Quantifying dance in the audience's mind: a methodological quest for neuroscience research

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Chapter 18

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Abstract

Audience research in the domain of neuroscience has advanced our understanding of how spectators process what they see on stage. The focus of this kind of research is primarily on the functioning of the human brain and behaviour, irrespective of spectators' lived experience. The widely used theoretical underpinning is the mirror neuron network, which manifests itself through a correspondence between the neuronal activities of a passively watching audience member with that of the performer, as if the spectator was internally mirroring the actions seen on stage. It thus links to ideas of a shared sensorimotor experience between spectator and performer, which has a long tradition in the performing arts discourse in terms of audiences' kinaesthetic experience. Research showed that this experience is dependent on personal preferences, expertise and personality. One could thus argue that what is of particular interest is the spectacle that takes place in the audience's mind. Accordingly, the cultural, formal and qualitative aspects of a performance constitute an important methodological factor. This chapter provides an overview of the conditions of scientific technologies employed; and explains how these contradict principles of creative and cultural practices of the performing arts, which has led to shifts in methodological discussions.

The Experience of a Performance

> *I can take any empty space and call it a bare stage. A man walks across this empty space whilst someone else is watching him, and this is all is for an act of theatre to be engaged. (Brook 1968*)

A defining element of a performance is the spectator (Brook 1968). Watching others is ingrained in our culture and can give us a unique sense of our existence. Many of us share the experience of having seen a performance that touched us profoundly, shaping not only how we see the world around us, but also how we experience ourselves. Yet, how exactly can a performance have this effect? What impacts and possibly transformative effects does watching the performing arts have on our bodies and minds? And given the numerous unanswered questions about how a spectator experiences a performance, what kind of answers can neuroscientific audience research provide?

In this chapter, I discuss neuroscientific research on audiences to the performing arts, with a particular focus on dance. I will thus use the term 'dance' throughout to refer to any style of dance or type of performance in a theatrical setting or outdoor space that includes various manifestations of non-participatory audience events. This can range from conventional western classical ballet to physical theatre as well as political actions or cultural events, but is limited to those contexts where a distinct part of the dance entails a physically passive audience that consumes the actions choreographed to be witnessed. The aim of this chapter is to exemplify the technological, methodological and contextual constraints of brain imaging research of such dance performances. It includes an overview of the effects that design decisions can have on the observations and interpretations of audience experiences.

In general, it is important to put research findings into context. This includes the subject studied as well as the research disciplines and methodologies involved. Once the possibilities and limitations of research methods are understood, they can be developed further. One objective of this chapter is thus to provide a thorough examination of the appropriate use of neuroscientific methodology in the context of audience research in a manner that supports the understanding of researchers from different disciplines. It is important for disciplines to come together, as increased communication between disciplines is likely to offer new insights and ideas. Yet for this to be successful, each discipline is required to grasp the other's underlying assumptions. For example, research that seeks to evaluate the social, cultural and ecological value of audience experiences can and should inform neuroscientific research about critical aspects that might have been missed otherwise. Recognising some of the cause-and-effect relationships that cross over discipline boundaries between dance and neuroscience can ultimately advance neuroscience in unexpected ways, as well as support the creation of novel and innovative audiences and performance practices. Moreover, with the increasing use of neuroscience-inspired policymaking in areas such as audience experiences, it is important to understand how neuroscientific findings are inextricably linked with the chosen methodology. For many, the neurosciences and the performing arts are a desirable pairing. Yet present misconceptions need to be addressed, for the relationship not to hamper their outcomes for researchers and audiences alike.

The Disciplines: Neuroscience and the Performing Arts

> The aim of science is precisely to search for the truth and that, in spite of difficulties and limited successes; it even manages to approach it.' (Veronesi 2014 on Popper)

The sciences and the performing arts are both 'end-gaining' practices: the sciences aim for published manuscripts; the performing arts for public performances. However, the conditions under which audiences gauge the outputs differ vastly. The sciences aim to find the truth, and communicate how closely a study managed to approach it, whereas the performing arts transmit emotions, sensory or cognitive experiences to an audience (Reason and Reynolds 2010), often aiming to instigate personal or societal transformations.
One might think that by using appropriate scientific methodologies one could measure, understand and eventually predict an audience's reaction. However, the sciences study

complex problems through their individual parts. For the sciences, a performance with a small set of clearly defined and controlled parameters would be ideal. In other words, the sciences link controlled visual, auditory, or tactile presentations (i.e. the 'stimulus') with neuronal activity (i.e. the 'response'). But few dance performances exist that would work with those selective, controlled criteria.

Indeed, whilst dance has received great attention from the neurosciences over the last decade (e.g. Bläsing et al. 2012; Karpati et al. 2015); it has – in particular in the early studies – been employed in such a reductionist manner that the stimulus examined and represented as 'dance', was almost not recognisable as dance (see Jola et al. 2012). Notably, very few studies can give the reader access to the stimulus material. Yet the stimuli are crucial to evaluate and situate the research findings. What is evident from much of the information that is available, is that basic aesthetic, choreographic, dramaturgic, action component characteristics (e.g. 'efforts'), and historical facets as well as individuals' cultural heritage, are commonly neglected. Yet, in the performing arts, it is these factors that are of importance in the process of creation and reception. Also, as performances are aimed to affect the spectator as a whole, and the overall audience experience includes the scenography, lighting, music, physical characteristics of the dancers, costumes and more (e.g. Vukadinović and Marković 2012), it is questionable whether scientific findings orientated around 'partial experiences' can provide insight into audience experiences comparable to real life. In other words, is it possible to grasp the experience as a whole when presented with tampered parts?

