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The Effect of Inversion and Motor Expertise on Body Compatibility

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<u>The Effect of Inversion and Motor Expertise on Body Compatibility</u>

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Abstract

Previous studies have established that when a subject's attention is directed to a specific body part, the subject is able to move that body part faster than a body part their attention was not drawn to. This is known as the body compatibility effect, and it has been shown that this effect only occurs when viewing upright images of the human body. In this study, we presented control subjects and expert acrobats with inverted and upright stimuli. We hypothesized that the amount of time the acrobats spent inverted would result in the acrobats exhibiting body compatibility effects for both upright and inverted stimuli. Compatibility effects were observed in the upright condition for both groups, but neither group exhibited any compatibility effects in the inverted position. Unexpectedly the acrobats responded significantly faster to incongruent trials compared to the control subjects, leading to the conclusion that there must be some form of priming occurring concurrently with the body compatibility task allowing the acrobats to respond faster than the control participants.

Literature Review

Throughout each day it is common practice to mimic and modify actions of others. When we are asked to copy an action, we do so consciously. While this conscious process of imitation is initiated by intent, humans also have a hardwired ability to imitate others automatically. This idea of automatic imitation was first observed in young children mimicking goal directed actions of an actor (Meltzoff et al, 2005), which led many to believe that the ability to imitate must be an innate process, as infants were able to imitate with out any instruction. The concept of automatic imitation refers to the idea that motor representations of an action are automatically activated whenever a movement is observed (Wigget et al. 2015). This idea of automatic imitation is thought to be responsible for body compatibility effects which occur when an observer's attention is directed to a specific body part on another person's body resulting in that same body part being primed for action in the observer. The following literature review examines the ideas of automatic imitation and body compatibility effects within the larger theoretical framework of body representation and motor expertise.

The study most pertinent to my thesis experiment was conducted by Wiggett et al. (2015). In this study Wiggett et al. displayed familiar body postures as well as unfamiliar postures that could not be adopted by the average person (difficult yoga poses or breakdancing positions). She displayed the familiar and unfamiliar postures in both upright and inverted positions. She then placed colored dots on the hand or foot of the person featured in each picture. The participants were instructed

to press either the space bar of a keyboard with their dominant hand or a foot pedal with their dominant foot depending on the color of the dot presented on each body. This experimental protocol was based on a previous study which showed that drawing a participant's attention to a specific body part via a colored dot was sufficient to create body compatibility effects (Bach et al 2006). As discussed above, body compatibility effects simply refer to the idea that if the observer's attention is drawn to a hand on another person's body (by either colored dot or motion) then that observer will be able to move their corresponding hand more quickly than if the hand was not primed, or their attention was drawn to a foot. In their experiment Wiggett et al. found that familiar body postures in typical orientations (upright with the hand above the foot), showed the expected body compatibility effects, while unfamiliar postures in typical orientations, and ufamiliar and familiar postures in atypical orientations yielded no body compatibility effects. The mechanisms for this effect are not well known, however these results led Wiggett to conclude that body part priming effects were only present for adoptable postures in typical orientations.

This finding suggests that both adoptability and orientation of an observed body play a crucial role in body compatibility effects and automatic imitation. Other studies (Bach et al 2006 and Heyes et al 2005), have established automatic imitation as a robust phenomenon using stimuli in typical orientations, but few studies have looked at the effect of changing body orientation on compatibility effects in observers. A study examining the effect of orientation on compatibility by Welsh et al. (2014) used stimuli of both humans and animals in bipedal and quadrapedal positions. They found that compatibility effects were observed in both positions,

but only when participants viewed pictures of human bodies. Thus these authors showed that compatibility effects extend beyond typical standing configurations of humans, yet it is not clear how far these effects extend to other postures before they are no longer observed.

In one study aimed at determining the effect of spatial orientation of body parts on body compatibility effects, Wiggett et al (2012) changed the orientation of hands and feet relative to each other and measured the effect of these orientation differences on an imitation task. They used animation software to present images of a disembodied hand and foot in different spatial orientations to test how orientation alters body compatibility effects. Their results revealed that both spatial and body compatibility effects were present in observers; spatial compatibility refers to the idea that presented movement primes movement in the observer if the movement occurs in the same spatial location as the observers movement (i.e. movement on the right side of the body primes observer movement on the left side of the body, as both these body parts occupy the same spatial location). Body part compatibility effects refers to when actions presented primes movement of the corresponding body part in the observer, thus these priming effects rely on an anatomical reference frame instead of a purely spatial one. As this study was able to demonstrate that these spatial and body compatibility effects occurred separately from each other, this lead to the conclusion that these perceptual systems are dissociable in some way. However their results regarding the effect of stimuli orientation matching body orientation were extremely convoluted. Thus it remains

unclear exactly how orientation affects automatic imitation as most of the literature focuses on the effect of motor representations on automatic imitation processes.

There is evidence that bodies in different orientations are harder to process, as shown by response times on a body rotation task. In one study gymnasts and judo experts were asked to complete a standard shape rotation task as well as a body rotation task (Weigelt, Steggemann, Blasing and Shack, 2008). During the shape rotation task participants were presented a capital letter in two different orientations and asked to determine whether the letters were the same or mirror images of each other. Similarly, for the body rotation task, pictures of different bodies in different poses were presented (i.e. holding out the left arm, or raising the right leg), two pictures were displayed at the same time in different orientations to each other and the participants were asked to determine if the poses were the same pose or mirror images of each other. This study found that gymnasts and judo experts performed significantly better on the body rotation task, than control subjects did, however they didn't perform significantly better on the shape rotation task. This finding suggests the ability to mentally rotate bodies might require specific motor expertise or perceptual practice. This evidence shows that it is harder for the average person to manipulate bodies in inverted positions, compared to upright postures.

The ability to process inverted bodies was further investigated by Reed et al (2003). Using a forced choice same/different paradigm, Reed et al. found that there was a strong inversion effect for human body positions, meaning that bodies were

processed the fastest when they were shown in an upright position, and the slowest when they were rotated 180 degrees. This study also compared recognition of similar and different postures for biomechanically possible and impossible actions. When biomechanically impossible stimuli were used the inversion effect was reduced. These studies suggest that bodies are processed configurally much like faces, as bodies cannot be identified as accurately or quickly when they are inverted, which suggests that bodies and faces might be processed in the same manner. The principle of configural processing refers to the idea that parts of a stimulus, such as a face or body, are processed by their component parts, instead of being processed as one complete unit. This finding may explain the findings of the Wiggett et al (2015) study, as expertise within a class of objects, such as body configurations, could increase people's ability to accurately identify bodies in various orientations based off a variety of configural information. One of the most notable examples of this is the cross-race effect, as this effect showed that faces are processed both categorically and configurally, and that configural processing is necessary in order for a face to be accurately identified (Bothwell, Brigham and Malpass, 1989).

