# Running to catch the ball

SIR — When fielders run backwards or forwards to catch a ball they run at a speed which keeps $d^2(\tan\alpha)/dt^2$ zero, where $\alpha$ is the angle of elevation of gaze from catcher to ball. This ensures that they intercept the ball before it reaches the ground (provided they can run fast enough to keep $d^2(\tan\alpha)/dt^2$ zero) whatever the effect of aerodynamic drag on the ball's trajectory.

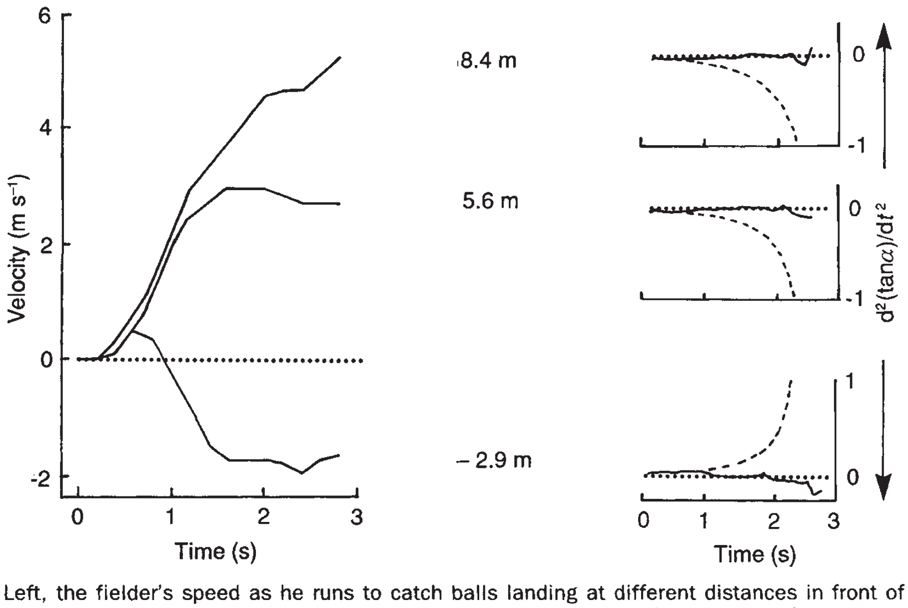
We video recorded a skilful fielder as he ran to catch cricket balls fired into the air from a bowling machine at 20–25 m $s^{-1}$ and an elevation of 45°. The balls came directly towards him so he had to decide whether to run back, forward or stay where he was, but not whether to move left or right. His velocity as he ran to catch the ball is plotted against time on the left of the figure. He is shown running various distances from 2.9 m backwards to 8.4 m forwards. The curves end when he catches the ball. It can be seen that he is always running (he has a non-zero velocity) when he catches the ball. He does not run to the point where it will fall, and then wait for it.

The right-hand side of the figure shows $d^2(\tan\alpha)/dt^2$ for each run. In each case the dashed line shows the value the fielder would have observed had he remained stationary and the solid line shows the value he actually observed as he ran. His strategy is clear. He waits for about half a second, then starts to run, accelerating until he reaches a velocity where $d^2(\tan\alpha)/dt^2 = 0$. Then he modulates his speed up to the point of catching, maintaining $d^2(\tan\alpha)/dt^2$ close to zero.

It can be seen why this algorithm is successful by considering what happens when the fielder misses the ball. If it drops to the ground in front of him, $\alpha$ = 0°. If it goes over his head, $\alpha$ = 90°. So any strategy which keeps $0° < \alpha < 90°$ throughout the flight will result in the fielder reaching the ball before it hits the ground or goes over his head.

To see why keeping $d^2(\tan\alpha)/dt^2 = 0$ ensures that $\alpha$ lies between 0° and 90° throughout the flight, consider what happens if the fielder starts to run while the ball is going up. In this situation, $\alpha$ will be increasing and $d(\tan\alpha)/dt$ positive. If he runs so that $d^2(\tan\alpha)/dt^2 = 0$, $\tan\alpha$ must be positive and finite at the end of the flight. As tan0° is 0 and tan90° is infinite it follows that $\alpha$ will lie between 0° and 90° at the end of the flight. Thus the ball will be intercepted. This is true independent of the effect of drag on the ball's trajectory, so it is a strategy for the real world, and not just a geometric curiosity which applies to intercepting objects in parabolic flight[1,2]. This strategy does not tell the fielder where or when the ball will land. It simply sets him on a course which will ensure interception.

Children probably discover this somewhat obscure strategy for keeping $\alpha$ between 0° and 90° by extrapolating from their experience of watching balls thrown towards them. If they remain stationary only balls which are going to land in their arms produce a value of $d^2(\tan\alpha)/dt^2$ close to zero throughout their flight[1]. When the child starts to run to catch the ball a natural strategy would be to try keeping $d^2(\tan\alpha)/dt^2$ low, as that has been associated with successful catching when stationary. This 'strategy' is obviously not available consciously. That its effectiveness is discovered demonstrates the power of the brain's unconscious problem-solving abilities.




Left, the fielder's speed as he runs to catch balls landing at different distances in front of (8.4 or 5.6 m) or behind (2.9 m) him. Each curve is the mean of five successful catches. Right, the value of $d^2(\tan\alpha)/dt^2$ as he ran. The angle of gaze from fielder to ball ($\alpha$) is estimated from film of the catcher's position and our model of the ball's trajectory.

**Peter McLeod**
*Department of Experimental Psychology, University of Oxford, Oxford OX1 3UD, UK*
**Zoltan Dienes**
*Department of Experimental Psychology, University of Sussex, Brighton BN1 9QG, UK*

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# Tetramer data reinterpreted

SIR — We recently described[1] a chemically crosslinked complex of relative molecular mass approximately 240,000 (240K) containing murine MHC class I heavy chains and $\beta_2$-microglobulin. The complex was generated using two different crosslinking reagents, was immunoprecipitated with two different monoclonal antibodies specific for distinct class I alleles, and was observed in a range of cell lines. It was observed on cell surface iodination and also when crosslinker was added to cells in culture before quenching and lysis. On pulse-chase analysis, the concentration of the complex increased with time, suggesting temporal assembly, while a 140K chaperone–class I complex[2] disappeared in a reciprocal manner. We suggested that the complex, which seemed to contain only class I heavy chains (HC) and $\beta_2$-microglobulin ($\beta_2$m), represented post-translationally assembled MHC class I tetramers. Since no other protein was seen by metabolic labelling or by iodination, we did not think it likely that any other protein was present in this complex.

At some intermediate concentration of crosslinker, intermediates of a final crosslinked product are expected to be generated and should be detectable on SDS–PAGE. If the 240K complex represents tetramers, the expected intermediates would be dimers and trimers. If it represents some other protein (P) crosslinked to class I, two bands (P-HC-$\beta_2$m and either P-HC or P-$\beta_2$m) would represent predicted crosslinking products. In our paper[1], we noted the absence of intermediate bands representing dimers and trimers. On a more systematic titration of crosslinker, we neither see the predicted dimers and trimers nor do we observe an intermediate product (P-HC or P-$\beta_2$m) that would have been predicted if the 240K complex represented some unlabelled protein crosslinked to