Perceiving Dance Movement Patterns:
Investigating self-recognition with a group of ballet dancers

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Abstract

There has been growing interest among cognitive scientists to understand motor/proprioceptive function and perception with dancers as participants (e.g. Brownlow, Dixon, Egbert, & Radcliffe, 1997; Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2004; Cross, Hamilton, & Grafton, in press). Recent research by Loula, Prasad, Harber, & Shiffrar (2005) showed that two main kinds of information could be used in self-recognition – both visual and motor signals – when subjects watched point-light videos of themselves and others dancing (among a number of other whole-body actions). The purpose of the current interdisciplinary dance and cognitive science study was to investigate how dancers specifically recognize the visual display of their own movements. In particular, it aimed to investigate aspects of Loula et al. and explore visual and motor/proprioceptive experience in self-recognition with a particular research design and apply findings to dance-specific concerns, such as dance teaching, motor control and learning, and dancer perception. The study was designed considering 3 primary questions: 1) Is proprioceptive/motor information important for self recognition?, 2) Does expertise influence visual perception?, and 3) If so, is visual or motor expertise more important? The researchers conducted 2 testing sessions with a specialised group of ballet dancers. During the first session, dancers performed specified ballet vocabulary using the point-light technique (Johansson, 1973). On a later date, the same group of dancers watched the processed point-light videos and answered questions regarding visual discrimination and self-recognition. The researchers found that performance was above chance (chance set at 50%) for visual discrimination and self-recognition of 'self' and 'other' point light displays. Dancers were found to be better at discriminating pairs of 2 of the same dancers than different dancer pairs, although not significantly. Comparison of the accuracy between the visual discrimination and self-recognition tasks revealed no significant difference. This suggested that dancers did not use any special private motor/proprioceptive information to complete the self-recognition task.

1. Introduction and Literature Review

1.1 Humans recognize action

Recent research in cognitive science, and related disciplines, has tried to demonstrate that the human visual system carefully reads social cues available in human movement (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Loula, Prasad, Harber, & Shiffrar, 2005). One main reason for this research has been because "our ability to generate actions and to recognize actions performed by others [and ourselves] is the bedrock of our social life" (Decety and Grèzes, 1999, p 172). In other words, *generating* actions has allowed humans to survive, e.g. grow food and defend against predators. Similarly *recognizing* actions has allowed humans to defend, e.g. detect if a moving object is an ally or predator. In addition, generating and recognizing actions has allowed humans to communicate beyond the limitations of spoken word, e.g. body language. But how, exactly, do humans recognize biological motion? Johansson's (1973, 1975) point-light technique showed early on that humans were good at action generation and recognition ability. Research identifying the mirror system (e.g. Rizzolatti, Fadiga, Gallese, Fogassi, 1996) suggested the same brain mechanisms may fire when watching a movement as when performing a movement and therefore play a large part in recognizing biological motion. As a result, self-recognition (e.g. Loula et al.) was considered a possible means to investigate visual and/or motor/proprioceptive input related to recognizing biological motion, specifically because humans only have motor/proprioceptive experience with their own movement. It was important to elaborate on previous research in these areas before introducing the current study.

1.2 Point lights and biological motion perception

Point light technique, developed by Johansson (1973), found that observers could identify human movement simply from watching a video of lights that had been put on a person's joints and filmed in a dark room.[1] Indeed, Johansson found that the human visual system could perceive "all the intricate coordination of frequencies, phase relations, amplitudes and acceleration patterns" of the human skeletal structure from simply viewing a few moving dots on a video screen (1975, p 87). Johansson (1973) found that observers were able to also specify what type of actions the point-light figures did, such as running or hopping.

[1] This was true for movement *only*. Johansson (1975) found that when the same observers looked at a set of static point-lights (e.g. a person sitting in a chair), the observer could not establish a human figure.

Point-light displays were found most useful to human action-recognition research because point-lights minimized human motion to a simple visual form and yet a number of social cues were still perceived. Point-light technique provided "robust shape-from-motion cues that [allowed] recognition" (Adolphs, 2003, p 167) and yet prevented the viewer from being distracted by other surface forms (e.g. body shape) and/or expressions of the face (Dittrich, Troscianko, Lea, & Morgan, 1996, p 728).

Further research with point light displays helped show just how sensitive human movement observation is. Kozlowski and Cutting (1977) found that participants could recognize the gender of a walker and distinguish whether it was themselves or someone else. Beardsworth and Buckner (1981) found persons were better at recognizing their own movement than friends', even though they had never seen themselves walking from an external point of view before. Subjects were also found to be better at recognizing whole body movement versus partial body movement (e.g. a hand). Likewise, Sumi (1984) found that participants could not recognize inverted point-light displays of motion. In addition, observers were found to accurately determine when movement was 'authentic' and when it was 'deceptive' (whether point-light actors picked up an actual heavy box or just pretended to) and could accurately determine future results of observed action (predict distance of thrown object from kinematics of thrower) via point light displays (Runeson & Frykholm, 1983, p 585). Dittrich et al. (1996, p 727) found that emotion could be recognized by subjects when they viewed dancers performing different emotions as point light displays. Brownlow, Dixon, Egbert, & Radcliffe (1997, p 411) found that dancers were better in fine discriminations between dancer trait and emotion characteristics from point-light displays. Therefore, point light display research proved that humans possess a 'unique and impressive visual sensitivity' to social cues of human movement (Loula et al., 2005, p 210).

1.3 Mirror System

So-called "mirror neurons" were first identified in macaque monkeys by Gallese, Fadiga, Fogassi, & Rizzolatti (1996). The researchers found that when a monkey observed a motor action conducted by an experimenter – i.e. grasping food on a tray – that the movement was also represented in the monkey's motor repertoire even though the monkey did not perform the action and had no muscular activation related to the action (e.g. EMG recordings; Rizzolatti et al., 1996, p 132). Basically, the monkey had a motor simulation of a movement from purely visual input.

This was an important finding for cognitive neuroscience because of its implications regarding humans' action recognition system (Jacob & Jeannerod, 2006, p 1). In fact, researchers (Rizzolatti et al., 1996) soon confirmed that a similar motor action simulation occurred with humans – the human brain also fired in a similar way when *watching* a movement as when *doing* a movement. This suggested that mirror neurons help humans understand motor events and give humans "the capacity…to recognize the presence of another individual performing an action, to differentiate the observed action from other actions, and to use this information in order to act appropriately" (p 137). However, recognition of one's own movement was beyond the scope of their findings,

> It will be too long to speculate here how the individual recognizes his own movements from those generated by others or how the pictorial aspect of the hand, which does not belong to the acting individual, becomes associated with his movements (p 137).

A few recent dance-specific studies have built on mirror system research. Calvo-Merino et al. (2005) found there were "differences in brain activity between watching an action that one has learned to do and an action that one has not" and "action observation was modulated by expertise and motor repertoire of the observer" (p 1243). In other words, if a subject had a specific (capoiera or ballet) acquired motor repertoire of a movement viewed (e.g. a ballet dancer watching a tour en l'air) he had a 'stronger' brain activity related to doing that action than those subjects that did not have the motor repertoire. This finding showed that the mirror system is "sensitive to much more abstract levels of action organization, such as those that differentiate dance styles" (p 1247) and mirror system representation is linked to learned motor skills. Cross, Hamilton, & Grafton (in press) built on this research and also found that contemporary dancers were sensitive to prior physical experience of contemporary dance choreography. The researchers found that, "…it is one's own ability to actually generate the movement that has the greatest influence on further increasing activity within action understanding areas [of the brain]" (p 9). [2] However, although this research supported a connection between motor experience and mirror system activation when watching a known movement, it did not explain how humans then attribute observed movement to the self.

1.4 Self-recognition

[2] Dance theorists have seemed to have known about this long before empirical proof: "The meaning of any dance comes alive for us only as we ourselves have a lived experience of the dance" (Sheets-Johnstone, 1979, p 4).

Consequently, there has been growing interest in human perception, motor-action systems and self-recognition (e.g. Decety & Grèzes 1999). However, links between action-recognition and self-recognition have received little explicit investigation (Tsakiris, Haggard, Franck, Mainy, Sirigu, 2005, p 216; Jeannerod, 2003, p 1). In addition, few studies have specifically asked "whether individuals can identify themselves when observing dynamic displays of self-generated versus other-generated action effects" (Knoblich & Prinz, 2001, p 457). Self-recognition, and the functional mechanisms associated with awareness of one's own body and actions, has been found important for a number of reasons (Jeannerod, p 1). One is for "the sense of agency", which is "the ability to recognize oneself as the agent of a behaviour" and "the way by which the self builds as an entity independent from the external world". Another reason is that "self-recognition is a prerequisite for attributing a behaviour to its proper agent (be it oneself or another person) and ultimately for establishing social communication with [other people]".

Offline and online authorship

A distinction must be made between the related, but separate, activity of offline and online action- and self- recognition. Online means the observer is simultaneously performing an action as perceiving an action. Offline means the observer perceives an action that he/she has previously performed. Online and offline recognition are related because they both are used to recognize self movement. They differ in the information available. In particular, online self-recognition has the immediate access of the motor/proprioceptive system, which just performed the action. Offline self-recognition has a time delay between *doing* the action and *viewing* the action which complicates whether the motor/proprioceptive information is accessible. Tsakiris et al. (2005) looked at the specific contribution of central motor commands in an online self-recognition task. Subjects saw a computer screen image of either their own right hand (in a glove) or the experimenter's hand (also in a glove) during an active or passive extension of their index finger and then had to decide whether the image displayed was their hand or not. The researchers found that self-recognition was more accurate when the subjects made the action themselves, showing that efferent information was important for detecting very small differences between what participants saw and what they did or felt (p 226). In particular, self-recognition was found to be low during passive movement and high with active movement – which suggested the central motor command (i.e. efference) contributed to self-recognition over-and-above simply feeling the finger move (proprioception only). In contrast, and yet related, the present study asked participants to distinguish if a viewed movement on a screen was their own or not *offline*. Meaning, the participants had motor/proprioceptive experience of the movements 8-9 weeks previous to viewing a visual representation of these movements, i.e. the visual observation was not simultaneous to execution.

Offline self-recognition

There has been conflict in the literature about how action recognition and offline self-recognition relate, if they relate at all (e.g. Jeannerod, 2003; Loula et al., 2005.). In other words, research has not yet proven how humans recognize action and socially attribute that action to either self or another person. Nonetheless, two theories prevail. One is that humans recognize self movement because of some sort of 'private motor code' system (e.g. Loula et al.) and the other is via the 'Who' system (e.g. Jeannerod, p 12). According to theories based around a private motor code, there is an implicit special motor/proprioceptive response when watching movement that allow humans to know if it is 'self', of which one has motor/proprioceptive experience, or of 'other', of which one does not have motor/proprioceptive experience. According to the 'Who' system (e.g. Vignemont & Fourneret, 2004), self-recognition is an explicit process above simple action-recognition. "Indeed, the activation of shared representations does not suffice by itself to determine who is moving, because their content does not specify the agent" (Vignemont & Fourneret, p 5). Thus, when watching human movement, there is first the action recognition via visual and motor representations and then the 'Who' system helps attribute that action to 'self' or 'other' according to cues necessary to attribute identity. Diagrams 1 & 2 were constructed as a way of understanding these different theories in a simplified way.

