VISUAL CONTROL OF HIGH-VELOCITY FOOT-TARGETING TASKS IN NOVICE AND EXPERT PERFORMERS

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The visual regulation of step length and duration during target-directed locomotion was examined in relation to gait mode, approach velocity, obstacle task, and practice during a series of four experiments. Visual regulation was found to decrease in novice performers but increase in expert performers when approach velocity increased. The aptitude of expert performers is partly due to their ability to visually regulate for a greater time and distance during the approach, resulting in more accurate final foot placement. The speed/accuracy trade-off may be a mechanism that protects novice performers from harm whilst negotiating obstacles in the everyday environment.

KEY WORDS: approach gait, visual control, target, obstacle, impact

INTRODUCTION: Many sports present challenges to foot targeting, such as the approach to the take-off board in gymnastics vaulting and in long jumping. A characteristic of successful performance in such tasks is the optimization of approach speed relative to the accuracy demands of final foot placement. The kinematic profile of target-directed locomotion has predominantly been examined in the high-velocity task of long jumping.

Three major themes describe the research to date on the kinematics of target-directed locomotion. The first concerns the speed/accuracy trade-off, which governs the speed of the approach and control of foot placement towards a target (Bradshaw & Sparrow, 2000). The second major focus of research has been on the visual control of step length in the approach towards targets, with attention on the onset of visual control, when the control of step length and duration during the approach changes from ballistic to some form of visual control process (e.g. Berg, Wade, & Greer, 1994). The third major research theme has been the control of step length locally when aiming for a target, consisting of the control of foot placement during the final stride towards the target (e.g. Sparrow et al, 1996). A lack of agreement in the literature concerns the time and distance of visual regulation relative to the target in locomotion. Differences in approach velocity, the spatial constraint of the target, impact task (whether hard or soft), and the experience of the performer are all variables that could affect the onset of visual regulation of step length. The aim of the current study was to determine the effects of these variables on the temporal and spatial characteristics of visual regulation of target-directed locomotion.

In a series of four experiments step length regulation was examined during the approach towards obstacles, in both novice and expert performers, to determine the effect of gait mode, approach speed, obstacle type, target length, and impact type. Impact type was categorized as either hard or soft, where the participant either negotiated and ran through the target (hard), or stopped at the target (soft). It was expected that approach speed would decrease for obstacles that imposed greater constraint, and that visual regulation would occur earlier when required to negotiate an obstacle at higher approach speeds.

METHODS: The effect of targeting tasks on step length regulation of the approach was examined, as shown in Figure 1. Experiments 1, 2, and 3 each examined six male and six female college-age novice performers, whilst Experiment 4 examined five female expert performers, who were all national-class gymnasts. In all experiments five trials were conducted for each targeting task. Two marker strips consisting of alternating 0.50m black and white intervals were placed on either side of the approach strip. One 50Hz-panning camera (Exp 1&2, S-VHS; Exp 3&4, DVCam) was set-up on a platform adjacent to the approach strip to film the trials. Toe position relative to the obstacle was examined from the video footage to determine the gait characteristics such as step length and duration. The measurement and analysis procedures employed in the experiments were tested prior to the beginning of data collection, by filming and measuring cardboard footprints placed at known distances along the approach strip. Measurements of the toe-to-target distances were found to be within $\pm$0.5cm. Statistical analysis conducted included linear regressions to test for linear relationships, and multivariate analysis of variance (MANOVA) with repeated measures, to test for significant differences between tasks and conditions.

