Mirror Neuron Activation Priming in Novice Versus Expert Ballet Dancers

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Mirror Neuron Activation Priming in Novice

Versus Expert Ballet Dancers

A thesis submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Psychology from the College of William and Mary

By

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Abstract

The mirror neuron system (MNS) includes a collection of neurons in the brain that respond to the performance and observation of similar motor actions. Exploration of this system has furthered the understanding and representation of learning through imitation, action understanding, motor system activation, empathy, and language processing, among other fields of interest in cognitive neuroscience. This study explores activation of the MNS by video or audio cueing in expert ballet dancers versus non-dancers in order to demonstrate how visual and audio presentation of familiar and non-familiar movements can prime an individual's performance on a serial motor response task. It was found that dancers are faster at initiating responses in comparison to non-dancers on all tasks. Additionally, it was found that regardless of group, participants had faster total reaction times when presented with video versus audio action stimuli. A stimulus by group interaction was also observed when measuring initial and total reaction time. Finally, all participants were found to have faster average total reaction times when presented with everyday, innate movements in comparison to ballet dance movements. Overall, this study demonstrates a variety of patterns of priming of the motor system from action observation and what we believe to be MNS activation. Namely, action observation appears to be uniquely facilitative (as compared to verbal cueing) and this facilitation is stronger with everyday, familiar actions as well as in populations that have more than average experience with the movement.
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Mirror Neuron Activation Priming in Novice Versus Expert Ballet Dancer Populations

The mirror neuron system (MNS) has elicited considerable interest in the psychology and neuroscience fields for its role in the mediation and activation of movement. Mirror neurons respond when an individual observes and performs a movement. In other words, when the observing individual sees another completing the movement and, by means of a shared perspective, understands what the acting individual is doing, activation of the MNS occurs. This process sets the stage for not only movement learning but also for the development of emotional and cognitive empathy. There has been a great deal of research performed to demonstrate the effect that the MNS has upon different types of cognitive processing. Many hypotheses have been presented and tested regarding the role that the MNS plays in imitation, intention, action understanding, empathy, and language processing (Rizzolatti, 2005).

*The mirror neuron system (MNS)*

The earliest MNS exploration showed that F5 cells in the premotor cortex in macaque monkeys were activated in response to both self performance and observation of others performing simple movement tasks (Rizzolatti & Craighero, 2004). In general, fMRI studies in humans reveal consistent activation of the frontal and parietal regions during MNS study (Braadbart, Williams, & Waiter, 2013; Grezes, Armony, Rowe, & Passingham, 2003; Haker, Kawohl, Herwig, & Rössler, 2013). Additionally, magnetoencephalography (MEG) and electroencephalography (EEG) have shown activation of the motor cortex in similar experimentation
(Rizzolatti, 2005). In EEG testing specifically, the MNS empathetic response is determined by the mu, or sensorimotor rhythm. This is a 8-12 Hz alpha or 12-25 beta frequency band activation in the sensorimotor cortex (Hari & Salmelin, 1997; Rizzolatti & Fabbri-Destro, 2008). While alpha rhythm is normally found when testing regions of the brain such as the occipital cortex (Perry, Stein & Bentin, 2011), mu rhythms are found in the sensorimotor cortex, and suppression has been correlated with the empathetic processing of one’s actions and the actions of others (Llanos, Rodriguez, Rodriguez-Sabate, Morales, & Sabate, 2013; Kumar, Riddoch & Humphries, 2013; Perry, Stein & Bentin, 2011).

Rizzolatti reviewed several MNS functions in different pieces of literature (Rizzolatti, 2005). He found that this system plays a key role in the immediate repetition of observed actions and learning through imitation. The MNS has also been shown to be involved in motor intention understanding. For example, fMRI imaging has revealed its activation during an observed grasping action in a matched context and unmatched context, illuminating the MNS role in understanding of intention in relation to action (Rizzolatti, 2005). Interestingly, emotional processing has also been shown to be associated with MNS activation. In another experiment discussed, it was found that participants presented with disgusting odorants revealed the same brain activation pattern as those seen during observation of the visual stimuli composed of facial expressions depicting disgust (Rizzolatti, 2005).

Kohler et al. (2002) examined the effect of action sound as it related to action understanding and the MNS. Using single-cell recording, they found that premotor cortex activation occurred when monkeys performed, observed, and heard the
sound corresponding to a particular action. The largest number of activated neurons occurred in response to the sound of a peanut breaking and paper ripping, both of which were tangible, familiar sounds to the monkeys. These researchers termed the activated neurons “audiovisual mirror neurons” and believed that they could have implications in terms of linguistic processing due to the current findings related to auditory processing. It was also suggested that audiovisual mirror neurons play a role in executive planning, execution of actions, and recognition of the actions of others (Kohler et al., 2002). Although this research looked at brain activity in response to object-related sounds of movements, it certainly has implications for the activation of the MNS in response to movement commands used in the present study.

