When doing the wrong thing is right

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Abstract

We designed an experiment to explore the learning effectiveness of three different ways of practicing dance movements. To our surprise we found that partial modeling, called *marking* in the dance world, is a better method than practicing the complete phrase, called practicing *full-out*; and both marking and full-out are better methods than practicing by repeated *mental simulation*. We suggest that marking is a form of practicing a dance phrase aspect-by-aspect. Our results also suggest that prior work on learning by observation and learning by mental practice may not scale up to complex movements.

Keywords: Dance practice; Marking; Mental Simulation; Aspect-by-Aspect.

Introduction

We report here on a surprising finding in an experiment that compared the relative effectiveness of three different ways of practicing dance phrases. We found that 1) partial modeling of a dance phrase by *marking* the phrase, as it is called in the dance world, is a better method than practicing the complete phrase, called practicing *full-out*; and 2) both marking and full-out are better learning methods than practicing by repeated *mental simulation*. This is surprising because when a dancer marks a phrase they are literally doing the wrong thing – like humming a piece of music instead of singing it. The result raises the interesting possibility that practicing a movement in a simplified manner, or aspect-by-aspect, rather than practicing all of its components at once, may be the best way to practice. In marking, subjects intentionally practice the phrase in an improper form, with distortions, exaggerations, simplifications, even with substitutions such as using hands for legs, or gestures for entire body movements, such as pirouettes. The official reason for marking is to save energy. But we believe that when cleverly mixed, this diversity may provide a powerful method for a dancer to explore the structure of a phrase more exhaustively than regular full-out practice.

Full-out **Marking** **Simulate in the Head**

Figure 1. The three conditions in the experiment.

This idea challenges common sense and previous work on complex motor learning. It is common sense that practicing something the way it should be performed ought to be more effective than practicing it with intentional distortions, or with essential components missing. If that were not so then repeatedly drawing a face in caricature rather than drawing it realistically ought to lead to drawing the face more realistically later. Similarly, practicing tennis stokes without a ball, or using the wrong approach and form ought to lead to better shots, at times, than always practicing in proper form. It is noteworthy that experiments have shown that both these marking-like methods are, at times, better forms of practice than always practicing in an undistorted, full way. In music performance, for example, using exaggeration in rehearsal is thought to be a helpful method of practicing, delivering results that surpass repeated full-out play [Hinz, 08]. Musicians practice passages both faster and slower than written. It is standard to manipulate phrasing, dynamics, articulation, intonation, and tempo, to name a few. [Chaffin et al 2002, Friberg et al, 06]. In sports viewing, [Hill & Pollack, 00; Pollack et al 01] found that subjects have learned to recognize complex actions better, such as certain types of tennis strokes, when some of the parts of the stroke have been exaggerated. Evidently, marking may have a place in training. But as a general method, practicing *only* distorted versions of the real thing, or versions that leave out essential components, is a counterintuitive method of rehearsal. Our unanticipated result is that this counterintuitive method is effective.

Our findings also challenge work on mental simulation. In sports psychology, imagery is often referred to as cognitive enactment or visualization, and is one of the most popular performance enhancement and rehabilitation techniques. It has been shown in numerous studies that mental simulation in sports contexts can significantly improve an athlete's performance on measures of style, speed and strategy. [Weinberg 08]. In music, Pascual-Leone [2001] reported a similar finding about learning to play a five-finger exercise on a piano keyboard. After five days, the group that mentally simulated playing, performed an exercise comparably to the third day level of those who practiced physically. All these experiments showed that mental practice leads to substantial improvement. We therefore came to the experiment believing our dancers would significantly benefit from their ten minutes of mental simulation.