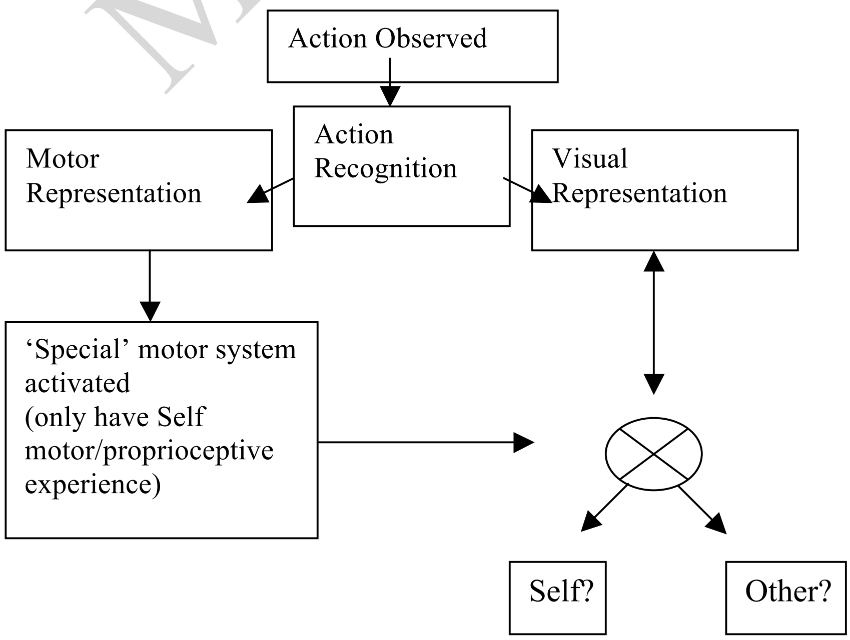

Diagram 1. 'Private motor code' is activated to recognize movement of the self: An action is observed, via mirror system which has both motor and visual representations. If the movement is human movement, there is a 'special private' motor command fired when viewing the visual information which helps attribute movement to self or other.

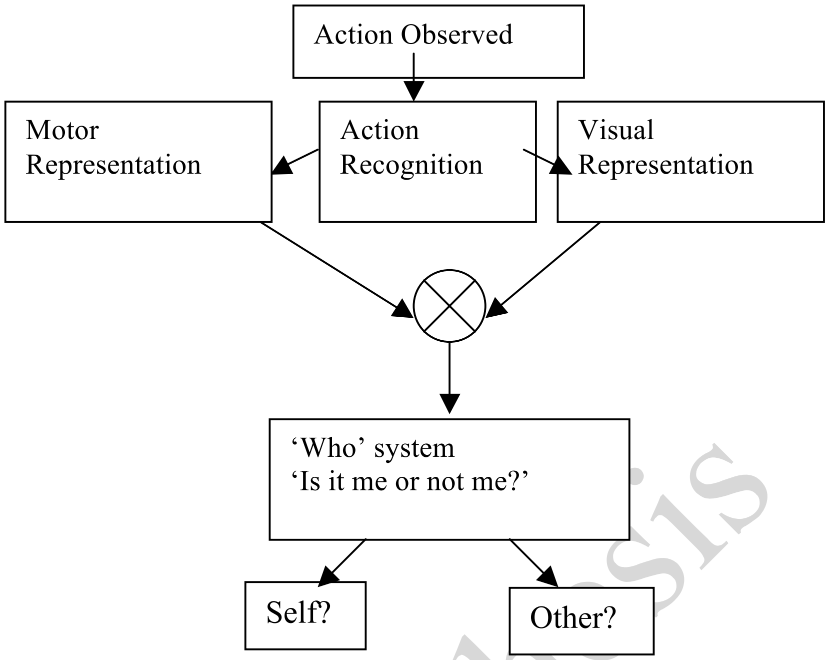

Diagram 2. 'Who' system helps recognize movement of self: An action is observed which has visual and motor representations via mirror system. A 'Who' system distinguishes between shared representation of self and other (Vignemont & Fourneret, 2004).

Internal forward model

A concept that was not considered in the above models, but also needs to be mentioned regarding self-recognition is the theory of 'internal forward models' (Wolpert, 1997, p 213; Decety & Grèzes, 1999, p 172). The basic premise of 'internal forward models is that when humans have visual and motor experience of an action, then this experience becomes represented in the motor system and used as a comparator when viewing action. The information 'recorded' in the motor system may then be used to either predict an action or be used as a comparator for an action produced. Said in another way, when observing human action, "…predictors capture the causal relationships between actions and their consequences, whereas controllers provide the necessary motor commands" (Jeannerod, 2003, p 8). This process is thought to work with online self-recognition, although other researchers (Decety & Grèzes, p 172) suggest it may also work offline. For instance, Runeson & Frykholm (1983) found participants could identify, viewing only point lights, when actors pretended to lift a heavy box. Researchers concluded that this supported a common-coding model (Prinz, 1997) in which perception and action share cognitive representations because the 'pretended' task did not match the observers' motor system comparator. There seems to be little doubt that a 'motor way of seeing' exists for human movement, however, with self-recognition it is yet inconclusive whether a forward predictive model works with a comparator *offline*. Nevertheless, recent findings regarding the mirror system (Gallese et al., 1996) make it likely that humans have *some type* of representation of an observed action during both online and offline action recognition. However, the conflict seems to remain in the 'how' this may work with self-recognition (Jeannerod, p 10-11).

1.5 Loula, Prasad, Harber, & Shiffrar (2005)

The primary source of the current study (Loula et al., 2005) used both the theory of a mirror system and point-light display technique to investigate offline self-recognition and 'identity perception'.

For the Loula et al. (2005) study participants were filmed as point-light displays doing a number of actions, such as jumping, walking, playing ping pong, dancing, etc. Weeks later, during a forced-choice task with point light displays, participants were asked to determine whether a point light movie clip (multiple trials) was themselves, a friend, or a stranger. In a subsequent task, participants viewed 2 different movies, including different actions, and distinguished if the actor was the same or different. The researchers found that "observers [were] most accurate in recognizing their own movements" and concluded that "because observers have the greatest motor experience with their own movements, this supports the hypothesis that the action system contributes to the visual analysis of human movement" (Loula et al., p 212). Because observers were better at recognizing friends than strangers, this supported that visual sensitivity to human movement also draws on visual experience. However, the relative sizes of visual and motor experience, and the fact that movies from a sagittal perspective of which the participants hypothetically had little to no visual experience were included, suggested that "motor experience is the larger contributor to the visual analysis of human movement, at least in the case of identity perception" (p 212-14). With the visual discrimination task, participants were also found to discriminate above chance (chance set at 50%) on all trials, performing best with trials involving 'self' (68%) and therefore, participants most accurately attributed movement to the self. Since "identity perception was best with one's own actions, lower but still above chance with the actions of a friend, and at chance with the actions of a stranger" (p 215), researchers concluded that the self-recognition superiority effect found in the forced-choice identity task could not be attributed to extraneous action-specific cues or to the use of a particular methodology. Although their findings supported identity perception theory, in which both motor and visual experience contribute to visual analysis of human motion, the researchers still state, "It is far from clear how observers could have greater awareness of the stylistic cues associated with rare actions than with common actions" (p 218).

1.6 The current study

Loula et al.'s (2005) use of dance, and their subsequent conclusions, raised several questions regarding self-recognition which inspired the current study; such as, did observers recognize themselves and friends' better with complex movements (e.g. dancing), than with simple movements (e.g. walking) because complex movements revealed more idiosyncrasies and simple movements were too stereotyped? Put another way, was the visual information driven by seeing themselves dancing enough to recognize themselves, whereas seeing themselves walking did not provide enough visual information? This may have been why Loula et al. (p 218) found that "each person's unique movement signature [was] more evident in less constrained actions". Or, did self and friend recognition occur better than chance because when looking at an action from one's motor repertoire the motor simulation program (i.e. mirror neurons) was activated? In other words, possibly motor/proprioceptive cues in the shown action perfectively matched with the proprioceptive/motor details in the mental simulation, and this 1-to-1 match drove self recognition?

What might occur with complex and yet constrained actions, such as ballet dance, however? With ballet dance there is a great deal of visual detail in the movement and yet little visual information when viewing the same movement performed by 2 different expert ballet dancers. Said in another way, on the one hand ballet dancers perform constrained movement (stereotyped among an experienced group), but on the other hand ballet dancers perform complex movement related to the 'normal' population (not as 'typical' as walking). Ballet dancers have years of experience with these complex movements, yet they also have attempted to limit the idiosyncrasy of their movements in order to fit a ballerina ideal (e.g. Novack, 1993; Vézina, 1998). A training premise in ballet is not to 'outshine' and show your unique personal movement style (Vézina, p 17) – as is more readily encouraged in contemporary dance – but to look as similar as possible to a certain ballet standard, e.g. certain 'look' of the attitude, arabesque, épaulement, etc. (until maybe at the solo/principal level).

What might happen if point light displays were made with ballet dancers and these dancers later had to visually distinguish between movies and between 'self' and an 'other' dancer? Would dancers easily determine differences between movies, supporting that ballet dance movement was idiosyncratic? Or if ballet proved non-idiosyncratic, how might dancers visually discriminate and/or self-recognize movement? In addition, would dancers be better, worse, or the same at identifying self between 2 movie pairs that they previously visually discriminated? Hypothetically, if dancers were better at identifying themselves in an explicit self-recognition task, versus an implicit visual discrimination task, with the same movie pairs, then some private motor information must have informed the dancers' self-recognition.

The current study attempted to address these questions, primarily to test Loula et al.'s (2005) statement, "…identity may be more accurately and readily assessed from expressive behaviours such as jumping and dancing" (p 219). Similarly, the research might test other claims that expert dancers have superior perceptual and attentional abilities which have helped them become faster at recognizing visual patterns and organizing information in meaningful units (Kimmerle & Côté-Laurence, 2003, p 128-9). In addition, might some type of 'private motor information' inform self-recognition, as Loula et al. claim, or if not, might some other type of mechanism, such as the 'Who' system, be responsible?

1.7 Why dance and self-recognition?

Clearly, dancers depend largely on perception and action to dance. If Decety and Grèzes' (1999, p 172) claim regarding "social life" was made specific to dance, it could also be said that generating and recognizing actions is the bedrock of dancers' professional life, particularly because dancers utilize action recognition on a number of levels to acquire, maintain, and advance technique and choreography, among other aspects of their dance profession. For example, when learning choreography, dancers continually refine their own movements, via action and perception, so that the movements 'look right' in order to 'get the part' or 'perform the dance properly'. Kimmerle & Côté-Laurence (2003) confirm that research is needed to understand the mental capabilities of dance experts:

> [dance experts] are able to selectively attend to meaningful visual information…Research is needed in this area to understand the mental capabilities of dance experts. Knowing how dance experts process information as they learn and perform would certainly shed light into how instructors should teach students to become good dancers (p 130).

Toward better understanding of dance expertise, the current research attempted to address questions such as: does an advanced dancer know what she looks like dancing? If so, or if not, what does this suggest about the skills learned with extensive ballet training?

