Use of Self Organizing Maps in Technique Analysis

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Abstract

This study looked at the coordination patterns of four participants performing three different basketball shots from different distances. The shots selected were the three-point shot, the free throw shot and the hook shot; the latter was included to encourage a phase transition between shots. We hypothesised lower variability between the three-point and free throw shots compared to the hook shot. The study uses Self-Organizing Maps (SOM) to expose the non-linearity of the movement and to try to explain more specifically what it is about the coordination patterns that make them different or similar.

The SOM proved to draw the researcher's attention to aspects of the movement that were not obvious from a visual analysis of the original movement either viewed from video or as computer animation. A speculative link between the observational learning literature on the importance of the kinematics of distal segments in skill acquisition and the visual information a coach or analyst may rely on for qualitative technique analysis was made. Although making the distinction between the three shooting conditions was meant to be a trivial exercise, in many cases for this dataset the SOM output and the natural inclination of the movement analyst did not agree: the SOM may provide a more objective method for explaining movement patterning.

Keywords: artificial neural networks, basketball shooting, movement coordination, movement variability, self-organizing maps.

Introduction

The objectives of this paper are to consider the results of a study using self-organizing maps (SOMs) of the coordination patterns of four participants performing three different basketball shots from different distances and to use the results of this study to reflect on the strengths of using SOMs in analysing sports movement techniques compared with more traditional approaches.

The free throw is a set shot that is awarded most commonly when an offensive player is fouled during the act of shooting. Each foul usually results in the offended player being awarded two free throws, which makes the free throw shot an important skill. The three-point shot is a more strategic shot; the probability of making the shot is much less but the reward is higher. The three-point shot is from further away than the free throw and is often performed in the presence of defenders. For these two reasons the three-point shot is almost always performed as a jump shot – both to afford more power for the shot and to release the ball higher thus reducing the chance of the defender blocking the shot. The shortest shot was a 4 m hook shot, in which the participants started facing away from the target, they would then turn and shoot. The hook shot is a lower percentage shot but, because of the release point, it is very difficult to defend. A ball release of a

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good hook shot is situated so the shooter's body is between the ball and the defender thus protecting the ball from being blocked.

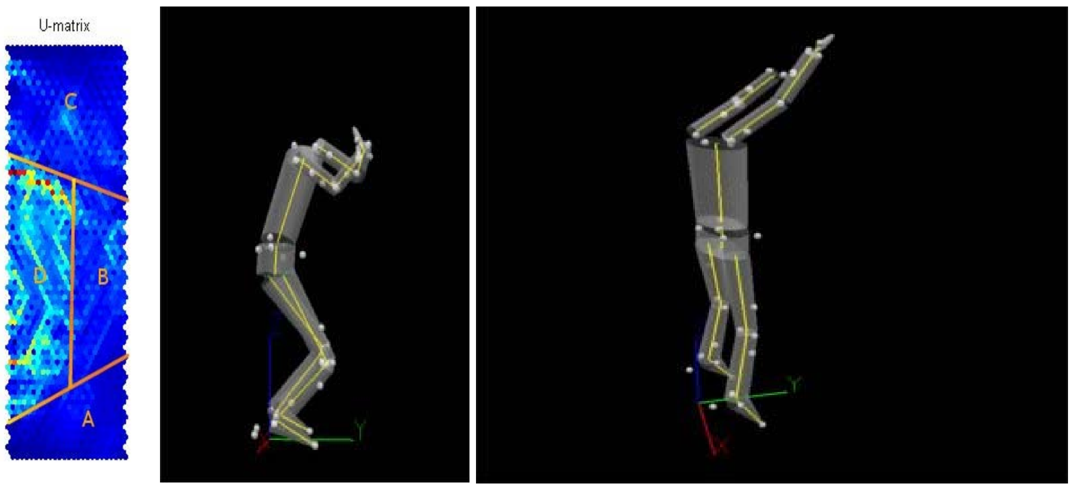
Methods

The input data for the SOM were time series (normalised to 101 data points) for sagittal plane joint angles from 10 free throws, hook shots and three-point shots of four experienced players. The SOM was trained on the dataset using files in the *SOM toolbox for MATLAB*. The network was initialised using the principal components technique in the 'lininit.m' function file in the toolbox. The initialisation resulted in a 42 by 13 node lattice for the output map. The 'data block' was passed to the 'som_make.m' function file with five rough training phases and 30 fine-tuning phases set as training parameters for the batch training algorithm. In the rough training phase the initial neighbourhood radius was set to six and the final radius to 1.5. The fine-tuning phase began with a neighbourhood radius of 1.5 and decayed to 1. Neighbourhood sizes were selected by default based on characteristics of the data. The quantisation error was 0.277 and the topographical error 0.031.

