Journal of New Music Research, 29 (2000), No. 3, pp. 225–233
0929-8215/00/2903-225$15.00

The Playing of an Accent – Preliminary Observations from Temporal and Kinematic Analysis of Percussionists*

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ABSTRACT

The movements and timing when playing an interleaved accent in drumming were studied for three professionals and one amateur. The movement analysis showed that the subjects prepared for the accented stroke by raising the drumstick up to a greater height. The movement strategies used, however, differed widely in appearance.

The timing analysis showed two basic features, a slow change in tempo over a longer time span ("drift"), and a short term variation between adjacent intervals ("flutter"). Cyclic patterns, with every fourth interval prolonged, could be seen in the flutter. The lengthening of the interval, beginning with the accented stroke, seems to be a common way for the player to give the accent more emphasis. A listening test was performed to investigate if these cyclic patterns conveyed information to a listener about the grouping of the strokes. Listeners identified sequences where the magnitude of the inter-onset interval fluctuations were large during the cyclic patterns.

INTRODUCTION

In music performance there are basic elements that – even though they may seem very simple – demand careful preparation to be well performed. Typical examples are the changing of hand positions on a stringed instrument, or the forming of the attack characteristics of a tone on a percussion instrument. Even such simple tasks need a well-established strategy in order to reach the intended result at the right moment.

All musicians interpret the score and some notes are given higher prominence than others. The three major means of giving a note more emphasis are to change dynamic level, duration and timbre. In contrast to many other musical instruments the timbre of most percussion instruments is not easily changed. Consequently, expressive changes in duration and dynamic level ought to be an important part of percussion playing.

As timing is crucial for the production of a rhythm, a player is forced to acquire some sort of strategy to fit expressive means into the rhythm. Any sudden change in the music, such as an accent, or a change of hand position on the instrument, has to be made without causing disturbance (or imbalance) in the phrase. Developing a technique for the preparation of these basic elements in playing will enable the player to perform them "automatically", with a minimum of attention and in a way which is well integrated with the music.

* Sound examples are available in the JNMR Electronic Appendix (EA), please see http://www.swets.nl./jnmr/jnmr.html

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In this study the playing of an interleaved accent in drumming has been investigated. This studied task is simple, but nevertheless something that needs preparation in order to be well performed. An overview of different strategies in movement and timing will be reported.

ACCENTS IN DRUMMING

In drumming, a common way to denote the character of a stroke preceding a sudden change in dynamic level is to use the terms *upstroke* and *downstroke*. These terms describe the desired final position of the stick in preparation for the next stroke. Together with the term for a soft, unaccented stroke, *tap*, they are commonly used to help the performer plan and carry out the right movements. Soft strokes will be played with the hand in a resting position about a decimetre above the drumhead and the drumstick barely rising above it, "tapping". Before a strong blow, the hand will need to lift up the drumstick after the preceding tap (upstroke), and then deliver the stroke. When strong strokes are repeatedly played the stick is usually allowed to bounce up to full height, *full stroke*. If the following stroke is to be a soft tap the stick must end up in the suitable lower position, downstroke. As an example, a pattern with interleaved accents every fourth note would then be played: Tap, tap, upstroke, downstroke, tap, tap, upstroke, downstroke etc. as seen in Figure 1 (Dahl, 1997).

The figure shows the orientation of the drumstick versus time during the playing of the rhythmic pattern described above. The stylised pictures were generated from data of the vertical positions of two points on a drumstick, taken from a standard video recording of an amateur playing the pattern described above at 150 beats/min (BPM, nominal beat separation 400 ms). The time separation between frames was 20 ms.

The unaccented, tapped strokes are of a gentle wave-like character. The stick is consistently pointing downwards and the angle towards the horizontal plane is small. 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. It can be noted that during the last hit in the sequence of three soft strokes (U1, U2), the hand has started an upward motion in preparation for the accented blow that follows (D1, D2).

A detailed description of the preparation for and execution of the second accented blow in the recorded sequence (D2) is shown in Figure 2 (Dahl, 1997). The numbered frames show the successive positions of the drumstick, some of them illustrated by inserted snapshots of the grip of the drumstick.

