior of such systems will be a summation of its constituent parts.

true / <u>false</u> **[17]**

According to Hamill and colleagues (2006), it is wrong to suggest that all variability has deleterious effects or that all variability is beneficial.

<u>true</u> / false **[18]**



In the figure above, borrowed from Goldberger (2006), a heart rate time series of a patient suffering from obstructive sleep apnea is depicted, with a mean value of 64.95 bpm and a standard deviation of 4.68 bpm. The mean value of its shuffled counterpart is the same, but the standard deviation differs between original and surrogate heart rate time series.

true / <u>false</u> **[19]**

Student name : **Student number :**

Question 8

Plotnik and colleagues (2009) used the phase coordination index (PCI) to quantify impairments in bilateral coordination in Parkinsonian gait. PCI is determined from the discrete relative phase between left and right heel strikes and depends on both the mean asymmetry in gait (labeled as accuracy, i.e., the difference in phase from a symmetric gait for which the relative phase is 180 degrees) and the coefficient of variation of the relative phase (i.e., standard deviation/mean), representing the degree of consistency of the stepping phase generation.

a) Suppose that the relative phase between heel strikes of the two legs is quite variable, with a standard deviation of 10 degrees. Then, PCI is smaller for a mean relative phase of 190 than of 170 degrees.

   true ***/ false*** **[20]**

b) The statement of Krasovsky and Levin (2009, in press) that "… because both accuracy and consistency of the PCI are correlated, their integration into 1 measure could mask specific impairments in either element" is invalid.

   true / ***false*** **[21]**

Student name : **Student number :**

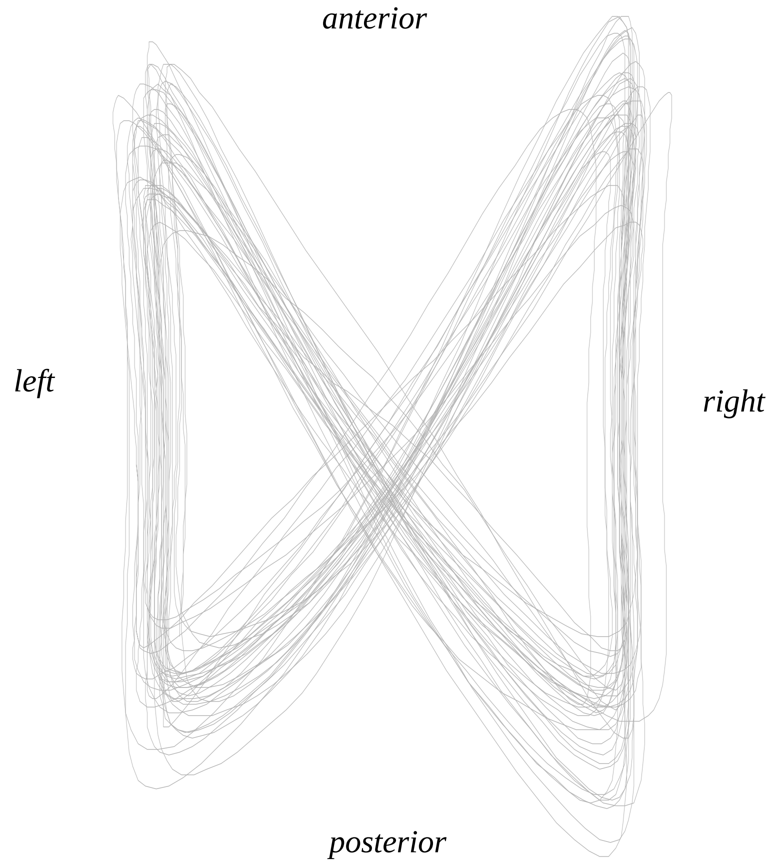
Question 9

This question pertains to acoustically-paced treadmill walking. A participant was asked to synchronize his left heel strikes with the beat of a metronome. The metronome rate was 1 Hz and the cadence was 75 steps per minute.

a) The participant takes more strides than prescribed.

true / <u>false</u> **[22]**

b) Sketch in the 'walkogram' depicted below time indices of left heel strike and the corresponding beat onsets **[5 points]**.



Time indices of left heel strike should all be on the valleys on the right side. Time indices of beat onsets should scatter around the walkogram, with relatively more (less) beat onset indicators at traces where the COP moves relatively slow (fast).