Wrightson and colleagues (2016) were interested in the effect that observing rigorous exercise might have on personal exercise performance and activation of the AON as seen in previous literature. In the first two experiments, participants completed an arm-crank task while observing videos depicting either exercise done at a typical speed, fifteen percent faster than typical speed, fifteen percent slower than typical speed, or they were shown a blank screen. In the third experiment, TMS was utilized while participants were exposed to the above conditions and again, performed the arm-crank task. The results of the three-part study revealed that observation of the fast exercise video condition improved the task performance, although no cortico-spinal excitability effects were observed (Wrightson, Twomey, & Smeeton, 2016). These findings are related to the present study in demonstrating
how observation of movement can prime the AON, or according to our assumptions about the MNS, to produce better serial motor response task performance.

Letesson and colleagues (2015) were interested in goal-oriented behavior, intention, and action priming, and their relationship to eye gaze specifically. In their experiment, action execution followed action observation, while manipulation of the congruency between the target of the agent's and observer's actions, and the observed and executed action spatial location also took place. Eye movements were recorded during observation while a motion evaluation was used to test the effect of action priming. Results showed a relationship between eye gaze and movement performance. Additionally, action cues primed the spatial and object congruency of the actions (Letesson, Grade, & Edwards, 2015). All of the concepts of interest in this study are related to MNS functioning while these findings can relate to the present study in terms of demonstrating action priming through observation.

With interests similar to those of the present study, Edwards and colleagues (2003) aimed to explore the effect which visual presentation of a particular action could have on the execution of that action following observation. Participants were given spectacles that through specific timed discharge of a crystallized liquid, would cause an opaque coloring and therefore obstructed view, in order to control viewing of the presented actions. Valid trials, in which grasp and movement of a the same size object as the subsequent task and invalid trials, in which grasp and movement of objects varying in size, were presented to the participants. Following these trials, they performed a movement task on their own. Results showed that participants were faster during the reaching component of the action when presented with the
valid versus invalid priming conditions. Although this study certainly provides evidence for the effect of priming in relation to the MNS, the authors point out that grasping in particular appears to be susceptible to priming unless intense top-down damage is acting to inhibit the action. This is evident in agnostic patients with damage to the ventral cortex who are still able to grasp objects although they are unaware of their presence. In contrast, damage following disruption of the dorsal cortex disrupts one’s grasping ability (Edwards, Humphreys, & Castiello, 2003).

Ménoret and colleagues performed an experiment in order to test the shared neural mechanisms that overlap action observation, simulation, and execution, all of which are relevant to the present study. Participants observed and performed congruent or non-congruent actions while under combined kinematics and electrophysiological recording. Results showed an increase in the movement speeds of the actions, and a higher number of negative motor-related potentials during congruent action observation in comparison to non-congruent action observation (Ménoret, Curie, des Portes, Nazir, & Paulignan, 2013).

**MNS activation in expert and non-expert populations**

There is considerable literature related to MNS activation across expert and non-expert performers. Tomeo and colleagues (2012) performed a study that measured the visuo-motor expertise of novice versus expert soccer players in recognizing false actions before they were committed. Expert goalkeepers, kickers, and novices were shown a series of penalty kick videos in which they had to predict the fate of the ball to either side of the goal during the initial body movement, at the time at which the foot made contact with the ball, and during the initial phase of the
ball trajectory. In a subsequent experiment, the cortico-spinal motor correlation to the ability of participants to correctly predict the kicks was measured using transcranial magnetic stimulation (TMS) to excite certain lower extremity areas following the observation of videos presented in the first experiment. It was found that both kickers and goalkeepers performed better in determining the direction of the kick in comparison to novices. Additionally, kickers were more susceptible than the goalkeepers or novices to falsely detecting actions that were incongruent with their initial set-up. Finally, diverse behavioral effects were found among the three groups in terms of cortico-spinal activation of the lower extremities that suggest inhibition and activation of motor systems in response to incongruent versus congruent actions (Tomeo, Cesari, Aglioti, & Urgesi, 2013). This literature provides abstract evidence for the role of the MNS in expert populations.

