Characterization of tea whisking by Japanese Tea Ceremony performers

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Abstract: We have been able to prove that subtle, small differences in the movements of practitioners of the Japanese Tea Ceremony are not trivial and thus are enough to characterize the whisking. This characterization showed that the practitioners follow a path that is where the motion converges to. In order to produce the movements over this track, the whole arm is needed. We have demonstrated that coordination is a key element of a good whisking action. By this effect, we have introduced the skills of the Japanese Tea Ceremony practitioners to the light of skill science.

Introduction

Human beings move all day, every day. It seems like a trivial subject to most due to the nature of it; it just happens. We have the ability to assess how difficult for us is the movements someone else is doing, to know within a matter of seconds if someone is better at dancing, for example, than other person. Nevertheless, putting this 'difference' into words is quite a hard task. Pinpointing the explanation behind a particular motion is not trivial.

Combinations of motions that produce a certain specific goal, motion skills, are of particular importance. Humans have created, developed, and shared physical skills for centuries. People strive to become better at them, whether it be playing musical instruments, performing a dance, or scoring a goal. For many years most of the secrets of these combinations of movements have been hidden in a dimension that is not easy to grasp by common means; they were simply too difficult to describe. But in the present day, thanks to computational techniques, more information can be obtained from the skills of the masters and be used for the advantage of new people that want to learn more effectively or even get to levels not achievable before. This is why the study of motion skills is relevant.

Japanese people have a particularly heavily tacit knowledge-dependent way of teaching their crafts to the next generations. As Kondo [1] mentions, the mentality is that the body learns by doing and that the techniques just stick to the body. This is especially true in the traditional 'ways' of arts that follow a Zen ideology in its foundations. Calligraphy, flower arrangement, and karate, among others, have in common the ideas of incorporating both body and mind into the practice of their craft. Out of these, Japanese traditional tea ceremony stands as an interesting example of tacit knowledge, even being mentioned as so by Nonaka [2] and Takeuchi [3], who helped introduced such term. The honing of the skills of performers of the way of the tea will be our main focus in this research.

Traditional Japanese Tea Ceremony has been around for centuries and its practices, along with the characteristic motions that are related to them, have not changed much since the age of *Sen no Rikyū*. It has been the subject of a wide variety of research, from anthropology to gender studies due to its morphing role in society through the years. Nevertheless, not much attention has been put on the way the practitioners move or learn these motions. In the present research we change that.

Motivation of the study

The present study serves to fulfill two purposes: shedding more light about the embedded information in the motion of the practitioners of *Chado* (The way of the tea) and to introduce a new activity to the attention of the skill science community. Japanese tea ceremony has, by its own will and nature, retained old teaching traditions that hide too much knowledge in the tacit domain. This has made recruiting new students harder as time goes by, because people nowadays, especially young people, do not have as much time and

patience as before. We hope that this research will contribute to making learning Chado easier for new people.

Motion skill is a field that has been growing in recent years due to the increase of computational power and the appearance of new techniques. Studies have been done in a wide variety of activities such as playing music instruments [4], dancing samba [5], and kneading clay [6]. Which this research, we wish to add Tea Ceremony to that list with the attention of attracting more people to research into this interesting activity from something different that the social sciences.

Objective of the study

Comprehend and characterize the physical actions of Japanese Tea Ceremony practitioners while whisking. And also to find the similarities and differences between Masters and Novices while whisking.

Experiment

For this research, a tool that could detect in to a fine precision the movement of the subjects that at the same time was not invasive and facilitated data analysis was necessary. In present day, motion capture systems that rely in markers and camera arrangements to identify their positions are reliable enough to be trusted with this task.

The camera arrangement consisted of eight optical cameras VICON Bonita B10 that were positioned in the corners and the middle of the sides of a square that was our area of interest. An additional VICON Bonita video camera was positioned in one of the corners that recorded normal images to compare to the data taken from the markers. This configuration allows for an accuracy of 0.5 mm that allowed us to look into fine detail about the whisking of the subjects. We used 9 mm markers provided with the system in the body parts of interest. In order to process the data of these markers we used the VICON Nexus 2.2 package.

With the motion capture arrangement in place, a model was needed to mark the body parts and collect data. The VICON Nexus 2.2 package has installed the Plug-In Gait model that provides marker position and data analysis options. Although, as the name suggests, the model is mainly focused for the analysis of walking patterns, we found its upper body model satisfied our needs and decided to use it as is.

