Movement, gesture, and meaning

A sensorimotor model for audience engagement with dance

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Interpretation is often difficult in dance, since movements, unlike words, have few combinatorial rules that guarantee a clear, unambiguous communication of ideas. Dance is unlike verbal language, for it usually credits meaning only vaguely. When it becomes more specific, it tends to move into the realm of pantomime, or sign language, or even to introduce verbal language.

(Solly Zuck 1995, p. 28)

The neuroscience of dance is a vibrant, fast growing field which embodies the promise of a genuine and productive interdisciplinary rapprochement between neuroscience and art. The strength of this field lies in the way it ties explanations of dance to an understanding of the sensorimotor processes that underwrite our ordinary perceptual engagement with the environment (see Blasing, Calvo-Merino, Cross, Jola, Honisch & Stevens 2012; Cross & Tschirren 2011). We use our own bodies to model observed behaviors in everyday contexts. Motor simulation and motor mimicry enhance our capacity to interpret the goals, motives, and emotions of others. These processes are critical to action understanding, empathy, and the social coordination of behavior. A range of recent studies demonstrate that these same processes enable us to recognize abstract dance movements as intentional actions with emotionally expressive and semantic content constitutive of their artistic meaning. In what follows I examine this research with an eye to the potential contribution neuroscience can make to our understanding of choreographed movements as artworks, as dances opposed to ordinary everyday actions.

1. What is the neuroscience of art?

There is a natural methodological fit between cognitive science and art. Artworks are communicative devices. They are stimuli composed of abstract sets of marks, sounds, movements, etc. that are intentionally designed to trigger affective
perceptual, and cognitive responses in viewers constitutive of their expressive, aesthetic, and semantic content. This entails that questions about the understanding and appreciation of an artwork are, to a large extent, questions about the way consumers acquire, represent, manipulate, and use information carried in the formal structure of a work in order to recognize and evaluate its content (Carroll, Moore & Seeley 2012). Cognitive science, in its broadest sense, is the interdisciplinary study of the ways that organisms acquire, represent, manipulate, and use information in the production of behaviour. Theories and methods from cognitive neuroscience can therefore be used to model and explain the range of psychological processes that underwrite our engagement with artworks. Recent research in neuroaesthetics and neuroscience of art is dedicated to developing theories and methods to push this project forward (see Calvo-Merino, Jola, Glaser & Haggard 2008; Chatterjee 2011; Livingstone 2002; Seeley 2011; Zeki 1999).

A general model for neuroscience of art emerges from a standard story about artists’ methods. The sensory inputs to perceptual systems are replete with information about the structure and dynamics of the local environment. However, only a small fraction of this information is salient to our current behaviour at any given time. Selectivity is, therefore, a critical feature of perception. Evidence suggests that we solve this problem by focussing attention on minimal sets of features diagnostic for, or sufficient to determine the identity, shape, location, and affordances of objects and events in the environment (see Schyns 1995). Perceptual systems can, in this regard, be conceptualised as evolved mechanisms for detecting the task salience of features of the local environment, or selecting information from the flux of sensory inputs sufficient for object recognition and action. Artists develop a suite of formal strategies for calling sets of diagnostic features from ordinary perceptual experience and rendering them in a range of media, e.g. colour studies and sketches in the visual arts. These productive strategies work as communicative strategies because they are directed at sets of diagnostic features sufficient to trigger the ordinary operations of perceptual systems. This, in turn, entails a tight coupling between artists’ productive strategies and the operations of perceptual systems.

