Human Movement Science 10 (1991) 621-627
North-Holland

Research note

Experience and backswing movement time variability

A short note concerning a serendipitous observation *

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Abstract

Burgess-Limerick, R., B. Abernethy and R.J. Neal, 1991. Experience and backswing movement time variability: A short note concerning a serendipitous observation (Research note). Human Movement Science 10, 621-627.

Decreased variability of both response outcome and movement kinematics is generally thought to be a characteristic of skilled performance. This note reports an apparently paradoxical case in which expertise is associated with greater variability of an aspect of movement kinematics. The relative variability of backswing and downswing duration (standard deviation as a percent of movement time) was assessed for experienced and novice field hockey players performing a drive of an approaching ball. The experienced group exhibited higher relative variability of backswing duration than the novice group. It is argued that this variability is functional (in the sense that greater backswing duration variability is associated with superior task performance) and may result from the joint effects of players visually controlling movement during its execution (Bootsma 1988) and the experienced subjects' earlier pick-up of relevant information for visual control (cf. Abernethy and Russell 1987).

Decreased variability of response outcome is generally thought to be a strong correlate of skill development. This decreased outcome variability is traditionally held to be the result of the development of a more consistent set of efferent neural commands stored within a motor programme. An increase in the consistency of the motor programme

* This work was supported in part by Australian Research Council Grant A78832057. The authors wish to thank Dr. I.M. Franks for his helpful comments.

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would be expected to be reflected in decreased variability in the movement kinematics as well as in the response outcome (e.g., Darling and Cooke 1987; but see also Young and Schmidt 1990). Indeed some evidence suggests that experts' performance of real-world interceptive tasks is characterised by relatively consistent movement times. This evidence comes from a number of sports, notably baseball (Hubbard and Seng 1954), table tennis (Tyldesley and Whiting 1981), squash (Wollstein and Abernethy 1988) and hockey (Franks et al. 1985) where the downswing movement time (from first forward movement of the implement to impact) of experienced subjects has been found to remain relatively constant.

This note concerns a serendipitous observation in which experienced field hockey players were found to exhibit greater variability of backswing duration than novice players. We propose to describe the finding and the circumstances under which it was made and then briefly discuss how this observation might be reconciled with contemporary views of motor control and expertise.

Method

Subjects

The subjects of our observation were four experienced field hockey players and three novice players. The experienced players (two male, two female) had between four and 10 years playing experience and were currently competing in club fixtures at varying standards. Novices were female university students who had never played competition hockey.

Procedure

Each subject was filmed while performing 60 field hockey drives to an approaching ball. One high speed video camera (NAC 200 Hz) was positioned with its principal ray perpendicular to the approximate plane of motion of the swing. Filming took place indoors under normal lighting conditions with the addition of a 1000 watt spotlight placed behind the camera.

The subjects were required to produce two different responses. One was to hit the ball 'as hard as possible, as if shooting for goal'. The second was to hit the ball 'as if passing to a player three metres away'. The subjects aimed at a target the size of a hockey goal three metres away. The ball was propelled directly towards the subjects via a ramp at velocities ranging from 0.9 to 2.8 m/s (bimodal distribution, modes at 1.7 and 2.5 m/s, mean = 2.0 m/s, $sd = 0.6$ m/s). The speeds at which the ball approached are ecologically valid in the sense that they represent ball speeds where, in a game, the ball might be hit without first trapping it. One practice trial at each condition was performed to ensure the instructions were understood. Thirty trials were filmed under each of the response conditions with the order of trials randomized.

Data processing

Retroreflective markers placed on the hockey stick and the ball defined their respective displacements. A MOTIONANALYSIS Corporation (CA, USA) automated video digitising system (EXPERTVISION) was used to digitize and then calculate the centroid of each marker for each video field. The data were smoothed using a Butterworth digital filter. Time series arrays for the displacement and velocity of the ball and the stick were generated for the period from the start of backswing until 20 frames after impact. The initiation of the backswing was determined manually from the high speed video record, while all other temporal events were computed from the time series arrays.