Results

Qualitative Analysis

We chose to use the U-matrix (Figure 1.a) to visualise the output of the SOM. The nodes at the bottom of this figure represent the preparation phase of the shot, to the position indicated in Figure 1.b. Region B represents the action – or extension – phase of the movement, from the end of the preparation phase until the release phase. The release phase (Figure 1.c), lasting until the right wrist reached its maximum height, is region C on the U-matrix.



(a) (b) (c)

Figure 1. a) U-matrix and movement phases: A Preparation, B Extension (Action), C Release; D Unique movements; b) End of preparation phase; c) Release.

Typical trials passed from region A through B to C. If the movement was coordinated differently, the nodes in region D were activated; this region seemed to be reserved for unique movement patterns. Bright colours on the U-matrix denote larger difference between the weights of neighbouring output nodes. In effect, the brighter coloured areas can be conceived as 'higher weight walls' separating output nodes.

Our analysis has consisted of: qualitative analysis of the network output as a U-matrix; quantitative analysis of best matching unit similarity, expressed as Euclidean distances between trajectories, between shots and players. These have been supported, where relevant, by viewing computer animations of the shots.

The orange trajectory visualisations on the U-matrix (Figure 2 a,c,e) give a representation of the order of the best matching units with respect to time – basically from bottom to top. However, the trajectory can potentially be misleading as it gives the impression that the best matching units move fluidly through the U-matrix. Visualising trials with just the best matching units highlighted in white on black shows the discontinuity on the U-matrix for this dataset. On these 'node-hit' diagrams (Figure 2 b,d,f), the best matching units are coloured white and their size increases as the frequency of hits increases. For these units to stand out the rest of the U-matrix is blacked out.

The trajectories for the three-point shot and free throw are visually similar in Regions A and C of the U-matrix, suggesting that the coordination patterns in the preparation and release phases were similar. The trajectories differ in the middle area of the map, in Region B, the extension phase, in which the three-point shot moves closer to the right edge of the map (Figure 2.a) than the trajectories for the free throw (Figure 2.c). The trajectory for the hook shot (Figures 2 e,f) is qualitatively different from the other two shots for Player 1. The main visual difference in best matching unit trajectories was seen as the trajectory moves diagonally up and across the U-matrix in Region C.

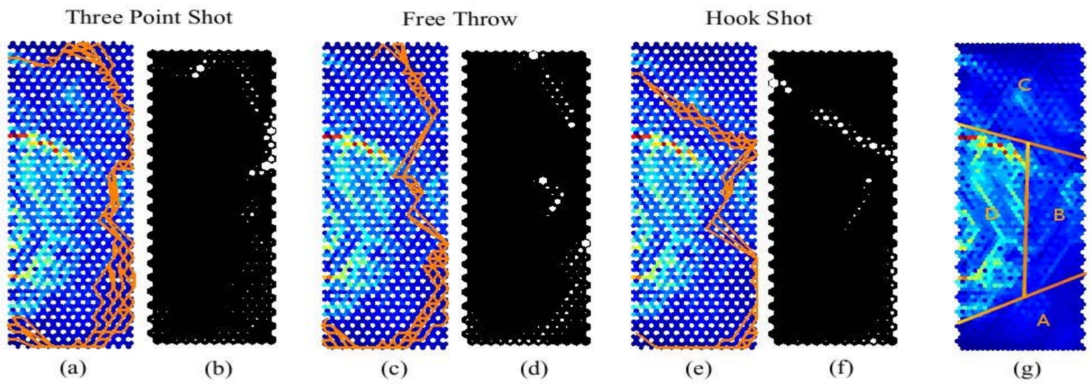


Figure 2. Qualitative trajectory analysis, Player 1. a) Three-point shot, U-matrix; b) Three-point shot, node hit diagram; c) Free throw, U-matrix; d) Free throw, node hit diagram; e) Hook shot, U-matrix; f) Hook shot, node hit diagram; g) U-matrix with movement phases.