The present study also dealt directly with aspects of motor control that may benefit aspects of dance learning, teaching, and choreography. Motor control and learning theories have been found to provide "invaluable information that can improve the dance technique class while preserving its artistic goals and integrity" (Krasnow and Chatfield, 1996, p 168). An example toward understanding motor control processes in dance was found by assimilating an example by Berthoz (2000, p 1) of a ski champion and how his/her brain "investigates the world" during movement:

> To become [an advanced dancer], it is not enough for the [dancer] to continuously process sensory cues and correct his/her trajectory; he/she must go over the [dance] in his/her mind, anticipate its stages and the state of his/her sensory receptors, foresee possible solutions to every error, take chances and make decisions before he/she makes a move.

Learning more about self-recognition in dance might expose more about parts in this process, such as when the dancer goes over a movement in his/her mind and/or how a dancer perceives his/her own movement.

Models for learning dance skills were found to detail motor learning and control in dance, and present the adapted skier example from another point-of-view. Kimmerle & Côté-Laurence (2003, p 61) provide a motor learning model for learning a dance action, which they call "the attempt, correct, and perfect model". This model (Figure 1) represents the global process of learning a dance skill and represents an ongoing loop which will vary according to dance experience.

Attempt
1. Pick up relevant cues
2. Form a mental image
3. Retrieve/construct a motor plan
4. Execute the skill

Correct
5. Monitor the performance externally and internally
6. Assess and reprogram the motor plan
7. Attempt the corrected skill

Perfect
8. Practice with ongoing monitoring
9. Revise the performance
10. Produce a skilled action
11. Combine the skill with other skills, music, and dancers

[Figure 1.] "Detailed model for learning dance skills"
Note. From *Teaching Dance Skills* (Figure 4.6, p 61), by M. Kimmerle & P. Côté-Laurence, 2003, New Jersey: J. Michael Ryan Publishing, Inc.

An adapted model is extended to advanced dancers specifically and provided an even more detailed 'picture' of the complexity of dance learning (Kimmerle & Côté-Laurence, 2003, p 124).

[Table 1.] "Characteristics of Experienced Dancers Throughout the Learning Process

Stages	Characteristics
Attempt	The experienced dancer understands the new skill presented visually and verbally Has keen visual, kinesthetic, and auditory perceptual abilities Can perceive the entire skill at once Can detect all relevant visual and auditory cues and ignore irrelevant ones Can analyze all components of the skill accurately and rapidly Can recall all components of a skill or all skills of a sequence in the proper order The experienced dancer has acquired a large number of dance images in long-term memory Can retrieve the proper mental image of the skill from long-term memory and bring it to short-term memory Can retrieve or construct an accurate motor plan for the new skill Can execute the new dance skill successfully
Correct	The experienced dancer has stored in long-term memory sensory images of how the correct movement "feels" Can monitor his own performance by attending to internal feedback provided by the movement itself; does not rely on external feedback from the instructor Can anticipate the next or a specific beat; can synchronize accurately Can identify elements of rhythm accurately Can detect and correct movement errors accurately and rapidly
Perfect	The experienced dancer has developed a highly refined control of his body Can perform complex dance skills successfully and consistently Can adapt to a change, modify a movement, and perform successfully on stage

Note. From *Teaching Dance Skills* (Table 7.1, p 124), by M. Kimmerle & P. Côté-Laurence, 2003, New Jersey: J. Michael Ryan Publishing, Inc.

The current study explored (not always directly) some of the steps of this model, in particular 'acquiring a skill into memory', 'retrieving an image of a skill', 'constructing a motor plan', and 'creating memory sensory images of how a correct movement feels'. Although the above models relate most readily to online self-recognition, nevertheless, Kimmerle & Côté-Laurence (2003) provide the only dance-specific motor control and learning models in the literature and it was important to consider them in relationship to the current study.

Research in dance has found that imagining a movement or using imagery before a dance class can be beneficial (e.g. Overby, 1990) and affect neuromuscular patterns (Krasnow & Chatfield, 1996, p 169). In a similar way, the current study examined what happens cognitively when dancers watch dance, or a type of dance action, and investigated how dancers imagine, or predict (i.e. according to forward internal models), their own dancing. In particular, motor imagery and self-recognition have been found to share action-recognition mechanisms (Jeannerod, 2003, p 9-11) and thus, self-recognition research might later be applied to motor imagery theories related to dance.

Dance training with mirrors

Might dancers' experience training with a mirror influence self-recognition? Dancers often train in a mirrored studio and mirrors have been found to heighten self-attention in previous research (e.g Carver & Scheier, 1978). Of note, Loula et al. (2005; p 210-11) comment that, "Except when watching themselves in a mirror, humans have relatively little experience viewing their own bodies… How can observers exhibit superior sensitivity to a stimulus with which they have relatively little visual experience?" Hagendoorn (2004a) similarly suggests a link between self-recognition, mirrors, and dance. He proposes dancers are observers with great visual experience and implies dancers' might have greater familiarity with watching themselves dance, assumingly via the mirror and/or video, "…since apart from dancers, most people [do not] often see themselves moving" (p 88). Tsakiris et al. (2005) provide further support to the mirror's effect on self-recognition by using a mirror example to illustrate the interplay between efferent information related to the motor command and afferent (i.e. vision and proprioception) information related to the sensory feedback:

> Imagine that you are entering into a hall, where a mirror, large enough to reflect many people, is just in front of you. It is not easy to locate the reflection of your own-self among those of others. Most people would make a gesture and try to visually locate it in the reflection. In other words, they would produce a movement and compare it against the visual feedback in order to detect themselves (p 216).

This example was seen to resemble dancers entering a mirrored studio of a popular, and crowded, dance class.

In addition, previous research (e.g. Ramachandran & Blakeslee, 1998) has found that perception of a mirror image can alter perception of one's own body. For instance, participants have been found to attribute a mirror image to the proprioception of their body – they have felt a mirror image in the same way they felt an actual limb. Similarly, participants in certain experimental conditions have been found to attribute a rubber hand to themselves and incorrectly perceive, both visually and proprioceptively, a rubber hand being moved by an experimenter as if they were the agent of the movement (Botvinick & Cohen, 1998, as cited in Jeannerod, 2003, p 2).

In addition, 'normal' people have failed to recognize their own actions and "misattribute to themselves actions performed by another agent" in experimental situations (Jeannerod, p 11).

1.8 Summary

Dancers are a unique population to study self-recognition. The present study also aimed to inform dance-specific motor control and learning, dance teaching, expose an aspect of ballet expertise, and consider implications to training with or without the mirror. The current research built on the aforementioned studies and provided another small sample to the currently limited (Jola & Mast, 2005) knowledge regarding dancers' cognitive experiences. In addition, it was important to distinguish that the difference between 'dance as art' and 'dance as action'.

> Describing dance skills as 'motor skills' and placing them into categories obviously does not do justice to the artistic nuances of dance, nor does it represent the totality of a dance skill. It simply gives a neutral starting point to begin to examine skill learning (Kimmerle & Côté-Laurence, 2003, p 15).

The current study is similarly a 'starting point' for a number of fruitful and interesting examinations.

2. Aims and Hypothesis

2.1 Aims

The aims of the present study were:

1. Create point light stimuli with a group of advanced ballet dancers
2. Conduct a series of forced-choice tasks with the point light stimuli, with the same group of dancers, to gather data regarding visual discrimination and self-recognition, building on previous research (Loula et al., 2005). In particular, test whether dancers recognize themselves because of motor/proprioceptive information linked to the acting self.

2.2 Research Questions

The project was designed considering 3 primary research questions: Is proprioceptive/motor information important for self-recognition? Does expertise influence visual perception? If so, is visual or motor expertise more important?

2.3 Hypothesis

Since ballet dancers are trained to do complex movement in a very similar way, idiosyncrasy should be controlled between ballet dancers doing the same movement as point lights displays. Non-idiosyncratic movement should control the strength of visual surface form cues and isolate the dancers' motor signals (i.e. mirror neurons) for self-recognition. If ballet dancers are able to discriminate pairs involving 'self' better during a visual discrimination task, then ego-based information is used when distinguishing strictly visual stimuli (such as point-light displays). If dancers are shown to be better at a self-recognition task, than a visual discrimination task, than there is something above and beyond visual information used to recognize the self.

3. Method

The current project included 2 testing sessions. Session 1 required video recording of point lights of ballet dancers executing select ballet movement vocabulary. Session 2 involved testing dancers' self-recognition via a custom-designed computer program in which the dancers viewed videos and answered questions. The study protocol was approved by the Laban Ethics Committee.

3.1 Session 1

Participants

Participants were recruited via handout (Appendix A) distribution and in-person recruitment at various full time vocational dance schools in London, United Kingdom. The following criteria were used to restrict recruitment to 'expert ballet dancers': a) dancers must exhibit certain ballet proficiency, as observed by researchers, b) dancers must be adept in advanced/professional-level ballet class, c) dancers must have 5+ years advanced to professional ballet dance training. Generally, ballet experts were defined according to the literature, which stated that expert dancers are those who exhibit a "superior procedural knowledge base that allowed them to successfully perform highly complex dance sequences, and adapt to unplanned situations rapidly and efficiently" (Kimmerle & Côté-Laurence, 2003, p 125). This criterion was needed to be sure ballet movement was as similar as possible across participants since, hypothetically, advanced dancers are taught to meet a certain ideal in training. Participants were also matched so that size (Runeson & Frykholm, 1983) and gender (Kozlowski and Cutting, 1977) could not be used for visual discrimination. Recruitment occurred across different schools because of dancer availability. Dancers who met these criteria, and were interested in the project, were contacted by the researcher via email or telephone.

Eleven female dancers participated in Session 1 out of interest and for financial compensation. Participants had no medical conditions which may have prevented them from carrying out testing. The mean age of the dancers was 26 (± 7), with a mean of 17.3 (± 2) years ballet training. All participants were Checchetti and/or Royal Academy of Dance (RAD) ballet trained. All participants had normal or corrected-to-normal vision. Ten of the dancers were right-handed.

The dancers were given a general idea of the project via an information sheet (Appendix B). However, the dancers were kept naïve to the hypothesis so as not to confound results. All participants gave informed consent (Appendix C) and were made aware that they could discontinue the study at any time.

Apparatus

Participants were recorded with a Sony DCR-TRV38 miniDV camera at 25 frames per second. Each participant and movement was slated. In addition, the 'night vision' feature was used to enable reflection of the joint marker devices in darkness.

The cone-like area described through the camera lens was marked as the filming and performance space. A centre point was marked at 1.8 m from the wall behind the performance space. Another centre point was marked at 3.9 m from the same wall to designate the top edge of the camera capture space. The camera was placed 1.2 m from the edge of bleachers (behind the camera) and directly in line with the centre points. See Figure 2 for a plan-view of these measurements. The distance between the camera and dancers only slightly varied between marker A and the camera so that the absolute height and width of each actor could not be used as identification cues in the point-light displays (Loula et al., 2005, p 212).

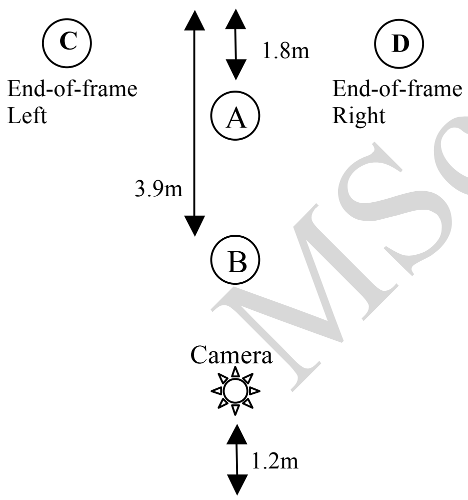

Figure 2. Plan-view of the filming set-up for Session 1.