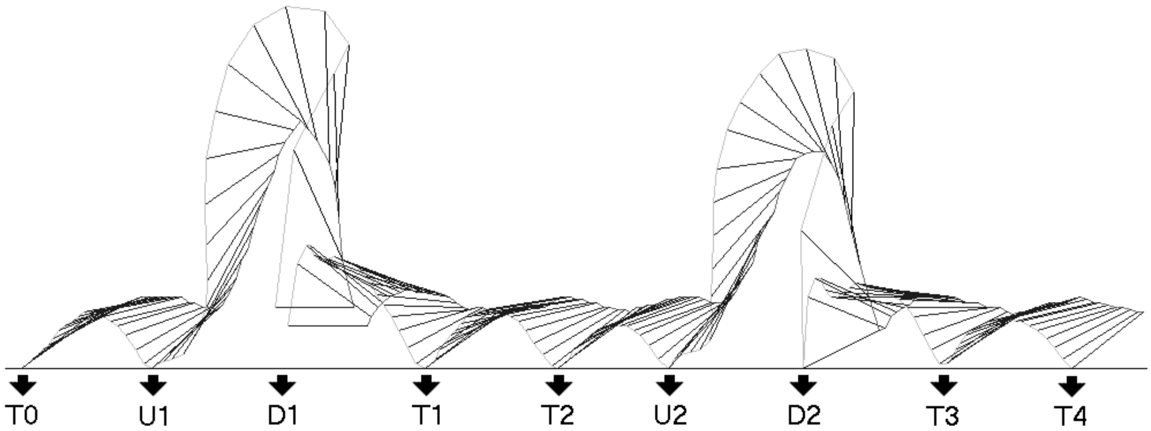

Fig. 1. Display of the position of the drumstick during a sequel of 8 strokes with a strong accent every fourth stroke. The hits on the striking surface (a practice pad) are indicated with arrows and marked with T for "tap", U for "upstroke" and D for "downstroke" (see text). The hit of the first accented 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 (the tip and the contact with the hand) taken from a standard video recording with a separation of 20 ms between frames.

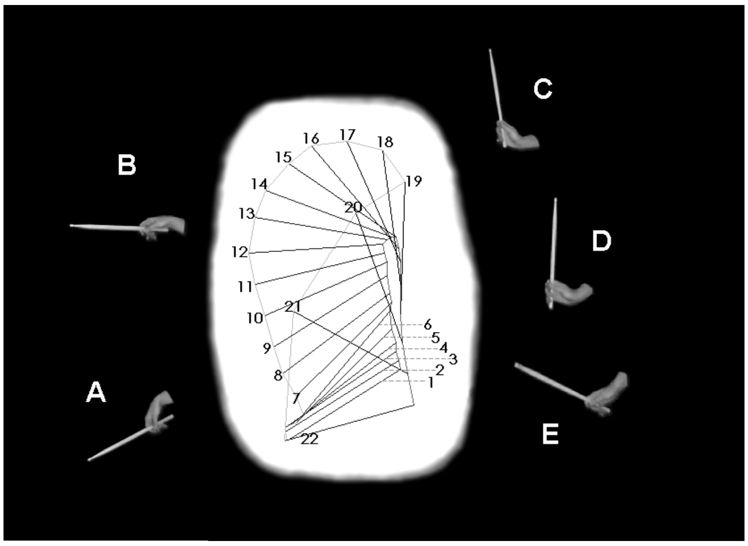

Fig. 2. Detailed view of the preparation of the second accented stroke (D2) in Figure 1. The figure shows the position of the drumstick in 22 numbered frames separated by 20 ms. The inserted snapshots (A – E) show the orientation of the hand and drumstick during the successive stages. Snapshot A corresponds to frames 1–4 (initial positions in the finals stages of the preceding upstroke U2), B to frames 12–13 (levelling), C to frame 18 (approaching vertical orientation), D to frame 19 (vertical "overshot"), and E to frame 21 (point of highest velocity, just before impact). The total time-span is 420 ms, counted from the hit of the preceding soft stroke (frame 1) to the hit of the accented blow (frame 22).