Experiment design

Our hypothesis proposes that Japanese Tea Ceremony practitioners develop a common behavior of motions as they progress to reach an ideal set by the grand master. In order to identify patterns in the actions, we decided to directly analyze the motions of performers of different skills and compare them in order to find similarities and differences. It was important to identify at least two groups, Novices and Masters, in order to find whether their actions match their practice time. This limits the amount of actions we can study, as novices do not have as much knowledge of chado as the more seasoned practitioners.

Whisking, or preparing the tea, had no problems with the time it was being observed. The motion is also simple and repetitive, which helps identify patterns. It is also a fundamental part of chado that cannot be found in other forms of arts or even of preparation of tea. It is an action learned since the beginning of the education of the practitioner as without it tea cannot be consumed. The preparation of a tea takes between 30 to 50 seconds to be finished, which provides enough time to collect data with the motion capture tool that can be further analyzed.

Another advantage of whisking is that it appeared to be a cyclical action. The hand of the subjects moved in what appeared to be a regular back and forth pattern above a well contained area defined by the tea bowl. With this considerations, whisking tea was chosen as the action of interest to compare masters and novices and test our hypothesis.

Experiment Objective

The objective of the experiment is to characterize the action of whisking of a group of practitioners. The defined characteristics will be used to compare the performances individually and by group of skill. Lastly, it searches to identify coordination in body parts and its

impact to the action itself.

Subjects

For this research, seven subjects collaborated with us. They are all practitioners of the Urasenke school. Five of them belong to the Tea Ceremony Club of the Japan Advanced Institute of Technology (JAIST) and the other two belong to a circle in the city of Kanazawa, Ishikawa. They are separated into three categories: masters, intermediates, and novices. Masters are all certified teachers and are allowed to pass on the teachings. We consider novices subjects with less than two years of practice. One subject does not fit into these categories and has been labeled an intermediate.

Experiment Description

The experiment was conducted in four different sessions in between December 2016 and January 2017. Subjects were inquired about their time of practice and, in the case of the teachers, teaching the Japanese Tea Ceremony. After a brief explanation of the motion capture system, subjects were asked to change into the special suits provided to attach the markers in their correct positions. For the Plug-In Gait Model some bodily measures are needed, and were taken before introducing the subject in the system.

The calibration routine was divided in two different takes. The first involved the subjects standing for five seconds with their arms open in a T shape. The second take started like the first one but continued with 30 seconds of free movement, although subjects were encouraged to move their joints as much as possible. This calibration step is necessary to conduct the experiment. When the system recognized the markers automatically, the data collection started.

Subjects were asked to prepare a bowl of tea while being recorded by the motion capture system. Each subject was asked to produce bowls three times. In order to reproduce the action as close as possible, each time subjects were asked to perform the motion starting from taking the whisk from the floor and ending with presenting the tea bowl to the guest.

Results

To analyze an action it is essential to identify the body parts that are most relevant to the movements observed. In the case of whisking, it was clear from the beginning that the right arm was of importance, but whether other sections of the body of the subjects also moved when preparing tea. In order to identify the relevant time series to our research, we observed the positions of all the position markers in the upper body.

The right arm of all subjects was the body part with the bigger variation during the chosen time frames, with the standard deviation being bigger than 3 mm in most cases and sometimes even surpassing 10 mm for the RFIN marker. The other arm contrasted as most subjects had a standard deviation of under 1 mm on all the markers positions in all three coordinates. This is because it is used to hold the tea bowl so that whisking is easier to perform.

We had identified that the right arm moved and the left did not move without checking the data, but it was unclear if the back had any role in the action of whisking. The posture and balance of the column are important in Tea Ceremony, and for whisking they appear to be under control. All subjects present less than a millimeter of standard deviation on the markers on their column. The same can be said for the markers in their chest. With this result we arrived to the conclusion that they do not move enough to make an impact or characterize the whisking action in any particular manner.

The head markers are the only body part that has bigger variation in the three axes. Nevertheless, as the thorax does not move, it means that is a motion not related directly to the whisking but rather small adjustments to better perceive the contents of the tea bowl. The result of this analysis leads us to further look into the motions of the right arm as our area of interest.