It is also interesting to consider that some choreographers themselves use what might be considered a reductionist approach in order to create new audience experiences. For example, dancers artificially restrict their movement possibilities (e.g. during improvisation), to find new innovative expressions; or a choreographer might contrast two parameters in a conceptual performance. Since we know that artists employ a reductionist approach to create a new audience experience, a reductionist approach employed by the sciences can be assumed to also change the audience experience. Although novel technological approaches allow us to 'look into' audiences' brains, such methodological questions remain largely unanswered (see Dance in Context). Indeed, being able to see audiences' neuronal responses to watching a spectacle is exciting; but often comes at the cost of a critical discourse on the subjects of the study.

The question 'what do audiences see?', 'how does an artwork communicate meaning to an audience?', or 'in which ways are art works transformative for the individual and the community?' are pertinent for those with an interest in either the performing arts or the human brain and behaviour. Yet employing one type of brain imaging technology, the questions might be reduced to 'which brain areas show enhanced activity when watching ballet compared to watching hip hop'? Another technology would again change the question, to ‘do ballet spectators watch hip hop with their ballet-trained gaze?’, or ‘does hip hop sound alone produce motor simulation?’ The questions, in other words, must not only segment the holistic audience experience into ever smaller parts, but also be formulated according to the technology used. The challenge is not only to pose discipline-specific and meaningful questions, but also to decide which method is most suitable to study what audiences see, feel, and think.

The Performance: From Artificial Laboratory-based Stimuli to Aesthetically Valid Performances

The theoretical underpinning of the majority of neuroscientific studies on watching dance is the mirror neuron network. Mirror neuron activity manifests itself through a correspondence between the neuronal activities of a passively watching audience member with that of a performer, that is: *as if* spectators were mentally mirroring the actions seen on stage. In the early studies on the mirror neuron activity in dance, the specificities of the cultural practice, type and quality of the works were rarely considered. The following discussion seeks to illustrate the complex tensions that exist in the relationship between laboratory-based experiments and real-world phenomena.

For example, in their seminal study, Calvo-Merino and colleagues (2005) measured how professionals’ physical expertise in ballet or capoeira influences the brain activity during passive observation of a selection of moves from those dance styles. The authors found that when dancers watched the movements for which they had acquired motor familiarity compared to movements they were not physically familiar with, a set of bilateral (i.e. premotor cortex, intraparietal sulcus on both hemispheres) and unilateral (right superior parietal lobe and left posterior superior temporal sulcus) brain areas showed higher activation, in line with the mirror neuron network. This study was remarkable at the time, since the clips showed complex abstract actions of the whole body, not just simple actions of an individual body limb. Yet, it lacked any discourse on the cultural differences between ballet and capoeira, as well as the consideration of participants’ experiential engagement. Albeit the movements were selected to match in criteria of speed, part of the body employed, body location in space and direction of body movement, ballet and capoeira use different dynamic qualities. A later investigation based on the same data set showed indeed that for novices (i.e. non-dancers), there is a difference in the sensorimotor aesthetic experience and cortical activity in response to the different qualities with which the movements were executed. More agitated moves, such as jumps, were liked on average more. Watching these movements also corresponded with increased cortical activity in visual and motor related areas of the spectator (Calvo-Merino et al. 2008). Notably, different forms of dance entail different types of moves, each activating particular neuronal responses in the audiences. In this context, capoeira is physically grounded with a clear and at times fast rhythmical beat and great muscle power in attacking actions, whereas ballet aims to portray infinite expansion, elevation, and an airborne floating effortlessness. However, even this perhaps neglects that in performance movement isn't watched in isolation but is part of a sequence and social context. Indeed, later research using complex long-durational real-life stimuli showed that the coherence, narrative and liveness play an important role in audience responses (Bachrach et al. 2016; Jola et al. 2012; Jola and Grosbras 2013). Furthermore, collaborations across disciplines emphasised spectators' subjective experiences, one of which is their kinaesthetic response.

Kinaesthetic responses are physical or embodied sensations the spectator experiences when watching dance. It is often associated with kinaesthetic empathy, whereby a seated dance spectator can have physical and visceral sensations, feelings and emotions that are corresponding to those felt by the moving performer, thus the terminology of shared kinaesthetic experiences. Kinaesthetic responses to watching dance as the primary experience has a long tradition in audience research (Reason and Reynolds 2010; Foster 2008; Martin 1939). Using stimuli that allow those kinaesthetic experiences to unfold is a first step closer to understanding audience experiences. If we can close the gap between dance as a multivarious artform and dance as controlled stimuli for laboratory-based studies, opportunities to advance technology, methodology and cross-disciplinary understanding can emerge, as discussed in the following sections on the barriers and resolutions.

The Audience: Performers or the Public?

When we talk about audience, we might think of a fairly broad group of people who happen to watch a performance. Yet, most participants of neuroscientific studies on watching dance have been performers themselves (see review Bläsing et al. 2012). There are several reasons for this. Firstly, as stated earlier, the predominant underlying concept of neuroscientific studies is the mirror neuron network. During the early investigations on mirror neuron activity, these neurons were considered paramount for 'action' specific processes and action-based research was thus dominating the field. Henceforth, testing experts who have superior action-related expertise seemed natural. Secondly, dance in neuroscience is often described as a 'language', with different styles being professionalised by different experts. Thus, the interest in employing dancers as experts who 'speak' and 'read' a particular style is obvious. Finally, as the resources are not unlimited, neuroscientists want to ensure that the participant group tested is likely to show an effect if the hypothesis is true. Hence, dancers are 'testing' novel paradigms on watching dance. These are some of the reasons why the large majority of our neuroscientific understanding stems from performers' neuronal responses, not the general public. Yet, the latter point raises a specific issue: Is dance made for the dancing or the non-dancing audience?

