Roles for Sensorimotor Behavior in Cognitive Awareness: An Immersive Sound Kinetic-based Motion Training System

Ioannis Tarnanas, Vicky Tarnana PhD

ABSTRACT

A variety of interactive musical tokens are presented to consider ways to isolate, amplify, and study cross-modal sensorimotor behavior. This presentation focuses on the methodical tasking of unconsciously augmenting human behavior to engage sensorimotor faculties. Our approach complements the current-day emphasis upon tracking methodology in the evaluation of cognitive and motoric behavior. This paper discusses the utility of two different interfaces, for learning exact limb motion, which is often required in sports, dance, and art. The first we have implemented and tested is called "Sound-kinetic feedback Midi-shoes (SFM)", and is based on an intuitive interaction method between three pressure sensors at the shoes and a musical protocol. Through the musical protocol, the motion of the trainer is “visualized” in real time as a synchronization pattern (superimposed on the trainee initially) based on the newly discovered interaction between the musical perception and the spatial kinetic regions of the brain [Rauscher 94]. The second interface translates the breathing pattern of the trainee into a musical pattern. Such an interaction, namely taking advantage of the kinesthetic memory of the mouth muscles and the music synchronization of the user's motion in real-time. With the basic hypothesis that such a system would enable error free unconscious interaction and help a student learn motion as good and fast compared to indirect teaching methods (e.g. watching the master and imitating it), we have tested and compared our Sound Kinetic-based training system to that of the real. Our preliminary results show that such a Sound Kinetic-based training method, by conveying more direct motion information, has a strong potential for producing a positive transfer effect for motor learning.

Keywords: Physical Feedback, Motion Training, Musical Interaction Metaphor, Kinaesthesis, Transfer Effect.

1. INTRODUCTION

This presentation of tunable musical tokens and vibrotactile tokens is an illustrated offering based on the modeling of prescribed (tasked) sensorimotor behavior guided through cognitive administration. Physical feedback in this model remains a significant component in how gross motor behavior can be used to visualize cognitive process. Physical feedback is displayed according to visual tokens with acuity controllers (tunable tokens). These tokens are used to discuss the capture of human behavior as a dynamic series of exchanges "feed through" energetic behavior, a refinement of switching, or according to the engagement and allocation sensorimotor behaviors. The capture of human behavior remains a problem of discerning the exchange between intention and a prescribed attack as cross-modal options in: the engagement, activation, pursuit of a sustained control.

These tunable tokens are presented in this presentation to shift behavioral assessment toward a visualization of relationships which is based upon associative neighborhoods rather than using a deterministism, numerical simulation modeling [Pausch 97] or stochastic methods. Tunable controls offer a feedback mechanism which represents a matching (selective scheme) based on associative neighborhoods. Thus, in addition to the effect of "trying it out beforehand in a similar environment", immersive Sound-Kinetic Feedback is expected to give the trainee a better frame of reference compared to training with a traditional trainer-based system [Raynor 98].

This paper discusses the utility of Sound-Kinetic Feedback for a different class of training, for learning motion profiles of one's own limbs, that is often required in sports, dance, and art (e.g. a golf swing, martial arts, calligraphy, etc). Our central concept behind the Sound-Kinetic-based motion training is called "Sound-kinetic feedback Midi-shoes (SFM)", and is based on an intuitive interaction method called the musical interaction metaphor. With the basic hypothesis that such a system would help a student learn motion as good and fast compared to indirect teaching methods (e.g. watching the master and imitating it), we conducted the following experiments. We have tested four subject groups who used the same SFM devices to trace the same motion profiles. There were two types of learning environments (musical metaphor based and Real/Indirect) and two types of motion profiles (fast and slow), thus four subject groups. We have controlled the difficulty of the motion following task (e.g. by increasing the degrees of freedom required for the motion) and measured the accuracy of the learned motion for comparison.