Failure to find this improvement from mental simulation also bears on the findings of [Cross et al, 09], who, in several experiments, found that repeated observation of a target phrase – and hence 'practice' in the motor resonance system – leads to comparable performance to full-out physical practice. Simulation has been to shown to facilitate in much the same way as observation – by activation of covert actions via the motor resonance system, [Jeannerod, 01]. The unexpected result by Cross et al [op cit] was found to hold for learning the rhythm and steps for pieces in a game like Dance Dance Revolution (DDR), where subjects must stamp their right or left foot onto footprints on a mat in time with music. Subjects watched the video repeatedly and may have played covertly. In our experiment, the phrases to be mastered were far more complex than DDR, involving movement of the entire body, with dynamics and feeling, and not driven in response to a stimulus. And they were simulated and not observed. But if observation works so well there is reason to suspect that mental simulation should not as well.

If our results about marking are true then marking during dance practice should not be seen as a sign of fatigue or laziness, as so often it is in dance studios. Rather, it may be a strategic method for selective training. This opens the door to developing more effective methods of selectively working on 'aspects' of a phrase. This likely applies to domains other than dance. We speculate that the success of marking also tells us something about how the body itself can be used to help manage attention, improve focus and even facilitate simulation in a selective way. The body may well draw attention to what is important in the way a hand in speed-reading drags the eyes along so that a speed reader can move through the page faster and more effectively. It is yet another way the body itself can be involved in cognition.

Conjecture and Method. In designing the experiment, our conjecture was that:

a. practicing a dance phrase full-out would lead to better performance than mental simulation, and
b. marking would lie somewhere in the middle: better than mental simulation but worse than full-out.
c. Mental simulation would also lead to better performance.

Owing to the presumed power of the motor resonance system we wanted to see if anything *extra* would be gained by adding body activity to the mental simulation and projection we thought already occurred during marking. Our belief was that dancers would learn something from marking, just not as much as from practicing full-out. To test this idea we used the dancers from Random Dance, the contemporary company we have been studying. [Kirsh et al, 09; Kirsh, 12] All are super-experts, having been chosen from an audition pool of 800 professional dancers throughout Europe and the States.

Procedure: The design required dividing the ten dancers into three groups: A, B, C. All three groups were then brought into the studio and taught a dance phrase new to them, lasting about 55 seconds. The dancers were taught this phrase during a 10-minute teaching period, and at the end of it, the group left the studio and the dancers returned, one by one, to the studio and performed the dance in front of the teacher. As shown in figure 1 above, there were three conditions: practicing full-out, practicing by marking the phrase, and lying still mentally simulating the phrase. After the first round the dancers changed condition and were taught a second phrase of about the same duration and complexity as the first. The experimental design is a 3 by 3 Latin Square where each group is run in each condition. Thus, if group A started by Marking, they progressed to Full-Out, and then finished in the third trial in the Simulation condition.

Each dancer's performance was graded according to established criteria (technicality, memory, timing, and dynamics – discussed below), first by the teacher in real-time and later by two independent expert observers who reviewed the video frame by frame. Once all dancers were graded, the group returned to the same large studio and practiced the dance for 10 minutes. While practicing they were asked to face in different directions and not look at each other. Once this 10-minute practice period was over they left the studio and, as before, returned one by one to be graded by the same criteria as before. See figure 2. Learning is understood as the change in grade acquired during the 10-minute practice phase.

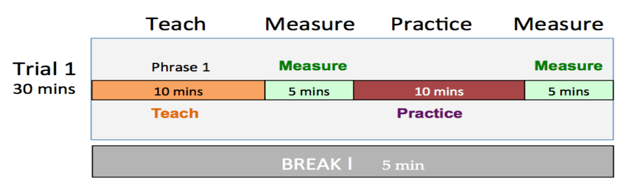

Figure 2. The temporal structure of the experiment is displayed. There were three trials.

Measures: In mastering a dance phrase it is customary to be evaluated on technicality, memory, timing and dynamics.

Technicality means the level of precision in positions and transitions. Are the forms full and well-formed (e.g. juicy, fully rounded)?

Memory, or level of detail, refers to the completeness of each movement. Was something left out – a hand gesture, a turn, a foot angle?