As the figure shows, the hand clearly starts the preparatory upward movement before the tip of the drumstick. The lead of the hand is about 100 ms before the tip moves upwards. Both the hand and tip then gain height quickly. The maximum velocity the tip reached on its way up to the turning point, which was about 70 cm above the striking surface, is about 4 m/s. In comparison, the highest position of the hand is only about 50 cm and the maximum upward velocity 2 m/s.

COMPARISON BETWEEN PLAYERS

In order to further investigate the preparatory movement for an accented stroke, a motion analysis was made of the performance of three professional drummers and one amateur. The movements were recorded using a motion detection system, tracing the displacement of clusters of LEDs on the player's right arm and on the drumstick. The players played on a rubber disc, with characteristics close to a regular practice pad, mounted on top of a custom-made force plate. All four subjects played a simple pattern consisting of single strokes with interleaved accents every fourth note at three different tempi and at three dynamic levels.

Figure 3 shows the trajectories of one of the LEDs at the tip of the drumstick, as seen from the players'

Fig. 3. Comparison of the motion trajectories of the tip of the drumstick for all 4 subjects playing an accent every fourth note. The patterns are the trajectories for one of the LEDs on the tip of the drumstick seen from the player's left side. All subjects played the described pattern at 160 BPM in *ff* for 20 s. Most obvious is the preparatory movement before the accented stroke, reaching above 70 cm for subject S2, while the displacement during the unaccented strokes generally stays below 25 cm (S1), 10 cm (S2), 31 cm (S3) and 38 cm (S4). All subjects show individual strategies for the playing of the accents, the shape and amplitude of the preparatory movement being very different.

left side, for each of the four subjects. The trajectories describe the path of the tip of the drumstick during 20 s of playing at *ff*, 160 BPM. Each subject has interpreted the task differently. This is clearly illustrated by the different shapes of the movement patterns. The preparatory movement for the accented stroke can be seen as the outer loop in each of the four patterns. For subject S2 the vertical displacement of the stick before the downstroke exceeds 70 cm, while the unaccented strokes remain at a height of about 10 cm. None of the other players displayed such large differences in the vertical position of the stick. The relationship between vertical displacement of the stick for the unaccented/accented strokes was about 25/41 cm (S1), 31/41 cm (S3) and 38/60 cm (S4). The different appearances of the movement patterns imply a variation in the strategies used by the players. These variations may reflect the different musical traditions in which the players are playing (jazz, classical, military and rock).

TIMING ANALYSIS

If we hypothesise that one of the reasons for the preparatory movement prior to the accent is to deliver the accent "on time" – how do these subjects perform in timing? This question was studied by analysing the inter-onset intervals (IOIs) for the 4 subjects and the 9 cases (3 tempi $\times$ 3 dynamic levels). Figure 4 shows the IOIs in sequence for the 9 cases for subject S1 (Dahl, 1998). Inter-onset interval number n is defined as the interval between stroke number n and $n + 1$. From the picture, two over-all observations can be made; the subject displays both a long term change in tempo ("drift") as well as short term variations between adjacent IOIs ("flutter").

The drift in tempo can be either increasing or decreasing, as shown in Figure 4. To estimate the drift across the sequences (20 s long), linear trendlines were fitted to the data. Typically the drift amounted to 0.2% per measure, when normalised relative to the