A significant amount of research in the neuroscience of art is devoted to teasing out the productive relationship between artists’ formal and compositional strategies and the neurophysiological operations of perceptual systems. However, correlations between these productive strategies and the operations of perceptual systems do not alone suffice to explain the artistic salience of the formal and compositional elements of an artwork. What one needs is a story that links explanations of how artworks work as perceptual stimuli to explanations of how we recognise and understand the artistic salience of their formal, expressive, and semantic features. This kind of an explanation is forthcoming in a standard story about artists’ methods (Gombrich 1960). Consider the case of realistic depiction in landscape painting. Productive practices in this context include colour studies, formal studies, preliminary drawing studies, and a range of other strategies that are designed to recover sets of environmental features sufficient for adequate depiction. However, there is no ideal formal solution to the problem of depiction. Any of a range of formal/compositional strategies will suffice to render these environmental features. This entails that artists must choose how to execute their subject matter from a broad range of potential strategies. What are the constraints that guide these choices – the perceptual, expressive, aesthetic, and semantic effects, the artistically salient experiences and interpretations, that artists intend to induce in consumers. In this regard artworks can be conceptualised as attentional engines, or stimuli intentionally designed to direct attention to their artistically salient diagnostic features. Neuroscience is a tool that can be used to explore, model, and explain the psychological processes that underwrite the success of artworks as attentional devices. Therefore, neuroscience can contribute to our understanding of the artistic salience of the formal and compositional features of artworks.

3. What is the neuroscience of dance?

A set of core critical questions frame the application of this model for neuroscience of art to any particular artform. First, what are the general formal/compositional strategies constitutive of productive practices in that artform? Second, how are they used to vary and communicate diagnostic information? Third, what accounts for the artistic salience of these features and strategies? In framing these questions I do not mean to suggest that artforms are taxonomised by, or restricted to, particular media. Nor do I mean to imply that they are constrained by rigidly defined productive strategies. My claim is simply that these are questions that must be addressed in order to distinguish artworks from other classes of perceptual stimuli. Categories of art are flexibly defined by the range of productive practices associated with them at a time. These productive practices determine a common formal/compositional framework for artworks in that category and the nature of consumer engagement with them.

The building blocks of dance are expressive movements. We express any of a range of mental states, e.g. goals, intentions, or emotions, when we physically display them in our movements and postures. We orient our bodies towards the objects of our actions in everyday behaviour. Our bodies thereby display the explicit goals of our actions. Likewise, the character of our postures and movements carries information about the tenor of our actions, e.g. we are curious, cautious, or
eager to achieve a goal, which also indicates our emotional disposition towards the object of our actions, e.g. we are fascinated, frightened, or overjoyed respectively. Further, the expressive capacities of our bodies are not limited to explicitly goal directed actions. We often recognize the behaviors of others as more generally futile, anxious, or cheerful. Therefore, postures and movements also carry information about the abstract inner dispositions and mental states of agents. Together these bodily expressions display where the current behavioral strategies of an agent sit on the continuum between approach and withdrawal, and signal to others how to engage with them in the social context of collective behavior. The diagnostic features that enable us to recognize the expressive character of movements are biological motion cues, stereotyped and patterned relationships among joints that enable us to recognize and track animate movements. Dance, therefore, depends on a general gestural semantics built from biological motion cues.

Point-light displays can be used to illustrate the expressive power of biological motion cues. Point-light displays are constructed by attaching lights to a target agent (directly, digitally in post production, or in the production phase in animations) and adjusting the brightness and contrast in the resulting video so that these points of light are the only thing that remains visible (Johansson 1973). Viewers easily recognize the movements depicted in the display if the point-lights are attached to the joints of a human actor. This is also true for the movements of animals. However, it is not the case for the animated movements of abstract geometric figures. Nor is it the case if the point-lights are attached between joints on the limbs of biological actors. This demonstrates that the relative positions of, and dynamics among, the joints of biological actors are configural cues that carry information about the stereotyped patterns of biological movement that support ordinary behavior.

Biological motion cues also carry information about the goals, intentions, and emotions of actors. Viewers are able to recognize the actions depicted in point-light displays, e.g. ball throwing or interpersonal dialogue (Ablstein, Blok & Ablstein 1997). Viewers are able to recognize gender, personality traits, and current emotional states in point-light displays of a range of human gestures (Troje-2008). Viewers are able to recognize both who is speaking and the emotions expressed by speakers and listeners in point-light displays of interpersonal dialogue (Clark, Bradshaw, 2003).

1. See reviewed April 1, 2004: http://www.epel.ucsd.edu/faculty/kliddle/JMMBleakley.html

2. See reviewed April 1, 2004: http://www.homeomorph.co.uk/Enorm/BibleLexicon.html. Claire Routier and her colleagues used a sample of 21 walkers to generate a set of effective gestures and biological movement cues which enabled them to generate computer animated artificial walkers with recognizably expressive gaits (Routier, Chapier, Christiansen & Giese 2009).