2. Related Work

The most prevalent form of computer-based motion training is through the use of interactive CD-ROM titles whose content may include step-by-step instructions (in text or voice) and short video clips and annotations. The effect of such indirect training is quite questionable as the trainee must interpret large part of the implicit motor control related knowledge by oneself and at the same time evaluate oneself.

Another popular approach in sports training uses three dimensional motion capture equipments for motion analysis. For instance, BioVision [BioVision] uses a vision-based motion capture system to animate trainee's golf swing in a three dimensional wire frame. The instructor explains and corrects the student, both looking at the animation afterwards.

Virtual reality has been used for training extensively. Perhaps the most famous training system is the NPSNET/SIMNET, a network-based simulation for tactical military training [NPSNET]. Others include hostage situation resolution training [Shawver 97], battleship fire escape training [Everett 96], fear of flying treatment [Hodges 95], machine operation training [Johnson 98]. One can easily realize that these systems are mostly situation-based training system; the user is expected to perform series of actions, and the particular motion is not very important. It is quite difficult to find Sound Kinetic-based systems for motion training.

An interface similar to the Ghost metaphor introduced in this paper is reported in a system called Caren [VMW 97] developed out of a joint European ESPRIT research program. The purpose of Caren is to train and rehabilitate patient to overcome balance disorders. A patient standing on a moving force plate is to correct one's balance by looking at the avatar (representing the patient) and transparent boxes bounding the avatar's limbs representing the correct posture on a large projection screen [Caren 99]. Although the idea of using ghostly boxes is similar to our approach, their technical emphasis seem to be in motion capture rather than in the effective interaction. Superimposition of bounding boxes was also used in a system called the ARGOS, a system for "tele-programming" a robot [Rastogi 96]. In ARGOS, a wire frame bounding box is overlayed on a remote manipulator seen through a camera system at the home site. The user can program the remote manipulator by controlling the wire frame robot.

3. The "SFM" Concept

The central concept of " Sound-kinetic feedback Midi-shoes" is the use synchronization of a musical kinesthetic memory interaction, the main ingredient of sound kinetic systems. Therefore, unlike Caren, The display for SFM must be a midi-enabled shoe; otherwise, the trainee is not able to see the ghost because the trainee's limbs will block the projection.

The use of a sound-kinetic feedback instead of a visual one creates a different type of spatial memory, which uses Kinaesthesis as the guide to perception [Tarnanas 2000]. Inspired by the Perceptual Control Theory we use kinesthetic behavior as the guide to perception [Powers 73].

3.1 Motion Evaluation and Guidance

In addition to the motion itself, performance data, the on-line information regarding how well the trainee is doing, is very important in effective motor learning [Schmidt 91]. Many performance measures are possible: accuracy based such as position/orientation difference, timing difference, number of oscillation, and speed-based such as task completion time. As the purpose of this system is in training, what is actually important is the learned performance in the real world afterwards. The correlation of performance in the Sound Kinetic world and in the real world afterwards is tested via a thermal processing camera.

In order to facilitate the learning process, in addition to the performance data, other guidance feedback is possible. For instance, a curvilinear or volumetric motion trace, colored marks at the critical points of motion, directional arrow (vectors with both directions and magnitudes), textual and voice guidance, alternative and simultaneous third person viewpoint are some of the conceivable examples. Also a very natural extension to providing such guidance features is the use of force feedback for motion guidance. Such a haptic guidance can be both active and passive: an active haptic interface would attempt to correct the trainee's motion, while a passive haptic guidance might exist as a virtual wall physically limiting the range of trainee's motion. Although conceptually intuitive, such a physically guided training for types of motion in which such haptic sense will be missing in an actual application is known to cause negative transfer effect, and thus, it is advised to use such a teaching technique only sparingly [Schmidt 91]. Therefore the use of a natural unconscious human interface notion, like the musical-spatial brain link, seems to be our only choice.

