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Points in mental space: an interdisciplinary study of imagery in movement creation.

Jon May[1],

Beatriz Calvo-Merino[2],

Scott deLahunta[3], Wayne McGregor[3],

Rhodri Cusack[4], Adrian Owen[4], Michele Veldsman[4], Cristina Ramponi[4] and Philip Barnard[4]

[1] School of Psychology, University of Plymouth

[2] Universidad Complutense de Madrid and Department of Psychology, City University London.

[3] Wayne McGregor | Random Dance, London

[4] MRC Cognition & Brain Sciences Unit, Cambridge.

Contact Author:

Professor Jon May,

School of Psychology

University of Plymouth,

Drake Circus

Plymouth

UK- PL4 8AA

jon.may@plymouth.ac.uk

Abstract

As part of a programme of research that is developing tools to enhance choreographic practice, an interdisciplinary team of cognitive scientists, neuroscientists and dance professionals collaborated on two studies examining the mental representations used to support movement creation. We studied choreographer Wayne McGregor's approach to movement creation through tasking, in which he asks dancers to create movement in response to task instructions that require a great deal of mental imagery and decision making.

In our first experiment, we used experience sampling methods (self-report scales and reports about the current focus of thought) with the full company of Wayne McGregor | Random Dance to describe what the dancers report thinking about while creating movement, and to establish how their experiences change as a function of different task conditions. In particular, we contrasted a conventional 'active' condition (where dancers are free to move around) with a 'static' condition (where they have to create movement mentally, without moving), because all neuroimaging studies of dance require participants to lie motionless within a scanner. We adapted the static mode from Experiment 1 for the neuroimaging session in Experiment 2. Here we recorded the brain activity of an experienced dancer from Wayne McGregor | Random Dance while she mentally undertook movement creation tasks similar to those used in our experience sampling experiment. Both studies involved imagery tasks of a primarily spatial-praxic nature (involving an imagined object or volume that could be approached and manipulated) and imagery that focused on content invoking emotional narratives.

In the first study, the dancers' awareness was focused more than they had anticipated upon conceptual rather than physical or bodily aspects. The very act of reflecting on, and categorising, their experiences provided the dancers with insights about their mental habits during innovative movement creation. Such insights provide conditions under which habits can be recognised and then altered to adopt alternative points in mental space from which to create movement material. Providing the dancers and McGregor with a means to communicate more productively about the properties of the task-based instructions has been acknowledged by the company to be of clear benefit and a useful addition to their working process.

In the second study we assessed the feasibility of using fMRI to study the neural underpinnings of choreographing movement tasks. The experiment enabled us to compare brain activity in imagery and movement creation. The data raise some key questions

concerning the mental context in which such thinking occurs and, given the clear limitations of the current fMRI and experience sampling work, how future research might usefully be directed.

Taken together, these two exploratory studies indicate that the experiential and neural attributes of imagery during movement creation are open to systematic investigation: innovative movement creation can start from alternative points in mental, as well as physical, space. This enables us to look forward to establishing with greater precision how tasks that challenge dancers in different ways may affect mental and neural processes and how variation in imagery use *across* dancers might contribute to the variety of movement creation that they produce. Notably, the act of reflecting on the experience of movement creation also offers some practical leverage to help dancers develop a wider range of strategies for innovation. These findings are being used to contribute to further work informing the development of personal, notebook-like, *Choreographic Thinking Tools*.

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Introduction

Several renowned choreographers, such as Trisha Brown, William Forsythe, Wayne McGregor and Merce Cunningham have explored their performers' expressive range through developing and refining techniques for generating and structuring novel forms of movement. This paper focuses on the mental strategies underpinning the movement innovation techniques used by one of these choreographers, Wayne McGregor and his company Wayne McGregor | Random Dance. In particular, we want to understand how different forms of mental imagery are involved in movement creation, and how different task constraints can change the nature of the imagery that is used. We are also concerned with the ecological validity of neuroimaging studies of choreography in which participants must necessarily lie still in a scanner, whereas movement creation typically combines mental and physical activity.

Wayne McGregor's approach to movement creation involves dancers making a wide range of embodied mental transformations. He asks his dancers to create movement in response to task instructions that require a great deal of mental imagery and decision making, and then observes the dancers' resulting movement, selecting and amplifying sections for potential re-use. It is this process of movement creation in response to different forms of task instruction that our collaborative studies have set out to better understand. Comparative literature scholar Carrie Noland in her essay on the creative process of choreographer Merce Cunningham, invites her readers to consider "choreography not as an aesthetic practice, but as the production of puzzles for the body to solve, puzzles that require it to cope, to enact its kinesthetic and proprioceptive capacities, in unusual and taxing conditions" (Noland, 2009). Our paper parallels Noland's analysis of Cunningham: we focus on the working practices of a single choreographer, Wayne McGregor, who also adopts a problem-solving approach to movement creation. Where Noland departs from the framework of dance scholarship to explore the techniques involved in Cunningham's process using ideas from anthropology and cognitive science, we use the methods and conceptual framework of behavioural science, cognitive science and neuropsychology to address the underpinnings of McGregor's innovative movement creation.

In common usage, mental imagery is often understood as mainly visual in nature, but we are all able to construct mental imagery in other sensory domains: imagining sounds, textures, tastes and smells. We can imagine movement, without actually executing it, and it would be expected that dancers would be especially well practiced at this form of mental imagery. Alongside sensory imagery, we can also construct more abstract mental representations, including emotional feelings, and highly conceptual thoughts. In our research, we seek to understand how all of these forms of mental imagery are used to support movement creation.

Mental imagery of all these forms pervades the content of the problems and tasks McGregor gives his dancers, and they approach both imagery and movement creation in the same underlying spirit of problem-solving as Cunningham (see Kirsh *et al.* 2009, for a summary of McGregor's methods). However, unlike Cunningham's approach, McGregor's challenge to his dancers is that they focus their attention on specific aspects of a mental image or images provided in the context of the problem or task. In executing the task the dancers are engaging in a process of movement creation in some direct correspondence to the stimuli the task sets out. Here is one example of a McGregor task:

> *'First thing to do is in your mind create a very simple, literal freehand sketch or drawing – in your mind. Choose a beginning on that sketch and then describe it physically or draw it – the whole thing rather than just an element of the whole thing. So it has duration. The third part of this is to discard the geometry (of the object that you drew) and replace that with colour. Then do another one.'*

This task clearly requires *a lot of mental work*, some obvious and some not so obvious. It involves imagining and holding in focus a geometric spatial image that does not actually exist in space, and has to be internally generated. The instruction to "describe or draw it" is a suggestion of the action (with no further directions), and the direction to replace it with colour implies a transformation in meaning or emotional connotation – which the dancer is invited to assimilate into their movement solution. This is a relatively simple task for McGregor to ask the dancers to do – but it still requires a number of unusual decisions to be made. It was also a task that was invented for the purpose of conducting the data collection for the first experiment reported on in this paper. Under normal creation conditions tasks are derived from the space of conceptual inspiration McGregor is working in for a particular choreography.

Other choreographers have developed methods for directly engaging the embodied mind of the dancer. William Forsythe's *Improvisation Technologies* (see Forsythe 1999) were described by Dana Caspersen, a performer with Forsythe, as "tools for the playful mind, not laws or some kind of choreographic machinery" (Caspersen, 2007). Such tools are "useful in that they tend to promote an inventive curiosity" and encourage "the dancer's mind to consider the vast number of states and organisations that the human body has to offer." These tools are doing the same thing that McGreogor's tasks seek to do. Another example of this form of choreographic practice is Trisha Brown's 1975 work *Locus,* in which the dancer "envisions the space around the body as a cube defining the choreography's architecture" (Brown and Rosenberg, 2009) as a means of generating new movements.

While movement creation is of strong interest to the choreographers so far mentioned, the use of other forms of mental imagery related to sensation, space, meaning and emotion is also widespread. This wider usage of imagery has been inferred from informal interviews with choreographers (e.g. Butterworth & Clarke 1998) and can also be found in reports of many specific practices used in the dance community, particularly in the field of somatics (e.g. the Skinner Releasing Technique, Anderson 2006) and in scientific studies of the use of mental imagery in dance (e.g. Jola & Mast, 2005). It is important to note that we are not discussing the question of whether task-based creation produces more aesthetically relevant material. We simply seek to describe the components of a part of McGregor's creation process and to provide some systematic evidence on the use of imagery in dance and movement creation. The intention of our research is to record dancers' *awareness* of their use of these forms of imagery during movement creation, and to relate these measures to evidence of patterns of brain activity from neuroimaging studies.

In our first experiment, we used experience sampling methods with the full company of Wayne McGregor | Random Dance to describe what the dancers report thinking about while creating movement, how the dancers vary one from another, and to establish how their experiences change as a function of different task conditions. In particular, we contrast a conventional 'active' condition (where dancers are free to move around) with a 'static' condition (where they have to create movement mentally, without moving), because all neuroimaging studies require participants to lie motionless within a scanner: this is an obvious problem for neuroscientific studies of behaviours that usually involve movement, such as dance. To date, we do not know how the position and activity of the participant in neuroimaging studies affects the mental processes and neural activity involved in movement creation.

In our second experiment, we recorded the brain activity of an experienced dancer from Wayne McGregor | Random Dance while mentally undertaking movement creation tasks similar to those used in our experience sampling experiment to open up debate concerning the extent to which fMRI data might act as a useful source of validation for otherwise purely subjective reports. Both studies involved imagery tasks of a primarily spatial-praxic nature (meaning an imagined object or volume that could be approached and manipulated) and imagery that focuses on content invoking emotion and socio-personal narratives.

This is our most ambitious attempt to date to fully report on the interdisciplinary research work that straddles the disciplines of dance and science, bringing together authors from different research backgrounds. The background theory to this study can be found in the Interacting Cognitive Subsystems model of cognition (e.g., Barnard 1985; Barnard *et al.*, 2007), especially the specific ideas about different forms of mental representation or imagery.

Unlike Noland's third-person observations of Cunningham, we interact directly with McGregor and the dancers as participants in experiments designed to help us (as scientists) and them (as dance practitioners) better understand innovative movement creation. Our goal is to develop tools that will enhance the practice of choreography by bringing scientific findings back to the studio in ways that can be used by McGregor and his dancers. This paper describes some of the scientific methods and results that have informed the initial development of some prototype tools and processes currently referred to in the studio as *Choreographic Thinking Tools*. These are notebooks containing prompts and notational devices that dancers can complete in the studio to aid reflection and awareness of the mental strategies that they are using.