A similar study was completed by Orgs and colleagues (2008). They tested professional contemporary dancers and non-dancers, as the present study does. However, they examined EEG response to sixteen contemporary dance movements versus everyday movements. The main finding was that the dance movements elicited EEG alpha/beta event-related desynchronization (ERD), or the mu rhythm suppression, in the sensorimotor areas in dancers but not in non-dancers. The researchers suggest that these findings are a result of activation of the MNS due to the familiarity of the movements to the dancer participants. Additionally, it was found that the ERD response was more distinct during observation of the dance versus everyday movements in both populations (Orgs, Dombrowski, Hell, & Jansen-Osmann, 2008). Both of these findings have tangible applications to the present
study. We will extend this work by examining not only visual stimuli in the form of video action performances, but also linguistic descriptions of these movements.

Calmels, Pichon, and Grèzes (2014) were curious as to whether expert populations can simulate an action that they temporarily cannot perform due to injury. Thirteen national female gymnasts who had experienced injury to a lower extremity during the initial phase of the experiment were chosen for testing on the brain action observation network (AON). Each of the participants was scanned once per month following the injury while being presented with gymnastics routines that they could not perform at that time. It was found that there were no discrepancies from injury to recovery in the level of activity in areas that compose the AON including the inferior parietal lobe, MT, V5, and the extrastriate body area (EBA). This suggests that injury does not greatly disturb expert AON activation. It was also found that severity of the injury correlated to higher activity of the cerebellum, suggesting that this brain region may be responsible for determining if a movement can be feasibly performed (Camels, Pichon, & Grezes, 2014).

Cannon and colleagues (2005) found that mirror neurons are goal-directed and specific to personal motor repertory, both of which are key concepts in predicting activation of the MNS in expert populations. They discuss an fMRI-based study performed by Calvo-Merino and colleagues (2005) in which similar ballet and capoeira dance movements were shown to professional ballet and capoeira dancers and to novices. They found that activation of the premotor and parietal areas was greater in the dancers than in the novices. In another reviewed research study, Cross and colleagues (2006) showed that expert ballet dancers who were taught a
sequence of movement over the course of five weeks, showed increased activation when presented with this sequence as opposed to an unfamiliar sequence. This finding suggests that the MNS is susceptible to activation when presented with a personal repertoire learned only recently. The authors also discuss research showing EEG mu suppression in expert populations such as karate experts, air rifle experts, and professional musicians (Cannon et al., 2005).

In their study, Cannon et al. were specifically interested in whether EEG mu suppression would occur for newly learned expertise of tool-use action. Prior to completion of a claw task, the participants were taught the use of the claw through personal practice, taught the use of the claw through observation, or given no training. The findings showed that the active experience group had greater mu rhythm desynchronization than the groups with observational experience or no prior training of the task. This suggests that the MNS is highly sensitive to one’s own personal repertoire as would be applicable to the expert ballet dancers in the present study (Cannon et al., 2005).

In continuation of the discussion on MNS activity when observing movements found in one’s own motor repertoire, Liuzza and colleagues (2012) performed a study that significantly furthers the idea of motor activation in response to self-related cues. Sixty-one child participants were asked to estimate the weight of an object after viewing either a grasp or fist object-related action. As expected in relation to the MNS, participants were faster at responding to the grasp versus the fist condition. More interestingly however, the participants reaction times were faster when the action was performed by a child’s hand versus an adult’s
hand, suggesting that a sense of mirrored action ownership plays a role in priming the motor system for activation (Liuzza, Setti, & Borghi, 2012). The results of this and other relevant literature will have applications in terms of deciding the key aspects of the present experimental methodology.

Kim et al. (2011) aimed to observe the difference in MNS activation between expert and non-expert female archers when presented with videos of archery movements. It was found that fMRI activation of the premotor and inferior parietal cortex was higher in expert archers. The researchers believed that this provided further scientific evidence for the theory that the true MNS represents one's own motor repertoire. Additionally, regions such as the cingulate cortex, retrosplenial cortex, and parahippocampal gyrus (associated specifically with episodic memory) were more activated in expert archers. This second finding suggests a relationship between memory, personal motor experience, and the MNS all of which are key concepts when discussing expert population-based studies (Kim et al., 2011).

The Present Study

The present study seeks to further the scientific understanding of the MNS by examining the behavioral responses following action observation of expert movements. We assume that observation of and audio exposure to dancer and everyday movements in dancer populations will evoke a MNS response, causing the dancer to be ready to initiate movement in the form of a motor response task. Similarly, we assume that the MNS of non-dancers will be primed by everyday movements, but not dancer movements, and therefore they will be ready to initiate movement following presentation of the everyday stimuli. In this study therefore,
we aim to look at the difference in dancer versus non-dancer response following the observation of movements uniquely performed by expert ballet dancers compared to the observation of everyday or innately familiar movements.