Field, Hampson & Rose 2005; Rose & Clarke 2009). Similarly, and more to the point of the current discussion, viewers are able to recognize the range of basic emotions expressed by choreographed dance movements in point-light displays, i.e. anger, fear, grief, joy, love, and disgust (Dittrich, Troschiano, Lea & Morgan 1996; Krumhansl & Schenk 1997). Point-light displays carry information about the dynamics of biological motion in the absence of any perceptual information about the appearance of the actors or the more general context, e.g. facial expressions, scene, setting, or sound. Although it is certainly the case that this broad range of perceptual information contributes to, and likely enhances, our capacity to recognize and understand expressive movements, these studies demonstrate that biological motion cues are alone diagnostic for, or sufficient to express, the goals, intentions, and emotions of an agent.

It has been argued that stereotyped expressive movements are detached from their natural contexts and used symbolically in a language of dance (Beauchlere 1983; Langer 1937). However, the appeal to a language of dance is, at best, metaphorical. Natural languages are composed of abstract symbols stitched together into meaningful sequences by formal systems of strict syntactic rules. The meaningfulness of symbols employed in natural languages is, therefore, an artefact of the way they are used, of the way they can be combined and related given these grammatical rules. No such rules exist for an expressive language of dance, or are any needed. Rather, we recognize the expressive qualities of dance movements because they are tuned to our natural capacity for kinesthetic empathy, our capacity to recognize the goals, intentions, and emotions of other agents in the interplay of tension and relaxation in our ordinary, everyday movements. Further, violations of syntactic rules in natural language produce nonsense sentences. Not so for dance. The stylistic conventions that define different genres of dance, e.g. classical ballet, modern ballet, modern dance, etc. are rules of thumb, not strict syntactic rules. Violations of these rules do not make a work incomprehensible. Rather, they call on us to make sense of them, to fit them to the more general cognitive context of dance history. Violations of stylistic rules are, as result, a fertile source of expressiveness in dance.

Some knowledge of salient conventions is necessary to understand how recognizably expressive movements are being used in dance. These movements are, after all, abstracted from the context of everyday behavior in all but the most literally narrative dance contexts. However, the way consumers learn the stylistic conventions that define categories of dance is nothing like the way we generally learn second languages. Second language learning is a long and arduous process that
requires us to learn to forget the rules governing our primary language in order to become immersed in the rules governing another. Learning the conventions of dance, on the other hand, requires nothing more than our natural capacity to recognize and contextualize expressive movements. We may need help identifying the relevant art critical diagnostic cues at first. But, with some modicum of familiarity with these parameters, we can easily bootstrap our way into novel categories of dance.

The central claim of the neuroscience of dance is that our understanding of the expressive qualities of choreographed movements emerges from the role motor simulation, motor mimicry, and effective mimicry play in ordinary perceptual contexts. A range of studies demonstrate that these processes underwrite a more general capacity to use our own bodies to model the actions and mental states of others in everyday perceptual contexts (for a review see Decety & Grézes 2006). Topologically organized areas in prefrontal cortex that code for the orientation and movement of muscles and limbs in ordinary actions are recruited in passive perceptual contexts where viewers merely observe the actions of another agent. Activation of these premotor areas is associated with increased electromyographical activity in the muscles that would be recruited to perform the perceived action. Further, stereotyped actions are associated with stereotyped emotional responses to ordinary contexts, e.g. smiles are associated with positively valenced emotional responses, frowns with negatively valenced emotional responses (Niedenthal 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber & Ric 2005). These responses become paired to one another over time. The net result is that adopting an expressive posture triggers the activation of the same neural processes that would be activated with the associated gut reaction and emotional response. Finally, motor simulation and mimicry are used to generate forward models of perceptual changes associated with the predicted behaviours of others in ordinary contexts. These processes enable us to recognize, understand, and track the behaviours of other agents, and interpret their emotional states. These same processes are used in the more abstract context of dance to motivate an embodied understanding of characters, and where appropriate story, constitutive of the expressive content of a work, e.g. the approach and withdrawal behaviour exhibited in the first and second pas de deux in Sergei Prokofiev’s Romeo and Juliet (expressing the hopefulness of new love and the unhappy desperation of their circumstances respectively), the pas de deux in George Balanchine’s Diamonds, and the duets in Kate Weaver’s Bridge of Sighs.4