Experiment 1: Experience sampling in the studio

Experience sampling has a long and sometimes controversial history in psychology, but has recently seen a resurgence of popularity. Experience Sampling Methodology is a family of empirical methods that allow researchers to obtain measurements of an individual's account of their internal mental events outside artificial laboratory settings and within the context of their normal everyday settings. In general, these methods involve interrupting an individual while they are going about an activity in its normal setting and asking them to make brief subjective reports about their current subjective state, via brief notes or rating scales. By probing immediate self-report of inner experience, this method enables researchers to measure a person's momentary thoughts, feelings and action-tendencies than by asking through more retrospective recall methods (for more detail see Feldman, Barrett & Barrett, 2001; Myin-Germeys *et al.*, 2009; Smyth *et al.*, 2001; Stone & Shiffman, 1994). This approach was employed in this experiment to assess momentary internal experience of each of the imagery components of interest.

The objective of our first experiment was to explore what contributed to dancers' thought patterns while creating movement in response to tasks set them by McGregor, and how changes in the nature of the task and the mode of creation affected these patterns of thought. We used two forms of task instruction, based on characteristic tasks that we had observed McGregor use previously. One task condition was based upon spatial-praxic imagery: one of the actual tasks used in this experiment was ‘Imagine an object. Reduce it to a line drawing. Visualise an element of it. Describe what is visible’. The other condition was based upon emotional instructions: one example from this experiment being ‘Think of a familiar song or piece of music. Focus on the memories, feelings or sensation it evokes, in you or someone else. Translate it into 3d and draw the meaning.’

As its name implies, the spatial-praxic task might be expected to draw primarily upon imagining physical objects and actions in a spatial frame of reference. The emotional task, in contrast, might be expected to draw upon deeper and more elaborate conceptual and schematic knowledge including narrative and interpersonal elements that are rooted in meanings. This might include the connotations of movements and how another person might relate or react to them. Our expectation was that these two forms of task instruction would lead to systematic differences in the nature of the mental imagery reported by dancers.

As an additional contrast, our experiential measures were collected from dancers completing choreography tasks in the studio in a conventional, physically active condition. However, as preparation for our second brain scanning experiment, where movement is not possible, we also employed a static condition, where dancers carried out the same kinds of tasks but simulated movement creation mentally rather than physically, while knowing that they would enact the movements at the end of the creation period. These contrasts between active and static creation should enable us to detect any major differences in strategy that result. We also wanted to find out how these ratings collected during task execution compared with the dancers’ general prior beliefs about their ‘typical’ experience of movement creation and so a pre-test was included for one of our methods to enable us to assess this issue.

Participants

Eight professional members of Random Dance took part in the experiment (four male, four female; ages ranging from 24 to 32 years). The dancers had all been members of Random Dance for at least two years (one had been a member for three years and another for five years), and so were used to working together as a group under the direction of Wayne McGregor. They took part as a group, in a rehearsal space in London, with all instructions being given by Wayne McGregor.

Method

Ethical approval for this experiment was granted by the University of Plymouth Faculty of Science. All participants gave written informed consent following a briefing session, in which they were given written and verbal information about the experiment. During this session, we explained to the dancers what we meant by mental imagery, and explained the idea that imagery could take different representational forms. We also explained that you could have several things going on in mind at once, but would be focally aware of just one form of representation at any one time, with others seeming to be in the background, ready for you to bring them into focal awareness. We were careful not to discuss any expectation that the tasks and modes of movement creation would change the forms of imagery that they used.

Testing took place over two days. On the first day, dancers completed the Experience and Imagery Scales (EIS), and on the second, the Thought Monitoring exercises. The EIS is a conventional retrospective report, used here mainly over a short immediately preceding period, and was aimed at capturing an overall characterization of the dancers' experience of creating movement and reflecting upon their beliefs about that experience looking back several minutes. The Thought Monitoring exercise attempts to capture more precisely the type of image in mind at any one moment in time. At the end of the second day, dancers were debriefed and took part in a group discussion about their impressions of the experiment.

On each day, the dancers completed four movement creation exercises each of approximately half-hour duration, two following spatial-praxic task instructions and two following emotional task instructions. Four dancers completed the spatial-praxic exercises first, and four the emotional, taking a twenty minute break between the pairs. The first of each pair of exercises was made actively, with dancers moving around the space as they normally would when creating movement, but the second was static, with dancers mentally creating movement while lying still in a comfortable position on the floor, only enacting the movement at the end of the exercise (see Table 1 for a timeline of this experiment).

The EIS were presented as a single A4 sheet containing 21 statements about different aspects of the dancers' mental experience and imagery during movement creation, presented using visual analogue scales (See Appendix). The text for each statement was centred above a 100mm line, and instructions at the top of the sheet asked dancers to make a mark anywhere on the line to indicate their experience, with textual anchors (such as 'Never' to 'Most of the time') being printed at either end of each line. On the front of the sheet, the first two items (labeled 'stuff out there') assessed whether dancers had been concentrating on events in the room rather than their own mental imagery, and if they had been distracted whether it was by sounds or sights. The next nine statements on the first page all assessed the degree that dancers were aware of using different levels of mental representation, and short labels were printed to the left of items: intuition (three items), body sensation, spatial-praxis, emotions, verbal thoughts, propositions, and limb/muscle urge. Another ten statements were printed on the other side of the sheet, and asked dancers to rate different aspects of their mental imagery. A free text box was included at the bottom of each side to allow dancers to note down anything else that they felt was important.

Before the first exercise, dancers completed the EIS to reflect their beliefs about their general or typical experience of movement creation. McGregor himself then verbally gave each group of four dancers the instructions for their first active exercise and they began creating movement. After four minutes, they were asked to stop and to complete the scales, based upon the exercise so far. This served as a practice set. When they had completed the scales, they were asked to continue with the exercise. They completed four further sets of scales, cued at eight minute intervals by the experimenter. The same procedure was followed for the remaining three exercises, except that no practice set was given, and so only four sets of scales were completed in each of these exercises. For the static movement creation exercises, the dancers lay on the floor after the instructions had been given, and remained motionless while mentally creating, only moving to complete the scales when prompted. At the end of the static exercises, dancers were given five minutes to actively rehearse the piece they had constructed, and then performed it while being filmed.

For each participant, the four sets of ratings collected during an exercise were used to obtain a mean rating for each of the 21 scale items for that exercise.

On the second day, dancers completed a similar sequence of four exercises, again balancing order of spatial-praxic and emotional instructions. During these exercises they were asked to stop and write down what they had been thinking immediately before they had been stopped, using one or two words, such that they would be able to remember and describe it after the task: the purpose of this was to focus them upon the thoughts that were at the forefront of their mind, so that they could then classify the content of these thoughts using the same eight categories used as experiential labels on the EIS. These categorisations were the measure we sought for analysis; the actual notes were too fragmentary and idiosyncratic to support analysis by anyone other than the notemaker.

During the first exercise, they were stopped eight times, at five minute intervals, with the first two stops serving as practice in recording their thoughts. During the other three exercises, they were stopped six times. As on day one, dancers rehearsed and performed their pieces after each of the static exercises.

Results

Experience and Imagery Scales

The mean ratings that dancers gave on the 21 EIS scales to describe their typical experience of movement creation varied between 30 and 77, with standard errors between between 4.1 and 12. Figure 1 shows these means, plus or minus one standard error, as wide grey bars. The spread of the error bar for each mean indicates the degree of consistency between dancers' ratings: a small bar indicates similar ratings, while a large bar indicates a wide spread of ratings.

The first two items indicated that dancers felt that they were not often influenced by events in their environment when creating movement ($M = 30$), but that when they were those events were just as likely to be sights as sounds ($M = 43$). Two-tailed one sample t tests showed that the first of these values differed from the midpoint of 50 ($t(7) = 3.38$, $p = .012$). but the second did not ($t(7)=0.91$, $p=.394$) - comparing the scale means against the midpoint allows us to infer whether the dancers were endorsing a statement (where $M>50$) or rejecting it (where $M<50$). A statement with a mean that is not statistically different to the midpoint is neither clearly endorsed, nor rejected. On this basis, their scores were around the midpoint when asked if their movements were often intuitive ($M = 46$, $t(7)=.038$, $p=.712$), whether these intuitions were unguided or guided by a latent plan ($M = 63$, $t(7)=1.04$, $p=.331$) and were equally often emotional as not emotional ($M = 53$, $t(7)=0.34$, $p=.742$).

Of the items addressing dancers' mental focus while creating movement, the highest rating was given to spatial-praxis ($M = 76$, $t(7)=6.2$, $p<.001$), followed by limb/muscle ($M = 68$, $t(7)=2.01$, $p=.084$), propositions ($M = 63$, $t(7)=1.29$, $p=.239$), emotions ($M = 62$, $t(7)1.18$, $p=.278$), body sensation ($M = 56$, $t(7)=.74$, $p=.484$) and verbal thoughts ($M = 55$, $t(7)=.42$, $p=.686$). While all of these forms of representation received mean ratings above the midpoint, only the spatial-praxis measure was significantly different from the midpoint of the scale.

The imagery items showed that dancers felt that the specific imagery that they created at the outset remained at the forefront of their minds while creating movement ($M = 77$, $t(7) = 5.16$, $p = .001$), and that this imagery guided their decision making ($M = 66$, $t(7) = 2.95$, $p = .021$) and senses of meaning linked to the imagery often came to mind ($M = 65$, $t(7) = 1.98$, $p = .089$). They were equivocal about the ease with which they could reconstruct their original imagery (M=37, t(7)=1.41, p=.201).

When spatial-praxic imagery was involved it was highly vivid (M = 74, t(7) = 4.62, p = .002). Their decision making was not typically based upon what another person might think (M = 35, t(7) = 3.13, p = .017), nor on how good a movement felt without reference to other meanings (M = 30, t(7) = 3.05, p = .019). Dancers were equivocal about whether spatial-praxic imagery was of a third person view of themselves (M = 40, t(7)=1.32, p=.229), how familiar movements felt (M = 61, t(7)=1.78, p=.118), and how happy they felt with their decisions (M = 50, t(7)=.01, p=.989).

The general pattern here is that dancers believe themselves to be creating movement intuitively to some intended plan of which they are not completely aware, using spatial-praxic, limb/muscle and abstract propositional imagery based on an initial idea throughout the exercise, recruiting component movements with which they are familiar. Of course the dancers often differed substantially in their typical ratings and so these means are only indicative.

Of further interest is how each dancer's ratings differed when they were made in response to actual experiences during the four exercises. These means ratings are shown in Figure 1 as the circles (spatial-praxic task) and diamonds (emotional task), with filled symbols indicating the tasks competed while actively moving, and the empty symbols those completed mentally, while lying static on the floor. To see if the two tasks and modes of creation changed the ratings in different ways, we used SPSS 18 to carry out separate repeated measures ANOVAs for each scale with the within-subject factors of Task (spatialpraxic v. emotional) and Mode (static v. active). Statistically significant effects were found for eight of the scales, and (given the low power of the Experiment, with only eight dancers) non-significant F values with effect sizes >.10 for another nine. The results of the ANOVAs are summarised in Table 2.