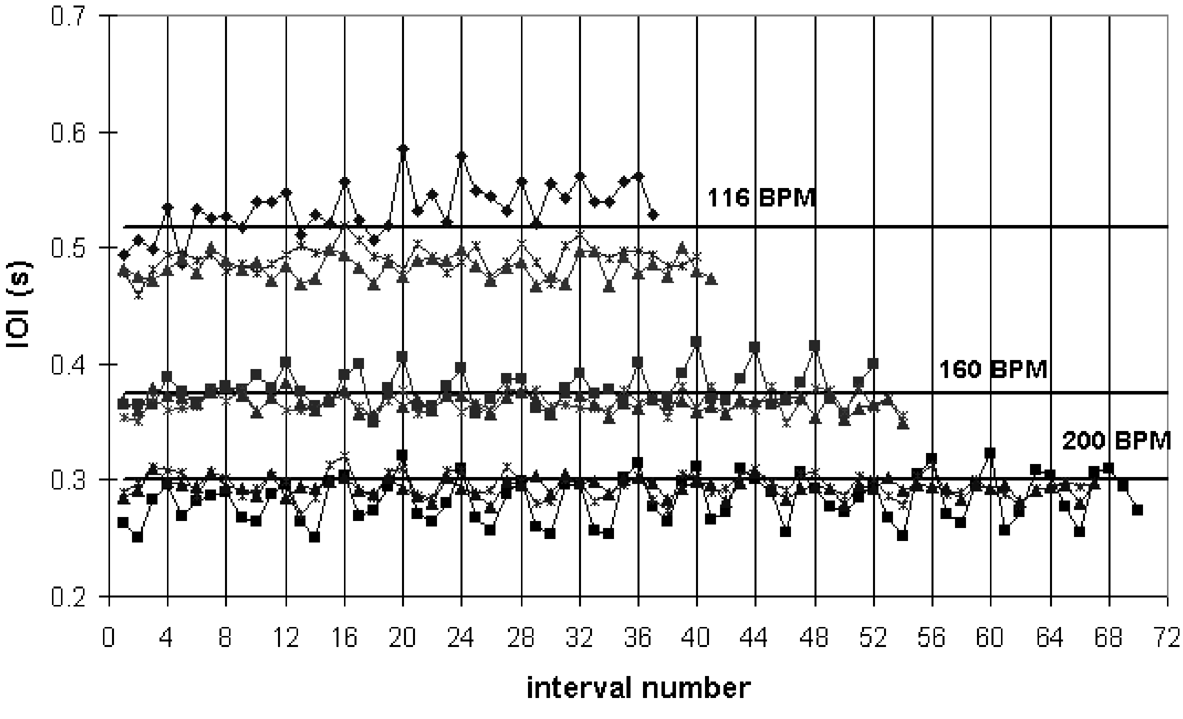

Fig. 4. Inter-onset intervals (IOIs) in absolute time for all combinations of tempo and dynamic levels for subject S1. The three dynamic levels are indicated by squares (*pp*), stars (*mf*) and triangles (*ff*). The full horizontal lines indicate the nominal tempi given by the metronome. Intervals 4, 8, 12... begin with an accented stroke. The drift and flutter are highest at *pp* level for this subject.

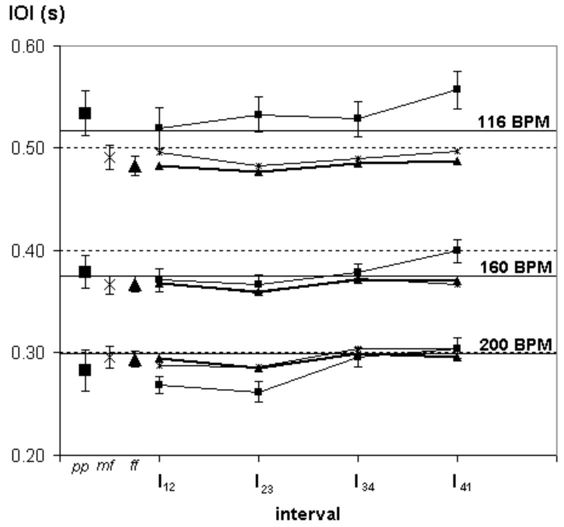

Fig. 5. Averaged IOIs across intervals I_{12}, I_{23}, I_{34} and I_{41} for each of the nine sequences (*pp–mf–ff*, 116, 160 and 200 BPM) for subject S1. The three dynamic levels are indicated by squares (*pp*), stars (*mf*) and triangles (*ff*). The averages are based on 10 values (116 BPM), 13 values (160 BPM) and 16 values (200 BPM). Grand averages across all intervals in a sequence are indicated by the symbols (*pp–mf–ff*) to the left of the curves. Standard deviations (vertical bar lines) are included in the *pp* sequences and the grand averages.

duration of the first measure. For this subject, the maximum drift was observed at *pp* 116 BPM (uppermost curve in Figure 4), reaching 0.9% per measure.