Thus it is reasonable that the gymnasts in Weigelt's study could have become experts in configurally processing inverted bodies due to the amount of time they spend inverted, allowing them to accurately process images of others while they are upside down. It remains to be seen how these effects directly effect automatic imitation; but it seems within reason that the lag of processing involved in configurally processing inverted bodies could mitigate any body compatibility effects for inverted postures, causing participants to take longer to respond with the

primed body part. Future research into this realm is necessary in order to understanding the mechanisms of body perception and automatic imitation. It remains unknown as to whether automatic imitation relies on the configural processing of bodies, or simply relies on selective attention to a body part. While these studies on inverted bodies suggest configural processes of inverted stimuli could lead to automatic imitation effects if proper motor and perceptual expertise are present, further research is necessary in order to fully determine the underlying processing system that leads to automatic imitation, and how it is moderated by available motor representation.

It has been established that observing the body part of another person leads to an increase in perceptual sensitivity of the same body part on the observer (Tipper et al 2001). Thus viewing parts of bodies belonging to others primes various somatosensory receptors in observers, not just available motor representations. This increase in sensory perception as well as motor priming has widely been attributed to the mirror neuron system. The mirror neuron system was discovered in the premotor cortex of monkeys (Gallese, Goldman, 1998). By recording the firing patterns of individual neurons in area A5 of macaque monkeys, Gallese and Goldman tested the visual and motor response patterns of these neurons to specific actions. They observed that specific neurons would only fire when the monkeys observed an object being grasped. This experiment gave rise to the discovery to two classes of neurons: canonical neurons, which are activated during observation of a graspable object and MNs, which are activated when an action is observed. This study also showed that MNs only respond to the observations of specific goal

directed actions, and that similar neural machinery is utilized during both observation and completion of a specific, goal directed task. These findings revealed that when observing specific actions, observers undergo motor activation in the same areas required to perform the observed action. Further research has greatly expanded this field and applied it to a wide variety of biological motion. The mirror neuron system is fascinating and complex, yet it is not until we combine it with the concepts embodiment that mirror neurons start to shed light on the possible origins of automatic imitations processes.

In an exceptionally creative study, Cross et al (2006) examined the effect of embodiment on action simulation. Cross et al. tested dancers as they rehearsed a complicated piece of modern dance over a five-week period. During this time they observed videos of portions of the dance they were learning while in an fMRI scanner. She observed robust activation in the supplementary motor area, ventral premotor cortex, inferior parietal lobe, superior temporal sulcus and M1. Collectively these brain regions are known as the simulation circuit. The activation in the simulation circuit was more pronounced when rehearsed movement was viewed as opposed to novel movements. The inferior parietal lobe and the ventral premotor cortex appeared to be specifically sensitive to embodied actions, as they were activated more strongly during more practiced movements than novel movements. These two regions are regions that have been extensively linked to the mirror neuron system (Rizzolatti and Craighero, 2004). Thus these findings show that embodiment processes lead to activation of the mirror neuron system in ways

that mere observation does not, proposing one possible link between the visual and motor pathways.

It is unsatisfying to use the broad label of mirror neurons to explain the various phenomenona encompassed by automatic imitation. By examining the different ways observers process first person actions as opposed to third person actions, Jackson et al (2006) proposed the direct-mapping hypothesis (or common-coding approach) as an explanation of how visual representations of actions correspond to motor representations. This hypothesis simply reinforces the idea that observed events and planned actions share similar neural machinery and representational domains. In this study Jackson observed that there was increased motor recruitment when viewing first person stimuli as compared to third person stimuli. Through imitation and observation tasks this study revealed that the extrastriate body area (EBA) is activated for imitation tasks more robustly than for observation tasks (observation tasks simply ask a participant to view an action on a screen, while imitation tasks require the participant watch an action and then repeat it). Imitation activity led to increased activity in the somatosensory cortex, left ventral premotor cortex and inferior and medial prefrontal gyrus.

Further studies have shown the important role of the EBA in integrating motor and visual input. Astafier et al 2004 showed that the EBA integrates visual and spatial attention and controls sensory motor signals involved in activating motor representations of the observer. Thus the EBA appears to play an integral role in proprioception. Astafier proposed that activation in the lateral posterior

cortex gives rise to body schema, and is closely linked to EBA activation. While the EBA does play a crucial role in action perception, it is important to realize the vast number of brain regions that appear to be involved in the perception and imitation of actions. For example Oosterhoof et al (2010) observed that the parietal postcentral gyrus appears to link actions with somatosensation. Downing et al (2001) observed that the lateral occipitotemporal cortex responded specifically to pictures of body parts, while the EBA appeared to guide actions and process body position and configuration. When examining the neural resources necessary to complete a simple task like the dot color identification task in Wiggett's study (2015) it is clear that there are a lot of brain regions working together to perform task: from the simulation circuit, to the EBA, occipitotemporal cortex, the visual processing system, to the parietal lobe, somatosensory cortex, premotor cortex and the prefrontal gyrus.

One of the confounding issues of automatic imitation is that it involves both spatial and anatomical compatibility, which is one reason why so many brain regions are required to complete imitation tasks. Bertenthal et al. (2006) conducted a study to determine if imitation effects were due to automatic imitation or merely a result spatial compatibility. They conducted multiple studies using spatial (actions that occur in the same spatial position as the observer imitating the action, but use a different part of the body) and imitative (anatomical) stimuli. They found that both anatomic and spatial effects influence the ability of the participant to imitate the presented motion. However priming effects from anatomically compatible stimuli declined significantly across trials, while effects of spatial compatibility remained

constant. These findings suggest that anatomical and spatial compatibility effects may be rooted in different brain regions, and are activated separately. However both are necessary in order for body compatibility effects to arise.

In a recent study, Mengotti, Corradi-Dell'Acqua and Rumiati (2012), used fMRI scanning to determine the neural correlates of anatomical versus spatial imitation. Mengotti et al. examined automatic imitation using the Direct-Matching hypothesis proposed by Prinz (1997). This theory states that observing an action facilitates its execution because the same neural resources are used for perception and action planning, thus activation can easily spread from one domain into the next, allowing perception to prime action. In their fMRI study, Mengotti et. al. asked participants to imitation hand movements they observed. The video stimuli featured hands that moved in specular (action displayed is the mirror image of the observer's movement) or non-specular fashion, and the imitation tasks presented were either spatially or anatomically compatible. Their behavioral findings were consistent with other studies in that participants were able to imitate movements faster when the movements were both spatially and anatomically compatible.