The dancers were focused on mental imagery equally in all four tasks, with ratings very similar to their typical experience. When they were distracted, however, the effect of Mode that is listed in Table 2 shows that they were much more likely to be distracted by sounds than sights during the static exercise, when they were lying on the floor, with their eyes closed. This is not too surprising; but the effect of Task in Table 2 shows that they were also less distracted by sights during the emotional tasks (in Figure 1, the diamonds are lower than the circles). The absence of an interaction between Task and Mode shows that the effect of the emotional task was the same in both static and active modes.

The degree to which dancers felt they were moving intuitively was also affected by the task, with the emotional task being more intuitive than the spatial-praxic task. From the means in Figure 1, it would seem as if this effect is bigger for the active mode, but this interaction was not statistically significant. When they were moving intuitively, there were no differences in the ratings for whether the movement felt spontaneous or guided by some plan, but the movements felt more emotional in the active emotional task, and less emotional in the active spatial-praxic task – hence the significant interaction in Table 2.

Turning to the dancers' awareness of attending to each of the six levels of mental representation (body to limb/muscle), it is apparent that only one of the ratings lies above the dancers' ratings of their typical experience. There were several noticeable effects of Task and Mode (indicated by the high values of partial eta-squared in Table 2, which estimates the proportion of variance in the data attributable to the effect), but due to the small number of dancers in the company, the low statistical power means that only one of these effects reaches statistical significance: the interaction of Task and Mode for the awareness of emotional experiences related to their movement. This indicates that when dancers were actively moving, the spatial-praxic task made them less aware of their emotional experiences; but when they were mentally creating movement while static, the emotional task made them less aware of emotional experiences. (This will be discussed further below.)

Of the non-significant effects, the largest is the interaction of Task and Mode for awareness of spatial-praxic thought: 'visual-like images in my mind's eye.' All four exercises produced ratings that were lower than dancers' typical experience, but lowest was the active emotional task, followed by the static spatial-praxic task..

The dancers' ratings for the use of imagery in their creative work and decision making showed that the static mode made it harder to bring to mind and reconstruct their original imagery while developing movements (this is the effect of Mode in Table 2; this scale ran from 'very little effort' at zero to 'a great deal of effort' at 100).

Dancers based decisions about their movements upon their initial imagery more often during the spatial-praxic task than the emotional task. In the static mode, they were more likely to base decision upon how good a movement would feel for the spatial-praxic task, and less likely to do so for the emotional task, compared to active mode, where both tasks produced ratings similar to the typical experience.

Finally, in response to the question 'How many of your decisions are you happy with?, the dancers were clearly unhappier with decisions made in the unfamiliar static mode than with the familiar active mode. The fact that the dancers were not happy with how they responded to the tasks when asked to complete them without moving emphasizes that their normal method of movement creation involves a wide range of embodied activity that is not available when they are asked to lie motionless, as in neuroimaging studies.

Thought Probes

The six thoughts probed from the eight dancers during each of the four exercises on day two were pooled (a total of 186 thoughts, since six thoughts were uncategorized), the number allocated by the dancers to each category counted up, and divided by the total to give a proportion (Figure 2). Overall the highest proportion were verbal thoughts (22%), followed by bodily sensations (17%), spatial-praxic thoughts (16%) and thoughts about events happening in the rehearsal space (such as the music being played, other dancers' proximity, or people walking around; 13%). These three categories together accounted for over two-thirds of thoughts (N = 127). Dancers very rarely categorized their thoughts as 'intuitive', at only 6% (N = 12) overall.

When the proportions of thoughts in each category reported for the four exercises are compared (Figure 3), differences between the two modes of movement creation and the two tasks are apparent. For both tasks, the static mode resulted in a decrease in propositional conceptualization and bodily sensation; but while the spatial-praxic task led to fewer verbal thoughts and more emotional, spatial-praxic, and limb/muscle planning thoughts, the Emotional task showed the opposite pattern. The emotional task also produced more thoughts about events in the external space in the static condition than the active.

The small number of dancers, and the non-independence of the six thoughts per dancer, mean that there is no practical way of testing for statistical significance in these patterns of thought content, but the differences observed do make some intuitive sense. The static exercise does not offer much opportunity for the use of bodily sensations, and there is a clear shift away from abstract propositional conceptualisation. For the spatial-praxic task, there is a shift towards planning limb/muscle actions, with more spatial-praxic and emotional thoughts in the static than the active conditions. In the emotional task, however, there is less limb/muscle planning and more verbal thoughts, as well as a tendency to be distracted more by events happening in the studio in the static condition.

Discussion

The largest, and least surprising, difference between the experiential and the typical ratings shown in Figure 1 is that dancers were less influenced by sights in the static exercises, when they were lying on the floor with their eyes closed, although the thought monitoring data shows that they were still distracted by events, especially during the emotional task. This is helpful in giving some face validity to the rating methodology. Dancers were also less happy about their decisions in the unfamiliar static condition. Beyond this, there are some interesting differences in the extent to which dancers feel that they are relying upon intuition, the role of emotional experience in their movement creation, and the reliance upon some form of imagery from the outset of each exercise.

The active exercises were more like the dancers' usual style of movement creation, and yet the filled symbols in Figure 1 show that their actual experience often differed from their expectations about what would be typical for them. In contrast to their typical ratings, they felt that they were making more use of intuition in the emotional task; for the active spatial-praxic task they felt less aware of emotional experiences related to their movements and their intuitions were less emotional. This is unlikely to be a contrast effect from the emotional task, because of the counterbalancing: four dancers had not yet experienced the emotional task when rating the spatial-praxic task. Interestingly, in the thought probe data they also reported fewer emotional thoughts in the active than in the static mode.

Compared to the rating scales, the thought monitoring data shows a different pattern for use of intuition, with thoughts rarely identified as intuitive. This may simply be because when asked about a thought at the moment it is happening, its precursors are more apparent, and so you are less likely to identify it as spontaneous. Similarly, while dancers used the rating scales to indicate that their typical experience would involve limb/muscle planning and few verbal thoughts, the thought monitoring showed verbal thoughts to be the most frequent category, with limb/muscle planning one of the rarer types: the dancers' awareness was focused more than they anticipated upon conceptual than physical or bodily aspects. The thought monitoring and experiential results could differ for a number of reasons: the rating scales are obviously subjective and retrospective, whereas the thought monitoring attempts to objectively sample specific thoughts at a discrete moment. However, only six probes were possible in each of the four sessions, and so the granularity of the monitoring is large: it would be easy for thoughts of a specific form to have occurred briefly and not to have been caught by a probe. What the thought monitoring really gives us is an indication of the amount of time spent thinking in a particular way, rather than the importance of that form of thinking. It is more helpful to compare the two forms of measurement across the tasks and modes, than to compare them with each other within a task or mode.

When dancers were asked to create movement mentally, without moving, there were clear differences in their experiential ratings. Compared to their typical ratings, they made less use of emotional experiences when they were completing the emotional task, and in both tasks they felt it harder to reconstruct their original imagery. In the more conventional active condition, they made less use of their imagery than typical in the emotional task, but more in the spatial-praxic task. Overall, compared to their typical ratings, dancers reported that they based their decisions about movement more often upon how good it felt as a part of a phrase.

Importantly for the development of practical *Choreographic Thinking Tools* to support movement innovation, post-task debriefing also indicated that the very act of reflecting on, and categorizing, their experiences provided the dancers with insights about their mental habits during innovative movement creation. Such insights provide conditions under which habits can be recognised and then altered to adopt alternative points in mental space from which to create movement material. Providing the dancers and McGregor with a means to communicate more productively about the properties of the task-based instructions has been acknowledged by the company to be of clear benefit and a useful addition to their working process.

Experiment 2: brain activity during choreographic thinking

Mental Imagery has been extensively investigated both in cognitive and neuroscience laboratories (Kosslyn, Ganis & Thompson, 2009) and in applied settings, for example to improve performance in competitive sports (Murphy, 1990). Studies of internal mental states such as imagery are controversial precisely because they have long been seen as subjective, and not open to objective quantification. Modern brain scanning techniques offer the prospect of providing collateral evidence for the involvement of different forms of imagery, since they enable us to test whether activity in function-specific brain regions known to be involved in, for example, visuo-spatial experiences, motor control or decision making is correlated with subjective reports of the use of that imagery. Owen & Coleman (2008), for example, used the detection of neural activity associated with different forms of imagined activity (playing tennis, or walking around one's home) to show that a patient in a vegetative state, who could not respond physically, could respond mentally to oral instructions. Moreover, several studies have examined the brain activity of creative artists (Bhattacharya & Petsche, 2005; Berkowitz & Ansari, 2008), including studies of improvisation in dance (e.g. Fink, Graif & Neubauer, 2009), and data obtained in this way offers the prospect of investigating the neural underpinnings of choreographic practice.

Cognitive neuroscience research has also investigated the neural mechanisms of motor imagery in the control of action (e.g. see deLange, Roelofs & Toni, 2008). In the same way that visual imagery and visual perception recruit similar brain regions (Ganis *et al*., 2004), several studies have shown that during imagination of a movement, the same sensorimotor regions are activated as when we observe a movement or actually execute it ourselves (Decety *et al*., 1994; Grèzes & Decety, 2001). Some studies have made use of the motor expertise model to investigate the link between the action execution and action perception network (Calvo-Merino *et al*., 2005; Calvo-Merino *et al*., 2006; Orgs *et al*., 2008) and motor learning (Cross *et al*. 2006). Other studies have focused on the underlying neural mechanisms of creativity in realms other than dance (Jung *et al*., 2010), especially in music (Limb and Braun, 2008) and drawing (Bhattacharya & Petsche, 2005). The bulk of these studies have been based upon the researchers' expectations concerning motor responses, rather than seeking to correlate activity with subjective reports of motor imagery, so while they have focused upon motor or movement related brain processes, wide ranging networks are implicated and the possible involvement of multiple forms of imagery in such tasks remains to be clarified.

To obtain evidence on the use of mental imagery in dance and creativity tasks, we set out to pilot with a single participant, the use of fMRI data to investigate the neural circuitry implicated in choreographing movement tasks. We have data from Experiment 1 indicating that changing the focus of the task from spatial-praxic to emotional representations changes the forms of imagery that dancers are aware of using in their movement creation. These changes do not always correspond with what one might expect if the changes were just due to demand effects, which would lead to the dancers reports reflecting their expectations about the needs of the tasks, and as with any self-report data, objective cross-validation would be helpful. A single case-study is useful here to show that it is possible to identify different patterns of brain activity with tasks that require or involve different forms of mental imagery. If successful, this would support future work with larger numbers of volunteers to validate if there is a general pattern across individuals in different forms of imagery.