The full horizontal lines in the figure indicate the nominal tempi given to the players by a metronome before each recording. As seen in the figure the subjects did not always start in the tempo given, but had a certain offset. The largest offset was observed at 116 BPM reaching 50 ms (average of the four IOIs in the first measure). This corresponds to almost 10% of the nominal IOI of 517 ms, equivalent to a decrease in tempo of 10 BPM.

The flutter, i.e., differences between adjacent IOIs, reaches up to a maximum of 65 ms at *pp*, 116 BPM for this subject. For all subjects the averaged flutter across sequences ranged between 10–40 ms, or between 2–8% of the associated tempo.

Traces of a cyclic pattern in inter-onset intervals corresponding to the four note pattern performed by the players, can be seen in the data, most clearly illustrated in the intervals # 36–50 of Figure 4. Here every fourth interval is prolonged and the following interval (beginning with the first stroke of the next measure) is shortened. When averaging across all intervals in each of the four positions in each measure this pattern is clearly seen (see Fig. 5).

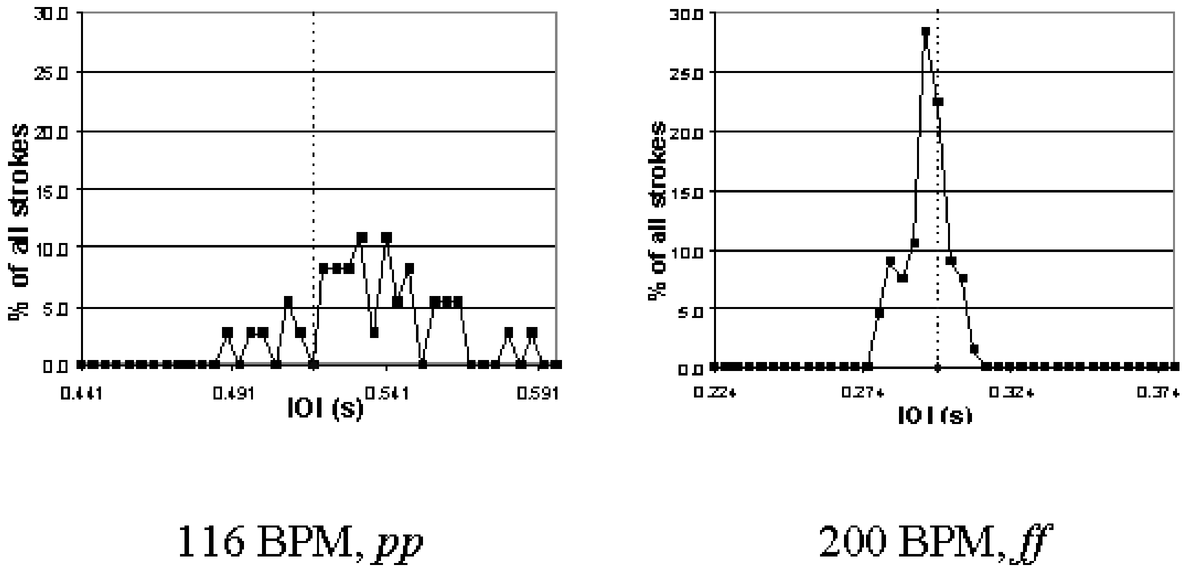

Fig. 6. Distributions of the inter-onset intervals (IOIs) for two cases for subject S1. The nominal tempi are indicated by the dotted lines. The data are collected in bins 4 ms wide. With increasing tempo and dynamic level the spread of IOIs shift from 100 ms (*pp*, 116 BPM) to 32 ms (*ff*, 200 BPM).

