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Measurements of the motion of the hand and drumstick in a drumming sequence with interleaved accented strokes - a pilot study

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Abstract

The motion of the hand and the tip of the drumstick in a simple repeated drumming pattern with interleaved accented blows have been studied using standard video equipment. The vertical positions of the tip of the drumstick and a reference point on the hand were measured. Typical timing relations and velocities are reported. A characteristic preparatory motion of the hand resembling a fishtail motion was observed for the accented blow.

Introduction

Relatively little is known about the biomechanics of music performance. A basic observation is that musicians at a professional level seem to have acquired a technique which enables a relaxed and reliable execution of basic elements in playing with a minimum of physical and mental effort. Typical examples would be changing hand positions on a stringed instrument, or forming the attack characteristics of a tone on a percussion instrument. Both these examples require close control and co-ordination of the hand and arm motions. It seems reasonable to assume that in performance, these “optimized” basic elements of playing are used as building blocks in the execution of more complex structures, such as phrases, a task which needs attentive planning over a longer time span.

Percussion players are particularly suited for initial studies of the biomechanics of music performance. The body movements are generally large and basically limited to the arm and wrist motion in the vertical plane. The difficulties involved in studying the small scale motion of the fingers – characteristic for the playing of most other instruments – are thereby avoided.

Experiments

A video recording of a non-professional player (the author) playing a repeated drumming sequence with a regular drumstick on a practice pad was made. The playing was recorded with a standard video camera, mounted perpendicularly to the striking plane. The time separation between frames was 20 ms. Two centimetre scales were mounted vertically in the immediate background, one placed at the tip of the drumstick and the other at the hand.

For each frame of the recording, the vertical positions of the tip of the drumstick and of a reference point on the hand (the joint on the index finger next to the drum stick (Figure 1) were measured. The point on the finger will be referred to as “the hand” in the following. An estimation of the inevitable small horizontal movements of the hand was also made.

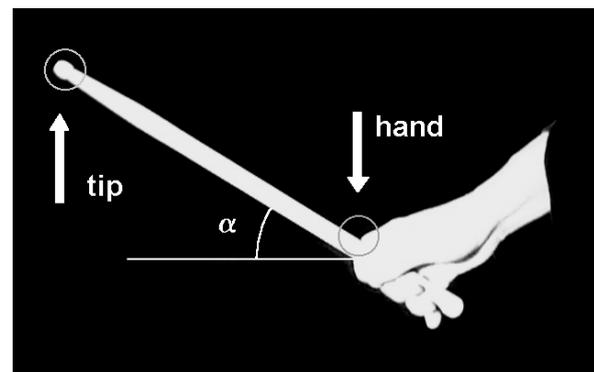


Figure 1. View of the drumstick and the hand. The arrows indicate the two reference points used for data collection (encircled); one at the tip of the drumstick and one on the index finger at the joint next to the stick (referred to as the “hand”). The angle between the stick and the horizontal plane is denoted by α .

Based on the data of the vertical positions, the velocity of the tip and the hand, as well as the angle α between the drumstick and the horizontal plane were calculated (Figure 1). The velocity was calculated as a three-point central-difference approximation. The reading error in vertical position was estimated to ± 1 cm, giving a calculated error in velocity of