In this pilot experiment, we again used spatial-praxic and emotional task instructions. As it is not possible to execute whole body movements in a brain scanner while recording the brain activity, we adapted the static mode from Experiment 1 for the neuroimaging session. For each task we used two phases: in a first phase our dancer was asked just to create imagery to meet the requirements of the instructions, without imagining movement; and in a second phase she was asked to create movement mentally, based upon that imagery. This approach enables us to identify any differences between two hypothetical aspects of choreographic thinking: the creation of imagery used for choreography, and the mental movement creation.

These two phases do not compare visual imagery with motor imagery, since each (along with other forms of imagery) may be involved in both phases; rather it is to discover which forms of imagery the dancer used in each phase. Of course, breaking the task down into these two phases makes it less like the dancer's normal practice, in which imagery creation and movement creation are intertwined, and it may be difficult for a dancer to execute each phase separately: among other things, this pilot sought to show that an expert dancer could in fact meet these unusual task requirements.

Method

We used fMRI to record brain activity of a right handed female (age = 39), who was an experienced dancer with 12 years experience with the tasks used by Wayne McGregor | Random Dance. Ethical approval for this experiment was granted by Cambridge Psychology Research Ethics Committee.

The scanning session included a block-design with three non-dance imagery reference tasks, and four dance-related experimental tasks (see Figure 4). We used the reference tasks to familiarise the dancer with the basic procedure (imagining playing tennis for motor imagery; imagining navigating around their home for spatial-praxic imagery, and a guided body scan for somatic imagery). The brain activations related to these tasks have been previously described (Boly, Coleman, Davis *et al*., 2007), therefore they are used as reference to identify brain regions related to motor and spatial imagery, and embodiment.

As in Experiment 1, spatial-praxic and emotional task instructions were used, but they were now further divided into two phases: first an imagery creation phase, followed by a movement creation phase. Two runs of the spatial-praxic tasks were conducted first, followed by two runs of the emotional tasks. Detailed task instructions concerning all tasks to be performed were given prior to entering the scanner, but to avoid the dancer creating imagery before scanning started, she was given six possible scenarios, and not told which to develop until scanning started. Since she was highly experienced, our instructions simply indicated the type and broad content of the task, leaving open those areas for task ambiguity and decision-making described in the introduction. In the spatial-praxic tasks, the dancer was asked to 'Imagine an abstract 3D volume in space such as a cube - it might or might not have specific properties like texture', and in the emotional tasks 'the personal characteristics of someone you know or know about reasonably well; might be a friend, relative, colleague or a public figure and might relate to how they move; if they are old or young, how they interact with others, express themselves emotionally.' Each imagery and movement creation phase lasted 5 minutes during which we alternated 30 seconds of the experimental task with 30 seconds of a control task (focusing on one's own breath), with the beginning of each 30 second block indicated to the dancer by an appropriate verbal cue i.e., "3D volume" and "familiar person" for the imagery creation phases, "develop ideas" for the movement creation phases, and "focus on breathing" for the control task phases.

The entire scanning session lasted 1.5 hours. Following the scanning itself the dancer was extensively questioned about the nature of imagery constructed as well as nature of the phrases developed.

Data Acquisition and Image Analysis

A 3T TIM Trio System (Siemens, Erlangen, Germany) was used to acquire echo-planar functional images (TR=2.0 s, TE=30 ms, FA=78°, matrix size 64x64, 32 slices each with a 25% gap, giving a voxel size of 3x3x3.75 mm, 11 sessions of 160 volumes). A T1-weighted MPRAGE anatomical volume used 1 mm3 voxels (flip angle=9°; TE=2.00 sec; GRAPPA acceleration factor = 2). Parameters were set to follow Boly *et al*. (2007) in order to be able to compare similarities in the reference non-dance tasks.

Data were analysed using the SPM5 software (www.fil.ion.ucl.ac.uk/spm). The first 10 volumes in each session were discarded to allow for T1 equilibrium. Standard spatial preprocessing comprised realignment to correct for head movement, rigid-body co-registration with the dancer's structural image, nonlinear normalization to the MNI T1-weighted template (2-mm isotropic voxels), and finally, smoothing with a Gaussian kernel of 8 mm FWHM. Raw images and the pattern of activation did not show artefacts that could be related to movement. For each session, events were modeled by convolving onset times with a canonical hemodynamic response function (HRF). Contrasts for each experimental condition were computed using a General Linear model (GLM).

The aim of the non-dance reference task was to familiarize the dancer with the procedure and to confirm that the dancer's brain responses related to imagery. Our *a priori* anatomical hypothesis was based on previous studies using similar tasks. We used a 10-mm radius sphere small volume corrected (SVC) p<0.05 on previously documented coordinates from motor imagery and spatial navigation tasks (Boly *et al*., 2007). For the dance tasks, we also used a small volume correction (with a sphere of 10mm radius) for areas in the action observation literature about which we had an *a priori* anatomical hypothesis. Significant activations outside predicted areas are reported at a corrected significance level of p< 0.05

after correcting for multiple comparisons over the whole brain to control the familywise error rate (FEW), with a cluster threshold of 20 voxels.

Results

On the basis of the post-scan debriefing we established the nature of the images generated in response to the spatial-praxic and emotional instructions and established some broad properties of how movement material that made up the phrases was created and developed. In both the imagery creation phases and static movement creation phases, quite varied and intricate strategies were involved, revealing a number of challenges both for analysis and interpretation. Our design involved two examples of both the spatial-praxic and emotional tasks and our dancer adopted different strategies for mentally creating movement material for the two examples: she imagined a huge intricate volume space and a simple cylinder in the two spatial-praxic tasks; in the two emotional tasks she used visual images of different personally significant people; and in the static movement creation phase she rehearsed the material she had created and then added new elements to the end of that sequence, rehearsed and added again and in this way accumulated material to form a practiced phrase. In one run of the emotional task she adopted a first-person perspective, and in the other run, a third-person perspective. For one run of the spatial-praxic task, she choreographed a solo, in the other run, a duet. This gross variation in cognitive activity between the two runs of each task means that it was not possible to contrast the spatial-praxic and emotional movement creation tasks directly. Our analysis therefore followed three major pathways.

First, we analysed the three non-dance reference tasks to establish consistency with prior research on motor and spatial-praxic imagery (Boly *et al.*, 2007). Second, we examined the pattern of activity involved in each imagery creation and static movement creation task compared to its concurrent control condition (breath focus), to illustrate the extensive brain networks involved in tasks such as this with intricate and varied demands, and also to allow for comparison with other fMRI work with dancers. Finally, we compared imagery creation with static movement creation tasks.

Spatial navigation (navigating around one’s home) activated left pre-supplementary motor area (pre-SMA), supplementary motor area (SMA) and bilateral dorsal premotor cortex (dPMc), parahippocampal cortex, retrosplenial cortex, occipito-parietal junction and precuneus. Motor imagery (playing tennis) activated bilateral pre-SMA, SMA, dPMC, and inferior parietal lobe in the right hemisphere (see complete list of activations in Table S1, in the supplementary material). Somatic imagery (body scan) also revealed a clear signature of activity in bilateral somatic areas along the post central gyrus, however, none of these activations survived corrections for multiple comparisons, and they will not be discussed further. These results were consistent with prior research (Boly *et al.*, 2007), indicating that for this dancer different task instructions did indeed give rise to the expected patterns of differential activation of relevant brain regions.

The spatial-praxis imagery creation task (compared to the control breath focus task) showed activations in a set of regions classically described in the action observation literature (Calvo-Merino *et al.*, 2005). These are the ventral and dorsal sections of the premotor cortex, and the inferior and superior parietal lobe. There was also activation in the middle temporal gyrus, close to the extrastriate body area, and in the orbitofrontal cortex (Figure 5A). These latter activations were also present in the emotional imagery creation task, along with weaker activity in the left superior parietal lobe (Figure 5B; a full list of activations are reported in Tables S2 and S3 in the supplementary material). The emotional imagery creation was generally stronger in the left hemisphere, and lacked the motor/action areas apparent in the spatial-praxic imagery creation.

For brain activity related to static movement creation we predicted a pattern of activation similar to that found in a previous study using whole body dance observation (Calvo-Merino *et al.*, 2005). Accordingly, we performed a small volume correction (SVC) for multiple comparisons using 10mm spheres centred on these areas. We found bilateral activations in dorsal and ventral premotor cortex, superior parietal lobe, intraparietal sulcus and posterior superior temporal sulcus (Figure 6A). Finally, we found stronger activity in right inferior frontal gyrus during the two static movement creation tasks compared to the two imagery creation tasks (Figure 6B). No activations survived correction when conducting the opposite contrast (a full list of activations are reported in Table S4 in the supplementary material).

Discussion

This fMRI pilot investigation evaluated the relationship between neural activations and subjective reports obtained under similar conditions and assessed the feasibility of studying the neural underpinnings of choreographic practice. These preliminary results are based on a single subject, therefore caution should be taken in interpreting and generalising the results. However, the study is based on a previous paradigm with well-established results that were replicated in several participants (Boly *et al.*, 2007). In related paradigms single case studies have pinpointed issues that have proven to be highly significant, as in the report by Owen, Coleman, Boly, *et al.*, (2006) of patterns of differential brain activation following requests to imagine playing tennis or navigating around ones home in a single patient in a vegetative state. The outcome with our dancer confirms feasibility, but obviously broader extension to population characteristics for the neural underpinnings of these types of imagery would require follow-up work with group designs. As noted in the results section, our three non-dance reference tasks supported the core validity of the overall fMRI procedure with respect to the involvement of different neural network components for different task instructions.

Our fMRI data showed that the spatial-praxis and emotional imagery tasks shared activations in orbitofrontal cortex, middle temporal regions and occipital cortex. The orbitofrontal cortex has often been linked to sensory integration, in representing the affective value of reinforcers, and in decision-making and expectation (Kringelbach, 2005). Common brain activations in middle temporal regions may reflect perceptual expertise responses usually associated with the nearby extrastriate cortex. This region is thought to hold a human body representation (Downing *et al*., 2001) as well as a dynamic action representation (Downing *et al*., 2006) that may have contributed to both imagery creation and static movement creation. Spatial-praxis imagery creation showed additional activation in the premotor and parietal cortices suggesting that sensorimotor representations were being used, even though motor behaviour was not being explicitly imagined. Although based on a single dancer, our results are nonetheless in broad agreement with previous motor imagery studies (Iacoboni *et al*., 1999; Grèzes and Decety, 2001; Calvo-Merino *et al*., 2005).