3.2 An Architecture for a Sound Kinetic-based Motion Training

Based on the features outlined in previous subsections, we have devised an architecture for a Sound kinetic-based motion training system. The bottom portion of the system shows the essential part of the system, a midi shoe consisted of a front region pressure sensor, a back pressure sensor and a Z-axis sensor (connected through wireless midi network), where the training occurs using the musical interaction metaphor. In addition to the above system core, there is a proximity sensor between the two shoes; a module for on-line motion evaluation and module for motion guidance can be added.

The top portion of the system is composed by a custom device that translates the breathing pattern of the trainee into a musical pattern in real-time. The design is natural, user-friendly and uses the mouth muscles to create a form of kinesthetic memory along with the breathing control pattern, which could be rehearsed later for the transfer affect.

The musical feedback is transferred to the trainee through some standard earphones, through a wireless midi network. The trainer can configure his motion type and preferences by first rehearsing the motor skill in slow time backwards (from the target to the starting position) or in the right order. Three sub-modules, Performance Simulation, Sequence Control, and Motion Database, are added for such a purpose.

4. Implementation: Virtual Calligraphy

There are currently two simple implementations of the "SFM" training system. One, is for learning calligraphy, a task specific system, and the other is for generic motion following tasks for experiments (to be explained later). Both systems are implemented using a G4 Macintosh (as rendering client and ICube Pro from Infusion systems, as a sensor server), two earphones, a breathing interface and two midi “SFM” shoes.

5. The Experiment

With the basic hypothesis that such a Sound kinetic system would help a student learn motion as good and fast compared to indirect teaching methods (e.g. watching the master and imitating it), we conducted the following experiments. We have tested four subject groups who used the same SFM devices to trace the same set of motion profiles of differing speed (slow and fast) in two different environments. Each subject group performed three different motion following tasks of different difficulties (in increasing degrees of freedom). There were 4 subjects in each group (16 subjects in total, all graduate students in gymnastics).

Table 1: Subject group classification

Classification		Type of Learning	
		Indirect/Real	Sound kinetic-based
Speed of Master Motion	Slow	Group R-S	Group Sk-S
	Fast	Group R-F	Group Sk-F

Subjects of Group R performed the three motion following tasks, watching the trainer's motions at a predesignated third person viewpoint. Subjects of Group Sk performed the same three motion following tasks using the musical metaphor in the Sound Kinetic Environment using the SFM shoes. We measured the comparative performance of the subjects using a simple error metric: an integrated difference between the master's and trainee's profile (the corresponding points between the master's and trainee's profiles were made manually).

The objective of this experiment is to investigate in the utility of SFM in motion training. In this study, we indirectly assess the learning effect by examining the user performance. The hypothesis is that the more correctly trained the user is, the higher the quality of learning is.

5.1 Does Sound Kinetic-based Training Help?

Figure 1 shows the resulting performances of the subjects plotted in graphs. The first question we hope to answer is whether Sound Kinetic Feedback helps in training. We attempt to answer this question indirectly by analyzing the user performance in respective environments. The more correctly trained the user is, the higher the quality of learning is.

By comparing the left and the right column, one can easily notice that the subjects using the Sound Kinetic training system followed more closely to the master's motion in every respect (position and orientation). We plan to quantify this observation by running a curve-matching algorithm [Cohen 97] that can compute the corresponding points between the master's and trainee's profile curves by minimizing the integrated "difference" metric between them. The metric can be based on pure geometric distance, or include tangential components, thus, reflecting the temporal property of the motion. We must also measure the statistical significance of any differences in performance.

