Research

Yoga practice is associated with superior motor imagery performance

Susannah H Hartnoll & T David Punt

University of Birmingham

Correspondence: smhartnoll@gmail.com

Abstract

Yoga is an activity that aims to integrate physical, mental and spiritual elements and is an increasingly popular approach to enhancing physical fitness. The integration of imagery within yoga practice is considered an important component and may be critical in contributing to the benefits of yoga that have been reported. In this study, we tested whether individuals who practice yoga demonstrate superior performance on an objective measure of implicit motor imagery. Thirty-six participants (18 yoga, 18 non-yoga) matched for age, sex and handedness, undertook the *hand laterality recognition task*; an objective measure of implicit motor imagery performance. Accuracy and response times were gathered and analysed to determine any group differences as well as any differences relating to the typical *hallmarks* of imagery (i.e. *dominance* and *awkwardness* effects) on the task. Response Times (RTs) in the yoga group were significantly faster than controls ($p < 0.05$) and there was also a trend towards greater accuracy for the Yoga group ($p = 0.073$). *Dominance* effects (faster responses to images corresponding with the dominant limb) and *Awkwardness* effects (faster responses to images corresponding with natural compared with awkward postures) were evident across groups, supporting the participants' use of motor imagery in undertaking the task. Additionally, a *Group* x *Awkwardness* interaction ($p < 0.05$) revealed that the enhanced imagery performance for the yoga group was most pronounced for awkward postures. This is the first study to show that yoga practice is associated with superior motor imagery performance; an association that may be important in explaining the established rehabilitative value of yoga for chronic pain.

Introduction

In contemporary western society, yoga is an increasingly popular approach to improving physical fitness and research has shown that its practice is associated with a range of physical and mental health benefits. However, this focus on physicality was never the intention of yoga.[1] A physical, mental and spiritual practice, yoga is thought to have its origins in India dating back over three thousand years. One of the many definitions of the word yoga is 'union' and in spiritual terms is described as the bringing together of individual and universal consciousness. On a practical level, yoga may be considered a means of 'bringing together' mind and body. As practitioners advance and begin to engage more deeply with the techniques, yoga is considered to become a largely mind-based practice.[2] The most common yoga practised in the West is Hatha Yoga,[3] and while there are many styles of this form (e.g. Ashtanga Vinyasa, Iyengar, and General Hatha), common practices include *asana* (the assumption of specific postures), *pranayama* (breath-control), meditation and *yoga nidra* (guided relaxation with imagery).

It is the integration of imagery within yoga that is the focus of this study. Language used in yoga classes instructs students to perform motor imagery of a desired action while also focusing on the associated kinaesthetic sensation, intended to heighten the sensory experience.[3] Such an approach appears to have similarities with motor imagery training where the instigation of internally driven images combined with layering of additional sensory (kinaesthetic) associations of the proposed action is encouraged.[4] It is known that a greater physiological response is observed when motor imagery training is conducted from an egocentric perspective[5] and such an approach is common in yoga, as students are repeatedly instructed to mentally simulate specific actions. Examples of such language include, "Begin to roll the upper legs inward and the lower legs slightly outwards. Your legs will not actually rotate in either direction, but you will become more aware of your leg muscles in the process."[3]

Given that imagery is a key component of yoga, one might predict that experienced yoga practitioners would have superior skills in performing motor imagery compared with those who do not. Establishing such a relationship is challenging as most measures of motor imagery suffer from being highly subjective. However, the hand laterality recognition task provides a solution.[6] In this task, individuals are presented with a series of images, each depicting a hand in various postures and asked to judge the laterality of each with accuracy and response time (RT) providing an index of performance.[6-8] Importantly, it is established that individuals perform the task by mentally rotating their own limbs to the positions of those depicted.[6, 9] Individuals are not instructed to follow this approach and may not be aware of how they solve the task. The hand laterality recognition task is therefore considered a measure of *implicit* motor imagery. [10] Typically, images depicting more awkward postures elicit poorer performance (i.e. slower and less accurate responses) than those depicting more natural postures.[6, 11] Similarly, images corresponding with the dominant limb elicit faster responses than images corresponding with the non-dominant limb.[12-14] The subsequent *awkwardness* and *dominance* effects that are produced by the hand laterality recognition task provide further confidence that the task is eliciting motor imagery rather than some other approach.