Dancers were asked to consider centre point A similar to a centre point on a proscenium stage also to minimize identification cues and maintain consistency across dancers. The dancers were made aware of the cone-shape of the camera capture area for the same reasons. Dancers were informed that movements should be en face as much as possible, to enable optimum capture of the reflective devices worn.

Stimulus generation

Part 1: Choreography

It was agreed by the research team that around 20 movements would be performed to ensure a substantial variety of stimuli. Appendix D details all choreography and notes.

Movements followed some predetermined restrictions. For instance, each movement was to be around 3-5 minutes in length. This was because the videoed movements would be used for the forced-choice task (Session 2). Previous research found that subjects have relatively poor perceptual identity judgement of masked human locomotion when stimuli are displayed only briefly (Cutting et al., 1988 as cited in Thornton, Pinto, Shiffrar, 1998, p 544) and found that 4-5 second clips are sufficient for perceptual forced-choice tasks (Calvo-Merino et al., 2005; Loula et al., 2005). A mix of gender-specific and unisex choreography was also included. This enabled stimuli use for future research building on the results of the current project and previous research regarding gender recognition (e.g. Kozlowski and Cutting, 1977; Runeson & Frykholm, 1983) and visual, versus motor, experience of movement (e.g. Calvo-Merino et al., 2005). Variations in velocity/tempo were also required since previous research (Flach, Knoblich, Prinz, 2003) found velocity influenced self-recognition. There needed to be a mix of simple and complex choreography to test idiosyncrasy of dance and self-recognition as well (Loula et al.). Hence, movements were choreographed which were simple technically, for similarity/stereotyping across dancers, as well as complex technically, to exhibit 'expertise'. Finally, to aid in movement variety, choreography mimicked different sections of a standard ballet class. This primarily ensured variety, i.e. static or travelling movements, as has been done with gait in previous research, i.e. either walking in-place on a treadmill (e.g. Jacobs & Shiffrar, 2005) or across the camera space (e.g. Kozlowski and Cutting).

Choreography was informed by a few key sources. The researcher's 15 years of ballet training, which included experience with a wide range of basic ballet vocabulary, informed the movements chosen. Ballet texts, such as *Classical Ballet* (Warren, 1989), were consulted to ensure that variety was obtained across all movements and for checking gender differences between movements. Ballet classes were observed at Laban, Danceworks, and Pineapple, in London, UK, for the same reasons. Since the researcher was trained primarily as a contemporary dancer, all choreography was also verified for accuracy, to ensure accepted ballet standards were met, by an expert – a ballet dancer with extensive classical ballet training and performance – who was naïve to the hypothesis study and design.

Movement speed and participant velocity was controlled with a Martix MR-800 (Quartz, Korea) metronome and a tempo was set for each movement. See Appendix D for timing specifications for all movements. The movements were both taught and performed with the metronome at its specified tempo to allow dance familiarity with the tempo before filming. Use of the same tempo for each movement ensured movements were performed at the same velocity across all participants (Flach et al., 2003). Music was considered as an alternative, but was not used because of its potential complication of dancers' idiosyncratic performance, particularly considering previous research regarding music and its influence on physical activity (e.g. Tenenbaum et al., 2004).

Stimulus generation
Part 2: Filming

A modified version of Johansson's (1973) classic point light technique was used for this study. Participants wore dark form-fitting clothing, such as dark leotard and tights, or unitard. Once in the appropriate attire, the dancers were fitted with 13 reflective markers on major joints and head (Loula et al., 2005). Wearable cyclist reflectors were modified to fit specified body parts.

The 1st session took place in dance studios which could provide a dark space at all times of the day. Although the space was made as dark as possible during filming, there was sufficient light for the participants and researchers to see general outlines and shadows of objects and persons within the space. A small flashlight was used by the researchers to read notes, set the metronome, etc.

The markers were secured to the participant with Velcro, tape, and/or safety pins, with the exception of the shoulder and hip markers which were pinned to a mesh/nylon black top and worn by the participant over her clothing, and the head marker which was attached to a lycra head band and worn across the participant's forehead. Some participants wore dark form-fitting clothing (e.g. black cotton/lycra cardigan), supplied by the researchers, if they did not want reflectors pinned to their own clothing.

Procedure
Each dancer was individually filmed during a 90-minute session as a point-light actor doing select ballet vocabulary. A total of 11 sessions were conducted over 3 days.

Each dancer was asked to warm-up while waiting for her session in the corridor or after she was fitted with the reflective markers. She was asked to warm-up as she would for centre work in a ballet class, particularly because the first filmed movements mimicked a ballet class in centre.

Once the dancer was fitted with the reflective devices properly, she was given time to become familiar with wearing and dancing with them on. Once comfortable, the participant proceeded to the filming space and the room was made dark. She was given time to become familiar with moving in low-light as well.

All participants were taught and given a chance to 'mark' each movement immediately before filming. This allowed movements to be as fresh and accurate as possible when videoed. Movements were taught by the same researcher and all the participants were given similar verbal cues for each movement to ensure that visual and verbal representations were similar across all participants (Thomas, Nelson, & Silverman, 2005, p 13, 68-69).

All participants were recorded performing 21 different movements (see Appendix D). Each movement was done for a minimum of 4 repetitions, which resulted in a minimum of 84 movements recorded for each dancer. However, some movements were repeated by participants if they were not performed accurately (e.g. falling off balance during a developpé).

3.2 Session 2

Participants

Eight to 9 weeks after filming all participants from Session 1 were invited to participate in Session 2. The delay minimized the likelihood that participants would remember the specific movements that they had performed during the filming (e.g. Loula et al., 2005). Session 2 consisted of a forced-choice task in which participants attempted to identify whether point-light movies were the same or different (Task 1) and whether point-light dancers were themselves or 'other' (i.e. another dancer; Task 2). Eight dancers participated in Session 2.

The participating dancers were told they would be watching videos and answering questions for this session (also on Information sheet, Appendix B) and were naïve to the hypothesis of the testing.

Apparatus

The stimuli were displayed on a Dell Latitude X300 laptop with a 15-in. red-green-blue color palette monitor set at a 1024x768 pixel resolution. Participant responses were obtained by computer keyboard.

Stimulus generation

Part 1: Movement selection

Movie clips were scrutinised and chosen according to certain pre-determined specifications; primarily, movements which distinguished gender (Kozlowski and Cutting, 1977), velocity (Flach et al., 2003), and variation in kinematics (Jacobs & Shiffrar, 2005; Loula et al., 2005). Table 2 outlines movements chosen and qualities used for determination. In addition, these factors were also chosen in consideration of future testing to build on recent research (Calvo-Merino et al., 2005).

Table 2. Breakdown of choreography chosen for Task 2.

GENDER				COMMON			
Slow		fast		Slow		fast	
Static	Travel	Static	Travel	Static	Travel	Static	Travel
5 Reverence into attitude	18 Entrelacé	6 American relevé combo	14 Glissade jeté combo	7 Battement Centre	10 Balancé sequence	4 Fan kick	16 Sissone combo

The point light movies from the 1st session were used for viewing and answering questions during the 2nd session. All videos were edited following the same multiple-step procedure for appropriate input into the computer program and for visual continuity across all videos. Each movement was edited and captured with Windows Movie Maker software as an .avi file. This file was then imported into Adobe Premiere Pro software and edited to be more precise, such as adjust the brightness and contrast where necessary and compress file size. Maintaining continuity for each clip ensured visual similarity as much as possible. Each movement and each version of the movement for each subject was saved as its own 4-second video file.

The files were also processed in Adobe After Effects software to enhance point-light quality. Brightness & Contrast and Gaussian blur settings were altered for each clip according to the researcher's visual estimation. Brightness & Contrast alteration brought down the background lighting and therefore any visual surface cues of the dancer's body, emphasized the black and white contrast of the clip, and enhanced the brightness of the point lights. Altering the Gaussian blur setting made each point light appear as the same size and eliminate occasional flickering which occurred with maximal contrast. Usually the same settings were applied to each clip, with only a few exceptions because of observed differences.

Stimulus generation
Part 2: Program set up

The videos were placed into a MatLab computer program (MathWorks, Natick, Massachusetts, USA) according to a 2 task design as outlined below. A total of 528 trials, each consisting of one 4-second movie of a point-light dancer performing 1 of the 21 movements possible, were shown. As stated, the use of 4-second video was based on previous research which found poor perception with only brief stimuli of human locomotion (Cutting et al., 1988 as cited in Thornton et al., 1998, p 544) and sufficient perception with 4 & 5 second stimuli in forced choice task experiments (Calvo-Merino et al., 2005; Loula et al., 2005). The 5-second videos used for previous studies (Loula et al.) was considered too long for participant memory for the forced choice question – 5 seconds for each movie would mean a total of 10 seconds before the forced choice question and, because of this length of time between the 2 movies, the participants might remember less of the 1st movie to compare it properly. Previous research (Calvo-Merino et al.) established that 4-seconds of video were sufficient for movement recognition.

Dancers were organized into groups of 3 for program setup and participants were also naïve to this design. Thus, each dancer viewed equal amounts of 2 different 'other' dancers. This allowed for greater analysis of the data. For instance, a dancer may be better at recognizing 'other dancer 1' but not 'other dancer 2' and this may suggest something about point-light display quality, self-recognition, and/or study design. Repeated trials also allowed the same amount of visual experience for each dancer in the group.

Task 1 – Visual discrimination task

The visual discrimination task was done to determine the extent to which the point-light displays were visually similar to the dancers. Self-recognition was implicit in this task. Participants were asked to discriminate whether 2 movies were the same or not. Therefore, trials shown were Self/Self, Self/Other, Other/Other. Videos displayed followed a general organization as shown in table 3. Diagram 3 is a schematic representation of the task, although the stimuli were moving point light clips and not still images as shown.

Table 3. Summary of the stimuli organization used for the visual discrimination task.

Movies/Stimuli		**Question**	**Movies shown (examples)**
Self	Self	Same or Different movie?	Sub01Move1v1 - Sub01Movie1v1 = same Sub01Move1v1 - Sub01Move2v2 = different
Self	Other	Same or Different movie?	Sub01Move3v1 – Sub01Move3v2 = different Sub01Move3v1 – Sub02Move3v1 = different
Other	Other	Same or Different movie?	Sub02Move4v1 – Sub02Move4v1 = same Sub03Move4v1 – Sub03Move4v1 = same Sub02Move6v1 – Sub03Move6v1 = different

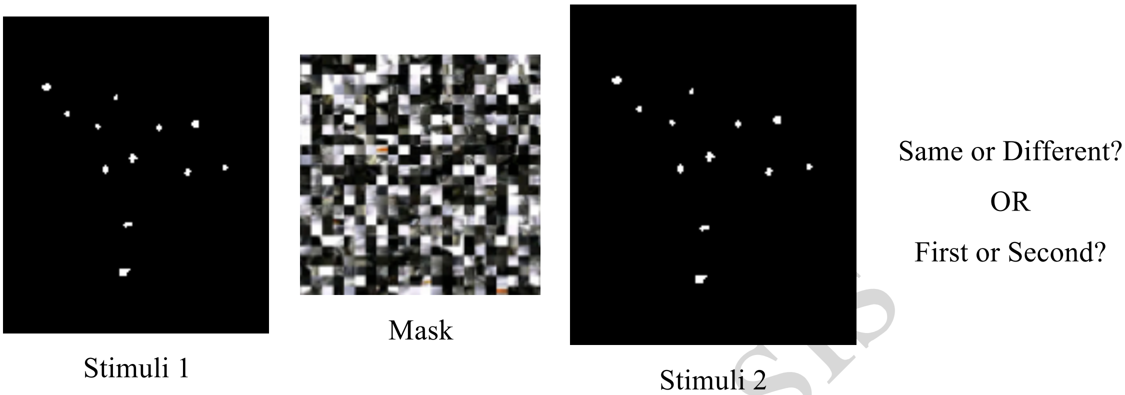

Diagram 3. Schematic diagram of Session 2. After the 2 stimuli and mask were shown, participants were asked either ‘Same or Different movie?’ or ‘First or Second’, depending on task.