Timing refers to the duration of individual steps and the duration of the transitions. Our timing coder used frame-by-frame measures of timing for great precision in comparing test conditions to the target standard.

Dynamics refers to the force, speed and acceleration of movements. Also included are various qualities of motion – resistance, emotionality, and intentionality.

On analyzing the experimental results we found that:

1) Marking was the most effective method of practicing, being slightly more learning efficient than practicing full-out (p =.0189);
2) Both marking and full-out led to substantially more learning than mental simulation (p = .0001);
3) Mental simulation was not a strong form of practice; there was negligible improvement between pre and post tests in the simulation condition and in many cases it led to a decrease in performance.

Our finding both support and violate our hypotheses. We were correct that the learning achieved by marking is more effective than mental simulation (mean difference = 1.19, with $p < .0001$) across the key dimensions of Memory, Technique and Timing. But we were surprised by its magnitude. We were greatly surprised that marking is more effective than Full-Out (mean difference =. 31, with p = .0189), though the difference is quite modest. We were also surprised that mental simulation did not facilitate at all. To compute these values we first performed one-way ANOVA's on all measures in all conditions and found highly significant differences throughout. We then ran pair-wise post-hoc comparisons (Tukey's HSD) and computed p values as shown in table 2. All p values were computed over z-scores to reduce noise caused by variability in dancers, measure-types, and graders.

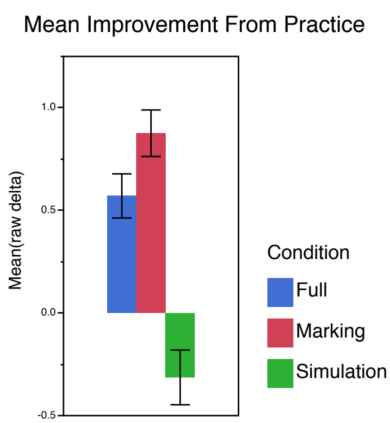

Table 1. Mean improvement from practice (the learning delta), as measured on a 5-point scale. The absolute difference in delta between Marking and Full-out is 0.31, which is significant when measured by the z-score for Technicality, Memory and Timing (p = .0189). Full is better for Dynamics but not significantly (p = .145).

Table 2 P values

Measure	M>F	F>M	M>S	F>S
Memory	.7334		<.0001	<.0001
Technicality	.0029		<.0001	.0005
Timing	.0194		<.0001	<.0001
Dynamics		.145	.0003	<.0001
Mem, Tech, Timing	.0189		<.0001	<.0001

We assumed that marking would add something to mental simulation because somehow the process of marking would facilitate mental simulation rather then interfering with it. Our main idea of a mechanism is that marking provides a physical anchor for mental simulation, thereby scaffolding imagination and leading to higher realism in simulation and increased priming of motor preparation. (See Kirsh, 10) We found qualitative support for this idea from interviews with the dancers. When asked what they think about when marking our subjects reported that they have in mind the full-out movement – though with fewer dynamics. They do not 'see' themselves as dancing in a distorted way, as they would if observing themselves in the mirror. They project off of their movement to the normative movement they want to be making. This is the movement they have in their mind's eye. Marking seems to serve as a physical scaffold for projecting movement imagery. Thus, part of our conjecture was right: marking is better than simulation, though nothing we found proves our conjectured explanation of why it is better (i.e. projection). We were surprised, however, by just how much more effective marking is than mental simulation as a practice technique.

We also found that marking is better than full-out as a practice technique. This falsified our conjecture that full-out practice is the best form of practice.