Results

During the subsequent analysis it was observed that the relative variability of backswing duration was higher in experienced subjects. The standard deviations of backswing and downswing movement times were assessed for the 30 trials for each subject in each condition. Variability is correlated with movement time and so a measure of relative variability was calculated (after Young and Schmidt 1990) by expressing the standard deviations of the backswing and downswing duration as a percentage of the corresponding mean duration. A three-way (experience × movement segment × task requirements)

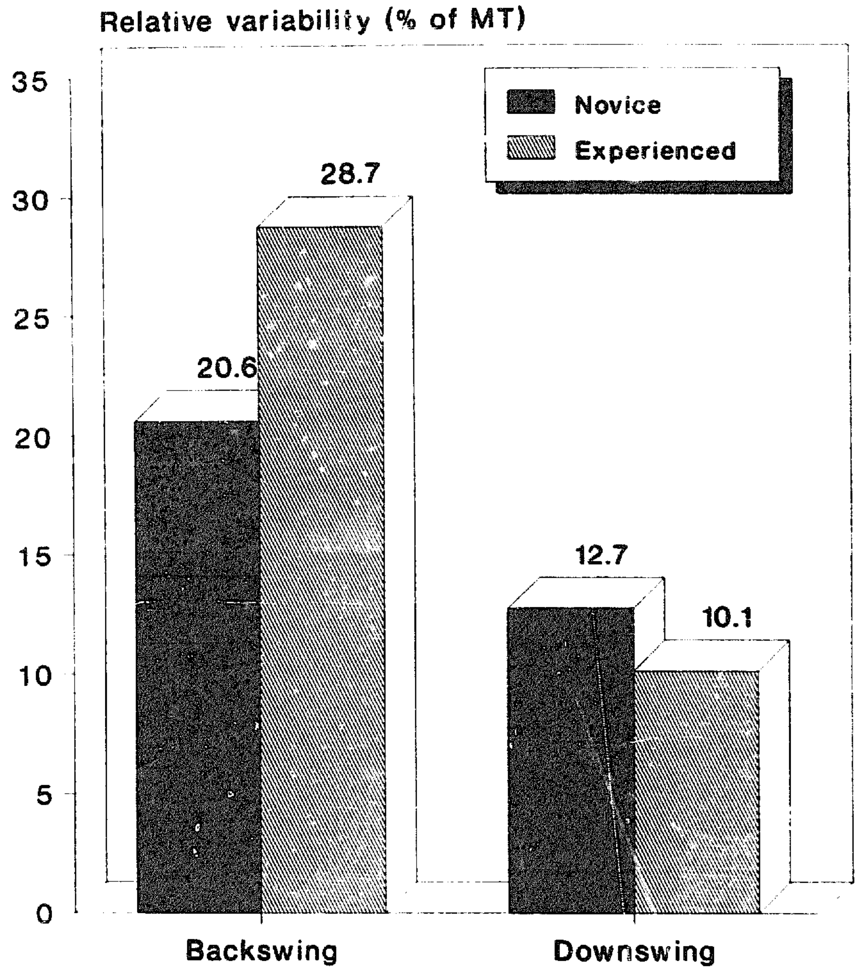

Fig. 1. Relative variability (standard deviation as a percentage of the mean segment duration) for backswing and downswing segments of experienced and novice hockey players driving an approaching ball.

ANOVA performed on this measure revealed a significant interaction between the factors of experience and movement segment, $F(1,5) = 9.198$, $p = 0.029$ (fig. 1). A Tukey HSD post-hoc test revealed that the relative variability of the backswing duration was higher in the experienced group. There was no significant difference between the groups in the relative variability of the downswing duration although the trend was for the novice group to be more variable (fig. 1).

When the least experienced of the experienced subjects was omitted from the analysis the effect was even more marked, $F(1,4) = 27.762$, $p = 0.008$. Again the post hoc analysis revealed that the experienced subjects exhibited relatively more variable backswing movement duration than the novice group. Further analysis of all subjects showed that the mean velocity with which the ball was hit was significantly correlated with the relative variability of the backswing duration ($r = 0.873$, $p < 0.01$). Given the low power of these statistical tests, due to the small sample size, the finding of such strong effects is remarkable and worthy of further investigation.