In this study, we compared hand laterality recognition task performance in yoga practitioners with that of a control group (i.e. age-matched individuals who do not practice yoga).

Materials and Methods

The study was approved by the University of Birmingham's Science, Technology, Engineering and Mathematics Ethical Review Committee, and conducted in coherence with the Declaration of Helsinki. Participants provided written informed consent prior to taking part. The study involved a mixed experimental design.

Participants

Thirty-six participants were included in the study. Eighteen participants (6 males, 17 right-handed) with a mean age of 48 years (range = 30-69, SD = 12.4) comprised the yoga group. All had been practising yoga continuously for a minimum of one hour per week, and for one year or more. Characteristics of the yoga group including years of experience, frequency of practice, and style of yoga followed are shown in Table 1. A further 18 participants (6 males, 18 right-handed) made up the control group. Participants in the control group stated they had no previous yoga experience. This group had a mean age of 49 years (range = 31-71, SD=13.3). An independent t-test confirmed that the two groups had comparable ages (t (34) = 0.26, p = 0.80).

Procedure

Participants completed a hand laterality recognition task on a laptop PC. The experiment was programmed using specialist software (E-Prime 2.0, www.pstnet.com/eprime). Experimental stimuli were black and white line drawings of hands replicated with permission.[15] There were four views of each hand (back, front, thumb and wrist) and each image was presented in twelve different degrees of rotation/orientation (0°–330°, each separated by 30°) (Figure 1). This gave rise to a total of 96 different images. Images were categorised as natural or awkward based on previous work by Nico and colleagues.[11]

The experiment took place in a quiet room. Participants sat in an upright posture at a comfortable distance (approximately 50cm) from the screen. The presentation of each image was preceded by a fixation cross in the middle of the screen for a random period between 1100ms

Components of Yoga Practice (%)	
Asana	100
Meditation	89
Yoga Nidra	83

Styles of Yoga (%)	
Restorative	50
General Hatha	22
Vinyasa/Dynamic	17
Ashtanga	11

Types of Meditation (%)	
Mindfulness	50
Unknown	38
Other	12
One-pointedness	0

Main reasons for practising Yoga
1. Relaxation
2. Strength
3. Flexibility

Years spent practising Yoga (%)	
1-3	34
5-10	5
10+	61

Frequency per week (%)	**1-2x**	**3-6x**	**7x**
Asana	32	26	42
Meditation	50	25	25
Yoga Nidra	33	47	20

Length of time spent per practice (%)	**5-15 mins**	**15-30 mins**	**30-60 mins**	**60-90 mins**	**90-120 mins**
Asana	-	-	33	50	17
Meditation	50	25	25	-	-
Yoga Nidra	60	40	-	-	-

Table 1. Characteristics of the Yoga Group

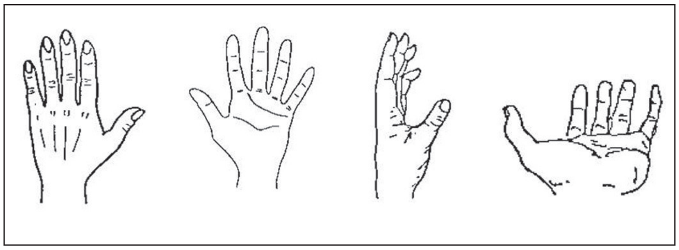

Figure 1. Examples of line drawings presented in the experiment.
There were four views of the left and right hands (back, front, thumb and wrist), and each were presented in 12 different degrees of rotation (0°–330°, each separated by 30°). In total, there were 96 different images. Left hand images are shown here at 0°.

and 1500ms. Images were displayed until a response was made. Participants indicated their left/right judgment by pressing keys on the laptop PC. Accordingly, participants indicated a right hand by pressing the 'N' key with their right index finger and a left hand by pressing the 'V' key with their left index finger. Index fingers remained resting on these keys throughout the experiment. Participants were instructed to respond as quickly and as accurately as possible.

Following a short practice involving eight images and responses, participants completed 3 blocks of 96 trials (images); 288 trials in all. The type of image (laterality, view, orientation) was randomised across trials. Accuracy and RT (in milliseconds) were recorded.