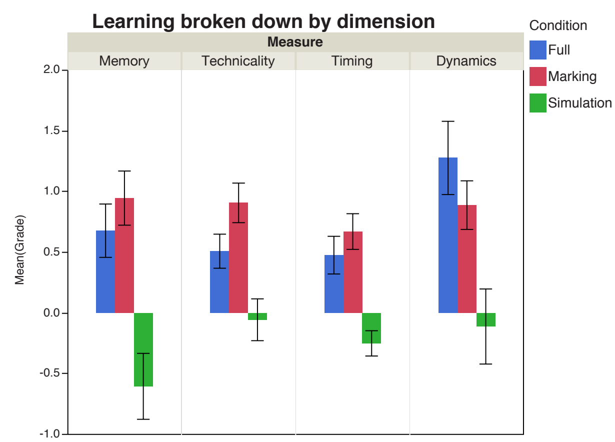

Table 3. Marking was significantly better than Full-out for learning the aspects of a phrase related to technicality and memory and trending to significance in timing. Not surprisingly it was less effective at learning dynamics, which are rarely practiced in marking. Mental simulation was most effective (but still yielding zero or negligible improvement) for thinking about technical elements (precision in movement). It led to decreased performance – negative learning – for movement details.

Marking vs. Full-Out Discussion: There are a few possible explanations why marking is better than full-out. The simplest is that it is possible to mark more steps in a 10-minute period than it is to execute them full-out. To explore this idea we coded the video'ed activity of four dancers as they practiced their phrase in the experiment: two subjects in marking, were compared with two subjects in full-out, for each phrase. The results unambiguously show that the marking group performed significantly more steps and repetitions than the full-out groups. See table 4. The reason marking might be a better way to practice, then, may be as simple as that dancers get in more trials in the same time by marking than by working full-out.

Phrase	Marking	Full-Out
I	351	275
II	317	300
III	317	188
Mean	**328**	**254**

Table 4. A simple enumeration of the number of steps executed in marking vs. full-out, matched by phrase.

Related to this number of steps argument is that marking might be a better form of practice because it is easier to fast forward or skip quickly through steps when marking, or to jump completely to new sequences. Full-out requires correct timing so there is no such thing as fast forward. Jumping to new sequences or sub-sequences is possible but it seems to be harder for dancers. From reviewing the steps that dancers practiced full-out we observed that the average sub-sequence was longer in full-out than in marking. See table 5. We observed this same phenomenon in actual dance sessions, where dancers jump to different parts of a phrase more often during marking.

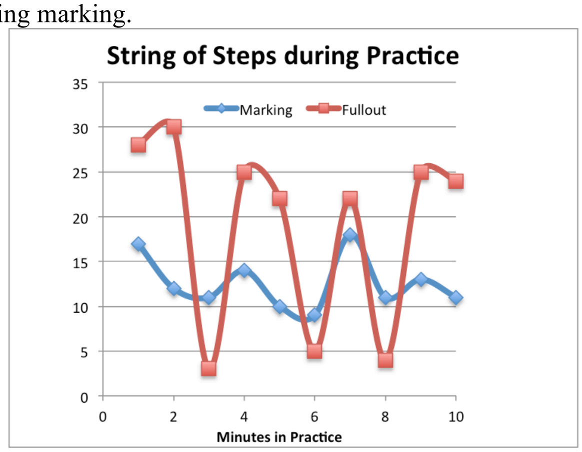

Table 5. The string-of-steps, on average, is shorter for marking (12) than full-out (19). A string-of-steps is a sequence of steps performed in the right order. Dancers jump around within and between sequences more often when marking than when practicing full-out. In full-out, dancers alternated between very long and very short string-of-steps.

A second possible explanation of why marking is best is that in full-out practice there are more aspects to attend to at once. Not all aspects are equally in need of practice. Every step has many qualities. For instance, in Laban Movement Analysis [Newlove, 05], a distinction is drawn between 'effort qualities': flow (free/bound), weight (light/heavy), time (sustained/sudden), space (direct/indirect) and 'shape qualities': Rising/Sinking, Spreading / Enclosing, Advancing / Retreating, Growing / Shrinking. In practice, a dancer cannot attend equally to all these qualities simultaneously. Attention must be focused more narrowly. When practicing full-out, however, dancers need to execute a movement as near to its full form as they can. This suggests that narrowing in on to a single aspect to practice will be harder because all aspects must be performed at once.