Figure 5 shows averages of all intervals between the first and second stroke in each measure (I_{12}), the second and third stroke (I_{23}) and so on for subject S1. The prolongation of interval I_{41}, beginning with the accented stroke, is most evident in the *pp* cases for this subject. The grand average across all IOIs in each sequence respectively is seen to the left. A tendency to increase the mean tempo when playing at a stronger dynamic level can be seen at the slowest tempo (116 BPM). When comparing all subjects, this tendency was observable for all three tempi.

The combined effect of drift and flutter can be seen when looking at the distribution of IOIs in Figure 6. The figure shows the distribution of IOIs for two of the 9 cases for subject S1 with the nominal tempo indicated by the dashed line. The variability is clearly largest at *pp* level, but decreases both with increasing tempo and dynamic level. At *pp* level 116 BPM, the IOIs vary between 489 and 589 ms (100 ms), while the spread is only from 280 to 312 ms (32 ms) at *ff* 200 BPM. When converted to percent of the mean IOI duration across the whole sequences, these limits correspond to 18.7% and 10.9% for the slow and fast tempo, respectively. In comparison, the JND for displacement of a beat in an isochronous sequence range between 2 and 5% of IOI, depending on the type of manipulation (see survey in Friberg & Sundberg, 1995).

LISTENING TEST

In order to investigate whether the cyclic patterns in IOI contained some information on the grouping of the notes, a listening test was set up. Four of the recorded sequences, together with one performance where irregular accents were played, were used for preparing synthesised files. The original data were

Table 1. Origin of the seven sequences used as stimuli in the listening test.

Sequence	Rhythm characteristics	Nominal tempo BPM	Dynamic level (original)	Performer
A1	accented 4/4 rhythm	160	*pp*	S1
A2	accented 4/4 rhythm	160	*pp*	S3
A3	accented 4/4 rhythm	200	*pp*	S3
A4	accented 4/4 rhythm	160	*mf*	S2
S	irregular accents (Stravinsky)	200	*ff*	S2
I	isochronous	160	–	–
W	clear 3/4 rhythm	157	–	–

Table 2. Relative occurrence of the 10 percussionists' placements of the sequences. The categories receiving the highest ranking for each sequence is given in bold. The expected grouping according to the score (recorded files) and to the specified timing patterns (synthesised files) respectively is shown shaded.

Sequence	Rhythm characteristics	no group %	2 group %	3 group %	4 group %
A1	4/4 rhythm	27	10	7	**57**
A2	4/4 rhythm	37	**43**	3	17
A3	4/4 rhythm	3	3	0	**93**
A4	4/4 rhythm	17	37	0	**47**
S	Irregular	**50**	27	20	3
I	isochronous	**67**	17	13	3
W	3/4 rhythm	3	13	**73**	10

Table 3. Relative occurrence of 10 novices' placements of the sequences. The categories receiving the highest ranking for each sequence is given in bold. The expected grouping according to the score (recorded files) and to the specified timing patterns (synthesised files) respectively is shown shaded.

Sequence	Rhythm characteristics	no group %	2 group %	3 group %	4 group %
A1	4/4 rhythm	23	23	17	**37**
A2	4/4 rhythm	30	13	10	**47**
A3	4/4 rhythm	7	0	17	**77**
A4	4/4 rhythm	0	**67**	13	20
S	Irregular	**53**	10	10	27
I	isochronous	**47**	30	7	17
W	3/4 rhythm	13	27	**47**	13

used as a timing template onto which one recorded stroke in *mf* was repeatedly pasted. In other words, the original strokes were replaced by a standardised stroke. In this manner only the timing information of the recorded sequences remained, leaving out dynamic level. Two completely artificial files were also synthesised, one fully isochronous and one with the repetition of the IOI-pattern 375, 375, 400 ms (groups of three strokes). A summary of the seven files used as stimuli is seen in Table 1. The synthesised files were replicated in three versions that differed in the amount of initial silence (0.5, 1.0 and 1.5 s) and "fade in". This was done to minimise the risk that the listeners grouped the strokes from the first stroke heard.

Two groups of subjects listened to the test sequences: 10 percussionists (professionals or advanced students) and 10 listeners without any musical training at all (novices). The listeners were asked to sort the sequences into four categories according to perceived grouping of strokes: groups of 2, 3 and 4 strokes, or no groups at all. Sorting was made possible using listening test software (Granqvist, 1996), by which the listeners could listen to each sequence as many times as they found necessary. A vertical scale was provided for the listeners to indicate how convincing the grouping of strokes had been.