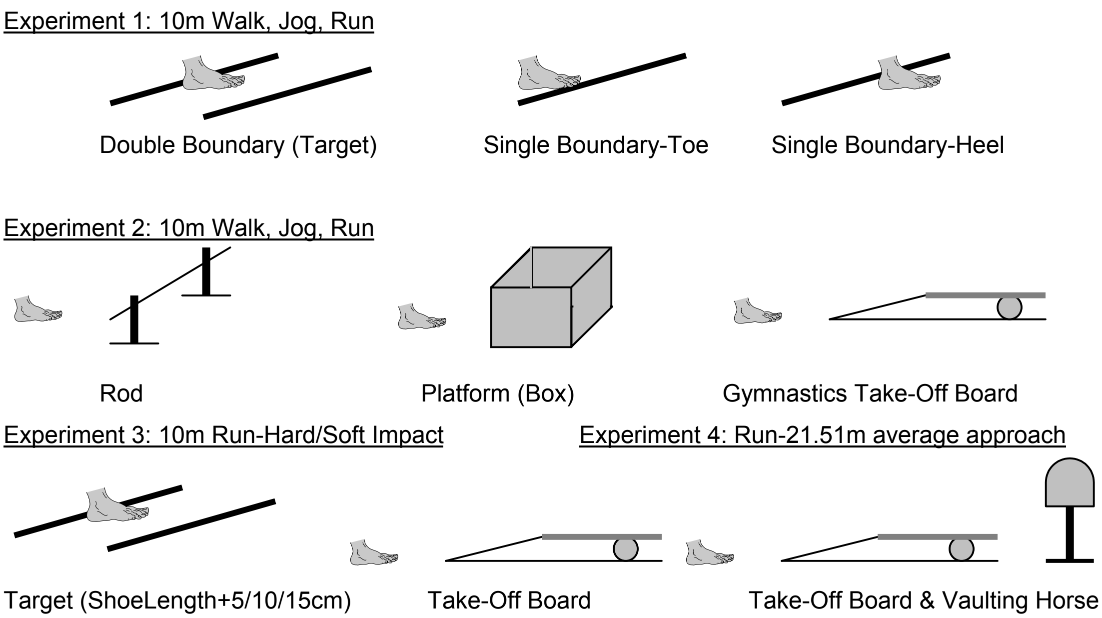

Figure 1 - The targeting tasks examined in each of the four separate experiments.

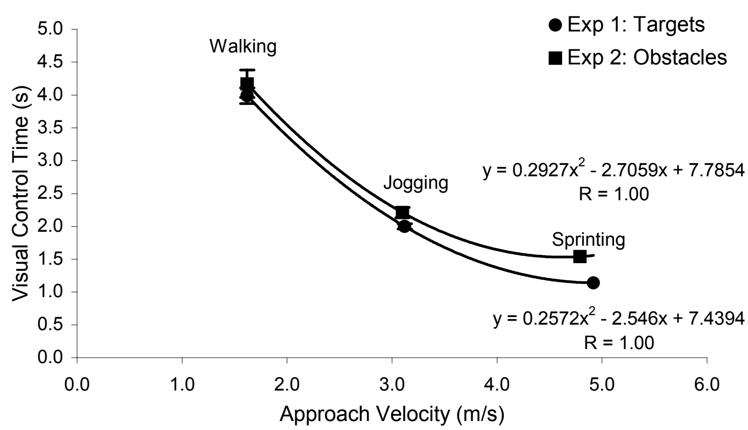

Figure 2 - The amount of time that is visually regulated during a 10m approach when walking, jogging, and sprinting towards an obstacle for novice performers.

RESULTS AND DISCUSSION: The distance to the obstacle at which visual regulation commenced in novice performers was unaffected by gait mode, approach velocity, target width, or impact type. On average, 4.88m of the 10m approach towards the obstacle was visually regulated. The amount of time that was visually regulated differed when participants were asked to approach an obstacle using the three gait modes of walking, jogging, and sprinting. As can be seen in Figure 2, visual control time increased when the participants walked towards the obstacle, as opposed to jogging, and/or running (Exp1: $p \leq 0.01$; Exp 2: $p \leq 0.01$). When novice participants were asked to sprint towards targets of three different widths, a speed/accuracy trade-off was found for both the hard and soft impact conditions (Hard Impact; $p \leq 0.01$, $y=-0.0271x+2.5273$, $R=0.99$; Soft Impact: $p \leq 0.05$, $y=-0.0238+2.6478$, $R=0.96$). Visual regulation decreased temporally, Figure 3, when approach speed increased due to the wider target width. The amount of time that is visually regulated, therefore, is affected by approach speed as opposed to simply gait mode. Thus, visual regulation time decreases with an increase in approach speed. One explanation for the speed/accuracy trade-off found in Experiment 3 and in earlier work (Bradshaw & Sparrow, 2000), is that the time visually regulated when approaching an obstacle at lower approach speeds is longer, allowing smaller systematic adjustments to footfall position, and resulting in greater final foot-positioning accuracy with the obstacle.

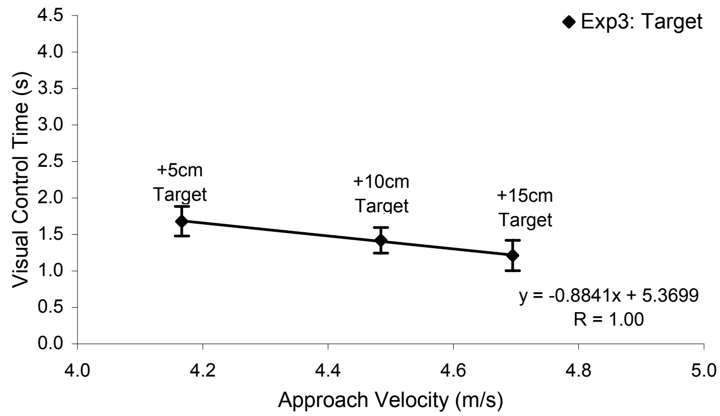

Figure 3 - The amount of time that is visually regulated during a 10m running approach towards a target of three different widths by novice performers.