Notably, the sciences have been criticised for their selective approach to participant groups in general as participants are predominantly from *W*estern, *e*ducated, *i*ndustrialised, *r*ich, and *d*emocratic societies, thus being described as the 'weirdest' people in the world (Henrich et al. 2010). Yet recent changes in the study of audience responses to watching dance have provided opportunities to involve audiences that are not practitioners. For instance, advancements in interactive digital data collection have opened up avenues for audience research in the arts, the commercial world, as well as the scientific study of audience responses. Whilst researchers have often measured the impact of a performance by means of conventional, methodological approaches derived from existing paradigms in psychology and cognitive neuroscience, a shift towards experimental studies in the performing arts that are scientifically sound yet can get closer to the real-world phenomena of dance have appeared. For instance, Jola and colleagues (2012; 2013; 2016) investigated somatosensory experiences while watching dance live of audiences that do not have prior physical training in dance. Importantly, these findings do not rebut existing theories on mirror neuron activity in action observation. They are however refining our understanding of underlying objective and subjective elements that lead to spectators' kinaesthetic experience when watching dance. Individual differences, such as participants' personality or their subjective preferences determine not only spectators' opinion about a piece, but also their neuronal responses. In a way, one can thus argue, the spectacle is in their mind's eye.

Capturing the Mind's Spectacle: Barriers and Resolutions

Over nearly two decades, neuroscientific studies have employed a variety of complex novel technological tools that measure audiences' brain responses to watching dance. Besides remarkable continuous development of these tools, data analysis has also expanded, allowing specific explorations of audience experience, as will be discussed below. To date, non-invasive methods that are safe for standard human experimentation, such as functional magnetic resonance brain imaging (fMRI), transcranial magnetic stimulation (TMS), or Electroencephalogram (EEG), have been used to measure brain activity of participants while watching dance (for reviews, see Bläsing et al. 2012; Karpati et al. 2015).[1] Whilst all of these tools measure brain activity, they do so through different means: changes in the level of oxygenated blood (fMRI), changes in electrophysiological signalling (EEG) as well as changes in sensorimotor cortex excitability (TMS). Evidently, each type of measurement has specific limitations in testing as well as the interpretation of the findings, in particular when applied to watching dance. Firstly, there are significant differences in the technologies' resolution in space and time. Secondly, the methods' applicability to access audience experiences is debatable. Thirdly, the methods were established with a focus on different perceptual, cognitive, and emotional processes that may or may not be applicable to dance. The following paragraphs discuss these three points.

[1] fMRI, EEG and TMS are most frequently used tools in the study of audiences' neuronal processes based on accessibility, safety and cost. Other brain imaging tools, such as Magnetencephalography (MEG), Positron Emission Tomography (PET), or Near-infrared spectroscopy (NIRS) exist, but the employment of these in studying responses to the performing arts are extremely rare (e.g., Hauck et al., 2013; Brown, Martinez & Parsons, 2006; and Hou et al., 2020, respectively).

1) Technological Constraints: Spatial and Temporal Resolution

There are evident differences in spatial and temporal resolution between EEG, fMRI and TMS, with fMRI[2] being the spatial front-runner, where differences in neuronal activity can be calculated approximately within areas of 1–2mm. Nevertheless, it is important to consider that within each 1x1x1mm unit of measure (so-called 'voxel'), there are on average 100,000 neurons with up to 700,000 connections to neighbouring cells. Henceforth, even images from novel scanners with higher resolutions of up to 0.2mm contain an immensely large number of neurons within each voxel. For example, on average, only 33.6% of neurons identified in a mirror neuron area have in fact mirroring properties, i.e. fire during passive observation and active execution (Casile et al. 2011, 3; Kilner and Lemon 2013). Therefore, as exemplified with the mirror neurons, whilst fMRI studies of audiences watching dance can identify brain areas that seem specific for certain tasks, not all neurons within those identified areas have the corresponding functional properties (e.g. are specific for those tasks). Moreover, various factors, such as participants' individual cortical morphology or head movements during a brain scan recording, can result in a 'blurred' image leading to artificial boundaries. Advances in scanning technology thus focus on increasing spatial resolution. At present, only invasive intracranial neuronal measures can record the activity of individual neurons (Halje et al. 2015). With patients undergoing brain surgery, it has been possible to directly measure single mirror neuron activity in humans (Mukamel et al. 2010). This type of testing is however clearly limited in its possibilities. As for non-invasive methods, such as fMRI, some spatial as well as temporal issues can also be addressed through novel methodological approaches in data gathering and analysis.

Neurons communicate with each other through electrical activity. fMRI measures brain activity indirectly, through the consequences of neuronal activity (i.e. change in the level of oxygenated blood, the Blood-Oxygen-Level Dependent, or short BOLD response). The changes in BOLD are somewhat 'sluggish'. They happen with a time-lag of between 4-6 seconds, which requires correction as part of the data analysis procedures. Moreover, the scanning itself takes time: a brain scan is a construction of several individual images assembled to a 3D image. Henceforth, most fMRI measurement and analysis methods blend together anything that happens within 2 seconds. In dance, a lot can happen within 2 seconds. For example, in just half of that time, the fastest folk dancers can achieve an astonishing 38 taps (James Devine) or 41 slaps (Ahmed Moussa). In analogy, a 'photograph' of those steps taken within the constraints of fMRI would have a very long exposure setting. This would inevitably lead to a spatial as well as a temporal 'blurred' image. Yet this is what the brain image of a spectator represents.

[2] fMRI measures brain activity during a task (therefore 'functional'), whereas MRI measures differences in brain structures only.

Compared to fMRI, TMS and EEG have a lower spatial (1cm for TMS and 5-9cm for EEG) but higher temporal resolution (in the range of milliseconds). TMS and EEG are non-invasive procedures but measure neuronal functioning more directly, through electrophysiological activity. Notably, to overcome some of the spatial and temporal resolution constraints, recent studies have combined fMRI, TMS, and EEG. In regard to an audience's experience, Grosbras et al. (2012) have, for example, followed a two-steps approach, by first identifying brain areas for emotional processing of dance spectators using fMRI, then employing TMS to disrupt the function of the identified area for another group of audiences. The authors found that inhibiting the functioning of the cognitive area of the emotion processing brain circuit in the left posterior parietal area enhanced the experience of synchronicity of movement and music as well as the positive emotions felt while watching a piece. This means that the authors first identified and then impeded the functioning of a brain area that normally enables spectators to cognitively evaluate the dance. Reducing this cognitive evaluation increased the experience of synchronicity. This suggests that increasing the evaluative engagement in the audience decreases their experience of synchronicity. Yet to my knowledge, this is the only neuroscientific study on audiences' watching experience that combined modern technologies.