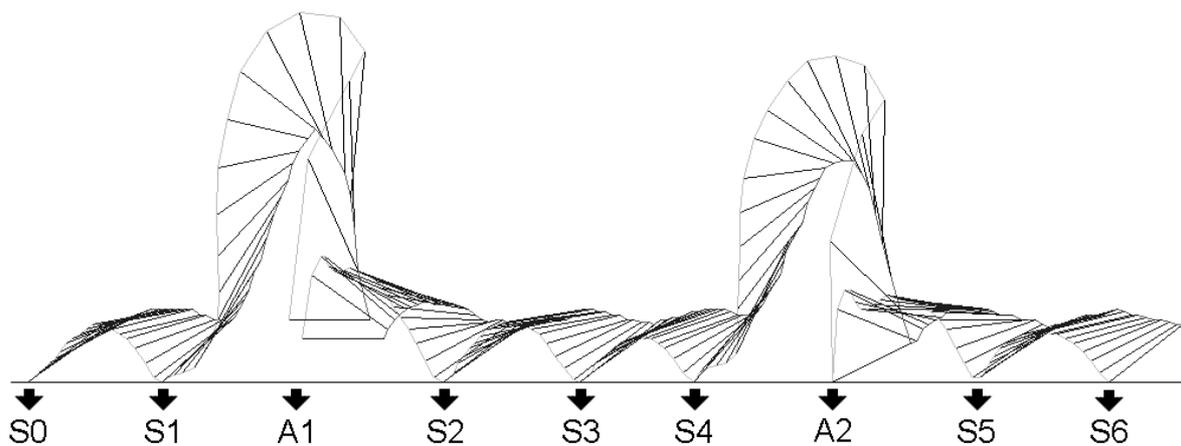


Figure 2a. Motion sequence of the drumstick. Registrations of the motion of the drumstick and hand during repeated drumming with a strong accent every fourth stroke. The hits on the striking surface (a practice pad) are indicated by arrows and marked with S for soft blows and A for accented. (The hit of the first accented stroke was not recorded due to poor time resolution.) The figure is based on measurements of the vertical position of two reference points on the drumstick and hand, respectively (Figure 1), taken from a video recording with a separation of 20 ms between frames.

± 0.5 m/s. The calculated error in α ranged from ± 2 deg (horizontal orientation) up to about ± 10 deg (almost vertical orientation). The large uncertainty for almost vertical orientation was reduced by checking the calculated values against the recorded angular position on the screen. The “effective length” of the drumstick from the tip to the reference point on the hand was 30 cm.

The recorded drumming pattern consisted of repeated single strokes at a tempo of 150 beats/min (nominal beat duration 400 ms) with one strongly accented blow every fourth note. The sequence was played with the right hand.

Results

General description of the sequence

The overall impression of the recorded performance was that of a regular playing with a relaxed posture. A clear strategy for the preparation of the accented blow was observed, best described as a “fishtail-like” movement of the hand.

A sequence of stylized pictures displaying the position of the drumstick versus time is shown in Figure 2(a). The pictures were generated from the data of the vertical positions of the tip and the hand. The three successive soft strokes are of a gentle, wave-like character. The amplitude of the hand movement is small, and so is the variation in the angle α of the

drumstick with respect to the horizontal plane. At the last hit in the sequence of three soft strokes (S1, S4), the hand starts an upward movement as a preparation for the accented blow (A1, A2). This upward movement starts while the tip still is in contact with the drumhead.

A detailed description of the preparation for and execution of the second accented blow in the recorded sequence (A2) is shown in Figure 2(b). The numbered frames show the successive positions of the drumstick, some of them illustrated by inserted snapshots of the grip of the drumstick.

During the first part of this preparatory movement the hand moves rapidly upwards making the drumstick follow, pointing downwards (frame 1 - 12). The tip of the drumstick catches up successively as the stick gains in angular velocity, but not until the hand has approached its maximum vertical position the stick is levelled (between frame 12 and 13). The angular motion of the stick continues uninterrupted and the stick ends up pointing vertically (frame 19). By this time, the hand has already turned its vertical path (frame 15) and started a descending motion which initiates the actual downstroke. When the hand is lowered in the initiation of the downstroke the wrist angle becomes more pronounced (cf. snapshots C and D in Figure 2(b)). This is an effect of a relaxed wrist which allows the stick to reach its maximal “vertical overshoot.” The small horizontal movements during the stroke is seen as a loop in the path of the hand.