Ballet is a dance category in which the repetition of particular movements is essential. Additionally, dancers are trained to observe the movements performed by their instructors or professionals and mirror them exactly. In addition to repetitive movement and precision, ballet is also an art form dependent on the French language and the terminology of each movement performed. To look at these particular aspects of this dance form in relation to visual and auditory activation of the MNS, expert ballet actions and everyday, innate movements were presented to participants through both video and audio conditions. Participants in the study included expert ballet dancers and novice, inexperienced non-dancers.

The main interest of this project is to examine how observation of action, or hearing the word that describes an action, activates the MNS and thereby primes the motor system to perform. That is, previous work has indicated that the observation of an action performed by another activates the premotor areas in the brain allowing simulation, or imagery, of the movement to occur as the observer works to understand the movement and perspective of the actor. We are interested in examining the extent to which the MNS activation results in improved subsequent motor sequence response. Essentially, we aim to answer the question of whether MNS activation primes the motor system, and if the observation of a movement can have the same effect as a verbal description of that movement.
Our original paradigm was focused on the MNS response using EEG programming. Unfortunately, the technology was ultimately unable to accommodate our use of video stimuli as various errors arose, and we had to reconfigure our task to focus instead on a behavioral, serial motor response task.

Our four main hypotheses are as follows. First, observation of unique ballet movements and everyday movements by ballet dancers will result in the highest MNS activation, due to the familiarity of both actions, thereby showing the greatest gain in serial motor response task performance in comparison to non-dancers. Next, observation of everyday movements by dancers and non-dancers will result in equal MNS response and subsequent gains in serial motor response task performance. However, the gain may be slightly less than that found in dancers observing dance movements because the everyday actions may be less compelling or interesting to observe. Third, listening to the auditory words describing ballet movements will result in an increase in MNS response and a small gain, in comparison to the observation of dance movements, in the serial motor response task in dancers. Additionally, there will be no gain shown in non-dancers because the words describing the dance movements should be relatively meaningless to them. Finally, listening to the audio stimuli of everyday movements will result in some increase in MNS for both dancers and non-dancers resulting in a small gain in serial response task performance in both groups.

Method

Participants
Forty-seven female participants between the ages of 19 to 22 (mean age 19.6 years, SD = 1.3) were recruited from one of two outlets at the College of William and Mary. Four dancers from an advanced ballet class taught on campus agreed to participate in the study and were compensated 20 dollars for their time. The rest of the dancer and non-dancer participants were recruited from the College of William and Mary Research Participant Pool and received course credit in exchange for their participation in the study. Dancers and non-dancers from the participant pool were invited based on their response to the William and Mary Psychology Department Mass Testing Questionnaire. The question of interest for the study was “Do you have any experience with ballet (i.e. taken a class, performed, or taught)?”. If the students answered 0 years of ballet experience, they were emailed the invitation code to participate in the study as a part of the non-dancer population. Similarly if they answered 7 or more years of ballet experience, they were invited to be apart of the dancer population. See Figure 1 for a breakdown of the range of years of ballet experience in the dancer population. In total, the average reaction times of 20 dancers and 27 non-dancers were used for statistical analysis.

One non-dancer was excluded for sporadic key pressing and those who answered one to six years of ballet experience on the question of interest were also excluded as we did not consider this to be within the confines of our definition for novice or expert dancer. However, it was discovered after analysis had been completed, that one dancer recruited from the advanced ballet class had only one year of ballet experience, and extensive modern dance experience. This is especially relevant due to the literature presented on how even only a few weeks of training
can evoke a primed response. Finally, based on the MNS sensitivity to one’s self repertoire as demonstrated in several of the above literature, male participants were excluded as the dancer and vocalist in the video and audio conditions were both female.

*Apparatus*

SuperLab was programmed for presenting the ballet dance and everyday movement stimuli as well as the “R” and “L” series and a fixation point to conclude each trial. A Dell Optiplex model 710 computer was used in order to display the program. Finally, a Cedrus Response Pad Model RB 830 was used in order to record participants’ responses to the task. Headphones were given to each participant to ensure that the audio portion of the experiment was presented correctly.

*Procedure and Stimuli*

Before beginning the study, all participants signed an informed consent form indicating that there were no major risks associated with the study, but that minor fatigue might occur. Participants were then instructed to the read the directions and indicate to the researcher when they were finished. The researcher would then reiterate what they had just read, emphasize to complete the task as quickly as possible, and to begin the experiment by pressing the “END” key on the response pad if they had no further questions.