The fMRI results of this study indicated that the parietal opercula in both hemispheres were involved with anatomical compatibility effects. This region was activated during anatomical tasks and in both specular and non-specular tasks, and agrees with previous fMRI data, which has implicated the parietal opecula in imitation of finger and limb movements. Interestingly there was no singular region that was associated with spatial compatibility, however the middle front and right

superior temporal sulci were activated when irrelevant spatial information had to be suppressed in order for the actions to be correctly imitated. In trials where anatomically compatible stimuli caused movement of the participant's hand, activation extended to the primary somatosensory and motor cortices as well activation in the cytoarchitectonic area OP 4, which is associated with integration of sensory-motor processes. This sensory and motor activation has been closely linked with the activity of the parietal opercula, providing one possible link between the parietal opecula and body perception and representation. The author's findings specifically highlight area OP 4 as the area where information about one's body orientation is merged with information about a body perceived in space, thus it could greatly effect how different people are able to perceive bodies in different orientations.

One of the most widely accepted theories explaining the interplay between the motor and visual systems is the associative sequencing model (ASM), which states that visual-motor connections are forged by experience, implying imitation is not a completely innate process as other studies previously suggested (Heyes et al., 2005). Heyes et al conducted a study using videos of a hand opening or closing and had the participant mimic the actions displayed during the video. The video displayed a hand in a sideways orientation, thus the fingers moved side to side when opening and closing, and the participant's hand was placed so that their fingers moved forward and backwards when opening and closing their hand. Thus Heyes et al. reinforced the idea that automatic imitation relies heavily on anatomical of stimuli, as the hand opening and closing task required participants to imitate an

action in a different spatial orientation than it was initially presented, yet body compatibility effects were still observed due to the actions identical anatomical orientation. In a subsequent trial she trained the participants to respond incongruently to the videos, thus they would complete the opposite action in response to the action that was being displayed. The participants then completed the task normally, following the appropriate cues given by the displayed hand. The incongruent training led to an increase in the response time of compatible trials, but did not lead to a decrease in the response times of incongruent trials. Thus it was shown that this short training was able to inhibit the automatic imitation response by inhibiting motor links between the visual and motor representations of these specific stimuli. This study led Heyes to develop the ASM theory as experience was able to modulate automatic imitation processes, which would not be the case if these processes were completely hardwired and innate.

Wiggett et al. (2011) provided further support for the ASM by showing that body related learning is a flexible process. They repeated Heyes et al. (2005) experiment using both bodies and shapes to form visual learning associations. Their incompatible training had a similar effect to the Heyes et al. results and showed that training and experience have a significant effect on motor-visual associations. These studies show that automatic imitation processes are heavily moderated by experience, and that the connections that serve as the basis for this automatic imitation process can be learned. The study by Cross et. al (2006) also implicated the mirror neuron system in learned motor representations by showing that neural activation and association is greatest when participants view actions they have

completed in the past. The finding of Wiggett et al. (2015) set the stage for this discussion of automatic imitation and implicated both body orientation and motor familiarity in explaining why body compatibility effects did not extend to pictures of unadoptable body orientations or bodies in irregular configurations. As seen in previous studies motor familiarity appears to have a large effect on automatic imitation and neural activation during imitation, as it appears that the connections between motor and visual areas are learned through experience.

In order to test whether automatic imitation effects stem from motor expertise and the ability to embody movement, studies have been conducted using biomechanically impossible stimuli. Constantini et. al, (2005), conducted a study to elucidate the neural underpinning of observing humanly impossible motion by studying observation of these movements. They created mechanically possible and impossible actions using fingers movements as well as videos of scissors moving in both possible and impossible ways. As expected there were differences in neural activation between body and non-body stimuli, as the body related stimuli led to increased activity in the frontal lobe as well as well as bilateral activation in the postcetnral gyrus and supramarginal gyrus. Impossible movements led to increased activation in the left inferior frontal gyrus and bilateral activation of the inferior parietal lobule, as well as the middle temporal gyrus and left posterior thalamus. The posterior cingulate (PCC) was more active during observation of impossible versus possible hand movements. The PCC links body-related sensation to action as well as conflict, and is thus crucial in determining whether an action can be adopted. It has also been suggested that the parietal lobe may store different postures, and

map them onto available motor programs. Thus the PCC and parietal lobe may decide whether a movement can and should be adopted or not.

The activation of the premotor cortex for impossible actions shows that actions are encoded regardless of whether they can physically be executed or not. This finding must be taken with a grain of salt, as it goes against previous fMRI data, and could be due to the similarities in movement between the possible and impossible actions. However if this is true it raises interesting issues for automatic imitation studies, as this premotor cortex activation could feasibly facilitate similar possible actions. These findings may play an important role when body postures are observed that are possible but unadoptable. When re-examining Wiggett et al (2015) initial finding that only adoptable body positions in normal (hands above feet) orientations yielded automatic imitation effects, this evidence of activity in the premotor cortex raises questions as to why automatic imitation effects are not seen. If the Direct-Matching hypothesis is true then this activity in the premotor cortex would lead to body compatibility effects. More research is required in this area to determine if biomechanically impossible full body postures yield the same premotor cortex activation as impossible hand motions do. If these full body impossible postures fail to activate the premotor cortex in the same way that hand motions did, an informational follow up study would be to determine whether this lack of activation was due to the inability to embody the impossible pose, or whether the unusual orientation did not allow for effective configural processing of the body.

Thomas et al., (2005) used tactile stimuli to further determine the effect of spatial and anatomical orientation on body compatibility. In this study, subjects were shown videos of a body being touched, and then were subsequently touched in the same location in spectral (the cue and target occupy the same spatial location, but are mirror images of each other) or anatomical space. In each variation of the study they conducted the congruency effect for detecting tactile events in the same anatomical position as video stimuli was faster and more robust than when stimuli presented were spectrally congruent to the observer. This finding established the importance of anatomical congruence on body compatibility effects and goes against most developmental literature, which states that babies imitate using spectral space comparisons. This study is unique in that it provides evidence of a shared interpersonal tactile representation, which may be a direct offshoot of the mirror neuron system. This shared representation supports the idea that these visual tactile representations are not only different from general spatial attention, but that the sensory events associated with our bodies as well as other's bodies can occupy a single location in our interpersonal body representation. These findings confirm theories of embodiment, which state that in order for actions to be processed they must be mentally represented and embodied.

An important delineation for both the proposed study as well as Wiggett et al. (2105) study is the difference between impossible and unadoptable body postures. While many postures and movements may be unadoptable for the average human, practice and hard work can make many seemingly impossible motions possible. Studies analyzing expert sports players have shown that motor expertise may play a

role in perception of specific actions, which may be due to ability to embody the stimuli presented. Although studies testing the effect of motor expertise on automatic imitation have not been conducted, studies have been conducted examining how expert sports players perceive sport related actions. Studies on dancers, including Cross et al, demonstrated that viewing actions that had also been embodied by previous practice lead to greater neural activation. As a follow up study to these previous studies conducted on dancers and gymnasts, Guldenpenning, et al. (2013) conducted a study on novice and expert beach volleyball players. They asked participants to classify target pictures of a beach volleyball player mid-shot as either a smash or a poke shot. These shots share similar body configurations. Before the target picture appeared the participants were subliminally primed with a picture that was either congruent or incongruent with the target picture featuring a posture taken mid-shot. Their results showed that expert volleyball players yielded a larger action congruency effect, and were able to identify the target shot when primed with pictures in earlier stages of the motion than novices. In a subsequent experiment they provided the novice participants with visual training, which did not lead to an increase in performance.