Data analysis
Accuracy and RTs were analysed. Mean accuracy was defined as the proportion of correctly identified images and expressed as a value between 0 (none correct), and 1 (all correct). Response time for each trial was the period between the image (stimulus) appearing on screen and the key press. Only correct responses were included in the related analyses. Mean accuracy and median RT for accurate trials were calculated for each participant and for each factor of interest. These data were subsequently analysed using SPSS version 22.0. Two (accuracy and RT) 2x2x2 Group [Yoga vs. Control] x Side [Dominant vs. Non-dominant) x Awkwardness (Natural vs. Awkward) analyses of variance (ANOVA) with repeated measures for the latter two factors (Side, Awkwardness) were conducted. Where these revealed interactions, the related simple effects were explored.

Results

There was a trend for greater accuracy in the Yoga group (M = 0.95, SD = 0.04) than in the Control group (M = 0.92, SD = 0.07) (F (1, 34) = 3.32, p = 0.077, η^2_p = 0.89]. Accuracy for images corresponding with dominant (M = 0.93, SD = 0.06) vs. non-dominant (M = 0.93, SD = 0.06) limbs was comparable (F (1, 34) = 0.05, p = 0.826, η^2_p = 0.001]. Accuracy for images corresponding with awkward postures (M = 0.90, SD = 0.09) was lower than those corresponding with natural postures (M = 0.97, SD = 0.04)) leading to a significant main effect for Awkwardness (F (1, 34) = 37.26, p < 0.001, η^2_p = 0.523). Accuracy data did not reveal any interactions.

The Yoga group (M = 1317msec, SD = 545msec) demonstrated faster responses than the Control group (M = 1725msec, SD = 545msec) leading to a significant main effect of Group (F (1, 34) = 5.04, p < 0.05, η^2_p = 0.129]. Response time data also showed a significant main effect of Dominance (F (1, 34) = 24.11, p < 0.001, η^2_p = 0.42); responses to images corresponding with the dominant hand (M = 1423msec, SD = 379msec) were faster than for images corresponding with the non-dominant hand (M = 1619msec, SD = 410msec). Additionally, responses to images corresponding with awkward postures (M = 1805 msec, SD = 485msec) were markedly slower than for natural postures (M = 1236msec, SD = 299msec) leading to a significant main effect of Awkwardness (F (1, 34) = 107.54, p < 0.001, η^2_p = 0.760). However, there was also a Group x Awkwardness interaction (F (1, 34) = 5.33, p < 0.05, η^2_p = 0.135). Exploration of this revealed that the yoga group's superiority was most evident for images corresponding with more awkward postures (F (1, 34) = 5.47, p = 0.025, η^2_p = 0.14) than for images corresponding with natural postures (F (1, 34) = 3.98, p = 0.05, η^2_p = 0.11). These data are shown in figure 2. Figure 3 shows the same data according to the degree of rotation from neutral (0°); see figure caption for more details. There were no other 2-way or complex interactions.

Discussion

A central component of yoga practice is the simulation of movement. One might therefore reasonably expect experienced yoga practitioners to develop an enhanced ability to perform motor imagery. We tested this hypothesis by comparing the performance of a group of experienced yoga practitioners with that of an age-matched control group on a task that implicitly elicits motor imagery; the hand laterality recognition task. Data presented here are supportive of the hypothesis; yoga practitioners demonstrated superior performance on the task. The enhanced motor imagery ability of the Yoga group was demonstrable through faster RTs to identify the laterality of hand images without any decrement in accuracy; indeed, accuracy was marginally

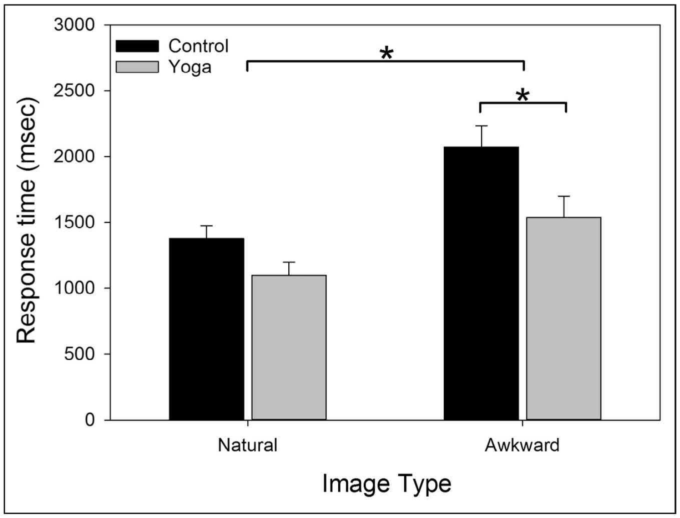

Figure 2. Mean response times for the Yoga and Control groups and for Natural vs. Awkward images.
Error bars denote the standard error of the mean.
Asterisks denote statistical significance.