2) Methodological Decisions: Design and Analysis

Within fMRI, TMS, and EEG, various forms of measurement and analyses methods have been developed and employed. These technologies each allow different kinds of questions to be asked about participants' brain processes involved in a study. The focus here is on those that have been used specifically in the study of audiences' responses to watching dance. Below, one methodological approach is exemplified for each type of measure considered particularly relevant for studies on dance spectators' experience.

Functional Magnetic Resonance Imaging (fMRI): Conventional and Recent Approaches

Conventional fMRI analyses calculate the *difference* in neuronal activity between specific tasks, such as neuronal activity during watching a ballet performance with music versus without. This contrast method is particularly suitable within the framework of action observation and the mirror neuron network. Notably, to identify mirror neuron areas, it is paramount to contrast neuronal activity during passive action observation and during action execution. However, the space in the scanner is very limited, which prohibits the execution of dance movements. As it is commonly assumed that the action observation network engages the putative mirror neuron system, most studies look at neuronal activity during different conditions of *passive* action observation – consequently, the activity of the mirror neuron network is not known.

Recent methods also allow comparison within and between participants' changes in neuronal activity over time, such as Resting state fMRI or Inter-Subject Correlation (ISC). The latter was developed in 2004 by Hasson and colleagues to explore spectators' shared brain activity when watching a film. ISC is particularly suited to access brain activity in response to 'naturalistic' scenes that are complex and long in duration, such as films. Since ISC is an explorative, data-driven analysis, it is ideally suited to taking into account aspects of timing (Nastase et al. 2019), without the need of a specific expectation (i.e. formulated a-priori hypothesis). This seems ideal for dance performances. However, one has to be clear that whilst it shows how a group of spectators' brains are synchronised, it does not show the amount of neuronal activity nor does it show a specific pre-defined function, such as mirror neuron activity. In other words, ISC does not show where in the brain a ballet with music is processed; but it shows where in the brain at what time a group of spectators share the neuronal response to what is happening on a video recording (i.e. the stage).

How a performance drives the neuronal temporal processing has since been the quest of a number of dance studies (e.g., Herbec et al. 2015; Jola et al. 2013; Noble et al. 2014; Pollick et al. 2019). Because ISC is not hypothesis driven, these studies can give the spectators' experience more credit. For example, we explored how novice audiences watch and process a recorded dance performance with and without music (Jola et al. 2013). The performance was a classical Indian dance (i.e. Bharatanatyam) performed by a soloist. Even though the non-expert audience was not able to decipher the meaning of the piece, their brains were synchronised across larger visual and auditory areas when they were watching the dance with music. In a later transdisciplinary mixed methods study (Reason et al. 2016), we again employed ISC to identify brain areas where a group of novice spectators processed dance with and without music. In the condition with no music, the performers' breathing was audible. Spectators' sensorimotor brain areas were significantly synchronised during this breathing only condition, over and above watching the dance with music to the accompanying Bach concerto.

It is therefore likely that ISC is a useful tool to identify not only time-bound activity to different forms of films or types of performances (Hasson et al. 2008), but also to different artistic choices and genres of performances. Moreover, whilst ISC is often used to measure the audience's neuronal synchronisation to an external stimulus, such as a performance, it was also employed to indicate the interaction between individuals (e.g. Hasson et al., 2012). Therefore, in theory, ISC can measure the levels of brain-to-brain coupling in a reciprocal social context, such as between an audience member and a performer (Hasson et al. 2012). However, one must remember that ISC is classically measured by means of a brain scanner, whereby movement is limited, and the possibility of reciprocal interactions reduced. A better method to measure direct interaction is by means of Electroencephalogram (EEG).

Electroencephalogram (EGG): What and How?

Activity in the human brain is electrical. When neurons communicate with each other, they do so through chemical signals and electrical impulses. When many neurons fire simultaneously, an electrical field is generated that is strong enough to be measured externally, outside the skull. EEG does exactly that. It measures small changes in electrical activity which are then amplified to be assessed and interpreted. EEG activity is predominantly measured either in the form of frequency bands or event-related potentials (ERPs). Whilst the former reflects different durational cognitive, attentional, and affective states, the latter indicates time-related responses to external triggers, such as visual or auditory stimuli.

Since ERPs can evidence perceptual and cognitive responses to specific repeated sensory events, they can be considered a particularly good measure of neuronal activity when watching dance performances. According to its event-related feature, ERPs have been identified in time and location, named in line with the peak direction (either Positive or Negative) and the time (milliseconds after stimulus). For example, P1 occurs as a positive potential 100ms after a visual stimulus. As for watching more complex dance performances, ERPs could highlight how and whether spectators' brains respond to choreographic choices or dramaturgic events.