3. Art, aesthetics, and the neuroscience of dance

The grounding assumption of the neuroscience of art is that, through trial and error, artists develop formal strategies and vocabularies that are fine-tuned to the neurophysiological processes that underwrite our cognitive capacities as normal perceivers in ordinary contexts. In the case of dance, the claim is that the productive practices of choreographers and performers are fine-tuned to our capacities to recognize and understand the expressive qualities of biological movements. This claim is supported by a range of behavioral studies which demonstrate that premotor and limbic system processes underwrite our capacity to recognize the expressive content of a dance in the movements of dancers. These studies shed light on the way stereotypical choreographic strategies are used to communicate the expressive content of their works. In this section I turn to the third core critical question: what accounts for the artistic salience of expressive movements in the context of a dance?

There is a general assumption within neuroscience of art that the close coupling of formal/compositional strategies with perceptual capacities yields a focused, or enhanced perceptual experience in consumers, a heightened perceptual awareness constitutive of aesthetic experience (see for instance Zeki & Lamb 1994, p. 697). This assumption reflects a bias towards aesthetic theories of art. Aesthetic theories of art define artworks as artfactual intentionally designed to trigger aesthetic experiences in consumers (Davies 1991). A lot of philosophical ink has been spilled over the question of just what exactly an aesthetic experience is. I would like to bracket that issue here. I assume that the artistic salience of some works does lie in their capacity to induce aesthetic experiences in consumers. However, in this section I would like to rehearse a range of objections which demonstrate that neuroscience of dance doesn’t succeed as an aesthetic theory of art (even granting that in some cases the intuition is sound).

The first difficulty is a familiar problem from the philosophy of art. Whatever else we want to say about the generality of a theory of art, it ought to suffice to discriminate artworks and aesthetic experiences from non-art artefacts and ordinary experiences. Theories of art are, after all, theories about the nature of art and associated behaviours. Consider the claim that the artistic salience of artworks somehow lies in their capacity to focus our perceptual awareness on key structural features of experience. This has been a central claim of formalist theories of aesthetics, e.g., Immanuel Kant (1790); Clive Bell (1914); Jerome Soltiz (1960); and Monroe Beaudry (1981). Sometimes this feature of aesthetic experience is referred to as ‘disinterestedness,’ or attention focused on structural features of experience independent of either their representational content or their utility for the perceiver. The thought is that, through trial and error, artists develop formal strategies coupled to the neurophysiological structure of perceptual systems.
that focus, and thereby enhance, a consumer's awareness of some phenomenal aspects of perceptual experience. In the case of dance these productive practices are thought to yield a heightened awareness of the expressive qualities of movement dynamics. The trouble is that laboratory stimuli and demonstrations are also explicitly fine-tuned for the focused perception of target features. For instance, point-light displays are an efficient means to achieve a focused, heightened awareness of the expressive qualities of movement dynamics. Therefore, on this account, point-light displays should be experienced as artworlds because they should suffice to induce an aesthetic experience in experimental contexts. But they aren't, because they don't. This problem illustrates a general difficulty for any attempt to explain the nature of art and aesthetic experience in terms of ordinary perceptual or cognitive processes: what, if anything, would then differentiate them from non-art artefacts and ordinary experiences?