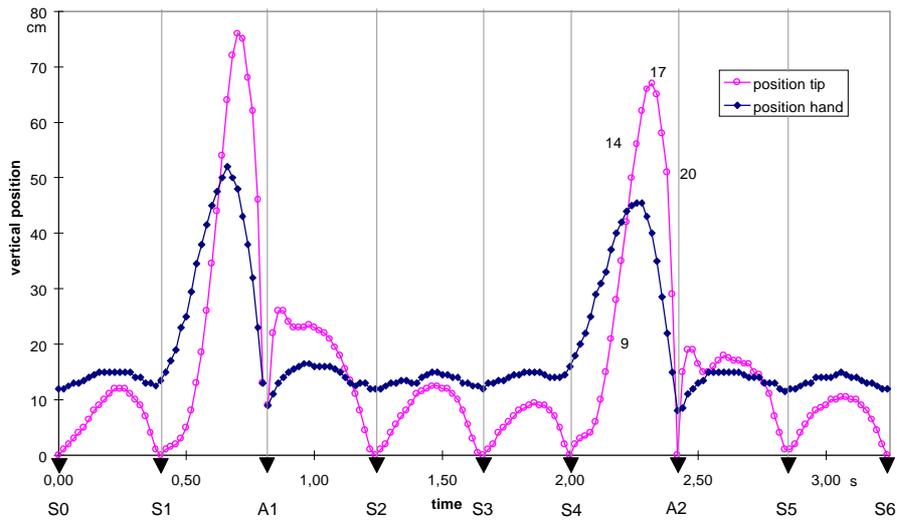


Figure 3a. Vertical position of the hand and tip of the drumstick during the drumming sequence in Fig. 2(a). The hits are indicated by arrows and marked by S (soft) and A (accented) as in Fig. 2 (a). Four of the frame numbers from Fig. 2 (b) have been inserted for comparison.

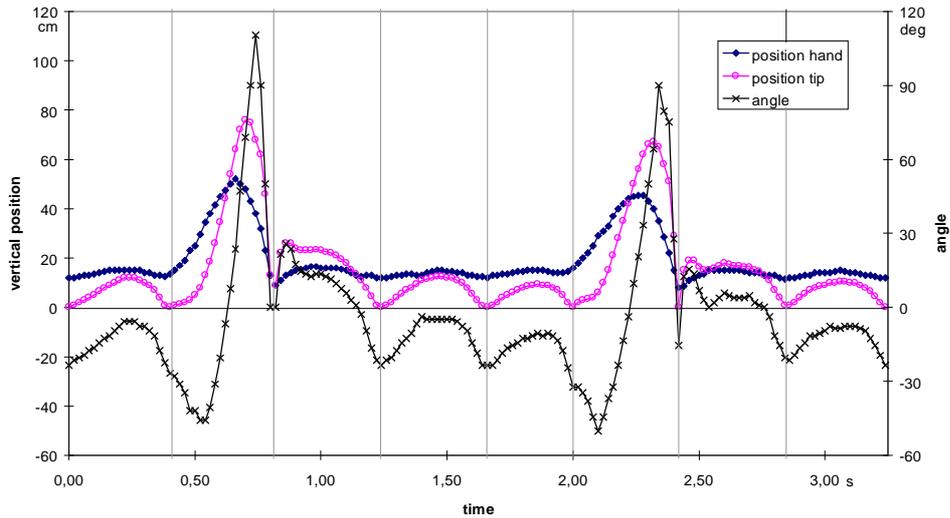


Figure 3b. Vertical position of the hand and the tip of the drumstick, and the angle α between the drumstick and the horizontal plane.

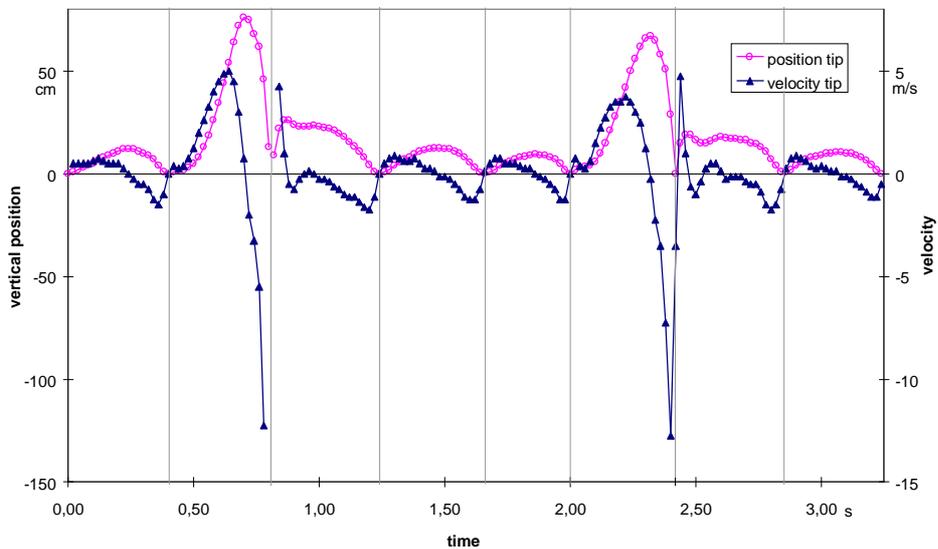


Figure 3c. Vertical position and velocity of the tip of the drumstick.