To my knowledge, however, only two studies used ERP in dance observation. Poikonen et al. (2016) employed a paradigm from tone perception and found that dancers' ERPs are suppressed but appear earlier than in non-dancers when they watch a choreography with music. This study is novel in that it employed EEG/ERP with natural durational stimuli whilst using a paradigm from another research area (auditory processing). Similarly, Orlandi et al. (2017) investigated the N400-effect, which has its roots in semantic processing. The N400 indicates a negative peak, 400ms after an unexpected semantically unrelated word, thus regarded as a neural marker for semantic processing. In their study, Orlandi and co-authors found that those with dance expertise showed an N400 effect when watching a video clip twice when the repetition had a slight variation in the movement. The authors discuss their findings in light of evidence that dance expertise modifies the ability to visually code whole-body complex movements. In line with the findings of Orlandi et al., other studies supported the suggestion that this N400 effect is not specific for language, but a signifier for different modalities, such as spatial processing (e.g. Brandeis and Jola 2001; Kutas and Federmeier 2011). Considering the fMRI study by Bachrach et al. (2016), we can observe a pattern whereby functional processes that were in the domain of language are now considered to be multimodal, playing a role also in listening to music, or watching dance. These examples also show how the study of watching dance can significantly contribute to our wider knowledge of general perceptual and cognitive processing. However, in all of these cases, the spectating is based on studying motor experts (i.e. dancers). Is it thus an effect of expertise? What spectacle does the general audience see?

Transcranial Magnetic Stimulation: Measuring Presence with the Single Pulse Procedure
Single pulse TMS is a method employed to explore on-time functioning of the human brain. A TMS trigger creates a magnetic field outside the skull, which stimulates the area

underneath. This induces a neuronal signal sent to the muscle groups represented in that area. Notably, the action potential sent from the brain to the muscles is the same as in a voluntary movement, however, evoked with TMS, it is so small that only a minuscule muscular twitch can be seen. The size of this twitch is an indication of how much the area of the cortex is engaged in actions processing: if the participant imagines or prepares an action, or attentively watches a dancer moving, the motor area is 'excited'. Therefore, for example, the same single trigger over the area of the brain that represents the arm muscle groups evokes a bigger response in the participants' arm muscles when they are watching a port de bras (i.e. ballet arm movement), than when they watch a digital clock blinking. This approach lies within the framework of the mirror neuron network albeit the measurement does not measure mirroring activity. The differences in audience engagement are based on motor-resonance, i.e. how much the motor cortex and spinal cord are activated. The actual basis of this excitement (i.e. whether this is mirroring activity or motor preparation, or imagination) is not identifiable as such.

Several studies have employed TMS to explore neuronal responses of dance audiences with no motor expertise (Jola et al. 2011; Jola et al. 2012; Jola and Grosbras 2013; Grosbras et al. 2012; Jola and Reason 2016). Since TMS is a mobile device, it can measure audiences' responses to dance as they occur in real life, i.e. with long(er) duration and in the rehearsal studio (Jola et al., 2012) or live in the theatre (Jola et al. 2011). The latter experiment was explorative and showed that audiences' engagement when watching *Sleeping Beauty* is highest at the start of the show as well as after each interval but decreases over the length of the performance as if spectators shift from an initial motor engagement to other emotional forms of involvement, likely related to the narrative of the dance. The former study investigated effects of visual expertise when watching different dance forms and found that when visually experienced ballet spectators watched ballet specific dance moves, movement related sensorimotor activity was increased, providing evidence that motor familiarity can be acquired through passive observation alone. Finally, we compared the audience's sensorimotor resonance to watching dance live in the theatre with audiences viewing it on video (Jola and Grosbras 2013). In line with other studies on children's engagement when watching TV, dance audiences showed higher sensorimotor resonance to live dance. They also reported more equal levels of enjoyment across the three live dance styles. Since enjoyment should be comparable across conditions, this observation is of great importance and advocates the use of live performances in empirical research.

3) Dance in Context: Applicability

Dance exists in a variety of forms and settings. Yet the core neuroscientific literature on dance does not represent the multifarious and multicultural context of dance. Whilst there have been attempts to address neuronal processing of individual strands of dance and performance, such as music or sound versus movement (e.g. Jola et al. 2013; Reason et al. 2016; Poitkonen et al. 2018a, 2018b, 2016), issues in regards to understanding dance in a cultural, historical, or embodied context remain. Whilst methodological choices are available, as exemplified above, with each choice, a particular aspect of watching dance takes centre stage: neuroscientific research is likely to capture dance with a narrowly defined focus in time or space. How much of that actually represents the audience's neuronal processing or even their experience of watching dance?

Dance is a somatic practice. However, the sensing body and breath, as well as the narrative have received little attention in neuroscientific audience research. Moreover, an MRI scanner has for example restricted space and the machine produces immense noise, diminishing a potentially positive somatic audience experience. Such embodied experiences are arguably sensitive to the surrounding. The context of 'ecological validity', which refers to the extent to which findings of a scientific study can be generalised to the real world, is thus particularly important in dance research (see Christensen and Jola 2015). Yet, with some exceptions, experimental or neuroscientific studies use immobile technologies, and experiments thus take place in a scientific laboratory with participants viewing a digitised performance individually on a 2D screen or through goggles. Even if the visual stimulation is as close as possible to the real performance, participating in a scientific experiment is not the same as attending a performance as an audience member, together with other spectators, for example. Moreover, even considering the most ecologically valid methodological approach, simply the awareness of participating in a scientific study as an audience member can impact on the spectatorship experience. In social psychology, it is believed that once participants are aware of being the subjects of investigation, they are understood to change their behaviours and henceforth influence the research findings (i.e. the Hawthorn effect; McCambridge et al. 2014). Yet in general, the participant or researcher should not influence the data beyond the design parameters. But attending a laboratory, being connected to machinery, as well as giving consent to the testing procedure, are all contributing factors to the experience of scientific experimentation, which is different from attending a dance performance. An argument for a phenomenological discourse on how being a scientific dance audience member affects the watching dance experience can be made.