The activity related to static movement creation showed a very similar pattern of activity to the imagery creation tasks, showing how important imagery creation is in movement creation. Analysis of the peak coordinates indicated that brain regions participating here were the same as those in studies where expert dancers watch familiar dance movements (Calvo-Merino *et al*., 2005). The only major difference found between movement creation and imagery creation was an increased activation of the right inferior frontal gyrus, which has been associated with representations of goal directed actions in movement observation and execution (Iacoboni *et al*., 1999). Moreover, this area has also been related to inhibition of prepotent responses (Christopoulos, Tobler, Bossaerts *et al*., 2009), but also in the multiple-demand network (Duncan, 2010), which is activated by many different cognitive demands including perceptual difficulty, novelty, and response conflict. While it is possible that this activity reflects the novelty for our dancer of creating movement while remaining stationary, and having to inhibit her own movement, it could also reflect the need to synthesise different and novel ideas about movement to complete the movement creation task, as the subjective reports from Experiment 1 suggested. While these data do provide some general support for the idea that both imagery and movement creation tasks are grounded in some elements of physical or action based thinking, they also raise some key questions concerning the wider mental context in which such thinking occurs and, given the clear limitations of the current fMRI and experience sampling work, how future research might usefully be directed. The variety of strategies adopted within each task by our very creative dancer, which prevented our direct comparison of spatial-praxic and emotional movement creation tasks, also shows that it is necessary either to impose clearer constraints upon the experimental tasks (e.g., to adopt a first-person perspective for one's own dance, rather than a third-person perspective of other dancers), or if time and resources allow, to collect data from several runs in order to maximize task specific variations in relation to general variation in brain activity.

An interesting illustration of how our findings might be further pursued concerns creativity. The neuroscience literature has given rise to considerable speculation concerning the role in creativity of the orbitofrontal and dorsolateral frontal areas implicated here in imagery and movement creation. For example, Jung *et al*. (2010) showed that cortical thickness in the left lateral orbitofrontal cortex correlates with higher creative achievement, while Limb and Braun (2008) showed a *deactivation* of dorsolateral frontal regions during jazz improvisation. The latter finding highlights a potential contrast with our own data that might be pursued in further research. Our movement creation tasks, as evidenced by both the experience sampling and fMRI data, appear to have large decision-making components. In post-task debriefing our dancer noted that the movement creation phases involved attempting to remember the movement sequence. In contrast, perhaps jazz or movement improvisation may minimise demands on memory and decision-making. It would follow that a direct comparison of dance improvisation and phrase creation in the scanner should show differential activation of dorsolateral frontal cortex. Such a finding, if realised, would support task-dependent activation not unlike the task dependence evidenced in our earlier experience sampling study. Choreographic thinking will quite likely depend on a variety of neural components recruited in a task dependent manner and the exact nature of the dependence is, on the basis of this pilot work, clearly open to hypothesis development and direct test.

Conclusion

Taken together, the two exploratory studies that we present here indicate that the neural and experiential attributes of imagery associated with movement creation are open to systematic investigation – movement creation can start from alternative points in mental space as well as physical space. This enables us to look forward to establishing with greater precision how tasks that challenge dancers in different ways may affect mental and neural processes and how variation in imagery use *across* dancers might contribute to differences in the movement that they create. Notably, the act of reflecting on the experience of movement creation also offers some practical leverage to help dancers develop a wider range of strategies for innovation. The dancers in Experiment 1 initially gave high ratings for their use of intuitive feelings to guide their movement creation, but in practice were able to identify more specific content for their thoughts, indicating that their movement creation is a skilled and intentional activity in which they form an idea at the outset and attempt to base their movement upon this initial representation. Individual dancers varied in the forms of imagery that they reported: future studies could compare dancers' preferred forms of imagery and standard measures of imagery vividness across a variety of forms of imagery (going beyond conventional measures of visual vs. motor imagery).

The differences between static and active movement creation found in Experiment 1 should make researchers cautious about drawing inferences from fMRI studies such as that reported in Experiment 2, because it is clear that choreographic movement creation is an embodied cognitive activity, in which the mind and body interact. Constraining the dancers to remain static changed the nature of their mental experiences and the content of their thoughts, making it harder for them to maintain a focus upon their original imagery and decreasing the amount of abstract propositional conceptualisation. The thought monitoring showed that the mental consequences of movement creation while static depended upon the task instructions the dancers were following (i.e., spatial-praxic or emotional) and so this also needs to be well defined. Nevertheless, the extensive recruitment of motor and decision making areas evident in the fMRI data encourages us to conclude that both approaches can yield valuable insights into the nature of creative choreography. Perhaps most importantly, our two studies emphasise the need for subjective as well as objective sources of evidence to be obtained, and for the need to consider the connections between subjective and objective measurement, as well as what any patterns that emerge from the comparisons might imply for choreographic practice.

Soon after participating in the two exploratory studies, McGregor and the company spent three weeks in residence at the Experimental Media and Performing Arts Centre, Troy, NY and the Chicago Dance Center working on the Choreographic Thinking Tools with the same background theory (ICS, Barnard 1985; Barnard *et al.* 2007) and using revised experience sampling and thought probes as a reflective tool for the dancers. The residency resulted in a working process the dancers could use to enhance their use of imagery in movement creation. The basics of this process involve a method of working with sources of inspiration or stimuli, extracting properties and strategies to translate these properties into movement material. What this does is free the individual dancer to make intuitive discoveries of novel movement material, and to be able to reflect on their process of movement creation. It also develops in trained dancers the ability to recognize ingrained movement patterns and to make unusual or perhaps even surprising choices in the creation process.

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List of Tables:

Table 1. Design of Experiment One. Dancers were divided into two groups to balance order of task instructions. Group A completed spatial-praxic tasks (S-P) followed by emotional tasks (Emo); Group B completed emotional followed by spatial-praxic tasks. EIS: Experience and Imagery Scales

Table 2. Summary of ANOVA results from Experiment One. All effects where *partial* η^2>.10 are listed; *ns* indicates *p*>.05. Partial η^2 is a measure of effect size: Cohen (1988, p.283) suggests that .01 is a small effect, .06 a medium effect, and .14 a large effect.

Table 1

Day One: EIS scales	min	measures	A	B
Typical Ratings	10			
Active Task	36	Practice scales after 4 min EIS :12, 20, 28 and 36 mins	S-P	Emo
Static Task	32	EIS : 8, 16, 24 and 32 min	S-P	Emo
Rehearse Static piece	5			
Perform Static piece	5			
rest break	20			
Active Task	32	EIS : 8, 16, 24 and 32 min	Emo	S-P
Static Task	32	EIS : 8, 16, 24 and 32 min	Emo	S-P
Rehearse Static piece	5			
Perform Static piece	5			
Day Two: Thought Probes				
Active Task	40	Practice probes: 5, 10 mins Probes: 15, 20, 25, 30, 35, 40 min	S-P	Emo
Static Task	30	Probes: 5, 10, 15, 20, 25, 30 min	S-P	Emo
Rehearse Static piece	5			
Perform Static piece	5			
rest break	20			
Active Task	30	Probes: 5, 10, 15, 20, 25, 30 min	Emo	S-P
Static Task	30	Probes: 5, 10, 15, 20, 25, 30 min	Emo	S-P
Rehearse Static piece	5			
Perform Static piece	5			

Table 2

	Task		*Mode*		*Task x Mode*	
Scale	*F* *(1,7)*	*p; partial* η^2	*F* *(1,7)*	*p; partial* η^2	*F* *(1,7)*	*p; partial* η^2
Stuff out there	--		--		--	
— Sounds/sights	6.91	.034; .50	11.92	.011; .63	--	
Intuition	8.24	.024; .54	1.40	ns; .17	1.47	ns; .17
— Spontaneous/guided	--		--		1.86	ns; .22
— Emotional/not emotional	5.65	.049; .45	--		10.18	.015; .59
Body Sensation	--		2.07	ns; .23	1.16	ns; .14
Spatialpraxis	--		--		2.76	ns; .28
Emotions	--		--		22.23	.002; .76
Verbal thoughts	--		--		--	
Propositions	--		2.28	ns; .25	--	
Limb/Muscle Urge	--		--		--	
Use of Imagery						
Imagery forefront	--		--		1.42	ns; .17
Reconstruct imagery	--		6.42	.039; .48	1.06	ns; .34
— Spatiopraxic vividness	1.20	ns; .15	--		1.42	ns; .17
—Third person	--		3.07	ns; .31	--	
Senses of meaning	2.90	ns; .29	--		1.11	ns; .14
Familiar movement	4.21	ns; .38	--		1.25	ns; .30
Decisions						
original imagery	7.53	.029; .52	--		1.50	ns; .26
feel good	5.74	.048; .45	--		5.87	.046; .46
other thinks	--		--		--	
happy	1.86	ns; .21	9.25	.019; .57	2.63	ns; .27

List of Figures:

Figure 1: Mean ratings for dancers' 'typical experience' of creating movement (grey bars, showing mean +/- one standard error), and their ratings while completing the four exercises (means and standard errors). Solid symbols indicate active tasks; empty symbols the static tasks; circles indicate spatial-praxic tasks and diamonds the emotional tasks. If a point is below the grey bar, then it is being experienced less than the dancers' typical experience. If it is above the grey bar, then it is being experienced more than typical.