The results of the listening test are presented in Tables 2 and 3. The tables display the relative occurrence of the listeners' placement of the sequences into the four different categories. An occurrence of 100% would mean that all 10 subjects placed all three versions of a sequence in the same category. In the tables, the category receiving the highest relative occurrence has been printed in bold for each sequence. In most cases, the perceived grouping follows the expectations according to the score (recorded files) and to the specified timing patterns (synthesised files), respectively.

Three of the IOI sequences which are of particular interest are shown in Figure 7: A4, subject S2 playing *mf* 160 BPM (top); A2, subject S3 playing *pp* 160 BPM (middle) and A3, subject S3 playing *pp* 200 BPM (bottom). The score was identical for all three sequences, quarter notes in 4/4 meter with an interleaved accent every fourth note. The three sequences show examples of different cyclic patterns in IOI (groups of 2 strokes, 4 strokes or no groups at all), and the placement in the categories differed between listeners.

Sequence A3, at the bottom of Figure 7, where every fourth interval is most clearly prolonged, was placed repeatedly in the 4 group (93% of times by percussionists and 77% by novices). In contrast, sequence A2 (in the middle), was placed in the 4 group only 17% of times by percussionists and 47% of times by novices. This is interesting since in both cases the instructions to the performer (subject S3) were the same, except for the nominal tempo. Both sequence A2 and A3 show evidence of cyclic patterns with every fourth interval prolonged, but the