It seems, therefore, that marking offers dancers just what they want: a way of working on their movements aspect by aspect. Dancers do not think they are dancing incorrectly when they mark; they think they are dancing incompletely. They are focusing on some aspect of each step – its timing, extension, path or shape.

This ability to confine attention selectively may also explain why marking is better than full-out in remembering details. Intuitively, marking is akin to ephemeral sketching, instead of using a paper of pencil to sketch, dancers use their bodies, and the sketch is gone as soon as it made. But, ephemeral of not, dancers can still work on specific aspects of movement, the way their hands or feet specifically should move. They can cycle back to these parts while leaving everything else stationary. This is something dancers cannot do when dancing full-out. This reinforces the idea that by marking they can practice in a more incremental, piecemeal fashion than when practicing full-out. During one pass a particular aspect of a movement can be the center of attention, whereas another aspect can be the center of attention on a second pass. To be sure, the final conception of the target object requires the subject to integrate and assemble the aspects together in a unified whole. So there remains a puzzle about how a subject can come up with an effective whole movement from a set of disparate aspects that may interact in complex ways. This need for integration may impose limits on the effectiveness of marking as a learning method. But it also suggests that if aspects are relatively independent from each other, then marking can be an effective way of practicing because it facilitates a divide and conquer strategy: work on the problematic parts of a phrase and then assemble all parts into the final product. This is likely to be a more powerful method than practicing a target phrase holistically, whether through mental simulation or full-out.

Marking vs. Mental Simulation Discussion: Prima facie, one reason mental practice – mental simulation – is less effective than marking is that when simulating, subjects do not receive sensory feedback from the body and the environment. In marking, by contrast, there is additional information available that a subject may use to reduce error. For instance, there is input about balance, gravity, weight and inertia. These physical features are not available through mental simulation, at least not in any realistic manner. This extra input from the physical world also means that dancers can re-evaluate their movement in a different way on the basis of how they interpret their perception of their own movement. The paradox of marking, however, is that the literal feedback from the body during marking is distorted feedback. Subjects are dancing incorrectly (in a very literal sense).

So the literal feedback they might use to determine an error measure, and so to sharpen their form, is not correct.

To resolve this paradox the place to start is with the dancers' own comment that when marking they have in mind their full-out movement, that marking is the physical scaffold for projecting to this normative imagery. To explain how an imperfect model of a movement – which is what marking literally is – can behave as a physical scaffold we need to introduce a few ideas. We begin with the concepts of projection, imagination and anchoring.

Projection is akin to attaching a mental image to a physical structure. When we project onto an object, we experience ourselves intentionally augmenting the object. The object anchors our mental image, and successful projection requires spatially locking the projected image onto the anchoring structure. To spatially lock, the mental image to be attached must be the right size and be connected to a specific location on the external structure.

When we *imagine* an object, we again are dealing with mental images but we do not attach it to anything in the seen world. It has no anchor and it need have no particular size. Mental simulation is a kind of imagination.

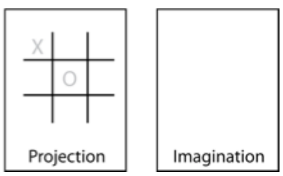

Fig 4. The differences between, projection and imagination can be understood as projecting an image of X and O onto a blank tic tac toe grid versus imagining an X and O on a grid while staring at a blank sheet of paper or better still, when blindfolded.

In Kirsh [09a], the results of running 20 subjects playing tic tac toe in the projection and imagination conditions was reported. To play the game all subjects first learned to name cells using 1 to 9 for a three by three board. They then would call out their move after hearing their opponent's. The numbers 1 to 3 were used for the top row, left to right, 4-6 for the middle row and 7 to 9 for the bottom row.