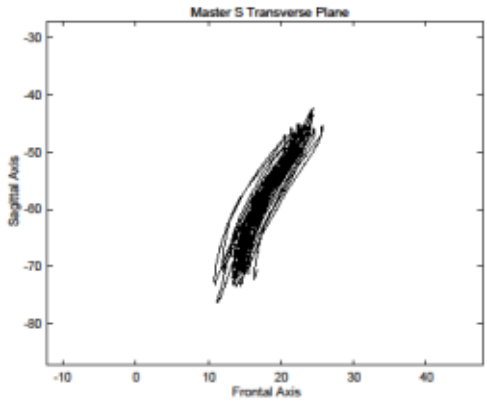

Figure 1 Position of the RFIN marker in the Transverse plane of a Master

The position of the RFIN marker is of particular importance to our research. It sits roughly on the top of the whisk and is can be considered the guidance point of it. It is also the point that practitioners see while whisking and the one they consciously control. For this reason, we will look at upper body positions in general and the changes in position of RFIN in particular to check differences between Masters and Novices.

The motion capture system provides data for the absolute positions of the markers in the reference frame of the room it is calibrated in. All data is in millimeters. In order to locate the most relevant data, we have selected time series of 500 frames of length in each case that represent the most stable action of whisking of each subject. To compare the actions of different subjects, we will analyze them by planes in the next subsections.

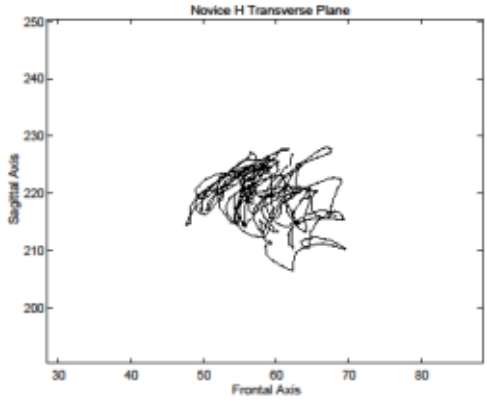

Figure 2 Position of the RFIN marker in the Transverse plane of a Novice

The transverse plane is defined as the plane that divides the body in two that is parallel to the floor. In the coordinate system used by the VICON Nexus system, a graph in this plane is an X vs Y coordinate representation of position. They correspond to the Frontal Axis and the Sagittal Axis respectively. This is the plane that is perpendicular to the view of the practitioner when preparing tea. It is the only plane that gives them information about the tea present status and their progress in the preparation.

The Master group of subjects present similar characteristics in their plots. They are diagonal lines with a significant positive correlation. This indicates that the whisk is more likely to travel on the same line as seen from the top of the tea bowl. The Novices and the Intermediate on the other hand, have no path to follow. We can observe that in Figure 2 that shows an erratic, compact motion about the center.

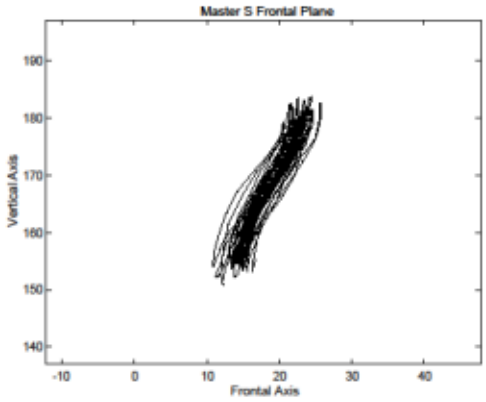

Figure 3 Position of the RFIN marker in the Frontal plane of a Master

The frontal plane is defined as the one that divides the body in anterior and posterior and is perpendicular to the floor. In the coordinate system used by the VICON Nexus system, a graph in this plane is an X vs Z coordinate representation of position. They correspond to the Frontal Axis and the Vertical Axis respectively. This is the plane one would see if standing in front of the person performing, as the plane name suggests.