Discussion

How might this observation be understood? Firstly it should be noted that the result is consistent with previously reported data. Hubbard and Seng (1954) found that expert baseball players started their forward swing at a constant time before impact. However, the duration of the preceding movement (the step) depended on the velocity of the ball. Wollstein and Abernethy (1988) concluded that skilled squash players maintain constant downswing movement times over different stroke types and approaching ball velocities but that the backswing movement times are much more variable. Franks et al. (1985) observed that an experienced field hockey player produced a temporally consistent downswing and variable backswing when driving a moving ball as hard as possible.

Temporal consistency of downswing movement times has been seen as an means of reducing the temporal degrees of freedom to be controlled by reducing the problem of coincidence to one of deciding when the approaching object is one movement time away (Tyldesley and Whiting 1975; Wollstein and Abernethy 1988). Tyldesley and Whiting's (1975) operational timing hypothesis proposed that a consistent output duration assisted accurate central decision making of when to commence movement. With increased skill it was envisaged that the extent of the movement controlled by the motor programme would increase, potentially to the point where part or all of the backswing might also come under the control of the same programme responsible for downswing consistency.

More recently Young and Schmidt (1990) examined the kinematic changes that occurred with practice of a laboratory task analogous to hitting a moving ball (albeit with no temporal uncertainty). They concluded that, with practice, subjects appeared to change from using one programme to using two smaller programmes with an interval of variable duration separating them. The current observation could be interpreted in a similar fashion. Perhaps novice field hockey players use a single motor programme to control both backswing and downswing while, after practice, players have one programme for backswing (or part of backswing) which is followed by an interval of varying duration, in which processing of visual information occurs, and then another programme which controls the remainder of backswing and downswing in a ballistic fashion. Temporal consistency of the second programme would still appear to be advantageous to performance.

However Bootsma (1989) found that subjects were better able to hit a dropping ball with their own arm than with a mechanical arm, even though the movement time of the mechanical arm was less variable. These results suggest that some of the variability observed within movement times must be functional. Bootsma and Van Wieringen (1990) confirmed this assertion in a more ecologically valid setting when they examined the kinematics of expert table tennis players. They demonstrated that the small amount of variability that existed in the experts' downswing movement time is functional because the temporal accuracy of these subjects was greater at ball contact than at the initiation of the downswing.

Bootsma (1988) proposed that players pick up visual information continuously and use this information to adjust and 'fine-tune' the movement during its execution. Although such a mode of control may be limited to some extent by the time required for information to be acted upon (cf. McLeod 1987), this time limitation may not be as large as has been previously thought. In arguing for this possibility Bootsma and Van Wieringen (1990: 22) note that 'a non-trivial distinction exists between using visual information in correcting an unexpected error (or reacting to an experimental stimulus) and visual guidance of movement during the natural unfolding of the act' (parentheses added).

Experienced players in a number of sports have been shown to pick up the essential information required to control movement earlier than novices (Abernethy and Russell 1987; Howarth et al. 1984; Jones and Miles 1978; Starkes 1987) at least where it applies to the use of advance cues. The same expert–novice differences may also apply in the pick-up of visual information required for coincidence with an approaching object. Novices may make adjustments (or attempt to make adjustments) later in the execution of their swings because their information pick-up is relatively late. Such a notion could explain all the previous and current observations. Perhaps experts appear more variable when the backswing is examined because they are in the process of fine-tuning the movement on the basis of relatively early visual information – information that novices are not attuned to and hence which does not form an active part of their ongoing movement control at this point. Experts may appear less variable when the downswing is examined because *they are already on course* and only small adjustments remain to be made to achieve successful interception. Novices in this same period may be forced to attempt more alterations in their movement kinematics due to their later pick up of relevant information. Work is currently in progress in our laboratory to explore these possibilities further.

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