A COMPARISON OF COMPENSATION FOR RELEASE TIMING AND MAXIMUM HAND SPEED IN RECREATIONAL AND COMPETITIVE DARTS PLAYERS

D.J. Burke and M.R. Yeadon

Loughborough University, Loughborough, UK.

The level of accuracy achieved by darts players is dependent on their timing capabilities, judgement of velocity and their use of technique. This paper examines the techniques used by a recreational and a competitive darts player in a throwing task. The inaccuracy of the throws by both players were attributed to variations in release timing and maximum hand speed, with variations in release timing found to be the primary factor in both subjects (94.8% and 99.2% of total variance). The degree of compensation for variations in release timing and maximum hand speed were calculated for both competitors. The greater accuracy achieved by the competitive player was found to be the result of better compensation from technique rather than less variation in release timing and maximum hand speed.

KEY WORDS: throwing, technique.

INTRODUCTION: In targeted throwing tasks, such as darts, variations in landing height arise from variations in release timing and maximum hand speed; such variations should be controlled or interact with each other in order to achieve accurate throws. Variation in the release conditions can be controlled to some extent but can never be eliminated and the throwing action used in darts is too brief (<200 ms) for feedback control mechanisms based on proprioception to be implemented to compensate for such variations (Müller and Loosch, 1999). Throwing technique can be optimised to minimise the effects of variations in release timing and hand speed on landing height using feedforward control. We hypothesised that the difference in throwing accuracy between recreational and competitive darts players can be attributed to the level of compensation between release speed and release angle achieved by the technique employed.

METHODS: Three-dimensional position data were collected on two subjects using 12 Vicon MX13 cameras operating at 800 Hz. The subjects were a recreational darts player with over 40 years experience and a current county player with over 20 years experience. The subjects threw a small ball (mass 16.5 g) 18 times from the official darts distance aiming at the centre of a dartboard placed at the official height. This task was similar to throwing a dart accurately and had the advantage that the projectile could be tracked by the Vicon motion capture system. The landmarks of the subject's throwing arm and hand were identified by three pairs of reflective markers placed to track the positions of shoulder, elbow and wrist joint centres and three markers attached to the first three digits (Figure 1).

Figure 1: Reflective marker set used to track the motion of the arm and hand (posterior shoulder, lateral elbow and posterior wrist markers not shown).

When the ball was in the hand its position relative to the hand was determined and this was used to reconstruct the position of a hypothetical ball in the hand after the time of release. Quintic splines were fitted to the time histories of the horizontal and vertical positions of the actual ball and hypothetical ball with closeness of fit based upon a noise estimate determined from the data (0.4 mm). Release time was estimated as the average of the latest time that the ball was in the hand and the earliest time the ball was in flight as determined by comparison of spline value of actual vertical ball height with heights from spline to hypothetical ball and parabolic fit to flight. Pronounced movements of the fingers at the time of release could possibly lead to a discrepancy between the release velocities calculated from the spline to the hypothetical ball and the velocity from the parabolic fit. In this case velocity offsets were calculated and these offsets were used in all subsequent hypothetical releases. The accuracy of the release time estimates were assessed by calculating the landing height from the release time estimate and comparing this with the measured landing height.

To determine the vertical variation at the target arising from variation in maximum hand speed it was assumed that the percentage variations in hand speed at release and in maximum hand speed were equal. Horizontal and vertical release position and velocity were regressed against maximum hand speed and the resulting regression equations were used to calculate release conditions. The landing height was calculated using equations of constant acceleration under gravity:

Horizontally: $x = x_0 + u_0 t$ giving t

Vertically: $z = z_0 + v_0 t - \frac{1}{2} g t^2$ giving landing height z

The variance arising from hand speed variation was subtracted from the total variance in landing height to determine the variance in landing height arising from timing variation and the corresponding release timing window was determined for each trial.

The expected landing height variation arising from the above variation in maximum hand speed when timing of release was unchanged was calculated for each trial. The horizontal and vertical release coordinates and velocities were regressed against maximum hand speed. The regression equations were used to calculate hypothetical release conditions and landing heights for each recorded throw with the hand speed varied by the observed percentage variation in maximum hand speed. The percentage reduction in variance arising from the actual technique was calculated to give the level of velocity compensation. The landing height variation corresponding to release timing variation was calculated for a hypothetical circular hand trajectory at constant angular velocity. The percentage reduction in variance from this value to that of the actual technique was calculated to give the level of release timing compensation.

RESULTS: The vertical accuracy of the 18 throws at the target centre by the recreational and competitive subjects was -29.8 ± 37.1 mm and -8.6 ± 25.3 mm respectively (see Figure 2). The standard deviations of the vertical accuracy are comparable with those achieved by the subjects in the studies of Smeets *et al.* (2002) [29mm and 61mm] and Müller and Loosch (1999) [31mm and 44mm achieved by the most experienced subjects]. (The difference between calculated and actual landing height was -13.8 ± 17.9 mm for the recreational player and -3.8 ± 3.8 mm for the competitive player. The variations in maximum hand speeds were 1.6% (6.18 ± 0.10 ms^{-1}) for the recreational player and 1.5% (6.45 ± 0.10 ms^{-1}) for the competitive player, which resulted in vertical variations at the target of 8.5 mm and 2.2 mm respectively. These variations correspond to 5.2% and 0.8% of the total variance for the recreational player and competitive player respectively. The remainder of the vertical variation, 36.1 mm for the recreational player and 25.2 mm for the competitive player, equivalent to 94.8% and 99.2% of the total variances, corresponded to release timing windows of 3.4 ± 0.5 ms and 5.9 ± 5.8 ms (i.e. a change in release time of ±1.7 ms would result in a change in landing height of 36.1 mm).