This study establishes that video training is not sufficient to increase implicit processing of movement, and reveals that athletes are better able to discriminate between different movement techniques than novice participants, as they exhibited larger priming effects when viewing still shots from earlier time point in the action. Along with the evidence presented by Cross et al (2006), this shows that motor

expertise plays an integral role in action perception, and thus may be important for automatic imitation as well.

There has been a significant amount of literature published establishing automatic imitation as a robust phenomenon. However the mechanisms of automatic imitation that give rise to the body congruency effect are not well elucidated. The published literature to date suggests that body orientation, adoptability of posture, and motor expertise of the participants may play a crucial role in determining when the body congruency effect is observed. It has been shown that bodies and movements are processed in an anatomical reference frame, and that the activity of the mirror neuron system gives rise to interpersonal body representations that are responsible for embodiment.

The mirror neuron system appears to work in conjunction with motor expertise to allow athletes and other expert movers to identify small differences in motion within their area of expertise that cannot be identified by novices even after visual identification training. This evidence shows that the mirror neuron system is plastic and is not entirely innate, thus automatic imitation effects could be dependent on development of the mirror neuron system, which would allow different poses to be embodied through specific motor expertise. These internal visual and sensory representations of bodies connected to the mirror neuron system collectively form body schema. While studies examining on the effect of expertise and body orientation on body schema and automatic imitation have never been conducted, a study of this nature would add to the scientific literature by

elucidating the effects of motor expertise on implicit motor representations as well as determining the plasticity of body schema as a whole.

Thus the main question of this experiment is how time spent inverted will affect the body compatibility effects. Our hypothesis is that inverted stimuli will lead to compatibility effects in acrobats who spend a significant portion of their time upside down, but not control subjects.

Method

Participants

Our experimental group of acrobats contained 40 expert circus performers. The acrobats were recruited through circus schools throughout Wales and the southern United Kingdom. Testing was conducted at three main circus schools: No Fit State in Cardiff, Circomedia in Bristol, and The Nation Centre for Circus Arts in London. Participants were compensated 10 pounds for 40 minutes of their time. Before data analysis 12 participants were eliminated: 1 had Asperger's, 1 had ADHD, 5 had dyslexia, 4 were over 40 years of age, and 1 lacked expertise in any acrobatic discipline. Of the remaining 28 acrobat participants, there were 11 males, 17 females and the average age was 27.7 years.

The control group contained 20 participants, 9 male and 11 female, with an average age of 20.35 years. All of the control participants were recruited from the Claremont Colleges and are currently enrolled as students. None of the control

subjects had any significant experience with circus arts, gymnastics or dance. They were compensated $10 for approximately 40 minutes of their time.

<u>Apparatus and Materials</u>

Each participant was presented with four tasks, a body compatibility task, a mental rotation task featuring three-dimensional images, a mental rotation task featuring bodies and a mindfulness questionnaire. This project will only focus on the outcome of the body compatibility task, which was always presented first to each participant. The tasks were presented on a 24" dell monitor and the participants responded by pressing the space bar on a provided keyboard, or by clicking a provided foot pedal (Savant Elite FS10J-USB, Kinesis). The body compatibility task was created and run using Matlab for Mac IOS on a Macbook Pro connected to the monitor, keyboard and foot pedal. During the body compatibility task the participants were shown 68 images four separate times in random order. The images presented were still pictures of an aerial silk performer in 18 distinct positions. His face was blurred and a colored dot (red or blue) was positioned on his hand or foot (see Figure 1). The body was shown in a variety of orientations, mostly inverted and upright positions. The red and blue dots were placed on a hand and a foot of each picture, creating 4 images per pose (red dot on foot, red dot on hand, blue dot on foot, blue dot on hand).

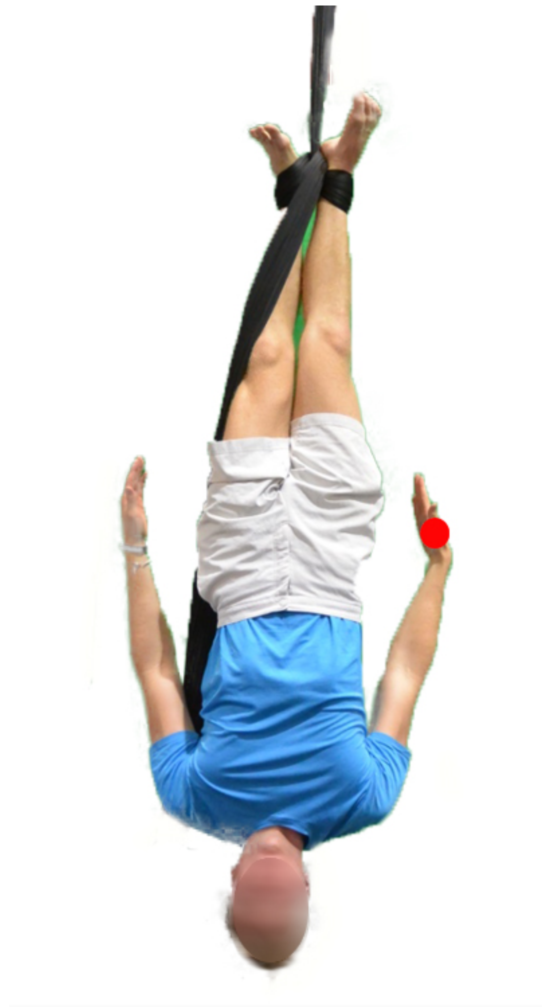

Figure 1: Example of picture shown in the body compatibility experiment

<u>Procedure</u>

After having each participant fill out a consent form, approved by University of Bangor Ethics Board participants were asked to fill out an extensive questionnaire, which collected data about their movement experience and any disabilities that could affect their performance on the subsequent tasks. The participants were then placed in front of a 24" dell monitor, and asked to place their dominant hand over the space bar of the provided keyboard. They were then asked to remove their shoes and place their foot on the provided foot pedal. Each

participant was instructed to press the space bar or foot pedal based off the color of the dot placed on the body presented on the computer screen, not the position of the dot. Half the participants were instructed to click the space bar every time a red dot was presented and the foot pedal every time a blue dot was presented; half of the participants were given the opposite instructions. Upon reading the instructions, each participant completed a practice block featuring 10 images. After the practice block there were 4 testing blocks that consisted of the same 68 pictures in random order. In between each test block participants were given a 15 second break, and the instructions were displayed again. Each trial was preceded by a fixation cross shown for 1400ms. The picture was then presented and the participant was given 1100ms to respond. If they responded correctly within that time frame the next trial began, if they responded incorrectly the word "incorrect" appeared on the screen before the next trial. If the participant took longer than 1100ms to respond the words "too slow" were presented before the next trial began. After all the tasks were completed each participant was given a sheet featuring each aerial silk position, and the participants were asked to rate their ability to adopt the posture on a scale from 1-10.