Yet at present, the scientific approach is first and foremost based on neuroscientific paradigms, theories, and knowledge. The caveats of building upon existing knowledge from cognitive is that:

a) It works within the model of a reductionist approach, yet, dance might be more than the sum of its parts and new interdisciplinary multimethod approaches need to be developed to grasp the meaning and experience of the full spectacle in the audience's mind as discussed extensively elsewhere (see for instance, Jola et al. 2012; Jola 2018 and 2020).
b) Reductionism in science has a different purpose and effect than in the arts, as Hantula (2018, 325) explains. In the arts, reductionism is used to evoke new

emotional responses in audiences. Henceforth, when the sciences employ reductionism to solve complex problems in the perception of stimuli that have aesthetic and emotional value, they create new problems in that the artificially modified stimuli change the onlookers' experience.

c) Predominantly, questions addressed are within the mirror neuron network or audio-visual integration paradigms and thus focus on neuronal differences between expert viewers (i.e. dancers) and novices; or multisensory processing compared to audio vs. visual processing. There are only a few studies that explored experiential aspects, such as embodied experiences or the sense of presence and liveness. Importantly, the scholarly understanding of dance as a cultural art form has not yet been the driving force in studies of audiences' neuronal processing.

The question thus is whether we can build a multi-layered understanding of the spectacle in the audience's mind through ever increasing numbers of outputs employing a variety of methods, techniques, and dance forms seemingly in a random assemblage? Researchers are indeed tempted to employ a variety of methods or designs; even onto the same set of data, such as by Poikonen et al. 2018a, 2018b. However, this can be problematic for interpretation, relevance, as well as statistical power. Nevertheless, it can be of value to explore a dataset from different angles if transparency is given. For instance, we have analysed the novices' live data three times for three different objectives: once to investigate effects of visual expertise for particular styles of performances (Jola et al. 2012), once to explore effects of watching dance live vs. on a digital media with an additional data set (Jola and Grosbras 2013) and once we used the data for a novel type of analysis in that we combined neuronal responses with participants' qualitative interview responses in regards to proximity and co-presence (Reason and Jola 2016). In each case, the core data is expanded with additional information (other participant group or qualitative interview responses). A similar approach followed the seminal fMRI study by Calvo-Merino et al. (2005) on dancers' motor representation as reflected in the mirror neuron activity. Their subsequent study on the sensorimotor aesthetics of performing arts analysed a third of the fMRI data (i.e. the novices) together with newly collected subjective ratings of the same participants (Calvo-Merino et al. 2008). In both cases, it is important to note that the new studies follow a different research question as the original publications from which part of the data was taken. This approach seems particularly relevant in dance research; not only based on limited resources, but as it as it exemplifies the multidimensional and multifaceted characteristics of dance.

Summary and Conclusion

The desire to know what other people's thoughts and feelings are is core to human nature. With the evolution of neuroimaging methods, we are excited that it has become possible to 'see' what is inside peoples' brains. In audience research, neuroscience has contributed to our understanding of how spectators process what they see on stage. Numerous empirical

evidence allows us to predict how certain aspects of a performance unfold in spectators' minds, providing us with an *objectivist account* of the experience. The widely used theoretical underpinning is the mirror neuron network. Mirror neuron activity manifests itself through a correspondence between the neuronal activities of a passively watching audience member with that of the performer, as if the spectator was executing the actions seen on stage in their mind. It thus links to ideas of a shared sensorimotor experience between spectator and performer, which has a long tradition in the performing arts discourse in terms of audiences' kinaesthetic experience. Research showed that this experience is dependent on personal preferences, expertise, and personality.
Clearly though, not all neuroscientific methods are equally applicable to study mirror neurons and more generally, the focus of this kind of research is primarily on the functioning of the human brain and behaviour, irrespective of spectators' experiential aspects. Nevertheless, recent research helps us expand our knowledge on how spectators' personal circumstances affect their mental brain theatre, providing us with a *subjectivist account*. One could argue that what is of particular interest in the neuroscientific study of audiences is the spectacle that takes place in audiences' minds. Following this line of argument, the cultural, formal, and qualitative aspects of a performance constitute a factor of methodological importance as it interacts with the audience's existing set of neuronal circumstances; or, in other words, their expectations, needs, and desires, in accordance with their idiosyncratic neuronal functioning. The latter is of particular interest here since it requires taking the audience experience into account. In particular, audiences' levels of visual and physical expertise, as well as their empathic abilities and personality, were found to play a crucial role in how a spectacle unfolds in their minds. Yet empirical research is prone to limitations and studies on watching audiences are all faced with the challenge: how to deal with the complexity of a performance practice with the methodological approaches at hand?

This chapter thus provided an overview of the conditions of scientific technologies employed; and explained how these conditions contradict principles of creative and cultural practices of the performing arts, which has led to new methodological discussions. The chapter also emphasised how neuroscientific audience research has influenced methodological developments toward higher recognition of qualitative and phenomenological aspects.

A focus was set on outlining how each methodological approach is best suited for a particular aspect of the study of spectatorship of the performing arts. Accordingly, research findings on audiences should be examined in light of the paradigms, theoretical models, and specific neuroscientific tools that have been employed. As discussed across the chapter, fMRI allows us to locate where in the spectator's brain the performance is processed; whereas EEG or TMS are better suited to study a performance's intangible characteristics of immersion or liveness. Therefore, each methodological approach is best suited for a particular aspect of the performing arts whilst it leaves out other important elements. Overall, in contemporary science, the requisites of methodological approaches in psychology and cognitive neuroscience contradict with principles of creative and cultural practices of the performing arts. One proposition thus is to argue that the performance does not happen on stage or in any form of external space, but in the audience's mind, in a manner that cannot be quantified.

Whilst attempts to use real-world settings in brain imaging studies exist (Spiers and Maguire 2007), to this day, there has not been an attempt to identify a dance performance based on the pattern of brain activity. For example, Multi-Voxel Pattern Analysis is a so-called stimulus 'blind' approach, which allows to extract hidden patterns in the fMRI signal that would be driven by the performance. Thus, based on the brain activity alone, one could potentially infer what dance performances audiences have in their minds. Further, as Spears and Maguire suggest, the inclusion of physiological measures could further refine our understanding of the brain and behaviour in real-world settings, albeit combining naturalistic stimuli with novel analysis methods are not trivial.