After 2 video clips were shown, one key was pressed if they were the same and another key if they were different. There were 96 trials for the Self-Self condition, with ½ of the movies being the same and ½ being different. There were 96 trials for the Self-Other condition, with all of the movies being different. There were 144 trials for the Other-Other condition, with 2/3 being the same and 1/3 being different. For the visual discrimination task, dancers viewed a total of 336 trials (excluding faults). Trial order was randomized across actions and participants.

Although the Self-Other movie comparison created an unbalanced design – meaning movies shown were *always* different – this part of the task was included because of the probability of correctly detecting a difference in 3 conditions (e.g. 90% of Self-Self ‘different’ pairs might be answered correct as ‘different’, 80% of Self-Other ‘different’ pairs might be answered correct as ‘different’, and 80% of Other-Other ‘different’ pairs might be answered correct as ‘different’) and responses would still indicate whether participants correctly detected the differences or not.

Task 2 – Self-recognition

The self-recognition task was done to investigate explicit self-recognition and determine whether participants could identify themselves better than chance.

Similar to Task 1, after 2 video clips were shown, one key was pressed if the dancer thought the first movie was 'self' and another if they thought the second movie was 'self'. Each set of stimuli had a balanced design. There were 192 trials with ½ of the trials with the participant in the first movie, and ½ with the participant in the second movie. Trial order was randomized across actions and participants.

Procedure

The 2nd stage of testing took place at a later date. Individual times were scheduled with each dancer.

The participants were directed to a small private testing room. The room provided a quiet testing space and prevented any disturbances to the participant during testing. The participants were told that the point light movies filmed in the previous session would be viewed for this 2nd session. They were told they would be shown movies on the computer and asked to answer questions about the movies they viewed.

Each participant completed a practice trial before beginning the experiment trials. The practice trials permitted the dancers to become familiar with the computer and the task. Different movies were used in the practice and experimental trials.

For the 1st task, the participants were told they would be watching 2 four second video clips of the same movement and then be asked on-screen if the movie was same or different. They were told to select the appropriate key for an answer (e.g. the Z-key on the left side was 'same' and the M-key on the right side was 'different'). Participants were told not to deliberate on an answer for too long and to choose their most immediate reaction. They were also told to just focus on the next movie if they missed one of them. The same researcher delivered the instructions to ensure verbal information was similar across all participants

For the self-recognition task 2, the dancers were told they would again see 2 movies, but this time would be asked to determine which movie was them dancing as point lights. They were told that only one of the movies would be them and if they had difficulty distinguishing which one was them (e.g. the movies were too similar to decide), they were asked to choose to their best ability. The dancers were told that after 2 movies were shown that they would be asked on the computer screen 'first or second?' and to choose with the key on their left if they thought they were in the 1st movie and the key on the right if they thought they were in the 2nd movie.

The 2 tasks were presented as follows:

Task 1 – 6 blocks of 56 movie sets

Task 2 – 4 blocks of 48 movie sets

In particular, this set-up allowed the participants a break between each block to account for attention span (Thomas et al., 2005, p 289), and to end testing if desired, according to ethical consideration of human participants (Thomas et al., p 88). After each block, the researcher also entered a code to start the next block. This was done about every 7-10 minutes, depending on block length.

After completing the video part of the session, participants completed a specially-designed questionnaire (Appendix E). This questionnaire helped gather information regarding training history and ballet experience. It also asked about their familiarity with the movements performed and viewed. For some of the questions, participants were asked to answer by putting a line on a spectrum. Qualitative questions regarding experience training with a mirror were also asked to consider other dance-specific implications to study results, such as: how much of their training occurred in a mirrored studio, if they rely on the mirror in dance training and/or rehearsal, or if they think the mirror has helped them know what they look like dancing.

No feedback was provided during or after the practice or experimental trials. The entire testing session 2 (video experiment plus questionnaire) lasted around 90 minutes. The dancers were compensated £20 for their participation, which included an extra £5 for their time beyond the original 120 minutes proposed for both sessions.

4. Results

4.1 Task 1: Visual Discrimination

Performance accuracy was calculated for each participant for Task 1: Visual Discrimination. Chance performance for this task was set at 50% correct discrimination (i.e. > chance = 75%). Performance clearly exceeded chance for all conditions. Performance was best for the Self-Self condition (83.6%), followed by Other-Other (79.8%) and Self-Other (70.6%) conditions. A paired t-test revealed no significant difference between conditions, Other-Other and Self-Other, $t(7) = 1.648$, $p>0.14$, Self-Other and Self-Self, $t(7) = -1.466$, $p>0.186$, Other-Other and Self-Self, $t(7) = -.957$, $p>0.37$. Figure 3 summarizes these results.

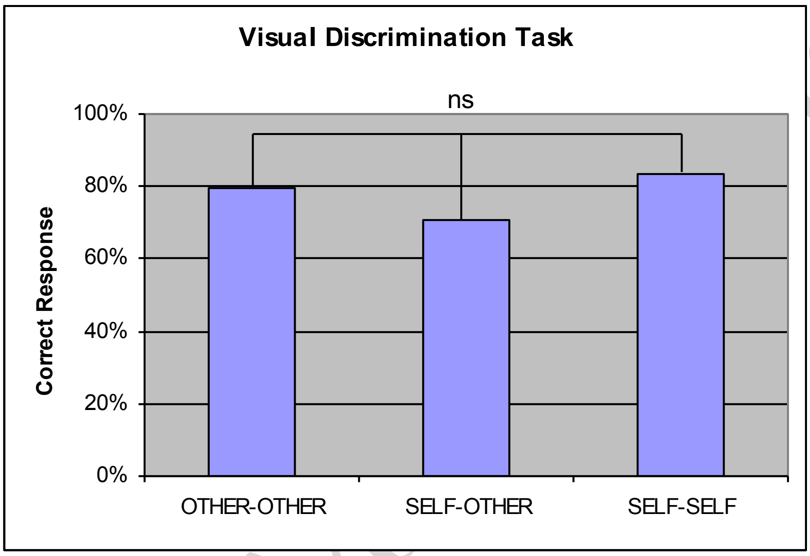

Figure 3. Average accuracy rates for all participants for Task 1: Visual Discrimination.

A breakdown of the Visual Discrimination results helped identify performance by sub-conditions. Performance was shown to be best for Other1-Other1 (85%) Other2-Other2 (83%), and Self-Self (84%). Performance was lower, but not significantly, for Other1-Other2 (72%), Self-Other1 (71%), and Self-Other2 (70%; Figure 4).

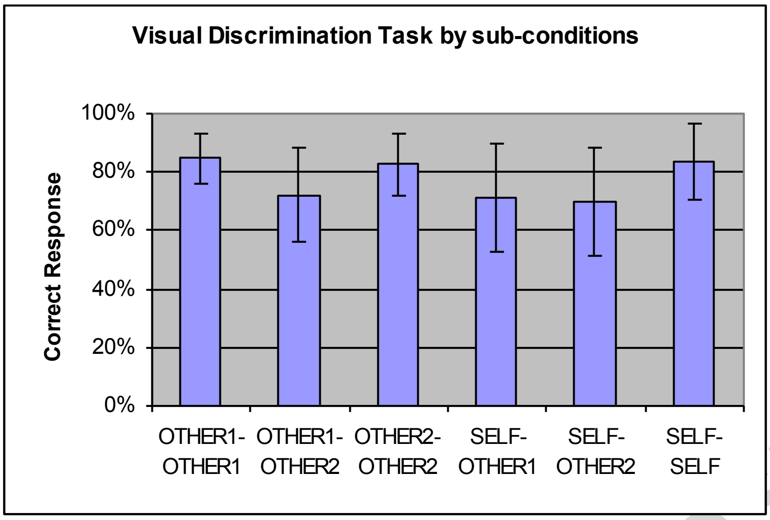

Figure 4. Average accuracy rates by sub-conditions for Task 1: Visual Discrimination for all participants. Bars indicate standard deviations.

4.2 Task 2: Self-recognition

Performance accuracy was calculated for each participant for Task 2: Self-recognition. The Self-Other conditions were repeated from Task 1, except that the dancers were asked to identify 1 of the videos as self since there was always a 'self' in the video pair. Chance performance for this task was also set at 50%. Accuracy was measured by the number of times they correctly identified 'self'. Participants clearly exceeded chance (75.4%) across all self-recognition trials. Participants incorrectly identified the 'other' dancer as 'self' below chance levels (24.6%). Figure 5 summarizes these results.

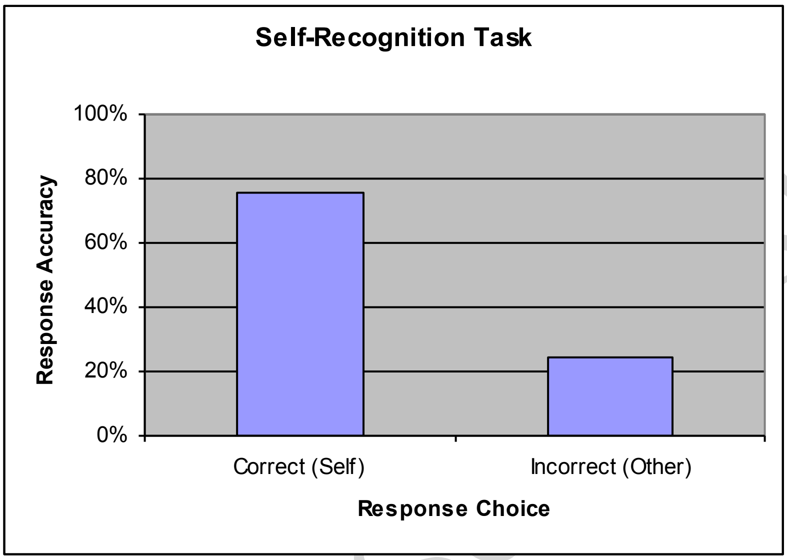

Figure 5. Average accuracy rates for all participants for Task 2: Self-recognition. Correct (Self) represents when the dancers correctly identified the 'self' clips. Incorrect (Other) represents when the dancers incorrectly attributed an 'other' dancer as self.