Results

The response time data for each participant was trimmed by deleting any incorrect RTs (a total of 572 trials, see Table 1), as well as any RT that was two standard deviations away from the mean (a total of 136 trials). After the data for each participant was trimmed, independent samples t-tests were conducted in

order to determine the demographic differences between the groups. These tests revealed there is a significant difference between the mean ages of each group, (M_{age} Acrobats = 28 years (SD = 6), M_{age} Novices = 20 years (SD = 1.34); t (43) = 5.241, p < 0.001). There was also a significant difference in the amount of time each week the participants spent inverted, as expected (participants were asked to rate the amount of time they spend upside down weekly on a scale from 1-10) ($M_{inversion}$ Acrobats = 7.07 (SD = 2.73), $M_{iversion}$ Controls = 1.85 (SD = 1.73); $t(42)= 7.088$, p <.001). Multiple regressions analyzing the effect of age and years of experience on the RTs collected revealed there was no effect of either of these factors on performance, however there was a significant positive correlation between age and amount of experience in the acrobat group ($r=.536$, n =47, $p<.001$).

<u>Accuracy</u>

A repeated measures ANOVA was conducted on the mean percentage correct for each condition (Table 1). A graphical representation of accuracy across all conditions can be seen in Figure 2. The ANOVA revealed that there was a main effect of congruency (F (1, 46) = 19.874, p<.001, , η^2 = .30). There was also an interaction between congruency and orientation (F (1, 46 = 5.677, p< .005, η^2 = .11). Notably there was no significant effect of orientation (p = .413) and no interaction between group and orientation (p = .621). Post-hoc t-tests were conducted on all possible interactions. The only significant post-hoc analysis was a paired t-test which examined the significant interaction between congruency and orientation and showed that congruent upright (M = 96.93, SD = 2.59) and congruent inverted (M =

94.10, $SD = 3.51$) $t(47) = 5.11$, $p < .001$) postures had significantly different accuracy rates.

Table 1: Percent Accuracy for Experimental Conditions

	Congruent		**Incongruent**	
	Acrobats	**Controls**	**Acrobats**	**Controls**
Upright	96.82	97.08	94.05	94.17
Inverted	95.60	97.24	94.81	95.63

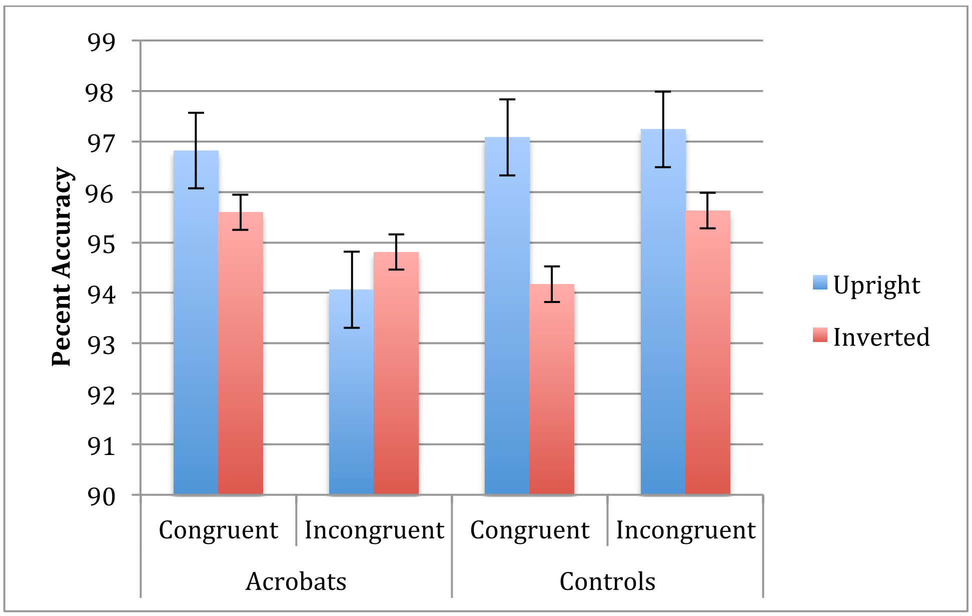

Figure 2: A graphical representation of the mean percentage correct for both groups for all conditions

<u>Response Time</u>

A repeated measures 2x2x2 ANOVA was conducted on the RT data. The within subject factors were orientation (upright or inverted) and congruency and the between subject variable was group (acrobat or control). The means for each condition in the body compatibility task can be seen in Table 2 and a graphical representation of RTs for each condition can be see in Figure 3.

Table 2: Average Response Times in Seconds for the Body Compatibility Task

	Congruent		**Incongruent**	
	Acrobats	**Controls**	**Acrobats**	**Controls**
Upright	.586 (σ=.049)	.590 (σ=.053)	.596 (σ=.055)	.611 (σ=.057)
Inverted	.596 (σ=.055)	.599 (σ=.057)	.594 (σ=.057)	.604 (σ=.057)

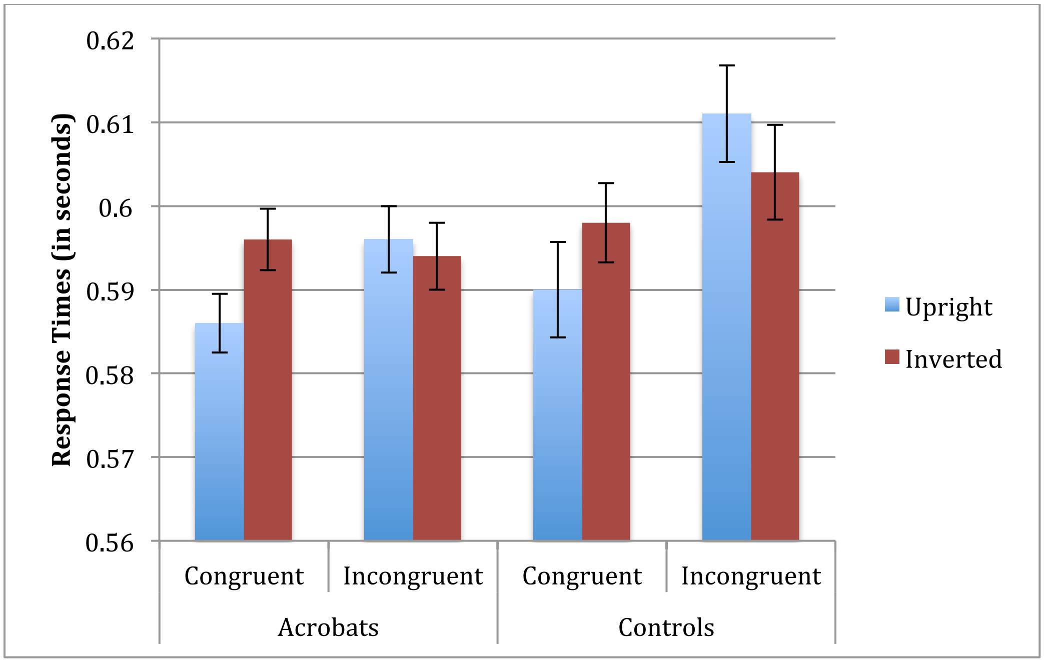

Figure 3: A graphical representation of the mean response times for both groups for all conditions