According to the science philosopher Popper, science progresses by means of risky predictions and results that are unexpected, surprising and sometimes spectacular. Recent propositions arise from different areas calling for the inclusion of other elements into the scientific enterprise, namely, those of a subjective, psychological or perhaps even aesthetic nature. In fact, some scholars have begun to consider the possibility of introducing a principle of aesthetic induction into the evaluation of scientific theories (Veronesi 2014, 184). The scientific understanding of audiences' experiences would benefit from such a pragmatic shift.

What should the future of neuroscientific audience research look like? Can we develop a method specifically for dance, similar to the development of ISC for film? As discussed above, our understanding of the spectacle in the audience's mind is very much driven by the technology, methodology, as well as the choice and form stimuli. Clearly, what audiences 'see' in their mind's eye also does not correspond to quantitative measures of individual parameters to what is happening on stage. In other words, we undoubtedly regard events happening on stage and neuronal processes in spectators' brains as conjoint; however, our use of language struggles with such conceptualisations (Bach 1986, 15). Even seemingly simple questions are in fact hugely complex. For example: How many things happened on stage? How many events took place in the first ten minutes of a show? And moreover, how do different audiences see those things as they bring their personal preferences, personality, and visual and motor experiences with them? The difficulty of answering these questions requires us to consider whether it is possible to quantify the spectacle in the audience's mind when we struggle to quantify the real thing.

References

Bachrach, A., Jola, C., & Pallier, C. 2016. 'Neuronal bases of structural coherence in contemporary dance observation.' *Neuroimage*. 1(124) (Pt A), 464–472. doi: 10.1016/j.neuroimage.2015.08.072.

Bläsing, B., Calvo-Merino, B., Cross, E. S., Jola, C., Honisch, J. & Stevens, C. J. 2012. 'Neurocognitive control in dance perception and performance'. *Acta Psychologica*. 139 (2), 300–308.

Brandeis, D., & Jola, C. 2001. 'Mapping spatial cognition of left-right relations.' *Brain Topography*, 14 (4), 320.

Brook, P. 1968. *The Empty Space: A Book About the Theatre*. (1st Touchstone Edition, 1996). New York: Touchstone.

Brown, S., Martinez, M. J., & Parsons, L. M. 2006. 'The neural basis of human dance.' *Cerebral Cortex,* 16 (8), 1157–67. doi: 10.1093/cercor/bhj057.

Calvo-Merino, B., Glaser, D.E., Grèzes, J., Passingham, R.E., Haggard, P. 2005. 'Action observation and acquired motor skills: an fMRI study with expert dancers.' *Cerebral Cortex* 15 (8), 1243–1249. doi: 10.1093/cercor/bhi007.

Calvo-Merino B., Jola, C., Glaser, D. E., & Haggard, P. 2008. 'Towards a sensorimotor aesthetics of performing art.' *Consciousness and Cognition*, *17* (3), 911–922.

Casile, A., Caggiano, V., Ferrari, P. F. 2011. 'The mirror neuron system: A fresh view.' *Neuroscientist*. 17950, 524–538.

Christensen, J. F., & Jola, C. 2015. 'Towards ecological validity in the research on cognitive and neural processes involved in dance appreciation.' In Huston, J. P., Nadal, M., Mora, F., Agnati, L. F. & Cela Conde, C. J. (eds.). *Art, Aesthetics, and the Brain*. Oxford: Oxford University Press, 223–253.

Foster, S. 2008. 'Movement's contagion: The kinesthetic impact of performance.' In T. Davis (Ed.), *The Cambridge Companion to Performance Studies*. Cambridge: Cambridge University Press. pp. 46–59. doi:10.1017/CCOL9780521874014.004.

Grosbras, M.H., Tan, H., & Pollick, F. 2012. 'Dance and emotion in posterior parietal cortex: a low-frequency rTMS study.' *Brain Stimulation*, 5 (2):130–136.

Hantula, D.A. 2018. 'Editorial: Reductionism and Holism in Behavior Science and Art.' *Perspect Behav Sci* 41, 325–333. https://doi.org/10.1007/s40614-018-00184-w

Hasson, U., Landesman, O. Knappmeyer, B., Vallines, I., Rubin, N., Heeger, D. J., 2008. 'Neurocinematics: The neuroscience of film.' *Projections*, 2 (1), 1–26. doi: 10:3167/proj.2008.020102.

Hauck, M., Metzner, S., Rohlffs, F., Lorenz, J., Engel, A. K. 2013. 'The influence of music and music therapy on pain-induced neuronal oscillations measured by magnetencephalography.' *Pain* 154, 539–547. doi: 10.1016/j.pain.2012.12.016

Hasson, U., Ghazanfar, A. A., Galantucci, B., Garrod, S., & Keysers, Chr. 2012. 'Brain-to-brain coupling: A mechanism for creating and sharing a social world.' *Trends in Cognitive Sciences,* 1 (2): 114–121. doi:10.1016/j.tics.2011.12.007

Henrich, J., Heine, S. & Norenzayan, A. 2010. 'The weirdest people in the world?' *Behavioral and Brain Sciences,* 33 (2/3), 1–75. doi:10.1017/S0140525X0999152X

Herbec, A., Kauppi, J. Pl, Jola, C., Tohka, J., & Pollick, F. E. 2015. 'Differences in fMRI intersubject correlation while viewing unedited and edited videos of dance performance.' *Cortex.* 71, 341–348.

Hou, Y., Song, B., Hu, Y., Pan, Y., & Hu, Y. 2020. 'The averaged inter-brain coherence between the audience and a violinist predicts the popularity of violin performance.' *NeuroImage,* 211: 116655. doi: 10.1016/j.neuroimage.2020.116655

Jola, C., Ehrenberg, S., & Reynolds, D. 2012. 'The experience of watching dance: phenomenological-neuroscience duets.' *Phenom Cogn Sci,* 11: 17–37. DOI 10.1007/s11097-010-9191-x

Jola, C., McAleer, P., Grosbras, M. H., Love, S. A., Morison, G., & Pollick, F. E. 2013. 'Uni- and multisensory brain areas are synchronised across spectators when watching unedited dance recordings'. *i-Perception*, 3;4 (4): 265–284.