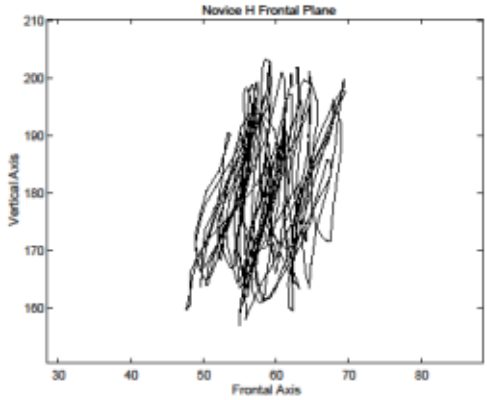

Figure 4 Position of the RFIN marker in the Frontal plane of a Novice

There are more similar plots in this plane, when compared to the one in the transverse plane. Novices H have predominant vertical paths that contrast with motions of the other subjects. However, they are not as dissimilar as the ones in the Transverse plane. The intermediate has a compact and regular pattern that is closer to the group of the Masters than to the Novices.

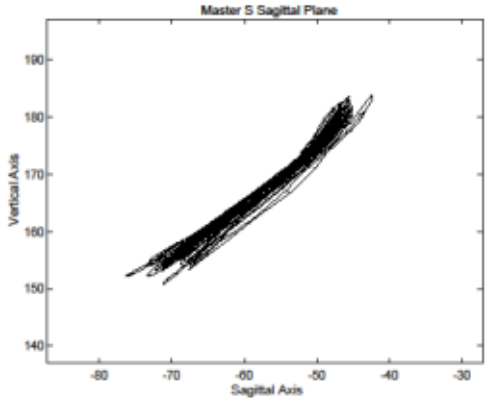

Figure 5 Position of the RFIN marker in the Sagittal plane of a Master

The sagittal plane is the imaginary line that crosses the body from back to front, dividing it in left and right and thus is perpendicular to the floor. In the coordinate system used by the VICON Nexus system, a graph in this plane is a Y vs Z coordinate representation of position. They correspond to the Sagittal Axis and the Vertical Axis respectively. When looking at the performer from the side, we are looking at this plane.

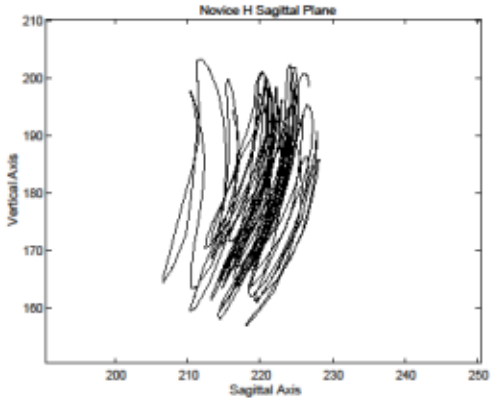

Figure 6 Position of the RFIN marker in the Sagittal plane of a Novice

Masters have a stable path in this plane. So far, the masters present the same characteristics and seem to have similar tendencies, in line with our hypothesis, which is a positive sign, although not definite to make conclusions. For this plane most subjects seem to have an identified path that they stick to in a regular basis. The back and forth action of whisking is responsible of this, as it dominates the influence on the position of the end of the whisk over the position of the hand itself.

Repetition in the action

Whisking is a seasonal action. The hand and therefore the whisk travel in a back and forth motion and are limited to the area of the tea bowl. After we identified that the Masters follow a path that is mostly a straight line in three dimensions, it was of interest to see how the time series behaved when compared to itself to better understand the action. We applied an auto correlation function to each data set with 300 lags to identify possible repetition in the time series.

All the time series are clearly non stationary, but this can be tolerated for the qualitative interpretation we are giving to the plots. They have a tendency to zero as the number of lags increases, indicating that the more time passes, all the subjects change their paths even if it is slightly. Nevertheless, there are considerable differences in the behavior of the plots for the Masters, the Intermediate, and the Novices.

As for Masters, the time series of all three coordinates are similar to themselves if the lag

is small. This correlation decreases with bigger lags. The result indicates that, although there exists a small drift, the phase remains more less the same as the amplitude of the sinusoidal shaped function decrease by the same rate of change. The maximums represent when the lagged signal is in phase with itself in n lags before, where n is the value in the horizontal axis. The minimums indicate antiphase. We can say that all Masters have a constant frequency along all the axes that result in similar plots.

Novices, on the other hand, do not present the same characteristics in their plots. Although the Vertical Axis time series presents a repetition in this group as well, it is not the same for the Frontal and Sagittal Axes. We cannot say that their motions repeat each other, with some of the subjects not having a stable action.