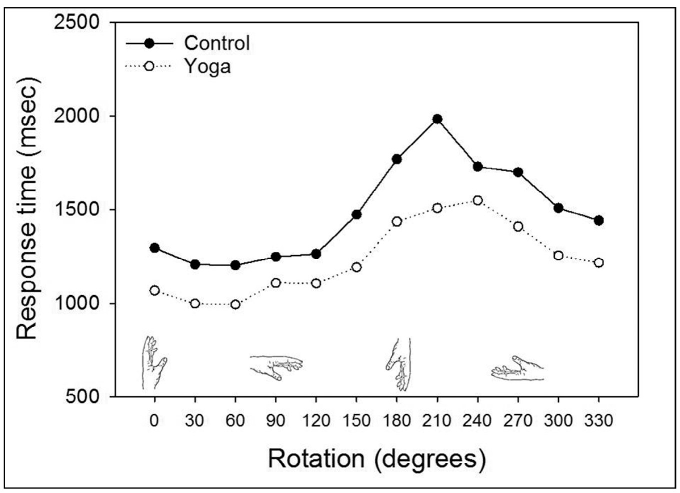

Figure 3. Mean response times for the Yoga and Control groups as images rotated from 0° to 330°.
Rotations clockwise from 330° to 120° represent natural (largely medial) positions, whereas rotations clockwise from 150° to 300° represent awkward (largely lateral) positions, in line with a previous study. [11]

superior for the Yoga group also. The results cannot therefore be explained by a speed-accuracy trade-off.

Comparison with an age-matched control group aimed to provide a means to attribute any performance difference in the Yoga group to 'yoga'. However, could it be that our control group's performance was not representative? This seems unlikely. Both accuracy and RTs were consistent with previous studies where a similar aged control group were included, and where stimuli and response mode were the same.[15] Other than practicing yoga, there were no evident differences between the two groups.

It was possible to show that both groups were using a motor strategy (i.e. motor imagery) in order to complete the task. This was evident through the exploration of what are often referred to as *dominance* and *awkwardness* effects, the typical *hallmarks* of motor imagery. For example, responses to images corresponding with the dominant limb were faster than responses corresponding with the non-dominant limb.[13, 14, 16] Additionally, responses to images corresponding with awkward postures were slower than responses to images corresponding with natural postures.[6, 11, 17, 18] While these findings provide confidence that both groups used motor imagery, the Yoga group were simply better at the task. Furthermore, as well as demonstrating generally enhanced performance on the task, the superiority of the Yoga group was particularly evident in their responses to images corresponding with more awkward postures. We interpret these findings as reflecting the experience and related expertise that yoga practitioners have developed in mentally simulating movement. To our knowledge, this is the first experimental demonstration that those who practise yoga display superior motor imagery performance. While motor imagery practised in yoga is explicit, it is striking that related expertise was shown in this study to translate to an implicit motor imagery task. It is important to recognise that the task in the study was not presented to participants as a motor imagery task. Individuals were not asked to imagine movements and neither were imagined movements requested. Although our data clearly show that motor imagery was elicited by the task, individuals are typically not aware of this when completing the task.[10]

The findings presented here contrast markedly with a previous study that showed no difference in performance on a laterality recognition task between a yoga group and a control group.[19] There are perhaps a number of reasons for these contrasting findings. Firstly, participants in the previous study were recruited as part of a large online cross-sectional study where one of multiple questions asked was whether individuals participated in yoga for 30 minutes a week or not. Related data were subsequently extracted for analysis. In contrast, in the present study, participants in the yoga group were recruited purposively, the sample including relatively experienced yoga practitioners with a minimum of one year's experience and practising for at least one hour per week. Secondly, while the hand laterality recognition task tends to reliably elicit implicit motor imagery, it is important to report data in a manner that provides confidence of this, as there are reports of alternative non-motor strategies being used.[17, 20] In this study, we probed the resulting data for awkwardness and dominance effects that carry the hallmarks of motor imagery (see above); there was no such analysis in the previous study.[19] The authors of that study acknowledge that as a result of their study being conducted online, they had little control over important technical elements of the study. As a laboratory-based study, we were able to closely supervise and standardise issues such as participant posture[21] and response mode[14] which can have a significant effect on performance in laterality recognition tasks. Additionally, our task was not vulnerable to the errors that can be associated with online RT studies.[22-24]