Neuroscience of dance has emerged as a new area of research on the role of motor expertise in perception. The well-developed motor expertise of expert dancers is coupled to well-defined categories of perceptual stimulus. Consequently, measuring the perceptual sensitivity of expert dancers to a range of dance styles and genres has been used as a means to test the generalization of motor expertise effects in perception. The canonical work in this regard is Beatriz Calvo-Merino’s EMRI study of perceptual differences between ballet and capoeira dancers (Calvo-Merino et al. 2005). Capoeira is a contemporary Brazilian dance form that is compositionally similar to, but formally distinct from, ballet – the leaps, spins, and duets of the former are choreographed from a unique set of formal movements derived from martial arts. Calvo-Merino and her colleagues measured the relative cortical activation among three groups of participants: dancers from the Royal Ballet of London, expert capoeira dancers, and non-dancers, while they watched clips of choreographed ballet and capoeira solo and duet acts. The results showed significant differences between all three groups. Ballet dancers showed heightened activation in premotor areas and parietal areas associated with action observation and kinaesthetic empathy for videos of ballet movements compared to capoeira dancers. Capoeira dancers showed heightened relative activation in premotor areas and parietal areas associated with action observation and kinaesthetic empathy for videos of capoeira movements compared to ballet dancers. The relative activation in target premotor and parietal areas was significantly lower among non-dancers than either ballet or capoeira dancers. And, more importantly, there was no significant difference between the two conditions for this group.

Calvo-Merino’s study is interesting and important. It suggests a non-scientific method for studying the influence of particular stylistic conventions in our engagement with dance. However, the promise of the study comes with a caveat. The controls, naïve viewers who lacked salient motor expertise, were not sensitive to perceptual differences necessary to discriminate ballet and capoeira from one another as categories of dance. Of course, the goal of the study was to explore motor expertise effects in perception, not the aesthetic responses of naïve viewers to dance. Naïve viewers do exhibit aesthetic responses to some types of abstract movement features (Calvo-Merino et al. 2008). However, and this is the critical point, non-dancers in the study were not perceptually sensitive to the biological motion cues diagnostic for the appropriate categories of art. This entails that non-dancers were not perceptually sensitive to those aspects of the choreographed movements hypothesized to be diagnostic for the artistic salience of particular works of dance. Therefore, it is not clear that kinaesthetic empathy is sufficient to provide viewers access to the range of artistic conventions necessary to recognize and understand choreographed movements as works of dance.

The problems identified here present a general challenge for the methodology of neuroscience of art. The identification of a close coupling between the formal/compositional structure of an artwork and the structure of perceptual systems is not alone sufficient to explain the artistic salience of the features of particular artworks. Although this may be a sound strategy for explaining how artworks perceptually communicate their content, it does not suffice to explain how consumers recognize the artistic salience of that content. Analogous difficulties arise when we turn to the dance side of neuroscience of dance. Consider Yvonne Rainier’s solo in Trio A and the duet in Merce Cunningham’s Septet (Atlas 2003). The female lead in Septet plays the role of an inanimate partner, expressively inert, manipulatively and sensually dependent on the support of the dancer. The focus of the dance is, as a result, the detached form, the kinaesthetic and dynamics, of her movements. Likewise, the generation that followed Merce Cunningham in New York embraced pure movement. The anti-expressionist flavour of the works performed in the early 1960s at the Judson Dance Theatre, like Trio A, embraced the often invisible, expressively neutral, repetitive, stereotyped movements of everyday activities. Of course the extreme expressive neutrality of the movements in these pieces is striking, and strikingly expressive in its own right. But, whatever their artistic salience, it is not identical to, nor adequately captured by, focused attention on the perceptual experience of, their explicit expressive quality, neutrality. It lies somewhere else. Sometimes conceptually difficult artworks like Septet and Trio A are singled out and set aside as aesthetic outliers. This is a common strategy used to handle counterexamples to aesthetic theories of art. Seen against the context of the broad range of aesthetic objects we favour in our everyday lives, e.g. design items and


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architectural spaces, this strategy may have some merit. But it is out of place within the context of the category "art." The self-reflective conceptual play these works exhibit is a canonical artistic practice that has transparently defined our engagement with artworks since at least the advent of modernism in the mid-nineteenth century, and arguably has covertly always defined art (Danto 1983).