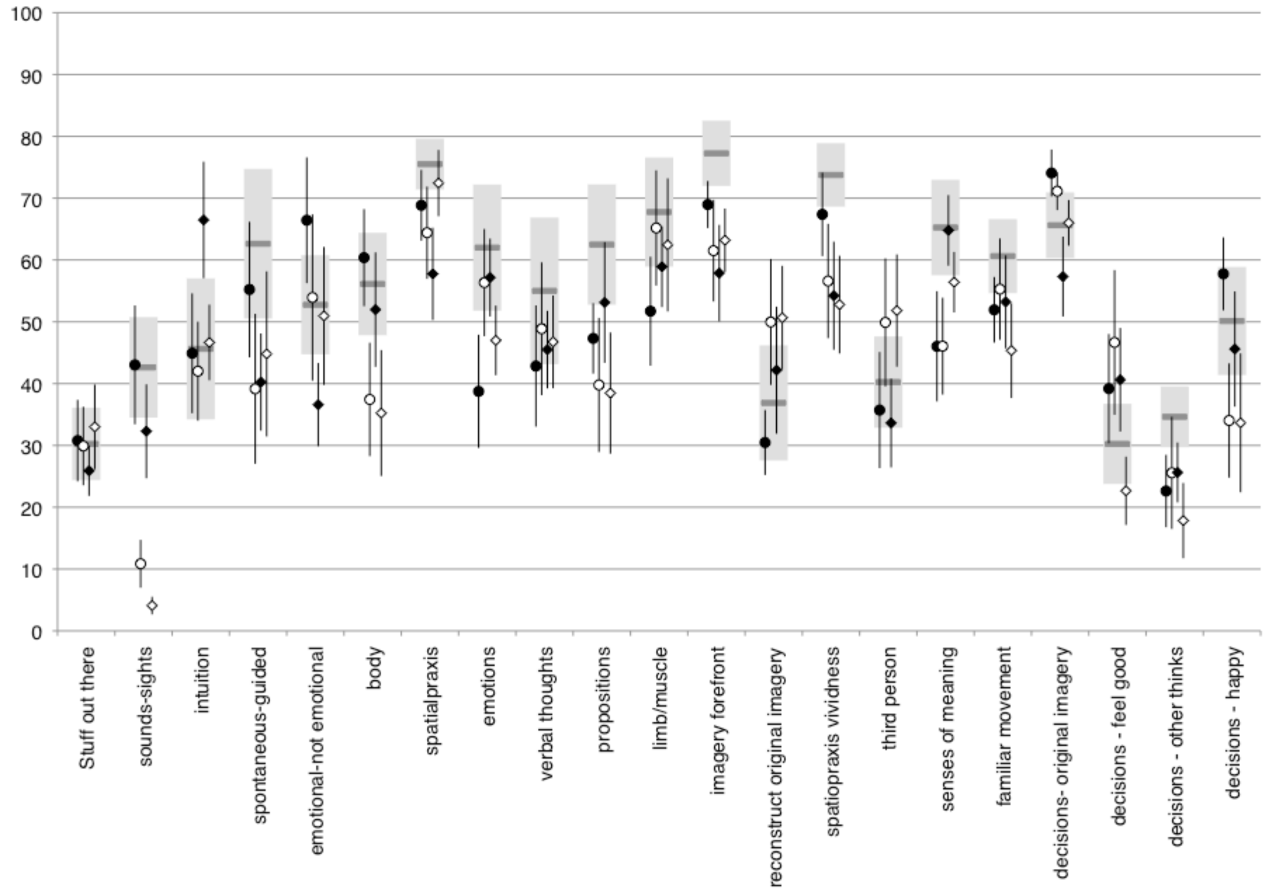
Figure 2: Overall Proportion of thoughts probed by category. Verbal thoughts are most frequent; intuition, proposition, emotion and limb/muscle thoughts rarest.

Figure 3: Compared to active movement creation (grey lines), in static movement creation (black lines), the spatial-praxic task (left diagram) showed fewer verbal thoughts, propositional conceptualisation and bodily sensations, and more spatial-praxic and emotional thoughts. The emotional task (right diagram) also showed less propositional conceptualisation, together with less limb/muscle planning, but more verbal thoughts and awareness of events in external space.

Figure 4. Design of Experiment 2: For each of the three reference tasks, the dancer completed five 30s blocks of imagery creation, alternating with 30s of the control breath focus task. For the dance related tasks, the dancer completed five 30s blocks of imagery creation alternating with breath focus, followed by five 30s blocks of movement creation, also alternating with breath focus.

Figure 5. Brain rendering of areas that showed activity during (A) spatial praxis imagery creation and (B) emotional imagery creation, both relative to the control breath focus task. (1a, 1b) bilateral premotor cortex, (2) superior parietal lobe, (3) middle temporal gyrus (4a, 4b) orbitofrontal cortex ($p<.0.05$, whole brain corrected. Projections of the activation foci on the surface of standard brain (Montreal Neurological Institute, MNI).

Figure 6: Brain rendering of areas that showed greater activity during static movement creation relative to (A) control breath focus task and (B) imagery creation task. (1a, 1b) bilateral premotor cortex, (2) superior parietal lobe, (3) middle temporal gyrus, (4) right inferior frontal gyrus. ($P<.0.05$, whole brain corrected. Projections of the activation foci on the surface of standard brain (Montreal Neurological Institute, MNI).



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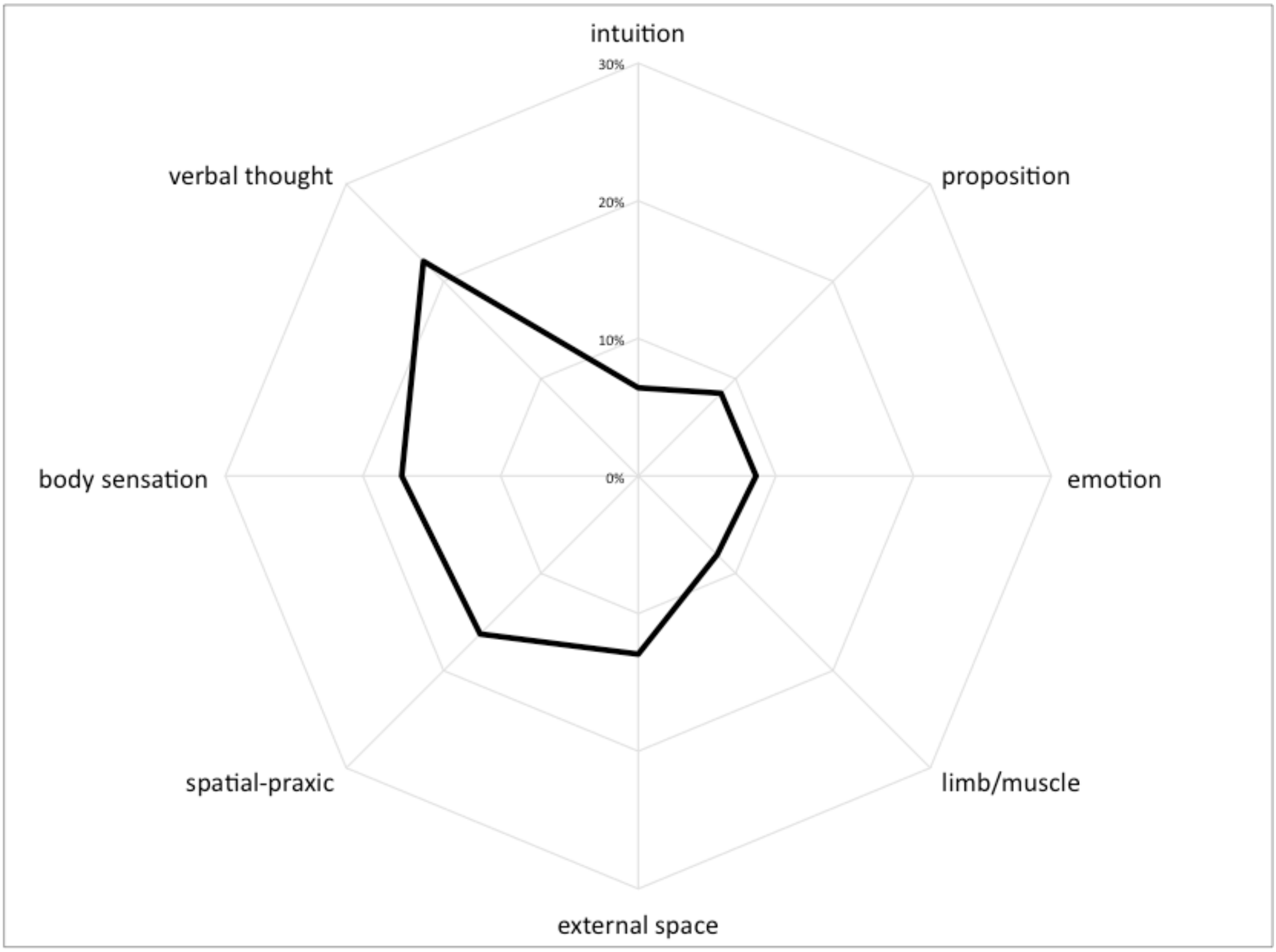

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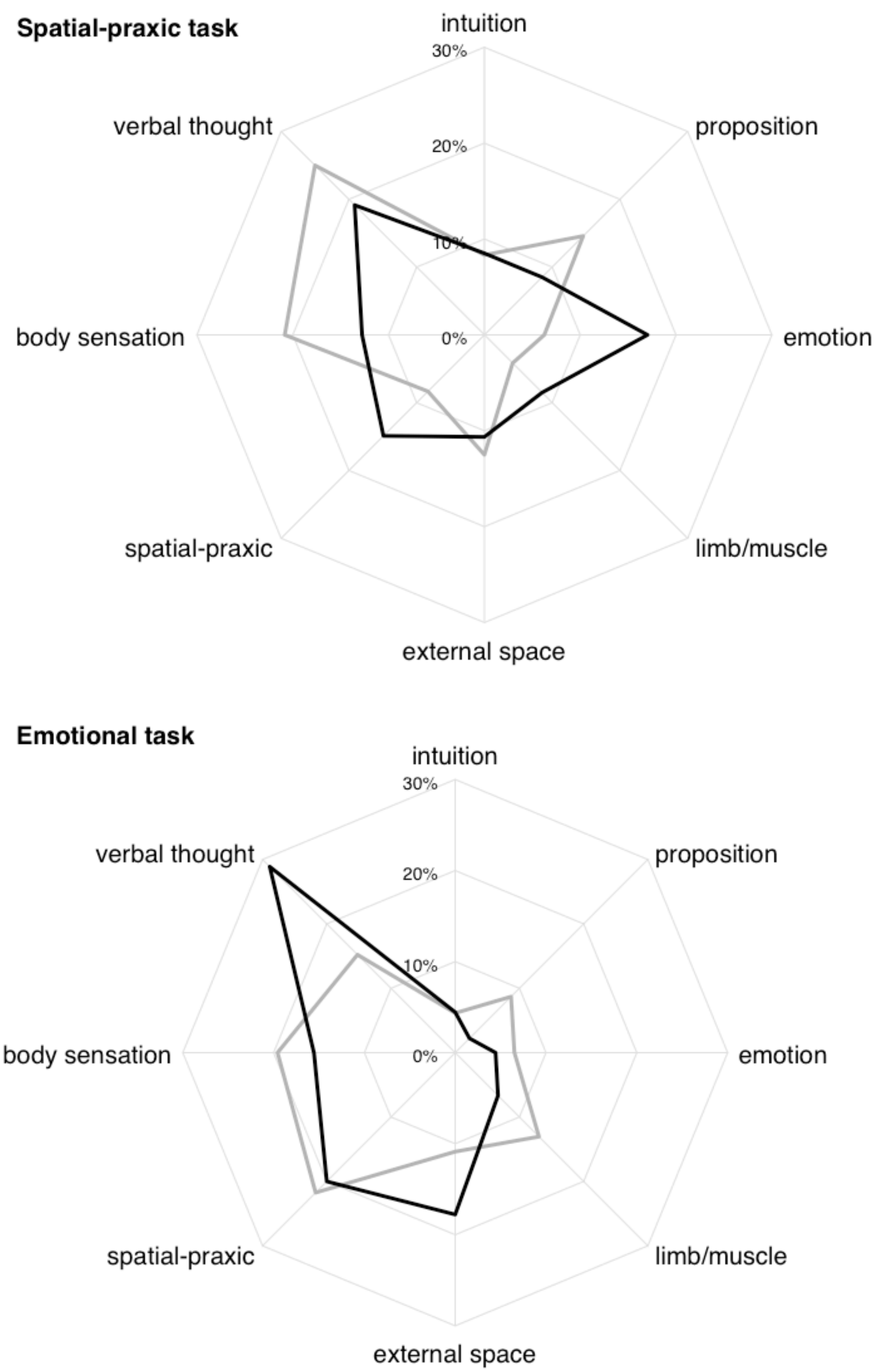