For Player 2 (Figure 3), the preparation phase for the three-point shot and the free throw are almost identical, occupying many of the same nodes and clustering similarly. During the release phase, the three-point shot moves diagonally up and to the left from the right edge of the map in Region C (Figures 3 a,b), similarly to the three-point shot and free throw of Player 1. The diagonal movement on the U-matrix of the free throw is not as long or as consistent as the three-point shot (compare Figure 3.a with Figure 3.c). The hook shot (Figure 3 e,f) is, again, qualitatively different from the other two shots. Unlike all other shooting conditions for all other players, the best matching unit trajectory for the hook shot for Player 2 does not always progress upwards on the U-matrix. For many trials the best matching units start in Region D and then move down into Region A. The node hit diagram in Figure 3.f shows the best matching units for most of the movement are within two brightly coloured borders in Region D of the U-matrix. This is different from any other shots in the dataset.

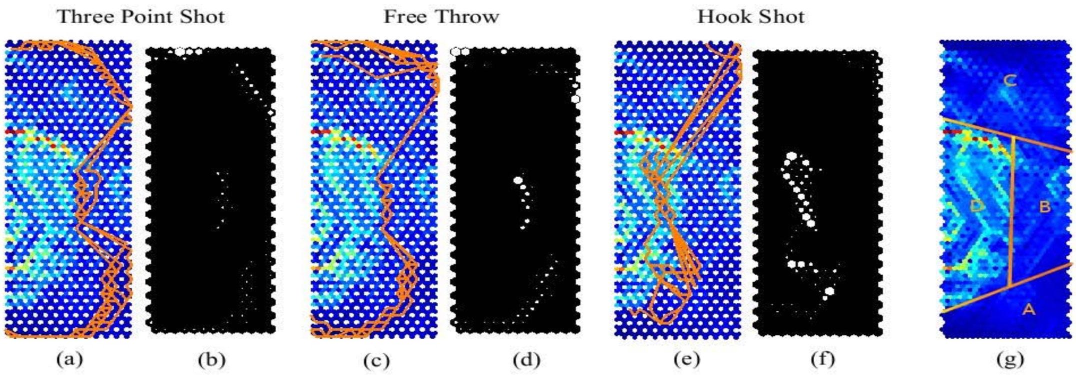


Figure 3. Qualitative trajectory analysis, Player 2. a) Three-point shot, U-matrix; b) Three-point shot, node hit diagram; c) Free throw, U-matrix; d) Free throw, node hit diagram; e) Hook shot, U-matrix; f) Hook shot, node hit diagram; g) U-matrix with movement phases.

The best matching unit trajectories for Player 3 are similar for the three-point shot and the free throw (Figures 4 a,c). The node hit diagrams show a large discontinuity as the movement transitions from preparation to release (see Figure 4 b,d). The trajectory jumps from Region A to a series of about three different nodes in Region D before jumping into Region C for the release phase of the shot. The jump into Region D is different from any of the other shots in the dataset. The hook shot is visually much different from the three-point shot and the free throw; it stays within Region D, without jumping across any borders, and along a very consistent trajectory of nodes (Figure 4 e).

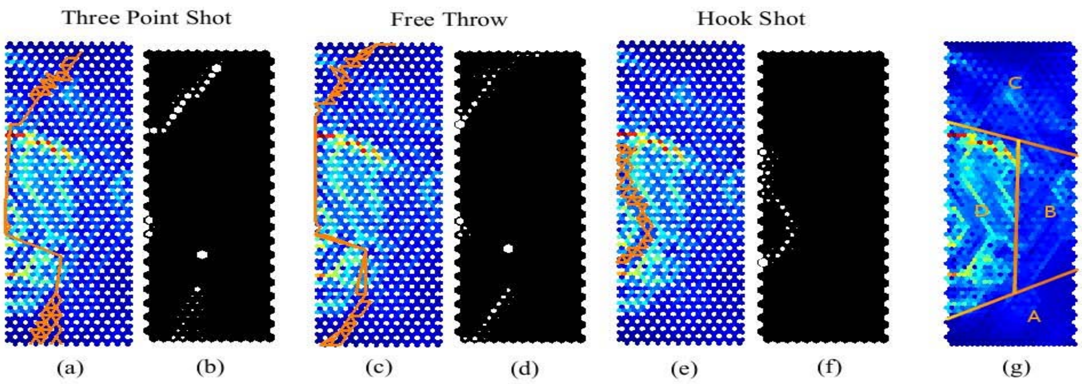


Figure 4. Qualitative trajectory analysis, Player 3. a) Three-point shot, U-matrix; b) Three-point shot, node hit diagram; c) Free throw, U-matrix; d) Free throw, node hit diagram; e) Hook shot, U-matrix; f) Hook shot, node hit diagram; g) U-matrix with movement phases.