The results were not simple. Subjects did not play tic tac toe faster in the 3 by 3 condition in any condition, which we had predicted. Having a grid to anchor projection did nothing in the three by three game where subjects rarely needed to recall more than 5 or 6 moves. To challenge the subjects, we then taught them to play four by four games. Here the visual memory load is greater and we found that having a grid appears to facilitate subjects. Projection > Imagination ($p = .002$). As predicted a grid now serves as an understructure or scaffold for projecting moves. However, given the unhelpfulness of a 3 by 3 scaffold it seems that the value of a scaffold increases with the complexity of task. In fact, scaffolding may be necessary for successful mental simulation of harder problems. This may explain why Cross et al found observation to be facilitative in simple dance whereas we found that mental simulation of complex dance was not facilitative.

Anchoring projection, therefore, is one possible explanation why marking helps dancers. The major limitation of this view is that anchoring and projection are themselves inadequately understood. For instance, how does anchoring a projection differ from using an external structure or process as a mediator, an idea that regularly surfaces in discussion of the effects of culture and learning [Vygotsky, 78; Wertsch, 07]?

Here's a case in point. If a musician uses his foot to keep beat, does his tapping anchor his projection (and performance) or mediate it? In this instance, the reason to call it an anchor is that the target rhythm is not a regular beat per se – the rhythm he taps – it is the musical rhythm played 'on top of the beat' (e.g. da joom da joom, daah tika daah tika). He is thinking about the rhythm and using his beating as a stable pulse to help him. This is analogous with the tic tac toe grid, because, presumably, the beat is running on an automatic oscillator, [Eck et al, 00] liberating higher motor planning centers to work on different, but coordinated, sorts of covert actions. Beating is a way of scaffolding rather than mediating the correct rhythm.

Compare tapping a basic rhythm with the gestures an orchestra leader makes as he conducts a musical piece. Once again the underlying beat is embodied, though gesturally now rather than by tapping a foot. But a conductor also adds emphasis to help instrumentalists interpret the music. By gesturing a conductor directs musicians to attend to specific musical features. Are those gestures anchoring the musicians' projection? Or are they mediating their performance, without relying on a third thing called projection to help them perform? Projection seems a mental extra, pointless. The musicians can follow the conductor's directions immediately, without a further process of projecting what they need to do.

Contrast conducting with this last case. In [Frank & Barner, 12] elementary students in Gujarat, India, were taught to add and multiply using an abacus and then asked to perform calculations without the physical abacus. This practice, known as mental abacus, involves visual manipulations of an imagined abacus. Interestingly, when students work on their mental abacus they almost always flick their fingers, miming the movement of the beads. Performance suffers when abacus users are not permitted to use their hands (Frank & Barner, ibid; Hatano, 77]. Apparently, gesture plays a vital role in creating, or at least sustaining, mental abacus structures. Hand motions interact with the visual system, improving mental simulation. As before we cannot say whether this process involves projecting off of gestures or is better understood as some sort of meditational process. But projection seems the simpler account. Gestures scaffold mental imagery for the human calculator.

Conclusion

In this study we set out to test whether marking is a more effective form of practice than mental simulation. It is. We also found that marking seems to be a better form of practice than the standard method of dancing full-out, and that mental simulation did not facilitate learning as it typically does.

When looking for the cause of marking's power we speculated that marking might function as the understructure for projection. When marking, a dancer creates a physical scaffold that facilitates projection. This would explain what 'extra' dancers get by physically marking a phrase rather than mentally rehearsing it. They get an external structure they can extrapolate from. This enables them to generate a conception of the final target that is more vivid, complete, and requiring less mental effort than the targets they imagine when they mentally rehearse without the support of overt movement. So it is not that a dancer is either marking or mentally simulating: marking is way to do mental simulation better.

We speculated further that mental simulation performed poorly because the target structure was a complex dance phrase about 1 minute long and this level of complexity exceeds most studies of the use of simulation.

Lastly, we conjectured that dancing is more effective than full-out because it allows dancers to focus on aspects of their movement rather than on all aspects at once, which is what is required during full-out. In music and most sports, it is customary to work on aspects of one's performance rather than working on everything all at once. Marking is tailor made for that purpose.

The success of marking warrants rethinking the best ways to practice motor activities.

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