In recent years, yoga has been shown to have therapeutic value in patients with persistent pain of the limbs; systematic reviews of randomised controlled trials have been conducted to support this.[25, 26] However, to date mechanisms underpinning these findings have been unclear.[27] It has been shown that patients with persistent pain are slower to recognise images corresponding with affected limbs [28, 29] and that the cortical representation of movement in affected limbs is correspondingly reduced.[30] Yoga aims to improve the awareness of one's body via a number of components including the practicing of simulated movements (motor imagery). Our findings of enhanced motor imagery in yoga practitioners suggest that yoga may contribute to optimising the cortical representation of the body in a manner consistent with the superior imagery demonstrated. However, yoga may be considered a complex intervention and its reported effects on body awareness (proprioception, interoception, embodiment)[31-33] may have also contributed to the enhanced performance we report here. Our study is unable to determine the relative contributions of these factors to the findings. Similarly, while we refer to the potential explanatory value that enhanced motor imagery may provide in understanding the therapeutic effects of yoga for individual with chronic pain, we accept that there are multiple theories that may lend themselves to this issue.[34]

Previous research has shown how superior motor performance of learned complex movements is reflected in the enhanced ability to simulate the same movements during action observation.[35, 36] Similarly, this study supports the positive impact of yoga on motor imagery performance. Future follow-up research could strengthen this relationship further. It would be interesting to examine whether a yoga-based intervention improves motor imagery performance in a prospective trial where the control group undertakes some form of physical activity other than yoga. Such a study has the potential to strengthen any causal relationship between yoga and superior motor imagery performance.

Conclusion

This study has shown that experienced yoga practitioners perform at a superior level compared with age-matched control participants on a task that implicitly elicits motor imagery. This finding supports the notion that practicing yoga can improve body awareness and may help to provide the hitherto elusive mechanism accounting for the potential rehabilitative value of yoga for individuals suffering persistent pain.

References

1. Satchidananda, S., *The yoga sutras of Patanjami. 1978*, Buckingham: Integral Yoga Publications.

2. Feuerstein, G., *The yoga tradition. 2001*, Chino Valley: Hohm Press.

3. Kappmeier-Foust , K.L. and D. Ambrosini, *Instructing Hatha Yoga. 2005*, Champaign: Human Kinetics Publishers.

4. Williams, S.E., S.J. Cooley, and J. Cumming, Layered stimulus response training improves motor imagery ability and movement execution. *Journal of Sport & Exercise Psychology, 2013.* 35(1): p. 60–71.

5. Guillot, A., et al., Brain activity during visual versus kinesthetic imagery: an fMRI study. *Human Brain Mapping, 2009.* 30(7): p. 2157–72.

6. Parsons, L.M., Imagined spatial transformations of one's hands and feet. *Cognitive Psychology, 1987.* 19(2): p. 178–241.

7. Cooper, L.A. and R.N. Shepard, Mental transformations in the identification of left and right hands. *Journal of Experimental Psychology-Human Perception and Performance, 1975.* 104(1): p. 48–56.

8. Ionta, S., et al., The influence of hands posture on mental rotation of hands and feet. *Experimental Brain Research, 2007.* 183(1): p. 1–7.

9. Parsons, L.M., Temporal and kinematic properties of motor behavior reflected in mentally simulated action. *Journal of Experimental Psychology-Human Perception and Performance, 1994.* 20(4): p. 709–730.

10. Parsons, L.M., Integrating cognitive psychology, neurology and neuroimaging. *Acta Psychologica, 2001.* 107(1-3): p. 155–181.

11. Nico, D., et al., Left and right hand recognition in upper limb amputees. *Brain, 2004.* 127(1): p. 120–132.

12. Gentilucci, M., E. Daprati, and M. Gangitano, Right-handers and left-handers have different representations of their own hand. *Cognitive Brain Research, 1998.* 6(3): p. 185–192.

13. Takeda, K., et al., Reaction time differences between left- and right-handers during mental rotation of hand pictures. *Laterality, 2010.* 15(4): p. 415–425.