To evaluate the difference in performance for Task 1 and Task 2 for the identical Self-Other pairs, results for these conditions were compared. Performance for Self-Other Task 1: Visual Discrimination (70.6%) and Self-Other Task 2: Self-recognition (75.5%) was similar. A paired t-test revealed no significant difference between these conditions, t(7) = -0.770, p>0.46. Figure 6 illustrates these results.

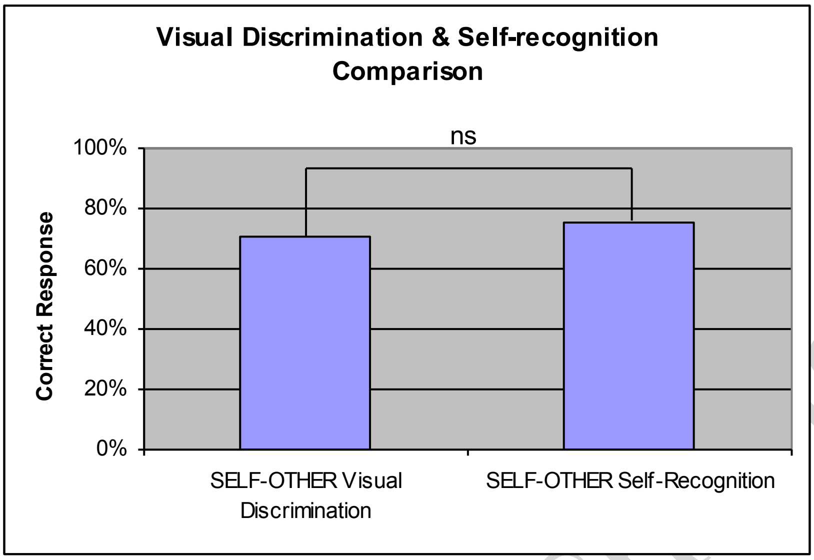

Figure 6. Comparison of the average accuracy rates of the Self-Other conditions for Visual Discrimination and Self-recognition.

4.3 Errors

The Self-Self task could not be compared directly with the Other-Other tasks because of stimuli differences among groups. More specifically, the conditions that showed 2 movies of the same dancer were found to have slightly different movie comparisons after all participants were tested. Meaning, the Self-Self had *same* trials which compared same dancer, same movie, same version, and also had *different* trials which compared the same dancer, same move, *different version*. Whereas the Other1-Other1 and Other2-Other2 conditions compared only *same* trials of same dancer, same movie, same version and the different trials were put into a separate Other1-Other2 condition which compared *different dancer*, same move, same version. In other words, even though the same movements were shown for all these conditions, the difference between 2 *different dancers* doing the same moves (Other1-Other2) could not be compared to the difference between the same dancer in *different versions* (Self-Self) of the same moves. Therefore, to compare the data accurately, the *different* trials in the Self-Self condition were removed from analysis.

4.4 Faults

For the first 4 participants the markers were secured on the body and/or clothing with duct tape and/or Velcro. However, the markers often fell off or became loose because the tape became damp from perspiration or was moved frequently during large body movements. Unfortunately, the first 4 dancers were all on the same day and the procedure could not be changed. This slight movement of the markers may have affected the point-light quality, i.e. revealed cues about the identity of the dancer, and therefore the results. Fortunately, for the remaining participants the markers were attached with safety pins and well secured. This method may have contributed to better quality of the point-light displays for the remaining dancers.

During the 2nd session, one of the movements, 'Move 14', did not play for participants 4, 5, and 7 because part of the code name was incorrect ('gft' was 'gfs'). Therefore, all trials with 'Move 14' for these participants were deleted to allow more precise representation of accuracy rates. In addition, sometimes participants did not press a key, possibly because they did not make a choice before the program automatically proceeded to the next movie set. When no key was pressed, the computer recorded '0' for that set. Before analysis, any trial that had a '0' for a key press was deleted to allow for more accurate calculation.

5. Discussion

The current study aimed to investigate self-recognition with a group of expert ballet dancers. To do so, researchers tested dancers' visual discrimination and self-recognition of point light stimuli during forced choice tasks. These tests were then compared to investigate visual and/or motor system contribution to self-recognition.

5.1 Idiosyncrasy

Results show that idiosyncrasy was successfully controlled between participants. Participants in previous research (Loula et al., 2005) looked at 2 different actions of highly idiosyncratic movement – free dancing – which greatly contributed to good performance for discriminating movies of self, but below chance for distinguishing movies of strangers. In contrast, the present study found observers to be above chance with *both* 'self' and 'other' pair conditions, which showed idiosyncrasy was controlled. If idiosyncrasy were not controlled, the conditions including 'self' would have been much higher than the 'other' conditions, since all dancers were compared to strangers with whom they had no visual experience (i.e. dancing with them in a dance class or in a club) and theoretically dancers would have had more visual and motor experience with their own movement. In addition, if movements were highly idiosyncratic, dancers would have been much better at identifying different person pairs (Other1-Other2 & Self-Other), since 2 different dancers would have the greatest amount of idiosyncrasy between each other and therefore be easier to distinguish. Instead, dancers had improved accuracy rates when the dancers were the same (Other1-Other1, Other2-Other2, & Self-Self). Therefore, high accuracy rates in the present study could not be mistaken for simply being good at distinguishing idiosyncrasy between dancers.

5.2 Self-recognition

The self-recognition results suggest that this group of dancers could still recognize the self even when movements were stereotyped across participants. In particular, dancers were found to be better than chance (75.4%) at recognizing their own movements when one of the movements was 'self' and one was 'other' (i.e. another ballet dancer of similar expertise). This related to recent research (e.g. Daprati, Wriessnegger, & Lacquaniti, in press) which also found observers to be above chance at distinguishing hand movements among 2 sets of movies of 'self' or 'other'. Yet, the self-recognition data alone does not show the degree to which visual and/or motor inputs may or may not contribute to these results. Simply because the dancers were good at recognizing themselves among 2 sets of movies, does not necessarily indicate their motor system played a greater role, as Loula et al. (2005) suggest.

5.3 Visual Discrimination and Self-recognition comparison

Comparing accuracy for the visual discrimination and self-recognition tasks (70.6% and 75.5% respectively) indicates that the participants did not require any additional information for the visual discrimination task than for the self-recognition task. This suggests that nothing above visual information informed self-recognition. Therefore, it can be interpreted from these results that information used for self-recognition, engaged by purely visual tasks, does not automatically evoke private information. In other words, this group of ballet dancers did not need information about the self (i.e. motor/proprioceptive information that only the self is privy to) to perceive and categorize movements accurately to self. Hence, there must be other reasons for accurate self-recognition among this group of dancers. This result contradicts Loula et al. (2005) claim that motor/proprioceptive information is used for self-recognition.

Although the differences were not significant, the trend supports the use of a 'Who' system (e.g. Jeannerod 2003; Vignemont & Fourneret, 2004). The results did not indicate that when watching pairs that involved 'self' there was some special private way of seeing the self. Instead, the results suggest that the 'self' may not have been needed for accurate visual self-recognition.

5.4 Control Group pilot

The results suggest dancers had some sort of visual expertise, which they used to complete the tasks. Indeed, ballet dancers may develop a visual expertise from a number of peripheral aspects of training. For instance, from the emphasis on mimicking an observed teacher, watching dance performances, watching peers regularly in classes, training with a mirror, etc. In an effort to understand whether visual expertise contributed to the dancers' accuracy rates, a few preliminary controls (n=3) were tested to see if any differences might exist. Because of the group size, this data is considered qualitative and only hints at differences to be pursued in future experiments.

The procedure used with the dancers was replicated for the controls. All controls were matched to a specific dancer (i.e. Sub01 -> Control01), so all the videos shown to Sub01 for the task were shown to Control01 and could be compared to make sure there was not some extreme visual information causing both subject and control to respond in a certain way. However, the self-recognition task could not be done because the controls did not make point-light displays. It should also be noted that for the control group any 'self' categories were really 'other' categories. An abbreviated questionnaire, mainly with task execution questions (e.g. 'How did you complete the task?') was also completed by the control group.

Dancer visual expertise?

Hypothetically, controls should be less accurate at the visual discrimination task than the dancers, since the controls would not have the same visual 'training' as the dancers. Again, statistical analysis was not yet appropriate for this comparison because the control group consisted of only 3 persons.

Dancers were found to have greater accuracy in the same person conditions, Other1-Other1, Other2-Other2, and Self-Self, which suggested that the dancers had greater visual expertise than controls because 2 movies of the same dancer would be most difficult to distinguish. The controls performed better when the persons were different suggesting that controls required more visual information to make an accurate discrimination (see Figure 7).

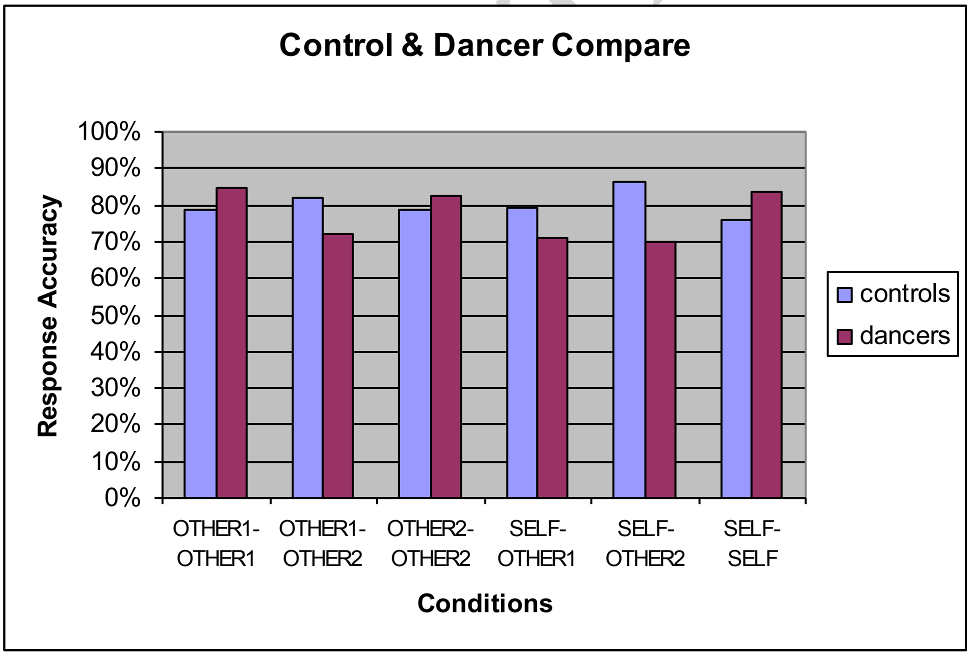

Figure 7. Comparison of average accuracy rates for the control group (n=3) and dancer group (n=8) for sub-conditions of the Visual Discrimination task.

This comparison also gives further evidence against a private motor system because dancers were worse than controls for most of the conditions involving 'self', excluding the Self-Self condition.