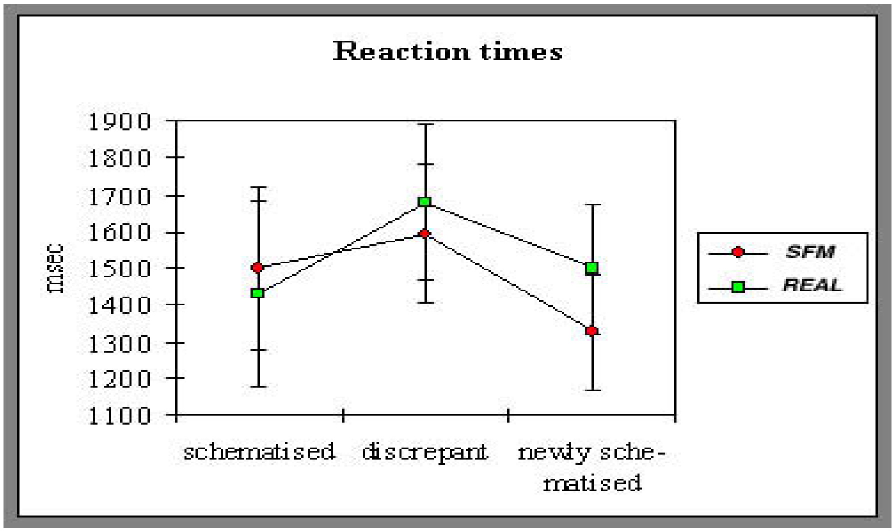

Figure 1

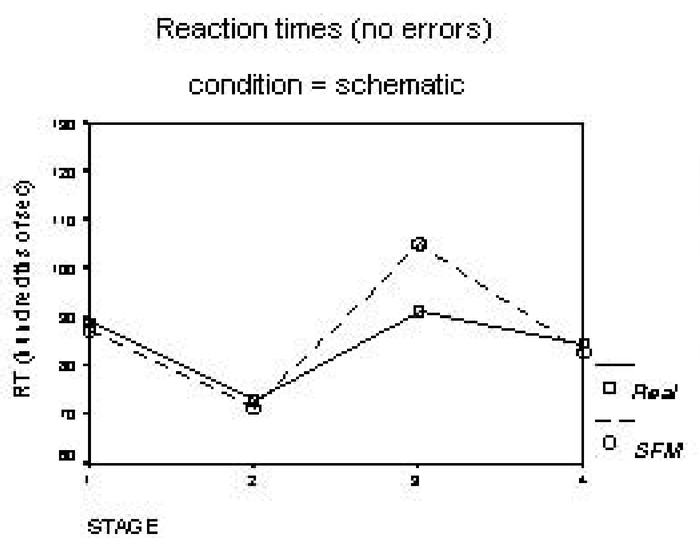

Figure 2

5.2 When is VR-based Training Most Useful?

By observing and comparing the performances shown in Figure 1 (slow movement) and Figure 2 (fast movement) data, we can easily notice that Sound Kinetic training produced better results for slower movement training and less difficult tasks. Likewise, quantifying the performance difference and measuring their statistical significance are planned for our next assignment.

Our preliminary results show that such an interaction method does have a strong potential for a positive transfer effect for certain types of motor learning. This finding is consistent with the work from the cognitive psychology research community [Schmidt 91].

6. Discussion and Conclusion

In this paper, we have proposed for a novel musical protocol metaphor for a Sound Kinetic-based motion training system. The musical metaphor is based on the use of the SFM shoes and a breathing interface device providing the user with real time motion related information sensorimotor feedback. We have run a comparative experiment to test if Sound Kinetic-based training indeed is useful for training and, our preliminary results (without quantitative analysis) a good potential for positive transfer learning effect. This result is consistent with the work from the cognitive psychology research community.

One of the interesting phenomenon we found in the course of the experiment was that while Sound Kinetic-based training was observed to produce more correct motion profiles, the overall motion seemed better remembered the indirect learning approach was used. This probably resulted in focusing more on the local path moment-by-moment, and less on the overall path. It is conceivable that an effective training system, thus, should provide both points of view. This was not a significant factor in our experiment; however, as we asked the SFM users to mentally try out the tasks first.

Relative timing is also very important in motion. In this study, we did not run the experiment in a way to extract this information. Maybe the thermal imaging technique could enable the monitoring of the “peak” performance and measure the interval between ht actual repetitions and the “flow” experience. Thus our future work will include improving the test design, extracting the timing information, and measuring the direct learning effect by testing the subjects the day after.

7. ACKNOWLEDGMENTS

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