Masters seem to have a better control of their Frontal Axis than their students. The more experienced the practitioner, the more evident it is that their motions are cyclical. Nevertheless, all the subjects present a decline, whether it be slow or fast, to converge with zero. This can be attributed to the small differences in movement in the human body and is expected to some degree. It does not clash with our notion of a path that is followed, as not all movements are made with the same amplitude on the same exact spot. It is worth remembering we are measuring in a domain in millimeters, so small variation is expected.

Phase analysis of joint angles

So far we have looked into the position of the RFIN marker in the three dimensional space. The fact that different body parts seem to move little or nothing at all when compared to the right arm lead us to believe the whisking action is defined solely by the movement of the right arm. But marker positions are not the only data that can be obtained with the Plug-In Gait model. The angles in the different joints in the body can also be calculated with it. In this section we will look into three joints in particular: the shoulder, the elbow, and the wrist.

The shoulder angle has three degrees of freedom as does the wrist, but the elbow can only be flexed or extended, so it is considered to have only one. This result with seven angles to be analyzed. They are all calculated relative to the plane in which the joint operates, so the position, body shape, or orientation have no impact in the analysis. This means we can directly compare behaviors of the joints between subjects.

Out of the seven angles that we were analyzing, shoulder flexion was identified to have no significant variation in the window of interest. This means that the arm does not travel back and forth, instead remaining at the same height for most of the action. The other six angles, however, present a sinusoidal pattern consistent to the whisking action. With this information, we will discard the shoulder flexion angle since it does not contribute to whisking

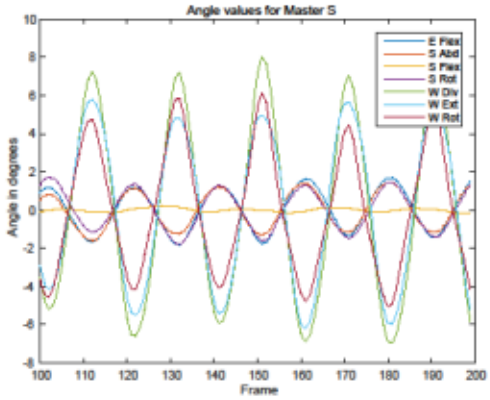

Figure 7 Angle values for a Master

The plots in Figure 7 and Figure 8 are examples of a 100 frame sample of the time series for all the angles. The lines are moved in the vertical axis in order to compare the behavior between them rather than the individual values. Wrist angles have a bigger amplitude than the angles of the shoulder and the elbow. This is the only characteristic we found that was consistent among all the subjects.

Masters have two different patterns of time series, with them being in antiphase. Master S in Figure 7 has the most consistent and stable motion. She has a period about 20 frames and not only the motion has a constant frequency but also a constant amplitude. Wrist angle amplitudes have similar values, as well as the shoulder rotation, abduction, and elbow flexion. Maximums of the wrist group align with minimums of the other three angles, indicating that all the angles have extremes at the same time. All her right arm moves at the same time.

A difference again can be seen in the Novices, between themselves and with the Masters. Novice H, for example, has a consistent motion in the wrist but lacks any significant movement in his shoulder and elbow as can be seen in Figure 8. This means that he controls the whisk with only his hand and not the whole arm. His wrist extension is also smaller compared to the other subjects, which is reflected in a small area of motion in the RFIN plots.

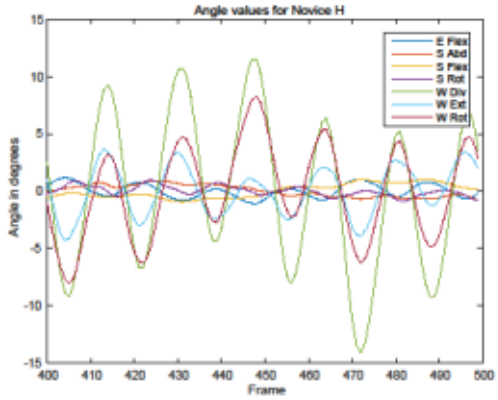

Figure 8 Angle values for a Novice

Hierarchical Clustering

In this section we analyze the coordination between the different motions in the arm while whisking. For this matter, we selected analyzing the phase of the motion of the angles considered in the last section. For each subject, we selected a sample of 1500 frames and recorded when the peaks of the motion of the seven angles occurred. This data would allow us to show groups of actions that are similar and differentiate them from others at the same time.

