KIN 3550: Motor Learning & Control
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A Brief Look Motor Learning & Control in Dancers: A Literature Review

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Reviewed Articles:

Perrin, P. (2002). Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait and Posture, 187-194. doi: 10.1016/S0966-6362(01)00149-7

Notarnicola, A., Maccagnano, G., Pesce, V., Pierro, S. D., Tafuri, S., & Moretti, B. (2014). Effect of teaching with or without mirror on balance in young female ballet students. *BMC Research Notes*, *7*, 426. doi: 10.1186/1756-0500-7-426

B. Calvo-Merino, D.E. Glaser, J. Grèzes, R.E. Passingham, P. Haggard; Action Observation and Acquired Motor Skills: An fMRI Study with Expert Dancers. *Cereb Cortex* 2005; 15 (8): 1243-1249. doi: 10.1093/cercor/bhi007

Dancers are unique athletes in a number of ways. As apart of their training and practice, dancers must master a wide variety of skills involving total body motion, control, and movement. Dancers must be able to use both sides of their body equally and meet extreme demands of the technical practice. Dancers spend long hours in classes and rehearsals, and never encounter an 'off-season' like other athletes. The demands of the artistic practice require the dancer to be immensely strong and flexible, performing difficult movements with what appears as ease to the audience. Because of these expectations and the physicality of the practice, dancers present an interesting study for kinesiologists and others studying motion and movement. The studies examined in this review all pertain to the study of the motor learning and control in dancers, covering a variety of subjects such as the effects of dance training on balance and postural control, the effects of learning with a mirror, and action observation.

The first study – "Judo better than dance develops sensorimotor adaptabilities involved in balance control" – sought to examine the effects of high-level athletic training on balance and postural control. To do so, they compared highly-skilled judoists and professional ballet dancers alongside controls "by means of static and dynamic posturographic tests" (Perrin). Both judoists and dancers must "master simultaneously static and dynamic balance" as apart of their practice. Through training, they must "adopt appropriate physiological and biomechanical attitudes as well as a specific psychological perception" (Perrin). In other words, those training in judo or ballet develop a way of moving and thinking about movement that allow them to have extraordinary balance and control to execute the movements of their practice. This is said to be based on "muscular synergies" and "sensorimotor strategy" developing and working in conjunction with one another throughout the entirety of their practice (Perrin). In order to examine just how deep this influences the individual's balance control, judoists and ballerinas were tested with controls that had no training in either.

The study consisted of 73 healthy adults between 20 and 35 years of age. 14 of these subjects were female dancers of the National Ballet of Nancy and Lorraine. All of the dancers had on average 10-15 years of training and had no acute injuries within the 6 months prior to the study. 17 of the adults were male judoists with at least 6 years of practice. All subjects were screened to ensure no retinal lesions, neurological pathology, nor plantar sole contact irritant dermatitis. The control group consisted of 21 men, 21 women with no sports license or practice of leisure physical activities at "a level liable to change postural control" (Perrin).

The set-up of the experiment consisted of a static test and a dynamic test using statokinsigrams to "measure sway path, or way (W), and area (A), travelled by the CFP [center of foot pressure] as well as anterior-posterior (AP) and lateral (Lat) oscillations" (Perrin). The subjects stood on vertical force platform and were tested over the course of twenty seconds with both eyes open and eyes closed. The dynamic test was very similar in that it focused on the same thing – center of foot pressure – however the platform moved in "slow, rotational oscillations… with a 4-degree amplitude, frequency of 0.5 Hz" for the entirety of the twenty seconds the subject stood. Dynamic testing was done with eyes closed as well as with eyes open.