For Player 4, the trajectories for the preparation phase of each shot are different. The three-point (Figure 5 a,b) and hook shot (Figure 5 e,f) best matching units were in Region A, as expected, whereas the free throw (Figure 5 c,d) began in Region D. In Region B, the three-point shot and hook shot trajectories travel to the left of the brightly coloured border near the right edge of the U-matrix whereas the free throw travels to the right of the border. The hook shot was by far the most variable in regions A and B. The release, shown in Region C, of the three-point shot and the free throw are quite similar, as shown in Figure 5 a,c. The release of all three shots of Player 4 resemble the release of Player 1. The trajectories for the three-point shot and the free throw move above the brightly coloured border in the middle of Region C, while the trajectory for the hook shot moves below the bright border.

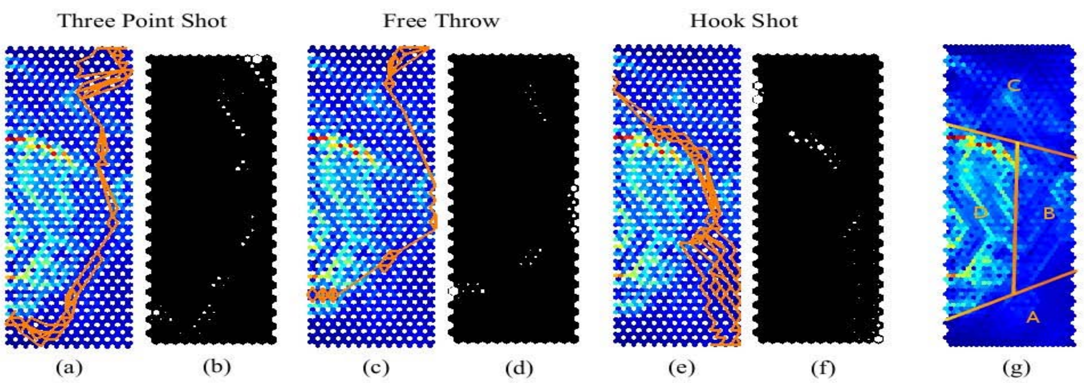


Figure 5. Qualitative trajectory analysis, Player 4. a) Three-point shot, U-matrix; b) Three-point shot, node hit diagram; c) Free throw, U-matrix; d) Free throw, node hit diagram; e) Hook shot, U-matrix; f) Hook shot, node hit diagram; g) U-matrix with movement phases.

Quantitative Analysis

Assessing the variability within each shooting condition for each player (Figure 6) reveals the obvious outlier to be Player 2's hook shot. The hook shot trials of Player 2 showed a much higher Euclidean distance between them than the other shot types for Player 2 and all shot types for the other three players. This finding is also supported by the individual trial trajectories in the previous sub-section.

We had hypothesised that because the coordination pattern for the three-point shot is formed based on the set shot used for the free throw, then for each player the three-point shot and the free throw would be more similar to each other than either would be to the hook shot. This hypothesis appears true for Player 2 and Player 3 but not for the other two players (Figure 7). The three-point shot and the hook shot were more similar than the three-point shot and the free throw for Player 1 and Player 4, although only marginally for Player 4.