5.5 'Mirror neurons'

If the current results suggest a visual expertise, what about theories regarding the mirror system (Gallese et al., 1996) and its activation during movement observation ('motor way of seeing')? At this point, 3 possible preliminary conclusions regarding the role of motor/proprioceptive information in this self-recognition task are suggested. These are, when watching the ballet movement as point light displays: 1) Dancers' visual system does not produce a motor representation (i.e. "no mirror system"). Previous research (Calvo-Merino et al., 2005; Gallese et al.; Rizzolatti et al., 1996) makes this conclusion unlikely, however; 2) Dancers' visual system does generally produce a motor representation, but it is not used (or engaged) for the visual discrimination tasks like the one used in this study, i.e. offline visual analysis of point lights; 3) Dancers' visual system activates a motor representation, but these motor representations are identical when the visual stimuli closely match one's own unique motor representation (i.e. 'stereotyped' ballet movement), and therefore there could be no difference to dancers' performance in the tasks in this study; or, no way of determining a difference with the current method used. However, additional experiments need to be carried out to substantiate or rule out these preliminary conclusions.

5.6 Dance-specific implications

Several dance-specific implications can be drawn from these results and may be particularly applicable to dancers and dance teachers. For instance, the lack of idiosyncrasy between ballet movements is interesting for its implications for ballet training. In some ways, it suggests that ballet dance training was successful, with this group of ballet dancers, in teaching them to do certain complex movements in a very similar way. This appears to be the 1st experimental study to support this aesthetic aspect of ballet.

Advanced ballet dancer group

Likewise, the results challenged that any difference between training styles existed among the dancers. Originally the researchers tried to obtain participants from the same ballet school because it was thought dancers with the exact same training would be the most stereotyped in their movement, particularly considering style variances attributed to different ballet methods (e.g. Checcetti versus Balanchine). Results suggest that 'advanced ballet technique' status may be enough for stereotyping across ballet dancers when reduced to point light displays. It is important to note that the dancers claimed they were either Checcetti and/or RAD trained on the questionnaires, so there was some consistency across participants. However, the results suggest, at least with low-level point-light recognition, different schools and ballet styles can not be differentiated at the advanced technique level.

These results also suggest that, once at a certain level of training, the advanced ballet dancer is part of a larger group kinematically. Meaning, if advanced dancers tend to produce the same trajectories during certain movements, then this 'advanced trajectory' may be quantified and set as a standard to measure what advanced ballet dancers can do. This hints that ballet technique might be quantified in the same way Olympic athletes (e.g. gymnasts) are. However, it is important to reiterate Kimmerle & Côté-Laurence's (2003, p 15) point, that placing dance skills into categories does not do justice to the artistic nuances of dance or represent the totality of dance skills. In particular, the author does not wish to suggest all of the art of ballet is quantifiable, but only that to a certain degree ballet technique, as it relates to joint positions and velocity, may be.

Seeing minute kinematic differences

The present findings give some empirical support to the claim that "experts have learned to recognize key features in a movement and to ignore unimportant features. In other words, they are able to selectively attend to meaningful visual information" (Kimmerle & Côté-Laurence, 2003, p 130). Since this group of expert ballet dancers performed above chance for the visual discrimination task, particularly with same dancer pairs, this supported that the ballet dancers were good at quickly detecting small differences with little visual cues and attending to the visual information that was most meaningful and necessary to recognize similarities or differences. In some ways, this suggests a ballet teaching expertise because of a need in technique teaching to recognize subtle kinematic differences. This may be particularly needed when teaching advanced ballet dancers who look very similar as a group or class.

Ballet dancer ideal

Another interpretation of the results might be in support of an 'ideal' in the dancers' mind's eye. Novack (1993) describes this ideal in ballet as always present, "For the children who study ballet, an orientation to the technical content of the ballet performance has been inculcated…" and "As a child watching the prima ballerina on stage, her evocative power for me resided only minimally in the role she played…The ballerina …had achieved technical perfection" (p 36-37). Or, as Foster (1997) puts it,

> the dancer's ideal body…combines with fantasized visual or kinesthetic images of a body, images of other dancers' bodies, and cinematic or video images of dancing bodies. The dancer's ideal body may specify size, shape, and proportion of its parts as well as expertise at executing specific movements (p 237).

A similar ideal may have been used as a template that the dancers in the present study referenced to perform the point light tasks. Dancers might have been viewing and using a comparison with a template ideal ('good technique') to identify one dancer from another during the visual discrimination task. In a similar way, this template might be used to judge the movement (e.g. height of leg/flexibility) in order to identify which point light video showed her or not in the self-recognition task. In support of this, one of the dancers after testing said, "For some of the pairs I knew the answer right away because the one dancers' leg went up really high and I don't have that kind-of flexibility," subtly expressing disappointment in this difference. In addition, a few dancers replied to the question 'What were you doing when you were looking at the video clips' on the questionnaire with, "Thinking of the movement, if it was correct" and "Looking at the body lines created when moving and comparing them".

It could not be concluded at this stage of testing whether visual and/or motor mechanisms (or both) contributed to some sort of ballet template. Theoretically though, the ballet dancers' ideal would have been primarily informed visually because they could have often *watched* the ideal ballet dancer, but could have never *proprioceptively felt* what the observed ideal dancer felt (as this was the ideal dancer's private motor/proprioceptive information). Therefore, an intriguing mystery remains regarding how dancers adapt and/or develop a motor/proprioceptive system to fit a ballet ideal. In fact, in what direction might the process occur? Does the visual 'ideal' help the motor skill develop, or does the motor skill alter the visual 'ideal'? Or, are these actions simultaneous and inseparable, if indeed this type of 'template matching' occurs at all?

The current studies' empirical support of an 'ideal' dancer template and controlled idiosyncrasy across dancers was complicated by comparing it with concepts in dance theory. One prominent concept is the idea of the 'hired body' by Foster (1997) in which certain training styles are accused of creating and forming the body as if it were merely a product to be bought and sold. "The hired body, built at a great distance from the self, reduces it to a pragmatic merchant of movement proffering whatever look appeals at the moment" (p 256). The current studies' results, particularly the lack of idiosyncrasy between dancers, in some way support that ballet has sculpted dancers into a facilitator of skills and not self. "The dancer's self exists to facilitate the craftlike acquisition of skills: it serves the choreographer and, ultimately, the tradition by ordering the body to practice and then to perform ideals of movement" (p 243). Vézina (1998) also supports this point of view regarding ballet training, claiming ballet has evolved into a methodical system of steps and rules which aims to tame the body (p 13). Vézina goes as far to say that ballet training is militaristic.

> In ballet training the emphasis on producing a homogeneous population has made it an art form that is madly obsessive with regard to objective learning. The all encompassing focus of dance training at the professional level is such that it inducts the student into a unilateral lifestyle based on similar principles as the military (p 52).

However, these critiques of the training and aesthetic traditions of ballet were not a part of the current studies' investigation or aims. The relationship is mentioned as an unexpected crossover between dance theory and experimental research. Further analysis is needed to link empirical results with theoretical ideas such as these.

Mirror use in dance

The mirror has similarly been found to relate to an 'ideal' in body image research (Ehrenberg, 2005; Vézina, 1998). Meaning, people often compare the image in the mirror with an ideal. The same could be said for dancers using the mirror – the dancers compare their mirror image with an ideal to match their viewed result in the mirror to the 'correct' image they want to attain. Fundamentally, that is why dancers use the mirror – to be sure they are doing the movement right and matching a visual representation of what is wanted. Although it is only speculation at this point, training with a mirror may also nurture a comparison with an ideal that the dancers then used for tasks in the current research. Put in another way, training with the mirror may nurture the dancer to rely on visual information to discriminate 'self' from 'other', rather than motor/proprioceptive information. In support of extensive mirror training, on the questionnaire the dancers claimed that "almost all" of their training occurred in a mirrored studio. According to dancers' estimation of how many years they think they have danced in front of a mirrored studio, the average was found to be 17 (±3) years of the average 17 (±2) years ballet training. However, since other studies (e.g. Beardsworth and Buckner, 1981; Johansson, 1973; Loula et al., 2005) have found non-dancers to also be good at self-recognition, it is difficult to say at this time if the mirror interpretation influenced self-recognition.

In addition, when asked if they *rely* on the mirror, since mirror presence does not necessarily indicate mirror use, the dancers' said they do not use the mirror all of the time. However, how a reliance on the mirror might have been spread across the dancers' career could not be determined, i.e. they might have relied heavily on the mirror when younger and less now that they are older and more experienced, or maybe the dancers only use the mirror to correct details, such as alignment, and not when they are dancing 'full-out'. In support of this latter suggestion, when asked 'how do you use the mirror now?' several dancers answered, “"I use it mostly to correct myself and use expression, whereas before I just used to stare”, "I look at it but only when the movement allows it”, and "I look [in the mirror] now to improve my technique”.

For the question 'do you think the mirror has helped you know what you look like dancing?' almost all of the dancers replied 'yes'. Yet, the dancers also commented that they use the mirror to “correct alignment” or because “sometimes you think you're doing one [movement] correctly and look at the mirror and see that it's not [correct]". Also, the 1 dancer who replied 'no' to this question said, “When you look on video it looks totally different to the mirror”. These comments were similar to findings in previous research with contemporary dancers (Ehrenberg, 2005). The complexity of the issue is that although almost all of the dancers thought the mirror helped them know what they look like dancing, mirror use was primarily used for checking and/or correcting movement. Thus, the movement they felt was sometimes not matched to the mirror image (therefore, they were not accurately knowing what they looked like) and then they corrected movement to a technical ideal of which they aspired. This raises the question: which is the image they use to know what they look like dancing? The 'incorrect' (pre-mirror) or 'correct' (post-mirror) one, both, or neither? Theoretically, if the dancers really know what they look like dancing, then the mirror image should always match what they think they look like before they look in the mirror, *or* what they think the movement they feel should look like. Or, could this expressed mismatch between feel and look further suggest that what the dancers feel, when dancing, does not necessarily contribute to knowing what they look like? Or, do dancers only know what they look like dancing *some* of the time? To complicate things further, the mirror presents a 2-dimensional illusion. Does it then follow that dancers using the mirror adapt an illusion to their concept of what they look like dancing? Further, specific, research regarding mirror use is needed to address these questions substantially.

Motor control model

The results and implications drawn from the current study support and yet also question the application of Kimmerle & Côté-Laurence's (Table 1; 2003, p 123) advanced dancer motor skill learning model to offline self-recognition. On the one hand, the present study's results empirically support that advanced dancers have keen visual perceptual abilities and can detect relevant visual cues and ignore irrelevant ones (Attempt stage). Although it is speculation at this point, the results may also support a few other steps: “The experienced dancer has acquired a large number of dance images in long-term memory”, “Can retrieve the proper mental image of the skill from long-term memory and bring it to short-term memory", and "The experienced dancer has stored in long-term memory sensory images of how the correct movement 'feels'". However, the current results, particularly combined with the qualitative mirror data, challenge whether the advanced dancer "can monitor his own performance by attending to internal feedback provided by the movement itself; does not rely on external feedback from the instructor" (Kimmerle & Côté-Laurence's, p 123), particularly because the dancers claimed to use the mirror, even at the advanced stage, for correcting movement. Thus, even advanced ballet dancers may not rely on internal feedback as much as previously assumed; although logically the advanced dancer would rely much *less* on external feedback because of the higher demands (than novice dancers) to perform on stage, in which little to no external feedback is available. Further research is needed to draw conclusions to these interpretations as well.