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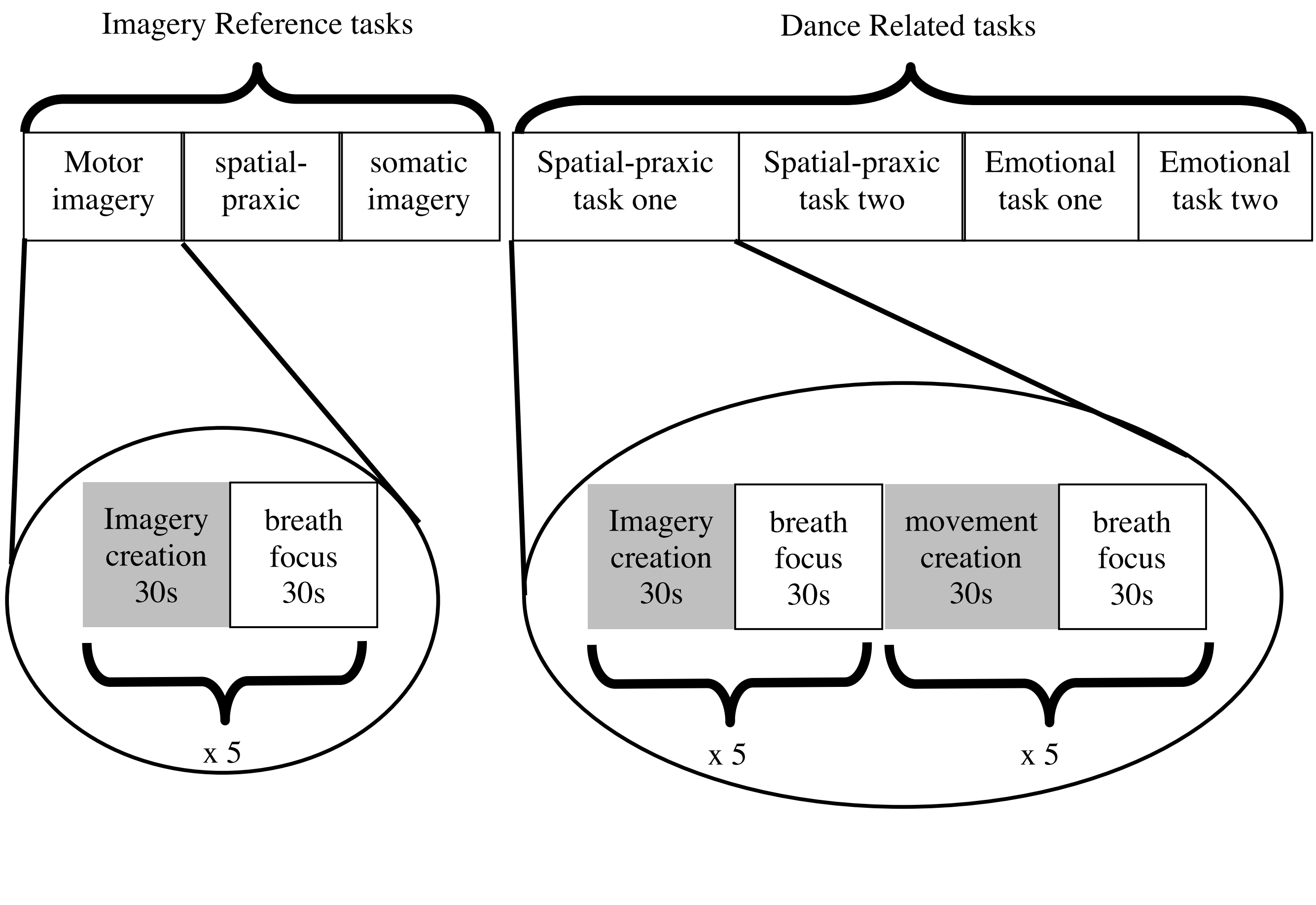

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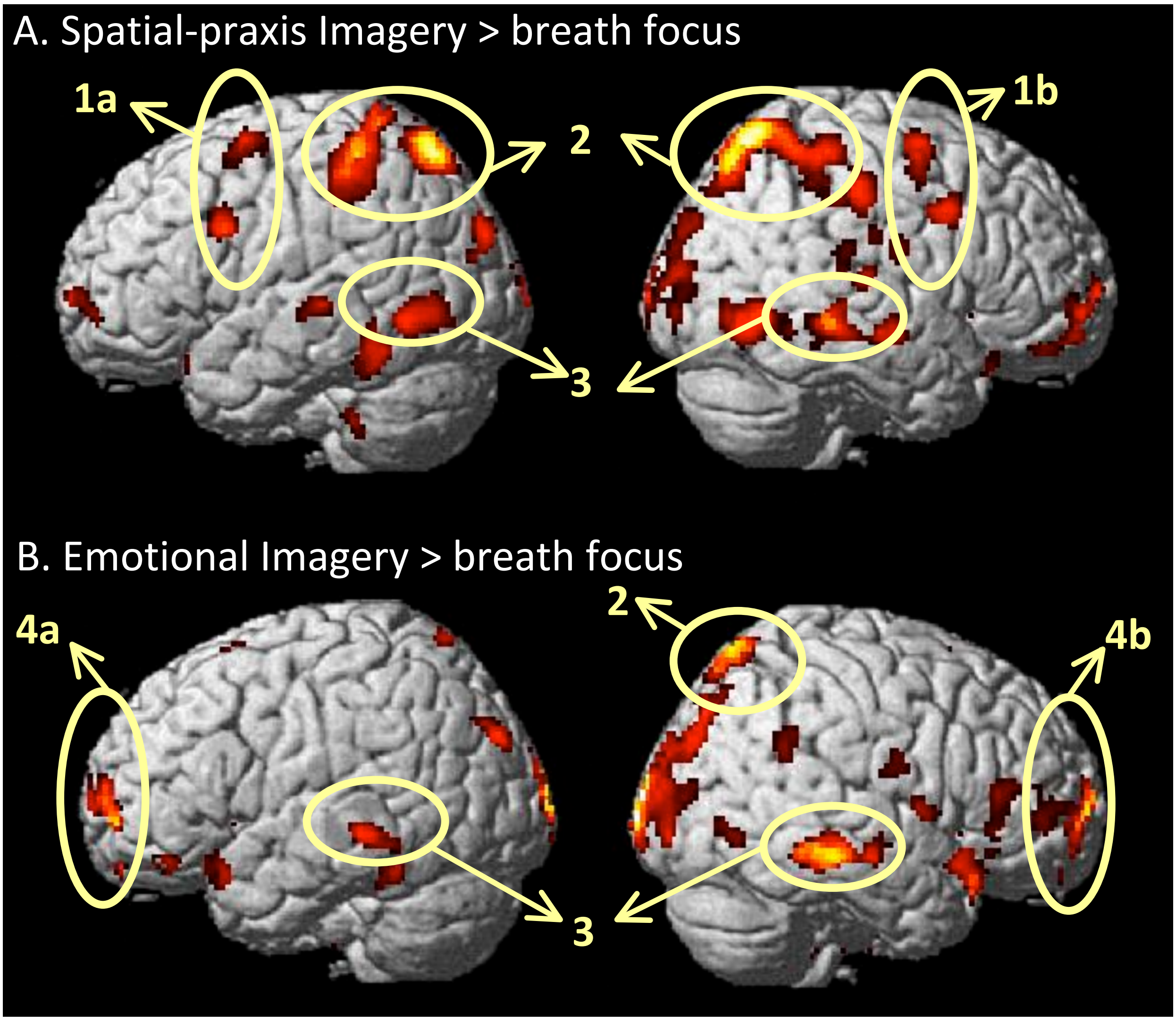

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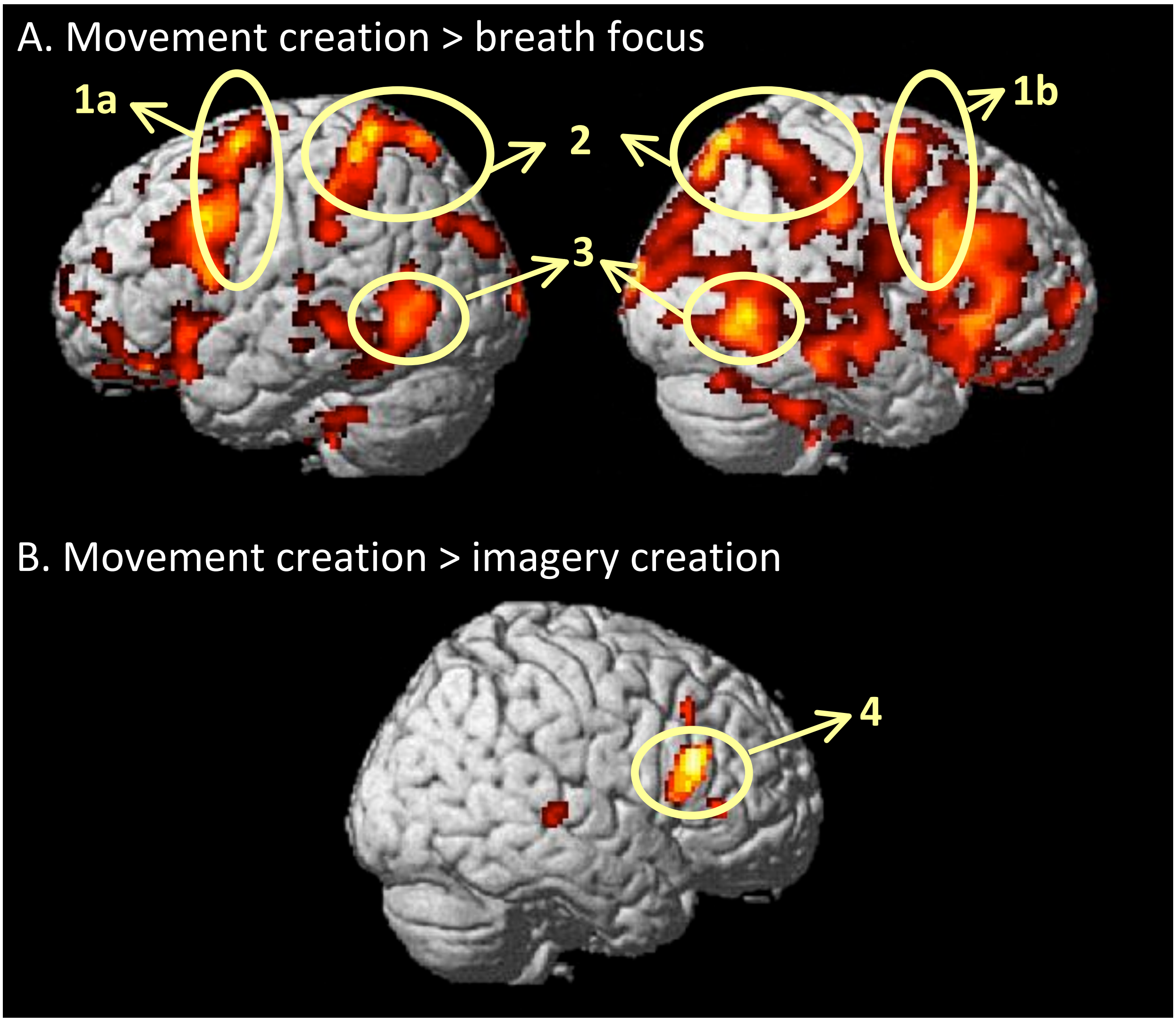

List of Supplementary Material:

Appendix A: the Experience and Imagery rating scales used in Experiment 1

Appendix B: Brain Region activations from Experiment 2.