Participants were instructed to wear headphones for the duration of the study and given the Cedrus Response Pad labeled with “R”, “L”, and “END” keys. A series of randomized stimuli were presented from four categories: nine ballet dance videos, 10 everyday movement videos, 10 ballet dance audio commands that
corresponded to those presented in the dance video stimuli, and 10 everyday movement audio stimuli that did not correspond to the everyday movement video stimuli. See further explanation of these stimuli types below.

Following each presented video a randomized series of four “R”s and “L”s were shown on the screen followed by a fixation point. Participants were told to repeat back as quickly as possible the series of “R”s and “L”s presented using their “R” and “L” keys at the onset of the fixate. They were instructed to press “END” to move on to the next video. The study took approximately 20 minutes in total to observe all 39 videos and complete the subsequent task for each. Participants were then thanked for their participation and awarded their course credit or compensation within the next 24 hours.

*Ballet Dance Video Stimuli*

The ballet dance video stimuli included 9 classic ballet movements performed by an expert ballet dancer with 17 years of ballet experience. The ballet movements were chosen based on the assumed innate familiarity of the movement to expert ballet dancers in addition to the inability to be recognized by a non-dancer. For example, the movement “plié” was not chosen for this study because although it would absolutely be recognized by ballet dancers, even complete non-dancers might recognize such a movement as it is often mentioned in popular culture. Unfortunately, due to a processing error when one of the ballet videos, demonstrating the “Penche” movement, was converted from a certain video file to another, the SuperLab programming rejected the video and therefore we were forced to eliminate it from the study. This is why there are 9 stimuli instead of 10 in
this particular category. See Appendix 1 for a listing of the ballet dance video stimuli and Figure 3 for an example image.

*Everyday Movement Video Stimuli*

The everyday dance video stimuli included 10 everyday, innate movements performed by the same dancer. These movements would be innately familiar to both dancers and non-dancers. In order to ensure control of our hypothesis that dancers would respond more to the dance movements in comparison to the non-dancers, the everyday movements were chosen specifically to look similar in nature to the ballet movements so that it could be assumed that the nature of the dance movements (i.e. pointed toe, upright posture, etc.) were specifically unfamiliar to non-dancers. This included mirrored directionality or specific extremity use. See Figure 4 for the demonstrated similarity between the “Tendu” movement depicted in Figure 3 and the “Shift weight forward” movement in the right foot. All video stimuli began with the entrance of the dancer from the right side of the screen, a slight pause in a standing position when she reached the center of the screen, the performed movement, and then her walking off screen to the left side. Please see Appendix 1 for a listing of the everyday movement video stimuli.

*Ballet Dance Audio Stimuli*

Ten dance audio stimuli, corresponding to the same ballet movements presented in the ballet dance video stimuli, were recorded by a female student fluent in French, with 10 years of language training and 14 years of ballet experience. The reason for the correlation between the dance video and audio stimuli is simply that there is a limited amount of ballet movement that would be
innately familiar to an expert dancer. See Appendix 2 for a listing of the ballet dance audio stimuli and Figure 5 for an example of the visual presentation during the audio stimuli.

_Everyday Movement Audio Stimuli_

Ten everyday audio stimuli were recorded by the same female, French-speaking student. These stimuli did not correspond to the everyday video stimuli because the movements in the everyday video stimuli were assumed just as innately familiar as the audio recordings. If we had attempted to describe the actions presented in the videos or vice versa, perform the audio actions, awkwardness would have occurred and in some cases object-use would have been necessary causing unwanted distractibility in the stimuli. It should also be noted that the everyday audio stimuli were made to sound as phonetically similar to the ballet commands as possible, as to again control for dancers responding specifically to the dance words, that non-dancers would not recognize. Both audio stimuli conditions followed the same timing pattern as the video stimuli with a five second pause, the presentation of word, and then a five second pause before the “R”/”L” sequence was presented. For the duration of the audio stimulus, a still image of the same background as that presented at the beginning of each movement video remained on the screen. See Appendix 2 for a listing of the everyday audio stimuli.

_Results_

The results from the study were analyzed in order to gain an average initial reaction time and an average total reaction time for ballet dance video stimuli, everyday movement video stimuli, ballet dance audio stimuli, and everyday
movement audio stimuli for each non-dancer and dancer participant using pivot table analysis. These average reaction times were input into Excel then the Statistical Package for the Social Sciences (SPSS), when an analysis of variance statistical analysis (ANOVA) was performed and the results below were obtained.