Control comparison

The comparison with the control group also brought into question what differences exist between ballet dancers and other (dance and non-dance) populations, at least regarding visual recognition. For instance, are ballet dancers better at distinguishing subtle differences between the same movement by the same dancer because of years of correcting subtle differences with their own reflection in the mirror? Does ballet training give dancers some sort of 'visual advantage' to watching ballet dance action? If so, what are the benefits of having a particular 'way of seeing'? Aesthetic preference with ballet movement has recently received attention from neuroscience (Calvo-Merino, Jola, Glaser, Haggard, in press), so further enquiry may help explain visual preferences of ballet dance movement. It may even help us understand why choreography by artists such as Jiri Kylian and William Forsythe have received so much attention and success in recent years – maybe these choreographers have successfully stimulated a particular way of seeing by working in-between the lines that ballet bodies typically create, challenging audience's visual expectations? In other words, this control data comparison, in combination with research on the aesthetics of dance, may somehow relate to differences in viewing 'typical ballet moves' (as used in the current study) and atypical ones (such as William Forsythe's choreography). However, these questions could not be properly addressed until a larger control group is obtained. In addition, the idea that the aesthetics of ballet dance may be quantifiable and studied empirically (e.g. Calvo-Merino et al., in press) is not without controversy and larger than the scope of the present study.

Additional questions

A number of questions remained unanswered as a result of doing this study – like so many other research projects, the researchers were left with more questions than answers. For instance, can further related research support ballet as an elite physical activity, in which people have trained their bodies to fit within a specialised group of kinematic precision that deserves elaboration, particularly regarding the cognitive mechanisms and learning process specific to this training? Is ballet dance training indeed emphasizing skill above all else and losing the individual in the process? If extensive ballet training 'moulds' a particular kind of motor and visual dancer (in simplistic terms), what does ballet training do for the dancer training in other styles, such as contemporary dance? What might happen if a similar study was conducted with contemporary dancers? Would a group of advanced Graham dancers, since Graham is similarly a codified technique, also prove non-idiosyncratic as a group? Or might contemporary dance be more 'idiosyncratic' than ballet dance? What ways are the advanced ballet dancer and advanced contemporary dancer different and/or the same, particularly considering visual and motor/proprioceptive system processes? Do dancers from different genres develop a different means to self-recognition or do they share similar 'ways of seeing'? Is the visual aspect of dance overemphasized in dance training, particularly in ballet? What level does the self play in dancers knowing what they look like dancing? Does this mean nurturing dancers' selves will help them be better dancers? Or does this contribute to being an elite dancer in some way?

5.8 Suggestions for future research

In addition to recommendations already mentioned, future specific experiments are suggested. Correcting for errors, such as the condition Other1-Other2 with different versions would allow comparison of all forced choice task data. Conducting a similar task with inverted movies with the same group of dancers, as done in previous research (Loula et al., 2005), might highlight whether movement or person cues were used to do the task. A larger group of control data would allow substantial conclusions regarding the dancer and control comparison. Carrying out a similar forced-choice task with male dancers would provide results from those who have visual but not motor experience with some of the gender-specific moves.

6. Conclusion

The current study found that advanced ballet dance controlled for idiosyncrasy across participants with point light displays. Comparing the visual discrimination and self-recognition task accuracy rates with this group of ballet dancers suggested that participants used nothing above visual cues, specifically any private motor/proprioceptive information, to recognize their own ballet movement. The findings raised several interpretations and implications for dance teaching, learning, and execution.

6.1 Advocacy for further collaborations

Recent research has found that an emphasis on self-recognition using gait may be misdirected, and suggest identity may be "more accurately and readily assessed with more expressive behaviours such as jumping and dancing" (Loula et al., 2005, p 219). Performing artists', such as skilled pianists', action system has been found to be most strongly activated during perception of self-produced actions and performers have been found to have a well-established and highly skilled action repertoire (Repp & Knoblich, 2004, p 604). In addition, researchers (Repp & Knoblich, p 608) have postulated that "experts' self-recognition might provide some fruitful approaches to studying perception-action links and their development" because skilled performers often have unique recognition characteristics from which to be identified (p 604). Previous research has supported the use of dancers for similar reasons. Calvo-Merino et al. (2005) found that dancers have a well-established and distinctive set of movements, expertise in a select motor repertoire, and experience with "intransitive movements of the whole body" (p 1244). A growing body of work has used visual stimuli that signal biological motion to study social cognition (Adolphs, 2003, p 165). Yet, there are very few systematic studies of self-recognition from action by expert performers (Repp & Knoblich, p 605).

The growing interest and benefit to cognitive science collaborations can also be seen in the dance science field at-large. For instance, the International Association for Dance Medicine & Science 2006 annual conference has a host of cognitive science-related presentations. Some of these include *The brain's sense of movement: Support from neuroscience for somatic practices in dance education,* by Glenna Batson and *Imagining a new movement,* by Corinne Jola, Marie-Claude Hepp-Reymond, and Fred W Mast. The titles give a general indication of where cognitive science and dance may be headed and how the current study fits into dance-specific inquiry. In addition, there have been a handful of projects (Hagendoorn 2004b; McGregor & deLahunta, 2005) to further support a partnership between dance and cognitive science as a new and fruitful area of artistic collaboration as well.

The current study also fits within a current trend in the literature regarding the brain and dance. For instance, Hagendoorn (2004a) gives an unprecedented type of meta-analysis of how brain function, philosophy, and dance might relate, as well as a similar summary of literature to the present study regarding biological motion. Jola & Mast (2004) further support the difficulty of understanding research on the brain and its value to dance, but highlight similar benefits dance may reap from this research:

> A changing value of dance in science will hopefully break distrust on the role of the brain in dance. This will help to overcome misguided discussions based on a rigid separation of the mind from the body (Novack, 1995). It should be noted that a dancer's control of complex movement patterns frequently relies on further cognitive processes (e.g. perception, memory, problem solving) (p 219).

In addition, it has been suggested that as part of [dance teacher] foundation knowledge, teachers should know about cognition, perception, and learning in dance (Kimmerle & Côté-Laurence, 2003, p 211). Jeannerod (1994, p 4) provided an example with music that was found relative to dance to help explain a hypothetical cognitive learning process. When a student is learning a musical instrument, he states, the immobile student may first watch the teacher play the instrument and the student may imagine the movement in his or her mind. While the student watches the teacher, "neurons relevant to motor preparation and planning may fire as if he were actually preparing the movement he watches" (p 5). The implication is that these "representation" neurons are the same as those that fire when the student is actually preparing to do actual action. Hagendoorn (2004a) claims the same process occurs for a dancers learning choreography, "Although the dancer remains immobile during the demonstration, he or she must somehow internalise the movement, that is he or she must form an image of the movement sequence as it unfolds" (p 92).

6.2 In closing

Both cognitive science and dance are not islands of scientific and artistic study. Particularly in recent years other fields have informed the sciences and the arts. Cognitive science is an umbrella field for a number of disciplines including, but not limited to, psychology, physiology, physics, computer science, and so on – many fields which have also proved useful to dance science research (e.g. Carr & Wyon, 2003; Chatfield, Burnes, & Rowe, 1990; Laws, 2002). More specifically, cognitive science investigates cognition, which requires a number of different approaches because of the complexity of humans' multi-faceted cognitive functioning.

For instance, consider trying to explain how a person understands how they move. This is not just a simple firing of a neuron, there are also psychological, learned cultural and physiological factors – and this is only to name a few of the functions involved. Therefore a large 'toolbox' is needed to dissect an investigation related to human action and perception. Similarly, dance encompasses a number of disciplines, although comparatively in a more practical way, including, but not limited to psychology, physiology, physics, philosophy, and so on. Dance plays with and challenges the system of human movement, including cognition. Dance often re-shapes learned cultural and psychological expectations, as well as challenge assumed physical limitations. Dance is not merely moving the body in space – it requires artistic human consciousness as well. In sum, there seems nothing better than to include the complex and fascinating world of dance to inform, expand, and illuminate the cognitive science 'toolbox'; and nothing better than for dance to grow in return.

Epilogue

This project was testament to the importance and vast amount of related and applicable research found in the fields of dance and cognitive science. Conducting the current study proved to me that there is much to be discovered by crossing these seemingly disparate disciplines. At the same time, it highlighted specific challenges within the field of dance science and bridging some occasionally large gaps. It seemed important for me to include a reflective writing on the overall process, particularly to share and document the challenges as a dance scientist dealing with complex scientific theory.

In some ways the experience of this project related to what I have heard previously questioned regarding career transitions for dancers. Mainly, how does one who has trained with a particular 'body' knowledge transfer that knowledge into another field? Does one have to start over in the field transitioning into? Or is there a way to transfer knowledge from one field to the next rather seamlessly? Similar questions crossed my mind when in the 'world of cognitive science'. Should I 'start over' in the field of cognitive science and weave my dance experience in later? Without a base knowledge in the cognitive science field, am I missing key concepts in my research and analysis? Can collaborators from different backgrounds communicate, even though there may be language (specific to each field) that may sometimes separate them? For example, during this project there were seemingly simple, but actually theoretically complex, concepts discussed during our meetings, concepts such as a 'the self', 'motor processing', 'internal forward models', etc. I did my best to 'wrap my head around' these concepts quickly, often gathering multiple articles with similar viewpoints, but it seemed time, experience, and patience were the best resources – just as years of dance training had brought me to a certain level of dance technique and skill. In addition, I wondered how the dance scientist takes the cutting edge of research in a complex scientific realm and then apply that to dance, when the top people in the cognitive science field might also struggle with applying the concepts to 'real-life' situations? For instance, it is only within the last few years that experimental studies in cognitive science have included whole body action. Previous research on human action has been more commonly reserved to limb action only, i.e. the hand. How might I 'whittle down' this knowledge in terms that I and my fellow dancers and dance teachers can understand, relate to as dancers, and apply to the dance field? Strangely, it seemed even the best of cognitive scientists might not be able to simplify these concepts easily. In particular, when it came to presenting the material on my own and writing this thesis, I realized how vast the concepts I was dealing with were.

In addition, in yet another context, my dance experience could not hold up to the esteemed realm of the mind – it remained the physical 'other' knowledge. Or did it? Dance science is a new field, constantly changing and adapting to new ways of seeing. I could be a part of that change. I could transform my unique kinaesthetic training and expertise with scientific theory. The dancing experience of my body could be enmeshed with theories of the mind (quite literally). I could challenge the pervading Cartesian duality of mind and body! Or could I? On the other hand, as a dance scientist I wanted to establish myself in the scientific realm, proving rigour in both method and analysis. The future could only tell how this change might manifest in my work.

On further reflection, at a certain level, learning is not surprisingly a struggle. Trying to forge paths in new and different ways, both for the field and for the individual, is difficult and thrilling. In no way could this ever be without challenges and frustrations, and similarly surprises, excitement and tremendous passion. I suppose one just need to understand, even with incredible hard work, the learning and growing process can be enjoyed for what it is, even at those times when nothing makes sense.

I include this brief epilogue in hopes that it may serve future dance scientists, although I peripherally hope it will serve as an experiential point-of-view of my process as well. For fellow dance scientists, this epilogue may prove simply a 'stepping stone' of rapid growth in the field of dance science. Meaning, in the future, this epilogue may simply become evidence of the challenges left behind in dance science history. However, it is more likely evidence of a dance scientist trying to fit into her niche. In the latter case, then, this epilogue might serve to comfort other burgeoning dance scientists that have an incredulous desire to learn and understand specific links between science and dance, but might be faced with a large gap between the disciplines and experience in them.

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