Video Clips from Experiment 1: Extracts from the creative documentary "Wayne McGregor, going somewhere" by Catherine Maximoff, produced by lesfilmsduprésent – 2011.

<http://www.lesfilmsdupresent.fr/2011/wayne-mcgregor---going-somewhere/>

Clip 1 (maximoff clip 1 512.m4v)

Wayne McGregor instructs the company with a spatialpraxic task which they then use to create movement in the static mode, while periodically being asked to complete the rating scales (7.2 Mb, 1m 40s).

Clip 2 (maximoff clip 2 512.m4v)

While actively creating movement, the dancers are asked to stop moving to complete some rating scales. The clip then shows them performing the pieces created. (8.3Mb, 1m 55s)

Clip 3 (maximoff clip 3 512.m4v)

In the debriefing session, the dancers explain how they felt about the day’s tasks (9.5 Mb 2m 40s)

APPENDIX B

Participant number:_______ Exercise number _______ and Stop 1 2 3 4 5 6

Judgements of mental experiences in the last period of making

First focus on the "types" of different mental experiences you had during the last period of making and place a mark on each bold line below. Think about a scale that runs from

Never to *Very rarely* to Quite often to *Often* to *Very Often* to *Most of the time*

Base your answers on the last period of making not what you "generally do"

STUFF OUT THERE

I was focussed on things going on around me in the space rather than my own mental imagery

Never ____ Most of the time

When focused on things in the space they were — n/a ☐

sounds ____ sights

INTUITION

I felt I was just moving intuitively

Never ____ Most of the time

When moving intuitively in the last period it typically felt — n/a ☐

Unguided or Spontaneous ____ Guided by latent plan

Emotional ____ Not emotional

BODY SENSATION

I was focused on physical sensations in my body – e.g. sensations in my limbs or torso etc.

Never ____ Most of the time

SPATIALPRAXIS

I was aware of a mental focus on spatial/visual-like images in my mind's eye

Never ____ Most of the time

EMOTIONS

I was aware of a mental focus on emotional experiences related to my movement (senses of ***specific*** emotional qualities or positive/negative feelings about what I was doing)

Never ____ Most of the time

VERBAL THOUGHTS

I was aware of verbal thoughts in my mind about what I was doing

Never ____ Most of the time

PROPOSITIONS

I was aware of concepts (non-emotional) about what I was doing ***that felt quite specific but did not come as words or visual images***

Never ____ Most of the time

LIMB/MUSCLE URGE

When not actually moving, I was aware of a mental focus on **physical** imagery of controlling bodily movement

Never ____ Most of the time (when not moving)

Write down anything else that you think was an important aspect of your overall experience	I was aware of

NOW TURN OVER 1

Use of imagery in creative work and decision-making Note different scales now across items

How often was the specific imagery you created at the outset (or elements of it) in **the forefront of** your mind?

Never ______________________________ Most of the time

How hard was it to bring back to mind and reconstruct your original imagery while developing movements?

Very little effort ______________________________ A great deal of effort

If spatial-praxic imagery was involved, then how vivid was your imagery?

n/a ☐

Not at all vivid ______________________________ As vivid as real life

If spatial-praxic imagery was involved, how much of your visual imagery included seeing ***yourself*** in your own mental picture but **from someone else's perspective**?

n/a ☐

None of it ______________________________ All of it

How often did senses of meaning linked to your initial imagery come into the forefront of your mind?

Never ______________________________ Most of the time

How often did you notice that a movement you produced felt familiar (from a prior performance or just moving habitually)

Never ______________________________ Most of the time

How many of your individual decisions involved making some mental reference to your initial imagery?

None of them ______________________________ All of them

How many of your individual decisions were based entirely on how good a movement felt as a part of your phrase without mental reference to anything else at all?

None of them ______________________________ All of them

How many of your individual decisions involved discarding or selecting material on the basis of what you thought someone else might think about them (i.e. a "significant " actual or potential observer)?

None of them ______________________________ All of them

How many of your decisions were you happy with?

None of them ______________________________ All of them

Please check you have answered all items

Write down anything else that you think was an important aspect of your use of imagery in decision making that you would like us to know

APPENDIX B

Table S1: Areas predicted that survive $p < 0.05$ small volume correction using a 10mm sphere over coordinates from a previous study (Boly *et al*., 2007).

Brain regions	MNI coordinates			Z -score
	x	*y*	*z*	
Tennis > breath focus				
R Pre-SMA	12	4	56	5.19
L Pre-SMA	-18	0	64	>7.9
R Dorsal premotor cortex	32	0	58	7.47
L Dorsal premotor cortex	-28	-2	56	5.65
SMA	0	-10	58	4.35
R Inferior parietal lobe	46	-36	38	4.10
Spatial navigation > breath focus				
L Pre-SMA	-4	16	42	6.02
R Dorsal premotor cortex	20	0	56	>7.9
L Dorsal premotor cortex	-28	2	56	6.65
R Parahippocampal cortex	32	-30	-32	4.35
L Parahippocampal cortex	-20	-38	-20	5.19
R Retrosplenial cortex	12	-56	8	6.39
L Retrosplenial cortex	-6	-50	2	4.47
R Occipito-parietal junction	22	-64	22	7.84
L Occipito-parietal junction	-26	-84	26	>7.9
R Precuneus	-24	-82	40	6.49
L Precuneus	28	-78	44	>7.9

Table S2: Brain responses significantly stronger during spatial-praxis imagery creation. These activations survived corrections for multiple comparison across the whole brain at $p < 0.05$. L/R: left and right hemispheres. Only activations in excess of 20 voxels are listed.

Brain regions	MNI coordinates			Z -score
	x	*Y*	z	
Spatial-praxis imagery > breath focus				
R Superior parietal lobe	20	-66	62	>7.9
L Precuneus	-18	-68	62	>7.9
R Inferior temporal gyrus	56	-70	-8	>7.9
L Precentral gyrus	-30	-44	58	>7.9
R Middle temporal gyrus	70	-40	-8	7.51
R Superior frontal gyrus	28	-2	60	7.39
L Middle temporal gyrus	-54	-62	-2	7.23
L Precental gyrus	-54	10	30	6.58
L Superior frontal gyrus	-22	-4	58	6.71
L Middle Occipital gyrus	-30	-88	30	6.69
R Precentral gyrus	52	8	36	6.57
R Superior medial gyrus	14	48	4	6.48
R Postcentral gyrus	68	-10	20	6.16
L Inferior temporal gyrus	68	-28	22	6.12
L Middle temporal gyrus	-68	-22	-2	5.79
L Cerebelum	-36	-40	-40	5.59
R superior temporal gyrus	56	-22	10	5.48
Middle cingulate	12	16	44	5.37
R Supramarginal gyrus	56	-18	26	5.28

Table S3: Brain responses significantly stronger during emotional imagery creation. These activations survived corrections for multiple comparison across the whole brain at p < 0.05. L/R: left and right hemispheres. Only activations in excess of 20 voxels are listed.

Brain regions	MNI coordinates			Z -score
	X	*y*	z	
Emotional narrative > rest				
R Superior parietal lobe	18	-68	66	>7.9
L Mid orbital gyrus	-6	60	-4	7.84
L Middle orbital gyrus	-22	42	-16	7.02
R Middle temporal gyrus	54	-30	-10	6.98
R Inferior frontal gyrus	58	36	12	6.28
L Precuneus	-10	-66	70	6.08
L Fusiform gyrus	-44	-42	-20	6.06
L SMA	-4	14	62	6.01
L Temporal pole	-48	18	-20	5.67
L Middle temporal gyrus	-62	-36	-6	5.63
R Postcentral gyrus	68	-4	26	5.61
R Middle cingulate	12	20	38	5.47
R Precuneus	20	-60	24	5.42

Table S4: Areas that survive p< 0.05 small volume correction using a 10mm sphere over coordinates from a previous study using observation of whole body dance movements (Calvo-Merino *et al*., 2005). For non-predicted areas, only activations in excess of 20 voxels are listed in this section of the table. L/R: left and right hemispheres.

Brain regions	MNI coordinates			Z -score
	x	*y*	z	
Movement creation > breath focus				
Predicted areas (SVC)				
L Superior precentral gyrus	-24	2	64	>7.9
R Superior precentral gyrus	30	0	62	>7.9
R Superior parietal lobe	16	-66	62	>7.9
L Superior parietal lobe	-14	-68	64	>7.9
R superior parietal lobe/ intraparietal sulcus	-32	-44	58	>7.9
Intraparietal sulcus/ Postcentral sulcus	36	-42	46	>7.9
L Precentral gyrus	-54	8	40	>7.9
R Precentral gyrus	54	14	38	6.88
L posterior superior temporal sulcus	-42	-74	36	5.56
Non predicted areas (corrected P < 0.05)				
L SMA	-2	18	50	5.92
R Inferior frontal gyrus	50	20	26	6.00
R Caudate nucleus	20	8	14	5.08
R superior occipital gyrus	18	-102	14	5.75
R Inferior frontal gyrus	48	34	10	5.71
L Insula lobe	-32	22	6	5.59
R Middle temporal gyrus	58	-60	2	7.19
L Putamen	-24	6	2	5.83
R Superior media gyrus	12	62	0	6.48
L Middle temporal gyrus	-54	-62	0	6.80
R Inferior frontal gyrus	30	32	-10	5.76
R Superior temporal gyrus	62	-8	-10	5.32
L Middle orbital gyrus	-22	40	-16	6.99
R Inferior temporal gyrus	62	-34	-20	6.50
R Temporal pole	42	24	-20	5.58