The first variable of interest analyzed was the average total reaction time, or ATRT, which is the time that it took the participants to repeat the entire “R”/”L” sequence. The second variable of interest analyzed was the overall average reaction time of participants to initiate repetition of the first presented “R” or “L” in the sequence after the onset of the fixate. We will refer to this as average initial reaction time, or AIRT.

**Average Total Reaction Time (ATRT)**

The means for ATRT are reported in Table 1 and Figure 6. Overall, dancers were faster than non-dancers in their total reaction times on all tasks. Moreover, regardless of participant group, response times were faster in the video compared to the audio conditions. Finally, response times were faster for everyday actions compared to dance actions regardless of participant group.

A 2(participant group) x 2(action type) x 2(stimulus type) repeated measures ANOVA was examined for main effects. Participant group, dancers and non-dancers, were a between-subject variable. Action type and stimulus type were within-subject variables. The repeated measure ANOVA testing for main effect of group approached significance, F(1, 45) = 2.258, p = 0.14. The main effect of stimulus type (video versus audio) approached significance, F(1, 45) = 2.633, p =
Additionally, a stimulus type by group interaction approached significance, $F(1, 45) = 2.294, p = 0.137$, showing that dancers were faster at video stimuli while non-dancers were faster at audio stimuli. Finally, testing the main effect of action type (dance versus everyday movement) also approached significance $F(1, 45) = 1.964, p = 0.171$. These relationships are presented in Figures 6-15.

**Average Initial Reaction Time (AIRT)**

The means for AIRT are reported in Table 2 and Figure 16. Overall, dancers were faster at initiating a response in comparison to non-dancers on all tasks. In this case, response times for audio and visual stimulus types were quite similar but not trending. A stimulus type by group interaction was also found in AIRT. There was no main effect of action type in AIRT.

The 2(participant group) x 2(action type) x 2(stimulus type) repeated measures ANOVA was examined for main effects. Participant group, dancers and non-dancers, were a between-subject variable. Action type and stimulus type were within-subject variables. The main effect of group approached significance, $F(1, 45) = 2.159, p = 0.149$. There was a significant stimulus type by group interaction, $F(1, 45) = 3.891, p < 0.05$, showing that dancers were faster at video stimuli while non-dancers were faster at audio stimuli. These relationships are presented in Figures 16-25.

**Discussion**

Through the ANOVA analysis performed, there were several findings that provide further evidence to higher activation of the MNS, especially in expert ballet dancer populations. First, in both average initial and average total reaction time, the
dancer population was faster than the non-dancers at performing the action task, trending in both cases. It can be speculated that due to the recognition of both everyday and dance stimuli, dancers are more engaged in the task and therefore perform better than non-dancers. Specifically, because dancers are recognizing not half, but all of the presented movements and their MNS are assumed to be primed during observation, dancers are faster at performing the serial motor response task. Additionally, dancers are trained to be ready to initiate an action whether the instructor demonstrates visually or simply lists the verbal commands of a ballet combination. Therefore, it is not surprising that in initiating and finishing the serial motor task, dancers are found to be faster than non-dancers on all tasks. This finding provides support for the first of our four original hypotheses.

MNS activation is also evident in the results of the ATRT of both dancers and non-dancers being faster when primed with video stimuli in comparison to audio stimuli. As demonstrated by the discussed literature review, audio associated with movement results in activation of the MNS. However, faster response time associated with video stimuli is evident of the true empathetic nature of MNS activation when participants view a movement, even one that they are unfamiliar with, in comparison to an audio presentation. By watching the movement visually rather than hearing it, participants are more likely to be ready to move and therefore it is not surprising that they respond more quickly to the serial motor task.

However, the stimulus by group interaction is an interesting effect in both ATRT and AIRT. It is surprising that dancers are faster in reaction time after
presentation of video stimuli while non-dancers are faster in reaction time after presentation of audio stimuli. It may be that the non-dancers were not primed by watching videos of dance action type as much as they were by imagining the movement that corresponded to the dance word.

Finally, it was found that the ATRT for both non-dancers and dancers was faster during the everyday action type stimuli in comparison to the dance stimuli. This is in correlation with our original hypothesis as we assumed dancers and non-dancers would recognize the familiarity of the everyday movements to a certain extent, causing MNS activation, and producing a faster serial motor response. Again, due to the familiarity of the movements with the self repertoire as discussed in detail in the literature, increased response time to the serial motor task is indicative of specific activation of the MNS in this experiment.