velocity of the tip reached on its way up to the turning point at about 70 cm above the striking surface is about 4 m/s. (Figure 3(c)). In comparison, the highest position of the hand is only about 50 cm and the maximum upward velocity 2 m/s.

In the present example with a beat rate of 150 beats/min (repetition period 400 ms), the preparation of the accented stroke lasts 260 ms approximately, counted from the impact of the last soft stroke (S1, S4) before the accented to the maximum elevation of the hand. This leaving 140 ms for the actual downstroke. The impact velocity of the tip reaches about 13 m/s, compared to 1 m/s for the soft strokes. These values correspond to about twice the hammer velocity at string impact in pianos at *ff* and *pp* respectively (Askenfelt & Jansson, 1991).

Note also the oscillating motion of the drumstick after the strong impacts (A1 and A2, Figures 2(a) and 3(a)). The tip of the rebounding stick bounces up to a position which is above the optimal starting position for the following soft blow. When not dampened by the player's hand the rebound will carry the stick high enough for another strong blow. (This is the mechanism the player takes advantage of when playing fast or demanding patterns, for example rolls.) In the present case, the influence of the player's dampening of the rebound can be seen as one period of an oscillating movement of the tip at about 8 Hz, corresponding to about a third of the beat period ($400/3 = 130$ ms).

Soft strokes

During the soft strokes, the position of the hand stays essentially constant, with a variation of only 5 cm approximately around a mean position about 12 cm above the striking surface. The motion of the tip is of course much larger, but gradually reduced during the sequence of the three blows from about 25 cm at a maximum at the first rebound to 10 cm at the third. As a consequence, there is a slow drift in mean α towards negative values superimposed on the periodic pattern of the three strokes. The angle at the impacts ($\alpha \approx -25$ deg) is not changed, however, as the elevation of the hand above the striking surface is not changed markedly. During the soft strokes the drumstick is consistently pointing downwards ($\alpha < 0$), the strong rebound after the accented blow excluded.

Discussion

The present study is of pilot character, utilizing a simple standard video recording with relatively

poor time resolution and a non-professional subject. Nevertheless, it seems reasonable to assume that it reveals some of the characteristic features of a performance of a drumming sequence with accented blows interleaved in a repeated series of soft strokes.

The observed smooth and relaxed performance could be assumed to be a general characteristic of professional drumming. A practiced player will try to minimize the use of sudden, forced, or jerking movements. If the drummer takes advantage of the rebound from the drumhead, the hand can be lifted high without much effort as in the preparation for the accented blows in the studied sequence. Not until the stick has passed its upper turning point an actual force delivery may be applied by the wrist (or fingers) to increase the speed. The result is a "whiplash" of the tip of the drumstick but the motion of the hand is smooth, resembling a fishtail-gesture.

This characteristic fishtail motion of the hand in the preparation and delivery of the accented blow is certainly used in other ways in drumming, like reaching a position on another drum far away in ample time. By starting the movement before the last note is finished the player gains time and thereby effort. While the hand and fingers still control the last stages of the present tone the lower and upper arm have already started to move in position for the next.

In order to ensure a free retreat of the drumstick from the drumhead the hand must be relaxed at impact. A strained hold of the stick will increase the contact time between stick and drumhead and cause a more dampened sound (which in some cases may be desired). Once, however, the rebound has carried the tip up and away from the drumhead the hand has to stabilize the stick if the following stroke is to be much softer than the previous.

Further studies already under way - using advanced motion detection equipment - will probably reveal more details in the motion of the hand and drumstick, especially during the most rapid events.

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