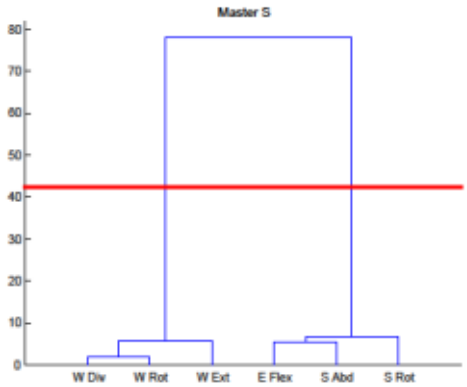

Figure 9 Dendrogram for linkage of a Master

For linkage we have used the hierarchical method using the average of the Euclidean distances between points. As for the number of clusters, have used an inconsistency coefficient cut off value of 0.9 for the identification of groupings. For representation, we have chosen the dendrograms to show the hierarchical binary cluster and have drawn a horizontal line where the clustering is optimal. All the calculations where conducted with the functions already included in the MATLAB package. The shoulder flexion angle has been discarded as it does not contribute to the motion as demonstrated in the last section, so the analysis was done only on two degrees of freedom for the shoulder, three for the wrist and the elbow flexion.

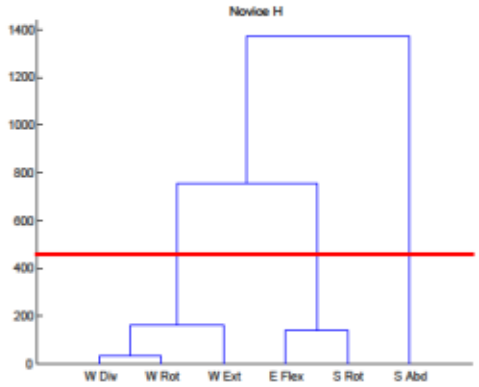

Figure 10 Dendrogram for linkage of a Novice

In Figure 9 we see an example of the clustering of the motions of Masters. All Masters and the Intermediate subject present a two cluster configuration with the same members in each group. The wrist angles are more likely to be in phase with each other and the combination of shoulder abduction, rotation, and elbow flexion are in a different phase. The pair of wrist deviation and wrist rotation have the least distance between them compared to other pairs most of the cases. This is in line with our findings in the 100 frame widows previously analyzed. This means the behavior is maintained throughout the whole action of whisking.

Novices, on the other hand, present three clusters and much bigger distances between links with at least one of the angles having a different cluster. In the case of Novice H in Figure 10 the uncoordinated angle is the shoulder abduction. Even though there are only three clusters for him,

the distances between points are much bigger when compared with the other subjects, thus indicating that the groupings are more stretched than other cases.

Conclusion

Masters and Novices have different overall behaviors while whisking tea. Although the action might look similar to the plain eye, the motion capture tool has helped identify the subtle differences. We have been able to identify that only the right arm has an impact on the action of preparing tea. The back has no significant deviation and thus has no contribution to the motion. We have identified a path that performers follow to produce tea. This track is an imaginary line that the practitioners develop through time. The Masters have developed the skill to remain in the same space going back and forth in a consistent, stable matter. We also identified that Masters sometimes move outside this track, but consistently return to it. We also believe the more the subject has practiced, the narrower this path gets. The Masters use the whole arm to produce the movement of the whisk in the bowl.

Novices on the other hand do not present the track and ramble around a point and have no back and forth motion. The intermediate presents characteristics similar to both groups. She has not developed a narrow, constant path in which the whisk moves, but has developed the consistency of using her whole arm at the same time as the Masters did. The main difference that the most seasoned practitioners have converge point and she does not.

Acknowledgements

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References

[1] M. Abe, T. Yamamoto and T. Fujinami, "A dynamical analysis of kneeading using a motion capture device," 2003.

[2] K. Ueno, K. Furukawa and M. Bain, "Motor Skill As Dynamic Constraint Satisfaction," *Linkoping Electronic Articles in Computer and Information Science,* 200.

[3] K. Matsumura, A Study of Samba Dance Using Acceleration Sensors, Japan Advanced Institute of Science and Technology, 2007.

[4] I. Nonaka and D. J. Teece, Managing industrial knowledge: creation, transfer and utilization, Sage, 2001.

[5] B. Durrance, "Some explicit thoughts on tacit learning," *Training & Development,* pp. 24-30, 1998.