The ANOVA showed a main effect of congruency (F (1,46) = 16.22, p<.001, η^2 = .26). The ANOVA also revealed a significant interaction between congruency and group (F (1,46) = 5.430, p<.024, η^2 = .11) , There was also a with-in subjects interaction between orientation and congruency(F(1,46) = 6.561, p = .014, η^2 = .125). Crucially there was no effect of orientation, (p = .371) and no significant interaction between group and orientation (F(1,46) = .250, p = .620, η^2 = .005) as shown in Figure 4.

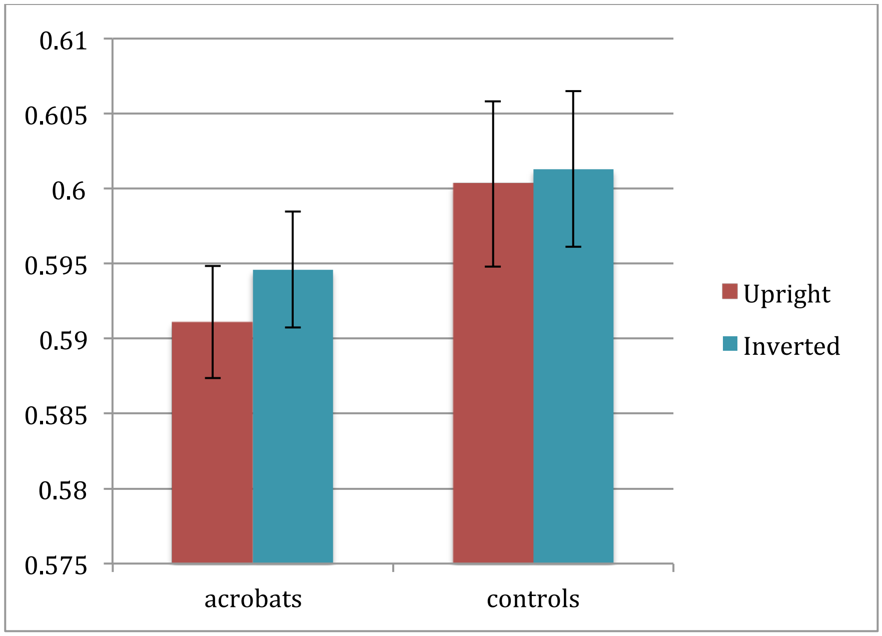

Figure 4: RTs of the acrobat and control participants for upright and inverted conditions

Post-hoc paired samples t-tests examining the significant interaction between congruency and orientation revealed that congruency effects were only present in upright postures ($t(47) = -4.240$, $p < .001$), as the RTs for the congruent upright postures ($M = .59$, $SD = .05$) were significantly faster than the incongruent upright postures ($M = .60$, $SD = .06$). No significant difference in RTS between congruent and incongruent conditions was observed for inverted postures. Figure 5 compares the differences in RTs for each group for congruent and incongruent conditions. This figure suggests there is a smaller difference in RTs of congruent and incongruent trials for the acrobats than the control participants, as there is no significant difference between RTs for congruent and incongruent trials in the acrobat group, but there is a significant difference between these conditions in the control group. This figure also shows that the acrobats performed significantly faster on incongruent trials than the control participants.

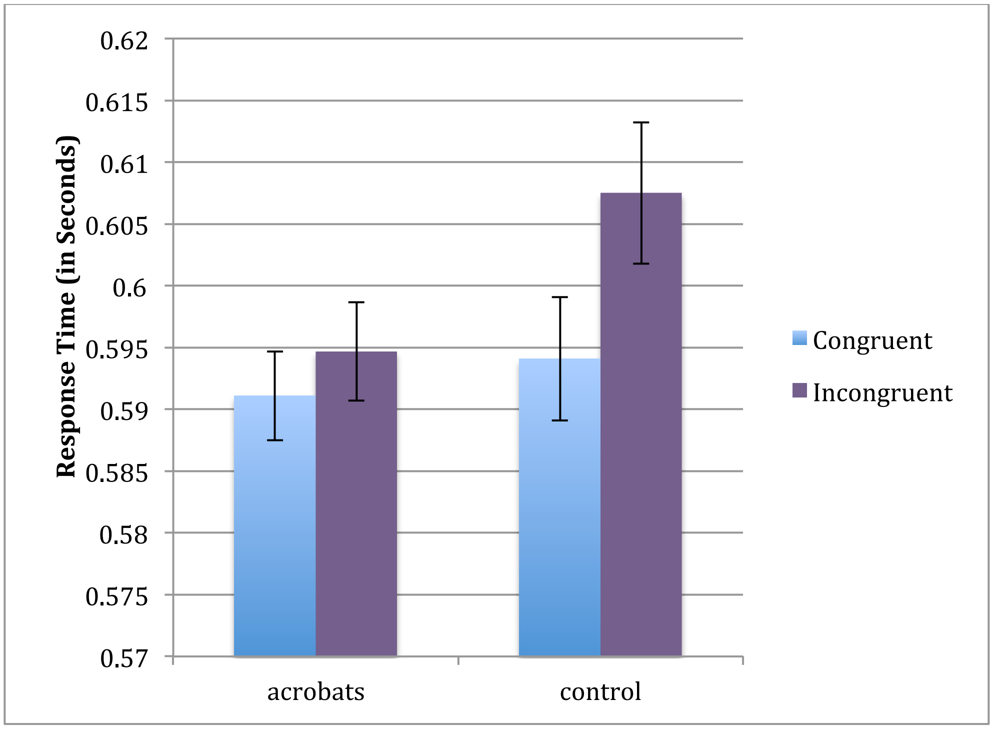

Figure 5: RTs of acrobat and control participants for congruent and incongruent trials

Post-hoc paired t-tests investigating the significant interaction between congruency and orientation revealed that only congruent trials had significantly different RTs based on orientation ($t(47) = 3.571$, $p = .001$), as participants were able to respond to congruent upright postures (M=.59, SD=0.05) faster than congruent inverted postures (M=.60 SD=0.05) as seen in Figure 6. No significant difference in RTs between upright and inverted postures was observed for the incongruent trials. Figure 7 compares accuracy and average RTs across each condition in order to visualize the relationships between speed and accuracy.