Variation in landing height corresponding to uncompensated maximum hand speed variations of 1.6% and 1.5% were found to be 22.8 mm and 18.7 mm for the recreational and competitive players respectively; showing that the techniques used by the two subjects reduced the variance due to velocity variation by 86.1% and 98.6% respectively. Variation in landing height when timing variation is without compensation was 107.5 mm for the recreational player and 250.1 mm for the competitive player so that the techniques used reduced the variance due to release timing variation by 88.7% and 99.0% respectively.

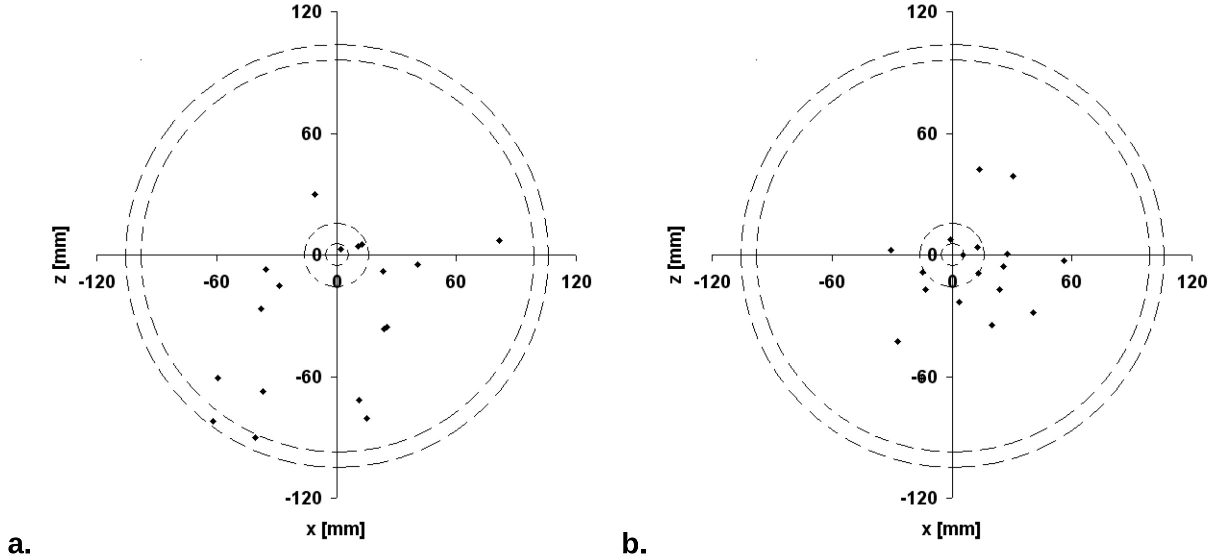

Figure 2. Illustration of the accuracy of the throws of the recreational (a.) and competitive (b.) subjects, including scale representations of the inner and outer bulls eye and the treble ring.

DISCUSSION: The contributions of release timing variations (>95%) and maximum hand speed variations (<5%) to the variance of the vertical accuracy of the throws indicate that variations in timing of release is the primary factor in darts performance in these two subjects. This is in agreement with Müller and Loosch (1999) who found that subjects' technique advanced with practice towards an 'equifinal path' that has reduced timing sensitivity. However this result conflicts with Smeets *et al.* (2002) who found that hand speed variation was the major contributor. The conflicting conclusion of Smeets *et al.* (2002) probably arose from incorrect estimation of release time since estimated release time for the best participant apparently released his darts close to the horizontal which would not have lead to a landing close to the centre of the board. The release time estimates in this study were calculated to be accurate to within 1.2 ± 2.2 ms for the recreational player and 0.0 ± 1.0 ms for the competitive player.

In this study the technique, timing capabilities and kinaesthetic awareness of each subject combined to result in the overall accuracy of their throws (shown in Figure 2). The competitive player was found to have similar ability when comparing the variation in maximum hand speed (1.5%) to that of the recreational player (1.6%). However his timing capabilities (5.9 ± 5.8 ms) were found to be inferior to those of the recreational player (3.4 ± 0.5 ms). Despite the large contribution (>95%) of timing to overall throwing accuracy the competitive player was able to achieve a more accurate throwing performance than the recreational player.

The competitive player was able to compensate for variations in maximum hand speed (98.6%) and timing of release (99.0%) using a better technique than the recreational player (86.1% and 88.7%). The effect of the superior technique used by the competitive player is that the inferior timing abilities of the player were counteracted by his better technique resulting in superior performance. Both techniques compensated for variations in timing of release more than the variations of maximum hand speed, illustrating that the importance of timing variations relative to that of hand speed variation has been recognised during the learning process and optimisation of technique. Possible compensatory techniques include coordinated movements of the shoulder and elbow affecting the radius of curvature of the hand path as well as changing the horizontal and vertical accelerations of the projectile. Further investigation into the mechanisms used for compensatory techniques should have coaching applications to the improvement of performance by identifying how compensation can be improved.

CONCLUSIONS: The variation in landing height was primarily due to variation in release timing rather than variation in maximum hand speed. Compensatory mechanisms have been employed by both subjects within their technique in order to minimise the expressions of their innate variations in release timing and maximum hand speed in the accuracy of their throws. The greater accuracy of the competitive player is a result of better use of compensatory mechanisms within his technique rather than less variation in release timing and maximum hand speed.

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