It is somewhat disappointing that most of the results presented here are only trending, while others are simply absent in confirming or disputing the two remaining hypotheses. It can be assumed that the issue with significance here lies in a power issue and that obtaining a smaller standard deviation would result in increasing the statistical power and therefore cause more significant data. The main effect of each of the analyses mentioned above is not coming in simply due to the high standard deviation. We will collect further data for this experiment to specifically increase the dancer population in hopes to gain statistically significant ANOVA results for all effects.

There are a few limitations of this study worth mentioning. First there were a myriad of programming issues that occurred, including that with our original EEG
goals and the eventual elimination of the ballet dance movement video “Penche” (see Appendix 1) due to the incompatibility of the image configuration. Additionally, we did not screen for any experience in gymnastics or other forms of dance which could elicit variation in the expert population definition. While the ballet dance movements exhibited in the video stimuli mirrored the ballet dance movement commands in the audio stimuli, with the exception of the one eliminated video, the everyday movement video and audio stimuli were not correlated. Although it was previously explained that logistically this was not possible without inevitable awkwardness, and that there are simply not enough ballet movements to have different stimuli for both conditions, this could cause variation or confusion in the participants' experience.

In terms of suggestion for further research in the activation of the MNS in expert populations, it would be interesting to observe a replication of this experiment in other forms of dance or athletic expertise where similarly, movement by audio and visual command is a key component of gaining expert status in the field of interest. Additionally, performing a control condition in which dancers and non-dancers perform the “R”/”L” motor response task with no video or audio priming to obtain a baseline response time to compare to that following priming would certainly increase the credibility of the current findings. Finally, we would absolutely encourage exploration of the MNS system mu rhythm suppression in EEG testing using the same task, that is exposure to both video and audio stimuli in the ballet dance and everyday conditions, by both expert ballet and novice dancers. If significant mu suppression was found, as demonstrated in the literature, it would
provide direct evidence of MNS activation and supplement the findings in the current study.

The present experimental conclusions could have implications in better understanding of the MNS, the process by one becomes and acts as an expert athlete or performer, and the general ability to initiate movement. In terms of this last point, better understanding of the neural mechanisms of movement initiation could have further implications in understanding the movement defects in neurodegenerative disorders. Overall, the findings of this experiment and the research suggested for further study in this area provide meaningful evidence of the activation of the MNS in expert populations.
References


Table 1. Average Total Reaction Times (ATRT) msec.

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Table 2. Average Initial Reaction Times (AIRT) msec.

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Figures

**Figure 1.** Assumed process by which MNS priming occurs and serial motor response task performance is enhanced.

Stimulus Presentation → MNS Activation → Priming and Readiness to Initiate Movement Occurring → Movement in Serial Motor Response Task Reaction
Figure 2. Dancer Population Ballet Experience (years)

Pie chart depicting the ballet experience in years of the dancer population.
**Figure 3. Ballet Dance Video Stimulus “Tendu”**

Example of a ballet dance video stimulus, “Tendu” movement still image.

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**Figure 4. Everyday Video Stimulus “Shift weight in a forward movement”**

Example of an everyday movement video stimulus, “Shift weight in a forward movement” still image. This is the mirrored everyday movement counterpart of the “Tendu” ballet dance movement in Figure 2.
Figure 5. Audio Stimulus Image

Figure depicting the image presented for the duration of the audio stimuli.
Figure 6. Dancer versus Non-Dancer Average Total Reaction Times

Graph depicting dancer versus non-dancer average total reaction times for stimulus type and action type.
Figure 7. Group Effect: Overall Group ATRT Effect

Graph depicting overall group (dancer versus non-dancer) effect of combined video and audio stimulus type upon average total reaction time.
**Figure 8.** Group Effect: Stimulus Type ATRT

Graph depicting overall group (dancer versus non-dancer) effect of separate video and audio stimulus type upon average total reaction time.
Figure 9. Group Effect: Action Type ATRT

Graph depicting overall group (dancer versus non-dancer) effect of separate dance action type and everyday action type stimuli upon average total reaction time.
Figure 10. Stimulus Type Effect: Overall Stimulus Type ATRT Effect

Graph depicting overall stimulus type (video versus audio) effect of combined dancer versus non-dancer group upon average total reaction time.
**Figure 11.** Stimulus Type Effect: Group ATRT

Graph depicting overall stimulus type (video versus audio) effect of separate dancer versus non-dancer group upon average total reaction time.
**Figure 12.** Stimulus Type Effect: Action Type ATRT

Graph depicting overall stimulus type (video versus audio) effect of separate dance versus everyday action type stimuli upon average total reaction time.
Figure 13. Action Type Effect: Overall Action Type ATRT Effect

Graph depicting overall action type (everyday versus dance) effect of combined dancer versus non-dancer group upon average total reaction time.
**Figure 14. Action Type Effect: Group ATRT**