14. Cocksworth, R.L. and T.D. Punt, When the left hand does not know what the left hand is doing: response mode affects mental rotation of hands. *Experimental Brain Research, 2013.* 228(1): p. 87–95.

15. Parsons, L.M., et al., Cerebrally lateralized mental representations of hand shape and movement. *Journal of Neuroscience, 1998.* 18(16): p. 6539–6548.

16. Ni Choisdealbha, A., N. Brady, and C. Maguinness, Differing roles for the dominant and non-dominant hands in the hand laterality task. *Experimental Brain Research, 2011.* 211(1): p. 73–85.

17. Tomasino, B. and R.I. Rumiati, Effects of strategies on mental rotation and hemispheric lateralization: neuropsychological evidence. *Journal of Cognitive Neuroscience, 2004.* 16(5): p. 878–888.

18. ter Horst, A.C., R. van Lier, and B. Steenbergen, Mental rotation task of hands: differential influence number of rotational axes. *Experimental Brain Research, 2010.* 203(2): p. 347–354.

19. Wallwork, S.B., et al., Are people who do yoga any better at a motor imagery task than those who do not? *British Journal of Sports Medicine, 2012.*

20. King, R., et al., My foot? Motor imagery-evoked pain, alternative strategies and implications for laterality recognition tasks. *Pain Medicine, 2015.* 16(3): p. 555–7.

21. de Lange, F.P., R.C. Helmich, and I. Toni, Posture influences motor imagery: an fMRI study. *Neuroimage, 2006.* 33(2): p. 609–617.

22. Plant, R.R. and G. Turner, Millisecond precision psychological research in a world of commodity computers: New hardware, new problems? *Behavior Research Methods, 2009.* 41(3): p. 598–614.

23. Reimers, S. and N. Stewart, Adobe Flash as a medium for online experimentation: A test of reaction time measurement capabilities. *Behavior Research Methods, 2007.* 39(3): p. 365–370.

24. Schmidt, W.C., Presentation accuracy of Web animation methods. *Behavior Research Methods, Instruments, and Computers, 2001.* 33(2): p. 187–200.

25. Büssing, A., et al., Effects of yoga interventions on pain and pain-associated disability: A meta-analysis. *Journal of Pain, 2012*. 13(1): p. 1–9.

26. Piazzini, D.B., et al., A systematic review of conservative treatment of carpal tunnel syndrome. *Clinical Rehabilitation, 2007*. 21(4): p. 299–314.

27. Wren, A.A., et al., Yoga for persistent pain: new findings and directions for an ancient practice. *Pain, 2011*. 152(3): p. 477–80.

28. Schwoebel, J., et al., Pain and the body schema - Evidence for peripheral effects on mental representations of movement. *Brain, 2001*. 124(10): p. 2098–2104.

29. Moseley, G.L., Why do people with complex regional pain syndrome take longer to recognize their affected hand? *Neurology, 2004*. 62(12): p. 2182–2186.

30. Maihofner, C., et al., The motor system shows adaptive changes in complex regional pain syndrome. *Brain, 2007*. 130(10): p. 2671–2687.

31. Fiori, F., N. David, and S.M. Aglioti, Processing of proprioceptive and vestibular body signals and self-transcendence in Ashtanga yoga practitioners. *Frontiers in Human Neuroscience, 2014*. 8.

32. Schmalzl, L., M.A. Crane-Godreau, and P. Payne, Movement-based embodied contemplative practices: Definitions and paradigms. *Frontiers in Human Neuroscience, 2014*. 8(1 APR).

33. David, N., F. Fiori, and S.M. Aglioti, Susceptibility to the rubber hand illusion does not tell the whole body-awareness story. *Cognitive, Affective and Behavioral Neuroscience, 2014*. 14(1): p. 297–306.

34. Gard, T., et al., Potential self-regulatory mechanisms of yoga for psychological health. *Front Hum Neurosci*, *2014*. 8: p. 770.

35. Calvo-Merino, B., et al., Action observation and acquired motor skills: an FMRI study with expert dancers. *Cereb.Cortex, 2005*. 15(8): p. 1243–1249.

36. Cross, E.S., A.F. Hamilton, and S.T. Grafton, Building a motor simulation de novo: observation of dance by dancers. *Neuroimage, 2006*. 31(3): p. 1257–67.