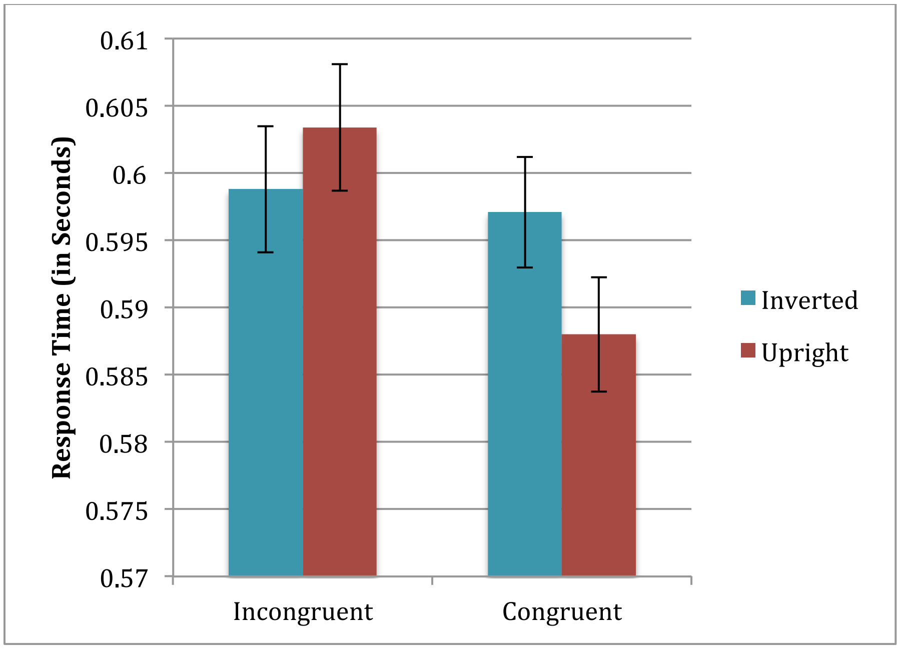

Figure 6: RTs of congruent and incongruent trials for inverted and upright conditions.

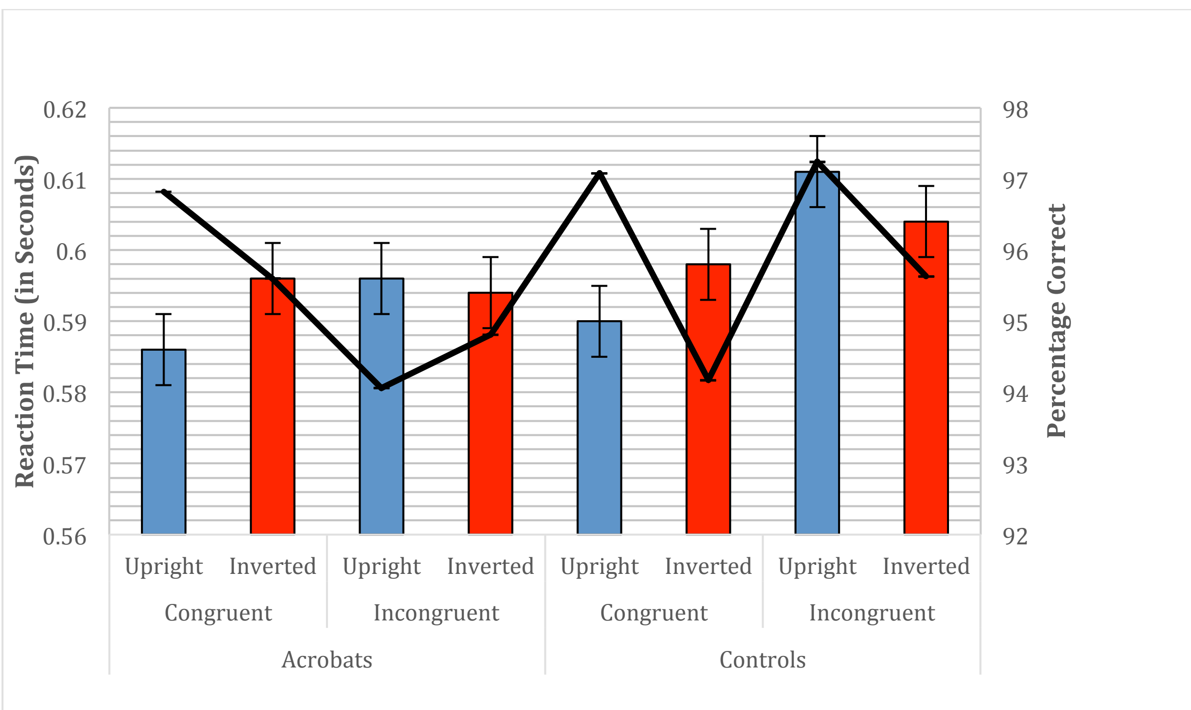

Figure 7: RTs for all four compatibility conditions. The line graph represents the percentage correct for all the conditions.

Discussion

As our results show, there appears to be an effect of body compatibility (i.e. the variable named congruency in the results section) for both acrobats and control participants, however this effect is only observed in upright postures. This result is in line with previous research, which has shown body compatibility effects for upright but not inverted postures. Because we were able to observe these compatibility effects in the upright condition we can conclude that our stimuli and experimental design are sufficient to lead to compatibility effects.

When examining response time data it is necessary to ensure no speed-accuracy trade off occurred. There was no significant different in accuracy rates between groups, however congruent upright trials had a significantly higher accuracy rate than congruent inverted trials. There was a significant difference in RTs between these two conditions, but the inverted RTs were slower than the upright RTs. Thus this data suggests that the inverted stimuli were more difficult, but there does not appear to be a speed-accuracy trade off for this condition, as speed decreased for the congruent inverted trials, the same condition that had the lower accuracy rate. Additionally there was no effect of orientation on accuracy and no difference between groups, which supports the assertion that there was no speed-accuracy trade offs made by the participants in this experiment.

While we expected control subjects to show no compatibility effects for inverted stimuli, we did expect acrobats to show the same body compatibility effects for both upright and inverted stimuli. Our results showed a significant interaction

between congruency and orientation, due to the fact that RTs for congruent upright trials were significantly faster than congruent inverted trials. This result shows that responses to upright trials were consistently faster, which is likely due to the fluency with which both groups can process upright bodies. Both groups have more experience processing upright bodies than inverted bodies as both groups have had to process upright bodies on a daily basis for their whole lives, which would lead to greater perceptual fluency than processing inverted bodies. Our results also show a main effect of congruency, which was due to faster RTs for congruent upright stimuli compared to incongruent upright stimuli. Thus the body compatibility effect was only seen for upright postures, as there were no significant differences between RTs of congruent inverted and incongruent inverted stimuli.