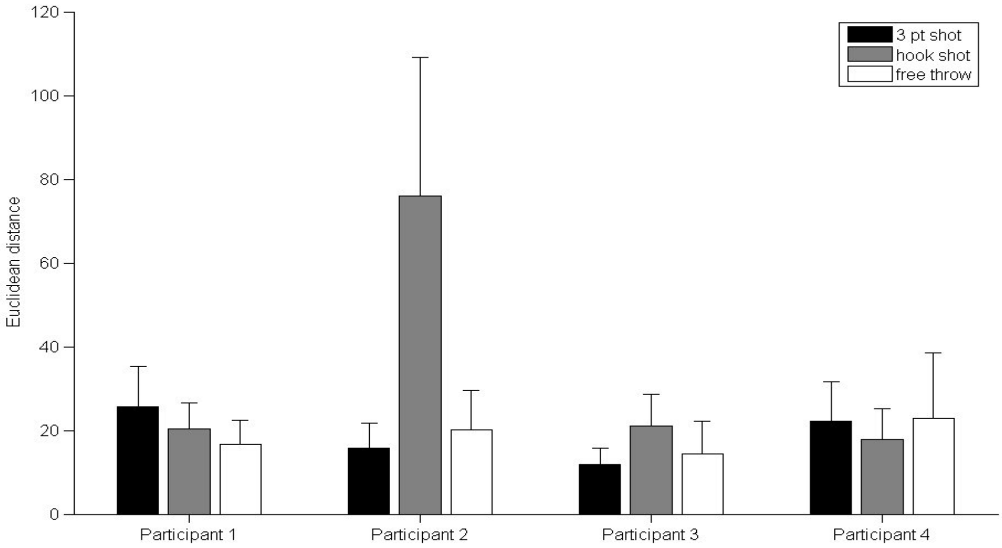


Figure 6. Quantitative analysis of within-player trajectory variability

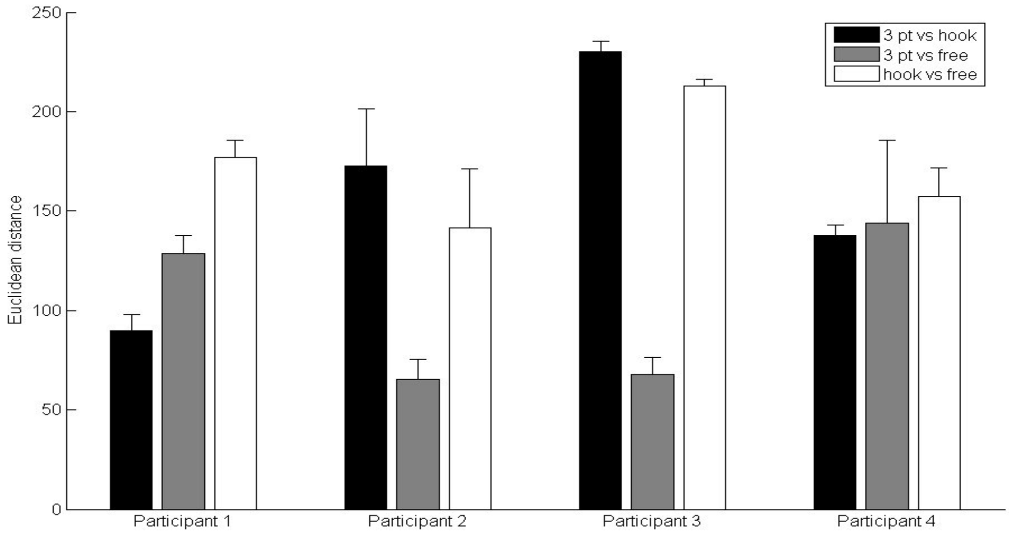


Figure 7. Quantitative analysis of trajectory variability between shooting conditions

Overall, the three-point shot was most similar across all players (Figure 8). The three most dissimilar three-point shot comparisons however, were all comparisons with Player 3, whose three-point shot was unique in passing through Region D. The hook shot bars are immediately noticeable as the largest except for the comparison between Players 1 and 4. This is due to the unique hook shots of Players 2 and 3.