The results of this study looked at the influence of high-level sport practice, and discovered that for the most part, the hypothesis of this practice having a positive effect on the postural control of the athlete was valid. In both static and dynamic tests with eyes open, judoists and dancers far exceeded the balance control of the control subjects. However, once the eyes were closed, the dancers' abilities to stay on balance significantly dropped to the level of or in some cases below that of the control subjects. In light of this, the researchers concluded that this was as a result of the difference of the skills demanded of the athletes. Judoists are required to be extremely proprioceptive, constantly changing and reacting to the environment around them

while maintaining intense internal focus. Dancers, on the other hand, rely heavily on visual perception and queues for movement. The movement to be performed is pre-meditated and voluntarily generated in a stable environment. That being said, "dance training strengthens the accuracy of proprioceptive inputs… but shifts with difficulty sensorimotor dominance from vision to proprioception" (Perrin). Sensorimotor dynamicism is not often practiced in dance due to the stability of their practice in both the environmental and the psychological sense. Dancers do not often use visual suppression in their practice. The direction of gaze is important both for artistic expression as well as to perceive surrounding. Additionally, most of the ballerina's training is done in a studio with flat, stable floors and mirrors lining at least one of the walls. These mirrors are used for constant feedback on the dancer's image and training, and thus influences the use of focus of the dancer as well. In the situation in which both a moving support was utilized and the dancers had their eyes closed, this integrated two new situations unusual in dance and dance training. The shift from using gaze fixation to aid in balance control to having to rely purely on proprioception challenged the sensorimotor adaptabilities of the dancers to a point that they had not previously experienced in training. In conclusion, the high-level training in either judo or ballet did demonstrate influence over balance control, however the difference in training demonstrated differences in "balance modalities" thus significantly changing the results when the dancers were taken out of their comfort zone (Perrin).

Similar to the discoveries of the first study with regards to the influence of focus on the dancers, the second study took a look into the effects of dancers training with a mirror on balance. Entitled "Effect of teaching with or without mirror on balance in young female ballet students", this study took a look at 64 young dancers aged 9-10 years old. Thirty-two of the dancers trained for six months in front of a mirror and the other thirty-two trained with out a mirror. The dancers took the same class from the same instructor for the entirety of the six-month trial. The dancers were evaluated by a Balance Error Scoring System (BESS) in which they were tested at recruitment as well as at the conclusion of the study. Results of this study showed that "the use of a mirror in a ballet classroom does not improve balance acquisition of the dancer" (Notarnicola). However, the use of the mirror did hold an impact over the improvement of the technical performance of the dancers (Notarnicola). Those training with the mirror were able to see themselves and thus do a self-check to make their own changes to their body. This improvement in technical aesthetics and achievement was not specifically measured by the study, but was observed in the opinions of those conducting the study. "Improvement found after 6 months confirms that at the age of the dancers studied motor skills and balance can easily be trained and improved" (Notarnicola). The authors of the study did find some flaws with their testing. The BESS only accounted for static movement, and "dancing allows for a good commando of static and dynamic movement" (Notarnicola). The study defines balance as "a complex function achieved by multi-sensory integration of visual, vestibular, and somesthetic afferences, central motor control, and context-specific response generation" (Notarnicola). In reflection of this definition, those conducting the study concluded that their examination of the dancer's improvement of balance may not have been entirely cohesive. While the mirror itself did not seem to have any effect on this static balance test at the start and end of the short period of six months, the researchers concluded that there was significant overall improvement in the balance of the dancers at the conclusion of the six-month period. Had the test extended a longer period of time, there may have been more change evident. Additionally, the researchers compared their results to a few other tests that were unofficially conducted in reflection of this. Tests examining dynamic balance found that dancers tested better than other athletes and static stability tests were only slightly better in comparison to other athletes. These results were purely

generated from the "specificity of the training for dance" in that "virtually any dance style challenge balance", unaffected by the use – or lack thereof – a mirror (Notarnicola).

Another concept that was not discussed in the previous study was the method through which the dancers were learning the movement. The mirror is used by instructors of dance classes to effectively demonstrate the choreographic combinations to be done. The mirror aids in allowing the dancers to see the instructor, as well as to allow the instructor to see the students while demonstrating movement. The concept of action observation and the connection to acquired motor skills was examined in a group of expert dancers to truly determine the relationship between action observation and the acquiring or the initiation of previously acquired motor skills. The central question driving this study was "When we observe someone performing an action, do our brains stimulate making that action?" (B. Calvo-Merino). In order to test this, researchers sought to "study differences in brain activity between watching an action that one has learned to do and an action that one has not" (B. Calvo-Merino). The purpose of this was to see if the brain processes of action observation are regulated by the motor repertoire and expertise of the observer (B. Calvo-Merino). Among those being examined were 10 male professional ballet dancers from the Royal Ballet, 9 professional capoeira dancers, and 10 non-expert control subjects. While "both dance styles involve a well-established, distinctive set of movements", both capoeira and ballet are "kinematically comparable" (B. Calvo-Merino).

