Introduction

It is well known that the movements of skilful musicians are developed from extensive practice and training sessions. Their movement patterns are gradually refined until they can perform the musical passages with the intended expression realised. These improved movement patterns evolve from many hours of practice in which the same musical sequences are repeated and the variability between the patterns decreases with practice. These countless repetitions seem to be a key component for fine-tuning the movement control system, so that fast, accurate and precise movements can be performed when playing a musical instrument (i.e., practice makes perfect).

In drumming the repetitive element is particularly evident as the production of rhythm itself is based on cyclic events. Percussion playing, in general, can require that the player perform the same rhythm on several different instruments with different physical properties (e.g., the stiffness of the drumhead and the mass, viscosity and shape of the mallet). Thus it seems reasonable to assume that a skilful percussionist will develop an energy efficient technique for playing that takes advantage of the effect of gravity on the arm and the dynamics of the striking tool (including the rebound). A stronger (accented) stroke would for example be achieved by initiating the stroke from a greater height (see Dahl 1997).

Methods

Three professional percussionists and one amateur were recorded with a Selspot motion capture system. The positions of the markers on the players’ arm, hand and drumstick were measured at a rate of 400 Hz. The striking force was registered by a force plate and recorded by a DAT recorder.

The task consisted of single strokes with interleaved accents played at three different tempi and three dynamic levels. To investigate the effect of the rebound on the movements, three different striking surfaces were attached to the force plate. Three different striking tools (drumstick, mallet and brush) were also used.

Figure 1: Schema of the experimental set-up

Figure 1: Schema of the experimental set-up
Results & Discussion
The movement trajectories for the marker on the drumstick for the four subjects are seen in Figure 2. The task was executed very consistently for each condition (in this case \textit{mf} at 200 beats per minute on a rubber surface), but the manner in which the four subjects played differed. While all subjects raised the striking tool to a greater height in preparation for the accented stroke the ratio between the preparatory heights for the unaccented and accented strokes differed considerably between subjects. Most markedly, subject S2 made the clearest distinction between the two types of strokes. The unaccented strokes were initiated from low height, whereas the path the drumstick follows in preparation for each accented stroke is seen as a wide loop, reaching shoulder height.

![Figure 2](image)

**Figure 2:** Trajectories of the drumstick seen from the four players’ left side. The sequence, consisting of single strokes with every fourth stroke accented, was played for 20 s at \textit{mf}, 200 beats per minute on a rubber surface. The four subjects executed the same instruction in different ways, but all four initiated the accented stroke from a greater height than the unaccented strokes.

The vertical displacement of the same marker vs. time for subject S2 playing, and the corresponding signal from the force plate can be seen in Figure 3. The raising of the stick in preparation for the accented blow is clearly seen. In fact, subject S2 starts to lift the stick already during the preceding stroke. This causes an angling of the stick, which is indicated by the higher position of the hit before the accent. After the maximum height the stick continues to describe a curved path towards the player (compare Figure 2) and the actual downstroke is initiated in a “whiplash” manner from about half the maximum height. Even if the preparatory movement seems exaggerated it did not cause the accented stroke to be delayed in time. Rather, it is the interval beginning with the accented stroke that is prolonged. Part of the explanation for this may be the strong rebound of the stick. The peak force for the accented strokes are about seven times as large as the unaccented and after the impact the stick is allowed to rebound and oscillate before the next stroke is initiated.

The consistency and the shape of the movement trajectories suggest that each subject have developed a “strategy” for the striking of an accented note. The strategy may differ according to the playing conditions (e.g., striking tool and surface) but also according to the interpretation. The different backgrounds the players had their main experience in (military snare-drum playing, classical percussion, jazz and rock drumset playing) may be reflected in the choice of striking force and the emphasis on the accented strokes relative to the unaccented. This emphasis was not only reflected in the striking force, but also in the timing between the strokes where all subjects showed a tendency of prolonging the interval beginning with the accented stroke.
Figure 3: Excerpt from the sequence played by subject S2 in Figure 2. The two panels show the vertical displacement of the marker on the drumstick vs. time (top) and the corresponding signal from the force plate (bottom). The red circles in the displacement signal indicate the hits. The peak force for the accented strokes are about seven times as large as the unaccented.

To summarise: playing a stroke stronger than the previous one is a simple task but it never the less needs a preparation in order to be well performed. The accented stroke is usually initiated from a greater height, which allows for an increased striking force with the least possible effort. More detailed analysis of the recorded data set is under way.

References

Acknowledgements
The author would like to thank the following persons for their help: Virgil P. Stokes for help with the experiment, first evaluation of data and comments on the abstract. Anders Askenfelt and Markku Haapakorpi for help with the setup of the experiment and Ingrid Sica for help with the preparation of the PDF-document.