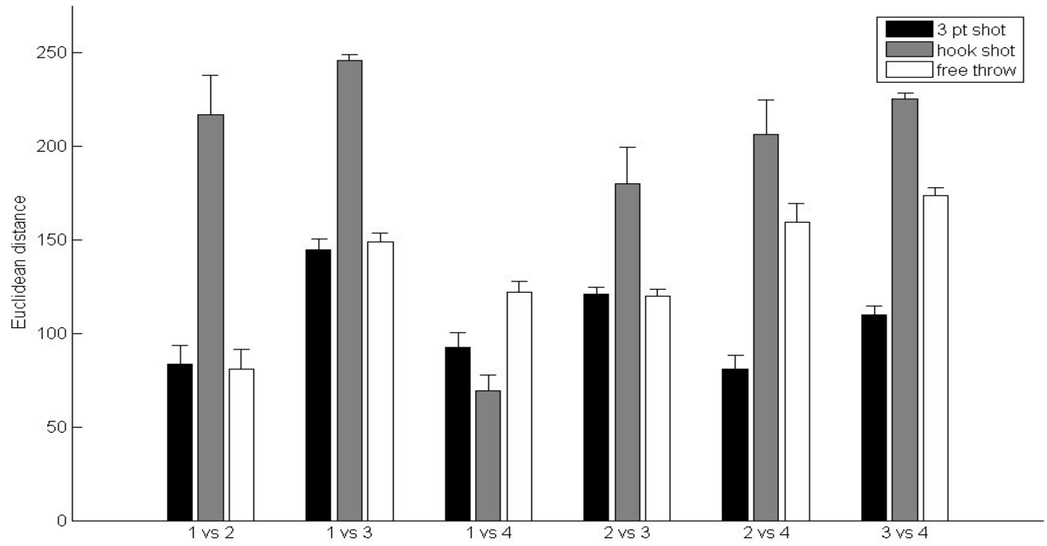


Figure 8. Quantitative analysis of trajectory variability between players

Discussion

The Jump Hook

Qualitatively, Player 1 supported the hypothesis that the three-point shot (Figure 2.a) and the free throw (Figure 2.b) would be most similar only for the preparation and release phases. Although all time frames of the movement were weighted equally, the SOM quantitatively classified the data for the three-point shot and hook shot in the extension phase to be a larger contributor to overall similarity, partly because of a slight delay at mid-flight between lower and upper body extension in these shots. Overall, the quantitative analysis of trajectory variability between shooting conditions showed the lowest variability for the three-point versus the hook shot; during the late extension phase and the beginning of the release of the shot, the three-point shot showed more similarity with the hook shot than with the free throw. This is shown in Figure 7 (participant 1). The free throw and three-point shot showed the next shortest Euclidean distance and the free throw and hook shot the largest.

For the three-point (Figure 5.a) and hook (Figure 5.e) shots, many similar nodes were activated in the extension phase (region B, Figure 5.g) for Player 4, adding further evidence to the idea that the kinematics involved in the jump in these two shots contribute to the data for each of these shooting conditions being more similar to each other than to the free throw, which does not involve a jump. The release phase of the three-point shot (Figure 5.a) and free throw (Figure 5.c) showed more similarity on the U-matrix. This was expected since the three-point shot and the free throw are two-handed shots, whereas the hook shot is a one-handed shot. Viewing the computer animation, the noticeable difference between the three-point shot and the free throw for Player 4 was the in-phase extension of the upper and lower body, while for the free throw the knees and hips reached maximum extension while the upper arms continued to flex and the elbows and ankles continued to extend. The upper arms then stopped, leaving both the ankles and elbows still extending – a somewhat atypical sequence. This sequence is shown on the U-matrix by nodes between the edge of the map and the right-most brightly coloured border in Region B (Figure 5.c). Player 4's free throw was the only shot for any of the players to activate these nodes.

The best matching units for the release phase of the hook shot for Players 1 and 4 were very close; this was supported by the short Euclidean distance for the hook shots between Players 1 and 4 (Figure 8, 1 vs 4). The high dimensionality of the time series data for these throws makes an in-depth, visual analysis of coordination difficult using conventional methods. Research into the information attended to in visual demonstrations has shown that the kinematics of distal segments (arms) has a greater impact than the kinematics of more proximal segments (legs) in skill acquisition. This may be used as evidence suggesting that certain information biases the movement analyst. Since the major difference associated with the hook shot compared to the other two shots is the one handed release, one could speculate that the movement of the distal segments over-influence the analyst into classifying the hook shot as a completely different movement. If this is the case, the SOM might provide a more objective method for analysing human movement than the traditional analysis of multiple time series data.

The Standing Hook

Qualitatively, the three-point shot and free throw, for both Player 2 (Figure 3 a,c) and Player 3 (Figure 4 a,c), were similar to each other for not only the preparation and release phases of the movement, as for Player 1, but also the extension phase of the movement. The hook shots were qualitatively different for each phase and occupied Region D on the U-matrix (Figure 3.e; Player 2: Figure 4.e; Player 3). Unique to Players 2 and 3 were that their hook shots lacked a significant jump along with an early release of their three-point shot. The jumping kinematics that separated the three-point shot and the free throw for Players 1 and 4 were much less pronounced for Players 2 and 3, reflected quantitatively in the short Euclidean distance between the three-point shot and free throw (Figure 7, Participant 2, Participant 3).

Conclusions

The SOM drew our attention to aspects of the movement that were not obvious from more traditional approaches – such as visual analysis of the original movement from video or from computer simulations, or from multiple time series data. In several cases, the SOM output and our natural inclinations as movement analysts did not agree; SOMs thus proved to be a useful tool in our analysis of coordination. The movement analyst might be distracted by visual information in the movement; the SOM might provide a more objective method for explaining movement coordination. This certainly warrants further research.