Jola, C. 2020. 'Scientist – performers – audiences. Different modes of meaning-making.' Pygmalion-revista de teatro general y comparado. 11, 65–85.

Jola, C. 2018. 'Choreographed science: merging dance and cognitive neuroscience.' In B. Bläsing, M. Puttke, & T. Schack, T. (eds./2nd Ed.). *The Neurocognition of Dance: Mind, Movement and Motor Skills*. London Abingdon, Oxon: Routledge, 258–288.

Jola, C. & Grosbras, M-H. 2013. 'In the here and now: enhanced motor corticospinal excitability in novices when watching live compared to video recorded dance.' *Cognitive Neuroscience*. 4 (2), 90–98.

Jola, C. & Reason, M., 2016. 'Audiences' experience of proximity and co-presence in live dance performance.' In Falletti, C., Sofia, G., & Jacono, V. (eds.). *Performance and Science: Interdisciplinary Dialoges.* London: Bloomsbury Publishing, 75–92.

Karpati, F.J., Giacosa, C., Foster, N.E., Penhune, V.B., & Hyde, K.L. 2015.' Dance and the brain: a review.' Ann N Y Acad Sci, 1337: 140–6. doi: 10.1111/nyas.12632

Kutas, M., Federmeier, K.D. 2011. 'Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP)' *Annu Rev Psychol.* 62: 621–647. doi: 10.1146/annurev.psych.093008.131123

Halje, P., Seeck, M., Blanke, O., & Ionta, S. 2015. 'Inferior frontal oscillations reveal visuo-motor matching for actions and speech: evidence from human intracranial recordings.' *Neuropsychologia*, 79, 206–214, http://dx.doi.org/10.1016/j.neuropsychologia.2015.08.015.

Kilner, J. M., & Lemon, R. N., 2013. 'What we know currently about mirror neurons. Minirevew,' *Current Biology*, 23, R1057–R1062.

Martin, J. 1939. *Introduction to the Dance*. New York: Dance Horizons. PMID: 30788671

McCambridge, J., Witton, J., & Elbourne, D. R., 2014. 'Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects.' *Journal of Clinical Epidemiology*, 67 (3), 267–277. doi: 10.1016/j.jclinepi.2013.08.015

Mukamel, R., Ekstrom, A. D., Kaplan, J., Iacoboni M., & Fried, I. 2010. 'Single-neuron responses in humans during execution and observation of actions.' *Current Biology,* 20, 750–756.

Nastase, S. A., Gazzola, V., Hasson, U., & Keysers, Chr. 2019. 'Measuring shared responses across subjects using intersubject correlation.' *Social Cognitive and Affective Neuroscience*, 669–687.

Noble, K., Glowinski, D., Murphy, H., Jola, C., McAleer, P., Darshane, N., Penfield, K., Kalyanasundaram, S., Camurri, A. & Pollick, F. E. 2014. 'Event segmentation and biological motion perception in watching dance.' *Art & Perception*. 2 (1–2), 59–74.

Orlandi, A., Zani, A., & Proverbio, A. M. 2017. 'Dance expertise modulates visual sensitivity to complex biological movements.' *Neuropsychologia*, *104*, 168–181.

Poikonen, H., Toiviainen, P., & Tervaniemi, M. 2016. 'Early auditory processing in musicians and dancers during a contemporary dance piece.' *Sci. Rep*., 6, 33056.

Poikonen, H., Toiviainen, P., & Tervaniemi, M. 2018a. 'Naturalistic music and dance: Cortical phase synchrony in musicians and dancers.' *PLoS One*, 13, e0196065.

Poikonen, H., Toiviainen, P., & Tervaniemi, M. 2018b. 'Dance on cortex: enhanced theta synchrony in experts when watching a dance piece.' *Eur. J. Neurosci*., 47, 433–445.

Pollick, F. E., Vicary, S., Noble, K., Jang, K. N., Stevens, C. J. 2019. 'Exploring collective experience in watching dance through intersubject correlation and functional connectivity of fMRI brain activity'. *Prog Brain Res*. 237: 373–397.

Raichle, M. E., 2008. 'A brief history of human brain mapping.' *Trends in Neurosciences,* 32 (2).

Reason, M., Jola, C., Kay, R., Reynolds, D., Kauppi, J-P., Grobras, M-H., Tohka, J. & Pollick, F. E. 2016. 'Spectators' aesthetic experience of sound and movement in dance performance: a transdisciplinary investigation.' *Psychology of Aesthetics, Creativity, and the Arts.* 10 (1), 42–55.

Reason, M., & Reynolds, D. 2010. 'Kinesthesia, Empathy, and Related Pleasures: An Inquiry into Audience Experiences of Watching Dance.' *Dance Research Journal*, 42 (2), 49–75. DOI: 10.1017/S0149767700001030

Spiers, H. J., & Maguire, E. A. 2007. 'Decoding human brain activity during real-world experiences.' *Trends in Cognitive Sciences*, 11 (8), 356–365.

Tanaka, S. 2020. 'Mirror Neuron Activity During Audiovisual Appreciation of Opera Performance.' *Frontiers in Psychology*, *11*, 3877.

Veronesi, C. 2014. 'Falsifications and scientific progress: Popper as sceptical optimist.' *Lettera Matematica, 1*, 179–184.

Vukadinović, M., & Marković, S. 2012. 'Aesthetic experience of dance performances.' *Psihologija*, *45* (1), 23–41.

Willems, R., Nastase, S. A., & Milivojevic, B. 2020. 'Narratives for Neuroscience.' *Trends in Neuroscience*, 43 (5), 271–273.