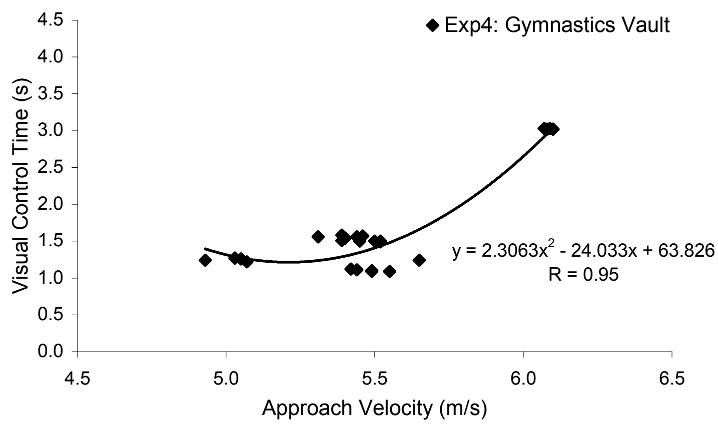

Figure 4 - The amount of time during the approach, which expert performers visually regulate when approaching obstacles during gymnastic vaulting.

In expert performers, visual regulation of the approach towards an obstacle, the take-off board, or towards two obstacles, the take-off board and vaulting horse, was found to be different to that of novice's. When task demands due to the number of obstacles increased, the gymnasts ran faster during the approach ($p \leq 0.01$). Interestingly, however, no significant differences were found between the two tasks in regards to the accuracy of foot placement on the take-off board.

The affect of the obstacles on approach velocity was dissimilar to novice performers who decreased their approach velocity when highly constrained by a target or obstacle, such as that seen for the single boundary targets and the double boundary target in Experiment 1 ($p \le 0.01$). When examining the pattern concerning visual control onset between the two tasks in expert performers, no significant differences were found due to approach velocity. On average the gymnasts approached the take-off board over a 21.50m distance in each task, of which 1.72s (41.85%) was visually regulated. In the highly practiced task of vaulting for the gymnasts, visual regulation increased in both distance and time with an increase in approach velocity, as can be seen in Figure 4. In the non-vaulting task, a task not practiced by the gymnasts from that approach distance, visual regulation decreased with an increase in approach velocity ($p \le 0.01$, $y=1.4173x^2-16.545x+49.545$, $R=0.90$). The different patterns concerning visual regulation and approach velocity in gymnasts, demonstrates the effect of practice on target-directed locomotion.

The control of the final stride to negotiate the obstacle in the different targeting tasks was revealed when comparing the results across the different approach velocities. Of particular interest, was that the rod was cleared at an invariant crossing position of 63.65% of stride length. It was found that the final step prior to the rod increased in length with an increase in approach velocity ($p \le 0.01$), whilst the step preceding decreases in length ($p \le 0.01$), so that the rod was cleared at a common percentage of overall stride. In the double-boundary targeting tasks, the foot was placed at a consistent distance of 1.89cm from the front boundary of the target, regardless of the width of the target. This suggests that the forward boundary was predominantly utilised to guide foot placement. Finally, an interaction was found between approach velocity and the placement of the hurdle when approaching the gymnastics take-off board, resulting in consistent foot placement upon the board (Exp 2; $y=0.2289x-0.2141$, $R=0.99$. Exp4: $y=0.4394x^3-6.5088x^2+31.826x-45.784$, $R=0.78$). The adjustment to the hurdle placement enables the speed/accuracy constraints of the task to be overcome.

CONCLUSION: The success or failure of a performer when visually regulating the length and duration of each step to negotiate a target or obstacle is contingent upon the speed of the approach and task experience. When approach velocity increased, visual regulation of step length decreased in novice performers, resulting in less accurate final foot placement. The key finding describing the pattern concerning approach velocity, visual regulation, and final foot placement accuracy in novice performers is the underlying mechanism contributing to the speed/accuracy trade-off phenomenon. With high levels of practice such as that seen in expert performers, visual regulation increases with approach velocity. The skill of expert performers is, therefore, partly due to their ability to visually regulate for a greater time and distance during the approach when velocity increases, allowing smaller and systematic step length adjustments to be executed, resulting in accurate final foot placement when negotiating a target. The speed/accuracy trade-off phenomenon first found in earlier work (Bradshaw & Sparrow, 2000) may be a mechanism that protects novice performers from harm whilst negotiating obstacles in the everyday environment.

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