Pack formation in cycling and orienteering

Avoiding conditions that draw competitors together may be a better way to test ability.

In cycling and orienteering competitions, competitors can become bunched into packs, which may mask an individual's true ability. Here we model this process with a view to determining when competitors' times are determined more by others than by their own ability. Our results may prove useful in helping to stage events so that pack formation can be avoided.

We integrated equations of motion in discrete time steps for interacting competitors moving in one dimension from start to finish, with passing allowed. Individually, the ith competitor moves at speed u_i, which increases by $u_i \times b$ (where b represents the 'boost' factor) when another competitor is within a certain range ahead.

The appropriate percentage value for the boost and length of the range will be different for different sports, but the same for different competition formats in the same sport. In cycling (Fig. 1), the boost is due to aerodynamic and psychological effects[1], whereas in orienteering it occurs when a competitor is able to follow another within sight without the need to map-read. In each case, the leading competitor is unaffected. The number of competitors, distribution of u_i values, and initial separations depend on the particular competition and may vary between races. For mass starts (zero initial separation), maximal bunching is seen to occur immediately. In time trials (constant initial separation, with u_i distributed randomly), packs are ultimately formed, but often only after a considerable time.

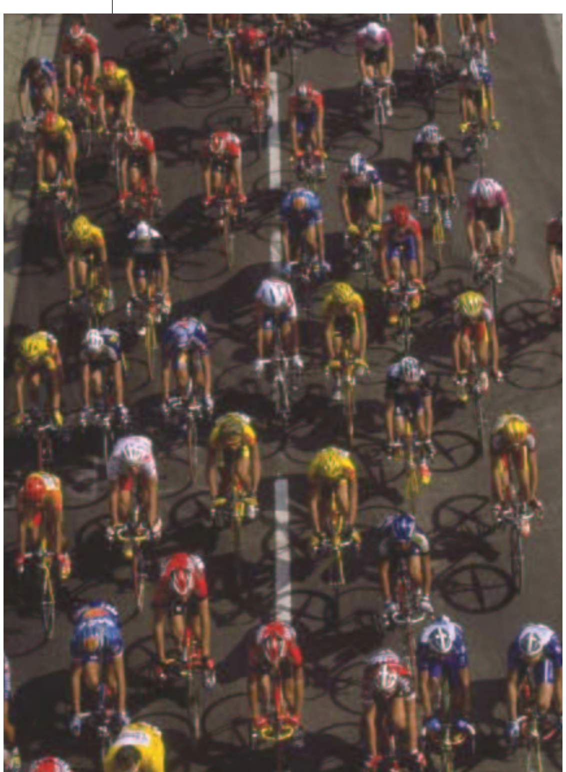

Figure 1 Go with the flow: in cycling races, competitors often bunch into packs, giving them an aerodynamic advantage which may belie an individual's true ability.

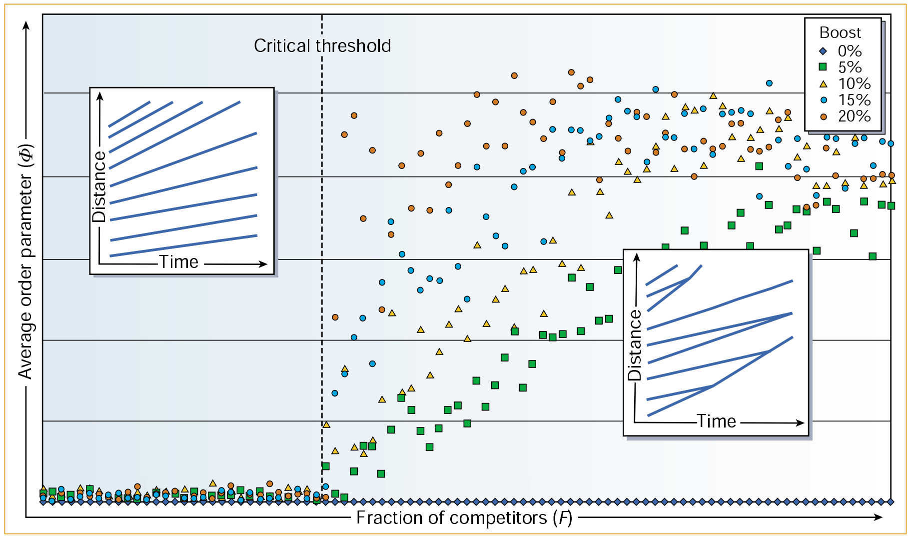

Figure 2 For quantitative study, we define an order parameter, Φ, which increases with packing: for $N+1$ competitors, $\Phi(t) = -N^{-1} \log \Pi_j[r_{j,j+1}(t)/2r_0 + 1/2]$, where $r_{j,j+1}(t)$ is the separation between the jth and $j+1$th competitors and r_0 is the mean separation. Competitors with u_i values that vary by more than the boost (b) cannot stay together, so the maximum value of Φ depends on the speed distribution. The main graph shows values of Φ with increasing F (as determined by setting $b=0$), from 500 chasing-start races, each with 30 competitors. In these races, competitors are started in order of highest $u'_i = u_i(1+R)$, where R is a random number between 0 and 0.1. Insets, details from simulations showing typical competitor behaviour in diverging (left, low F) and pack-forming (right, high F) regimes. Qualitative results are stable against noise (imposed as time-dependent fluctuations in u_i) up to the level of b.

Interesting cases are chasing starts, in which competitors are approximately sorted by u_i. For example, competitors' cycling start times in triathlons are determined by swim time (as swimming immediately preceeds cycling), which is correlated with cycling ability, and start times in some orienteering events are determined by a preliminary race. Here packs are formed after a short time, if at all. After a longer time, these packs (or individuals) move steadily apart. This reveals a sharp crossover between packing and non-packing behaviour: below a critical ratio of range to starting interval, most competitors move individually and move steadily further apart. Above this critical ratio, however, packs form that catch and absorb individuals.

Surprisingly, the position of the crossover depends on a single criterion: the fraction (F) of competitors who have abilities within the boost factor and who are able to get within range of others in the absence of boost interactions. If $F > 13\%$ (the critical threshold; Fig. 2), all competitors are rapidly swept into packs. In time trials, the onset of pack formation coincides with the time required to meet this criterion; b and u_i determine pack size.

Pack formation is stable against random fluctuations of u_i at each time point, provided that these are less than b, and is unchanged by adding a further boost that is proportional to pack size, or by making b range-dependent.

Data are available from orienteering races[2] in which competitors are electronically timed at a series of checkpoints. Our position/time simulation data compare well qualitatively to actual races, and the $F = 13\%$ threshold distinguishes those races in which pack formation dominates. Our results seem to be qualitatively similar to the formation of shockwaves or traffic jams[3], but an important difference is that our packs tend to be composed of the same competitors throughout.

We have derived the conditions for pack formation: packs form in chasing and time-trial races when more than 13% of competitors encounter others who are then able to stay with them because of the benefits of following.

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