Graph depicting overall action type (everyday versus dance) effect of separate dancer versus non-dancer group upon average total reaction time.
**Figure 15.** Action Type Effect: Stimulus Type ATRT

Graph depicting overall action type (everyday versus dance) effect of separate video versus audio stimulus type effect upon average total reaction time.
Figure 16. Dancer versus Non-Dancer Average Initial Reaction Times

Dancer versus Non-Dancer Average Initial Reaction Times

Graph depicting dancer versus non-dancer average initial reaction times for stimulus and action type.
Figure 17. Group Effect: Overall Group AIRT Effect

Graph depicting overall group (dancer versus non-dancer) effect of combined video and audio stimulus type upon average initial reaction time.
Figure 18. Group Effect: Stimulus Type AIRT

Graph depicting overall group (dancer versus non-dancer) effect of separate video and audio stimulus type upon average initial reaction time.
Figure 19. Group Effect: Action Type AIRT

Graph depicting overall group (dancer versus non-dancer) effect of separate dance action type and everyday action type stimuli upon average initial reaction time.
Figure 20. Stimulus Type Effect: Overall Stimulus Type AIRT Effect

Graph depicting overall stimulus type (video versus audio) effect of combined dancer versus non-dancer group upon average initial reaction time.
Figure 21. Stimulus Type Effect: Group AIRT

Graph depicting overall stimulus type (video versus audio) effect of separate dancer versus non-dancer group upon average initial reaction time.
Figure 22. Stimulus Type Effect: Action Type AIRT

Graph depicting overall stimulus type (video versus audio) effect of separate dance versus everyday action type stimuli upon average initial reaction time.
Figure 23. Action Type Effect: Overall Action Type AIRT Effect

Graph depicting overall action type (everyday versus dance) effect of combined dancer versus non-dancer group upon average initial reaction time.
**Figure 24. Action Type Effect: Group AIRT**

Graph depicting overall action type (everyday versus dance) effect of separate dancer versus non-dancer group upon average initial reaction time.
**Figure 25.** Action Type Effect: Stimulus Type AIRT

Graph depicting overall action type (everyday versus dance) effect of separate video versus audio stimulus type effect upon average initial reaction time.
Appendices

**Appendix 1. Video Stimuli-Dancer Versus Everyday**

<table>
<thead>
<tr>
<th><em>Ballet Dance Video Stimuli</em></th>
<th><em>Everyday Movement Video Stimuli</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Penché*</td>
<td>Picking up a pencil movement</td>
</tr>
<tr>
<td>Tendu</td>
<td>Shift weight in a forward movement</td>
</tr>
<tr>
<td>Rond de jambe</td>
<td>Little sweep foot circle with arms behind back movement</td>
</tr>
<tr>
<td>Grand battement</td>
<td>Kick forward (like soccer ball) movement</td>
</tr>
<tr>
<td>Frappé</td>
<td>Scuff the floor movement</td>
</tr>
<tr>
<td>Échappé</td>
<td>Jumping jack movement</td>
</tr>
<tr>
<td>Pas de bourrée</td>
<td>Step R and L with hands R and L movement</td>
</tr>
<tr>
<td>Grand jeté</td>
<td>Jumping over a puddle movement</td>
</tr>
<tr>
<td>Sissonne</td>
<td>Jump with both feet up movement</td>
</tr>
<tr>
<td>Coupé relevé (arms in 5th position) looking up</td>
<td>Reach up to get something, put knee/foot up movement</td>
</tr>
</tbody>
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Note: *video eliminated due to programming error.*
**Appendix 2. Audio Stimuli-Dancer Versus Everyday**

<table>
<thead>
<tr>
<th>Ballet Dance Audio Stimuli</th>
<th>Everyday Movement Audio Stimuli</th>
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<td>“Punch”</td>
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<td>“Tendu”</td>
<td>“Tickle”</td>
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<tr>
<td>“Rond de jambe”</td>
<td>“Runaround”</td>
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<tr>
<td>“Grand battement”</td>
<td>“Grab”</td>
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<td>“Frappé”</td>
<td>“Frown”</td>
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<td>“Échappé”</td>
<td>“Assemble”</td>
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<tr>
<td>“Pas de bourrée”</td>
<td>“Pour”</td>
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<tr>
<td>“Grand jeté”</td>
<td>“Glide’”</td>
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<tr>
<td>“Sissonne”</td>
<td>“Stumble”</td>
</tr>
<tr>
<td>“Coupé relevé”</td>
<td>“Cradle”</td>
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