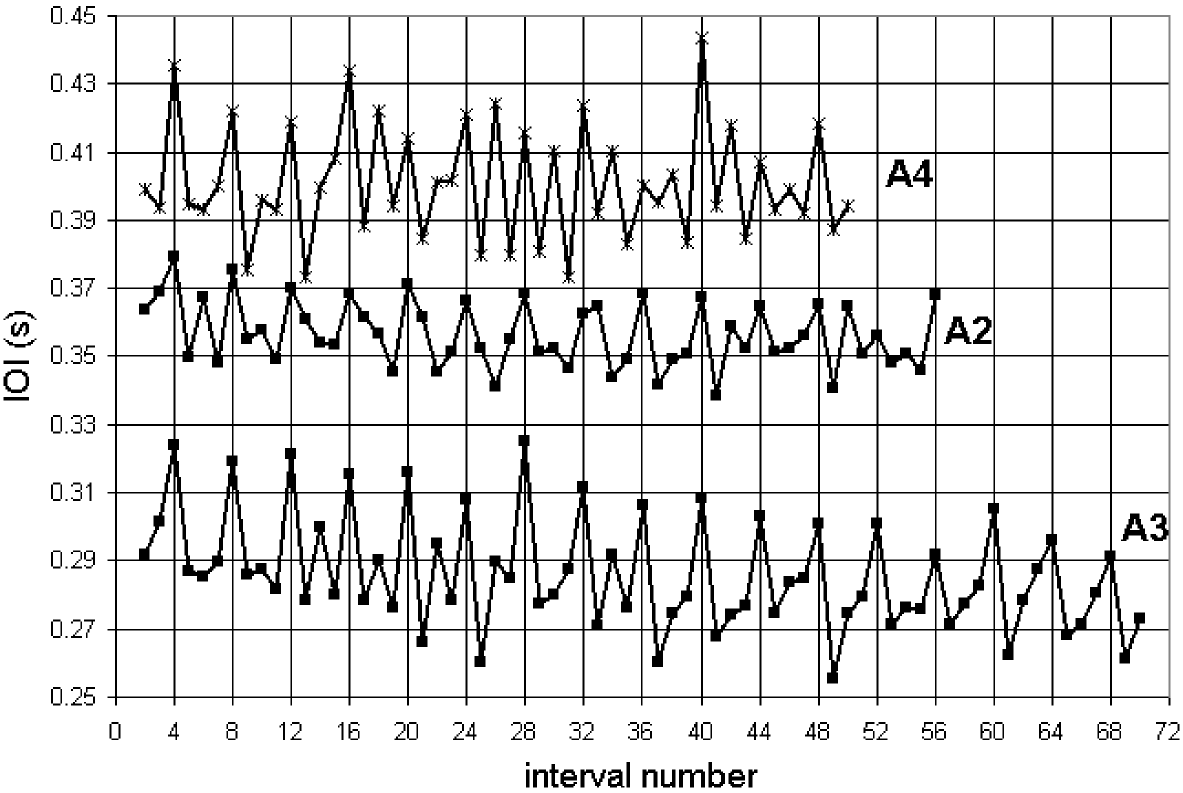

Fig. 7. Timing data for three of the sequences used in the listening test. The sequences were compiled from one recorded stroke replicated at the measured positions in time from; A4, subject S2 playing *mf* 160 BPM (top); A2, subject S3 playing *pp* 160 BPM (middle) and A3, subject S3 playing *pp* 200 BPM (bottom). The upper sequence display cyclic patterns of groups of 2 strokes (see e.g., interval # 24–32) as well as groups of 4 strokes (interval # 1–16). The patterns in the two lower sequences display groups of four strokes, although with different character. The differences in character of the three sequences were reflected by the results of the listening test (see text).

magnitude of the IOI fluctuations during the cyclic pattern differ. For sequence A2 the magnitude is relatively low, about 25 ms or 7% (normalised to the average IOI for the whole sequence), while sequence A3 displays a magnitude in the order of 40 ms, corresponding to 14%. Thus it seems that the magnitude of the IOI fluctuations is of importance to convey the grouping information to the listeners.

DISCUSSION AND CONCLUSIONS

The results of these studies show that there are large differences among players in the individual interpretations of a given task. This is most evident in the motion trajectories which describe the preparation for the accent in the played pattern. Although there are large differences between the subjects' execution of the preparatory movement, the common aim seems to be to raise the stick up to a greater height from where the accented downstroke is initiated. A high starting position of the downstroke makes it easier to achieve large contrasts in dynamic level between the accented and unaccented strokes.

The upward movement of the hand starts while the tip of the drumstick is still in contact with the striking surface (the drumhead or the practice pad). This requires the player to take advantage of the rebound from the instrument. When playing at soft levels, however, this rebound is very weak which makes the playing more difficult to control. This is reflected by the considerably larger range of IOI at *pp* and the slowest tempo (100 ms compared to 32 ms at 200 BPM *ff*).

If less dynamic difference between the unaccented and the accented note is desired, it is possible that the preparatory movement need not be so elaborate. An extra angling of the wrist might suffice.

Judging from the generally large preparatory movement prior to the accented note (see Fig. 3) the accented note might be expected to arrive a little late. Instead, when cyclic patterns occur, it is the following, unaccented, stroke that is delayed. This implies that the accented note is given more emphasis both in terms of dynamic level as well as in duration. Lengthening is a common means of marking accents in music and speech (Carlson et al., 1989). Such a pattern with a prolonged interval after the accented blow does not necessarily occur throughout a whole sequence. Still, as the listening test showed, this does not seem necessary in order to convey grouping information to the listener. It could be that the temporal information is only needed as a trigger every now and then for both player and listener.

In summary, the playing of an accent in drumming is a simple task but it may be manifested in many ways. The goal, however, is the same: to emphasise the accented note. In addition to the evident use of the dynamic level, lengthening of the duration of the interval beginning with the accented stroke seems to be a major means of implementing an accent in drumming.

Further analysis of the motion and timing data is under way, including statistical significance of the findings.

ACKNOWLEDGEMENTS

The author is indebted to Markku Haapakorpi and Virgil Stokes for their assistance in the movement experiments, to Svante Granqvist for preparation of picture sequences and help with the correlation program and to Peta White and Anders Askenfelt for valuable comments on the manuscript. Special thanks are due to the three professional percussionists and the subjects in the listening test. These studies were part of the project Music and Motion supported by the Bank of Sweden Tercentenary Foundation.

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