In previous action-observation studies, specifically those with masque monkeys, 'mirror' neurons have been reported to discharge when watching the experimenter or another monkey perform an action. This concept of mirror neuron is studied throughout this experiment, looking at where exactly the human action observation takes place in the brain through the use of functional magnetic resonance imaging. Additionally, the researchers sought to investigate "whether a person's action observation system is precisely tuned to his or her *individual* motor repertoire" (B. Calvo-Merino). Within this study, "motor repertoire is constrained not only by common musculoskeletal anatomy, but also by the acquired skills that a person has learned" (B. Calvo-Merino). All of the subjects are right-handed males, 18-28 years old with no neurological or psychiatric history that were all screened to ensure that they had not had training in the other dance style. Everything involved in videos used in the study was meticulous and specific. The individual performing was matched to the individuals watching as far as body and build, similar movements between the two styles displayed in the videos were shown, as well as the speed and direction of in which the body was moving was similar in both dance styles. All the videos were taken against a neutral chromablue background and the faces were blurred to absolve any personal connection based on emotional feeling and intent. The videos were 12 pairs of 3 second video clips, and each video was repeated four times with 4 "null events" (black screens) presented (B. Calvo-Merino). In order to keep the subjects fully engaged, the subjects were instructed to press a button "indicating 'how tiring' they thought each movement was" (B. Calvo-Merino).

In short, the results showed that action observation in humans involves an internal motor stimulation of the observed movement. All groups saw the same stimuli, however each group's brains responded to the stimuli in a way that directly effected the observer's specific motor experience and repertoire. Based on this study, action observation recruits these "mirror areas" to the extent that the observed action is represented in a subject's personal repertoire. In other words, the activation of the mirror areas of the brain are only evident if the action being observed is within the subject's skillset. Going further into the investigation of the results, it was revealed that the mirror system of neurons encodes complete action patterns, not just individual component movements as originally thought. It is sensitive to extremely abstract and

complicated levels of action organization, including those that differentiate dance styles, emphasizing the "expertise effect" of experts recognizing their own dance style and having consequent neurological reactions. This system of action observation is entirely concerned with observing skilled movements and action plans for more complex movements.

These results were demonstrated by a number of graphs and charts, as well as explanations of the specific areas of the brain that were activated by each stimuli for each group. "Dance stimuli obviously involved the whole body… suggest that movements of each body part are coded in independent, parallel, parieto-frontal circuits that subserve somatatopically organized motor representations of the different effectors" (B. Calvo-Merino). The network of motor areas involved with preparation and execution of action were activated simply by observation of actions, and was stronger when the subjects had specific motor representation for the action they observed.

Looking at these different dance studies provides a new perspective on the dancer as an athlete and a mover. Dance science is a relatively new field in comparison to the observation and studies of other athletes and sports. This is evident both in dance medicine, as well as in dance studies like the ones reviewed in this paper. In this, dance provides an interesting atmosphere of challenges and questions left unanswered by the kinesiological field. Dance seeks to push the boundaries of human movement and control, thus providing a slew of intriguing subjects to be examined and tested in comparison to other athletes. As demonstrated, some of these subjects are balance control and visual fixation, the effects of the mirror on both balance and technical success, and the effects of expertise on action observation. Reviewing all of these studies simply grazes the surface of what it makes dancers unique in comparison to other athletes. Because of the specificity of dance and dance training – regardless of the style – these studies must be meticulous and distinct to what is being examined and the purpose of the study.

Works Cited

B. Calvo-Merino, D.E. Glaser, J. Grèzes, R.E. Passingham, P. Haggard; Action Observation and Acquired Motor Skills: An fMRI Study with Expert Dancers. *Cereb Cortex* 2005; 15 (8): 1243-1249. doi: 10.1093/cercor/bhi007

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