These results alone do not support our hypothesis as they suggest that time spent inverted does not result in alternate mental body representations, as no congruency effects were observed in the acrobat group for the inverted stimuli. We expected that acrobats would have body representations for inverted postures due to the large amount of time they spend upside. Since the body compatibility effect is a result of mental body representations as well as motor and perceptual expertise, our results show that time spend upside down does not lead to the development of a novel inverted body schema. This data does not conclusively rule out the possibility of developing alternate body schema based on experience, as the acrobats could have formed inverted schema that were not as robust as the upright schema. Even in upright postures, the body compatibility effect is rather small, thus it is possible that this experimental design is not sensitive enough to effectively detect the

development of new body schema and representations, as these new schemas wouldn't lead to as robust of an effect as they would be activated less often and developed later on in life than their upright equivalent.

While this data did not support our hypothesis, it did raise additional questions regarding the ways acrobats and control participants differed in the compatibility task. Perhaps the most perplexing result was the significant interaction between congruency and group. This interaction was due the fact that acrobats performed significantly faster on incongruent trials than the control participants. The faster performance for incongruent trials can be seen in Figure 5. Thus our data does not support our original hypothesis, however it does show that there is a significant difference in the ways these groups process incongruent stimuli, revealing what could be a different perceptual phenomenon from what we anticipated.

The faster RTs of the acrobats for incongruent trials may be explained by exploring the possible perceptual changes and familiarity that result from participating in acrobatic disciplines. Circus acrobats are unique in that they spend a significant amount of time upside down. To be apart of this study acrobats had to participate in a discipline that featured significant amounts of inversion, whether trapeze, hand balancing of cyr wheel (See Figure 8 in the Appendix for visuals of the acrobatic disciplines featured in this study). Thus these acrobats are used to manipulating their bodies in inverted postures, which is a skill that takes years to cultivate. They are also used to viewing audiences, coaches, and classmates from an

inverted position. Often coaches will stand on the ground, instructing their students by pointing and gesturing, thus in order to follow directions effectively the student has to translate the commands given from an upright body to their current inverted posture. When viewing upright bodies from an inverted posture it appears as if the hands of the bystander appear below their feet, as the image of an upright body on the ground appears to be inverted when viewed by an acrobat in the air.

While we expected all these factors of inversion and motor expertise to result in acrobats exhibiting body compatibility effects when viewing inverted stimuli, no such effect was seen. Thus the lack of body compatibility effects suggest that time spent upside down may not lead to the creation of inverted perceptual body representations that are as strong as conventional upright body representations (or schema). All the pictures used as stimuli in this experiment featured a male on the aerial silks. While control participants may have seen aerial silks in a *Cirque Du Soleil* show once or twice in their lives, all of the circus acrobats were intimately familiar with silks, either because they train on them or they train on a similar apparatus. There is also enormous cross over between circus disciplines, and it is not infrequent for the same move to be performed on several apparatuses. Thus the circus acrobats were much more familiar, both visually and experientially, with shapes and poses that can be adopted on aerial silks than the control subject. Thus when the acrobats were presented with a picture of an aerial silk pose it is likely that familiar similar aerial silk moves and poses and their corresponding motor representations were primed.

Most poses on aerial silks place the participants in upright or inverted postures, as there are very few aerial silk postures that are strictly horizontal in nature. Thus when acrobats view a picture of a pose, familiar upright and inverted aerial silk poses are likely activated. For example when an incongruent upright stimulus is shown, the acrobats likely prime familiar inverted aerial silk postures as well. Thus while the hands may be shown above the feet in the presented stimulus, the participant may have primed mental images and motor representations of postures that feature the feet above the hands. This priming process would lead to a form of perceptual overlap, as both upright and inverted bodies are being primed in acrobat participants' brains. Thus if the dot is placed upon the foot of the featured acrobat on the aerial silks in the stimulus photo, acrobat participants would experience priming in their feet as expected by the body compatibility effect, but their hand would primed as well due to the priming of additional postures of the opposite orientation. Figure 9 shows an example of how this priming could lead to quicker RTs for the acrobats, as when an inverted pose is shown superimposed on an upright pose, the hand and foot occupy the same spatial position.

This theory can be used to explain how acrobats responded faster to incongruent stimuli than control participants. It suggests that both upright and inverted postures are primed whenever an acrobat views a posture shown on the aerial silks. This allows the acrobats to respond faster in incongruent trials, as the body part they must respond with has already been primed, which is not the case in control subjects. It is important to note that this effect, if present at all, is not as robust as the body compatibility effect, which is evidenced by the fact that both

groups responded similarly to congruent stimuli. This result does not affect the proposed priming theory, as congruent stimuli require that the participant respond with the same body part that their attention is drawn to.

Figure 9: An image of an upright posture on the aerial silks, with an inverted aerial silk posture overlaid on top of the upright posture. A blue dot corresponding to the location of the foot of the upright image is overlaid over both images.

It is important to note that through the course of the 272 trials presented to each participant in this experiment, control subjects may have habituated to the images. Thus while they previously would not have had any readily familiar associations with aerial silk poses, it is possible that they could build up a familiarity throughout the course of the trials. It is possible that this exposure led to small amounts of priming as discussed for acrobat participants, however it is unlikely that the pictures would evoke the same level of priming as proposed for the acrobats. The acrobats have more experience and available motor representations that match each pose that is primed, leading to a level of priming that could not be reached by simply habituating to the stimuli. This assumption is supported by the data from this experiment, however it could be useful for future experiments to collect data after each trial block in order to determine if control subjects habituated to the stimuli.

In future studies on this topic it would be beneficial to use a more sensitive test to determine the ways perceptual and motor expertise shape participants response to a stimuli. Having participants complete a similar task in an fMRI scanner may reveal brain regions used in the task, which could help determine whether or not new schema are created through extensive motor and perceptual experience. An fMRI study could determine differences in neural activation between the groups, pinpointing the location of new body representations, or determining the different ways that acrobats and control participants process bodies and congruency. An fMRI study could also reveal how available motor representations effect the body compatibility effect, as activation in different brain areas could be monitored

throughout the task. These experiments could offer a more definite explanation of why acrobats performed quicker on incongruent trials. Analyzing the results of the body and mental rotation tasks that were also part of this experiment may help shed light on how the perceptual processes of acrobats differ from control participants, in turn explaining the unexpected results of this study. It is also worth considering conducting another study where the stimuli consist of the same image of a body rotated in different orientations. This could mitigate familiar priming effects we may have encountered in this study with our aerial silk stimuli.

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Appendix

• Aerial Silks	
• Trapeze	
• Lyra	
• Cyr Wheel	

- Aerial Straps

- Hand balancing

Figure 8: Index of acrobatic disciplines practiced by the expert acrobatic participants