4. Art, meaning, and perception

The crux of the problem for neuroscience of dance is that the expressive properties of choreographed movements are not generally ends in themselves, they aren't alone the point of the work. Rather, they are a means for the expression of a range of ideas. Arthur Danto makes a distinction between what is seen and what is shown in our engagement with artworks that can be used to elucidate this point (Danto 2003a). What is seen in a work of visual art is what is explicitly visible in its surface, its formal properties and the depictive content that emerges from their compositional relationships. What is seen is transparently visible to any organism with perceptual capacities like ours, e.g., pigeons in Danto's assessment (Danto 2003a). What is shown, in contrast, emerges from a relationship between what is seen and what Danto calls an atmosphere of theory, or the contextual background of artistic practices against which the work was constructed and within which it is engaged (Danto 1983). What is seen is a tool used by artists to communicate what is shown, the meaning, or perhaps better the content of the work. The diagnostically of the formal features of a work, their artistic salience, is thereby a function of what is shown, not what is seen.

Danto's classic example is a hypothetical exhibition of red canvases that he describes at the beginning of Transfiguration of the Commonspace (Danto 1983, p. 1). The first work in the show is a fictional painting of the Isselelites crossing the Red Sea mentioned by Soren Kierkegaard in the aphorisms at the beginning of Either/Or (1843/1987, p. 28). Kierkegaard described the painting as a representation of the spiritual turmoil that haunted his life (apparently associated with the panic, fear, and claustrophobia of a displaced people being chased down the narrow corridor of a dried sea bed). Close to the world's most powerful army, towering walls of water threatening to collapse and drown them. This painting is followed by an anonymously painted abstract portrait called Kierkegaard's Mood, a Suprematist composition by Kazimir Malevich called Red Square, a painting called Nirvana, a still life with an embittered disciple of Henri Matisse called The Red Table Cloth, a canvas grounded in red lead that Giorgione had intended to use for an unpainted masterpiece, and a rag from a garage work-shop stained with red lead paint from a weekend project. These works are, at first glance, perceptually indistinguishable red canvases. However, they are quite distinct artefacts. Isselelites Crossing the Red Sea, I take it, isn't much of an artwork, but it would be a philosophical curiosity of some value if it existed, an interesting intellectual artefact. The portrait of Kierkegaard, on the other hand, would be seen as a canonical example of early modernist expressionism. Nirvana would be of interest as a contemporary postmodernist painting that comments on attitudes towards religion. Danto tells us that "red dust" is a term used by detectives to refer to the Sammaric order that leads to Nirvana. The still life after Matisse is stylish and derivative. But perhaps it would be of art historical interest as an example of the value of originality in art (or its limits). Giorgione's canvas is not an artwork. It would nonetheless be an interesting artistic artefact, a physical trace of his presence. The rag bears no relation to art at all. Of course, it is important to note that the works aren't really perceptually indistinguishable. We could easily tell them apart. But, and this is Danto's point in the end, whatever perceptual differences we would use to physically sort them one from another would not, in and of themselves, suffice to distinguish them from one another as the particular artworks that they are, or even mark them as belonging to one category of art or another.

Where do Danto's distinctions leave us? An artist uses what is seen, or better perceived, to communicate ideas, to show the consumer the content of her work. The content of a work need not be an explicit propositional meaning. It may be that the artist intends for the consumer to apprehensively reflect on some aspect of experience, or simply to enjoy the perceptible features of the work. Nonetheless, in each of these cases a consumer would have to parse out the relationship between what is seen and what is shown, the communicative intent of the work, in order to understand its artistic salience, in order to recognize it as an artwork it is, and even to understand how to engage with it in the first place. Let's return to Sept 2 again. Carolyn Brown describes the experience of dancing the piece as a feminist nightmare (Atius 2001). The following interpretation of the piece emerges from Brown's memory and a reading of Ann Dolly, "The Balanchine Woman: Of Hummingbirds and Channel Swimmers" (Dolly 1987). The romantic ballerina was a celebrity and the focus of attention in part because she was presented as enticing, alluring, and elusive. Analogously, the ballerina is the focus of attention in Balanchine's modern ballets. But here her strength and independence is signaled by the athleticism of her postures and movements. The role of the dancer in this context is to display the ballerina's strength. Her movements are framed and guided by her muscular control. He supports her poses and provides the extra energy necessary to facilitate her aeroelastic movements...and herein lies both the art critical problem and the artistic salience of the work. The ballerina's postures and movements are constrained, controlled, contorted, and coerced by the will of her male partner, some of which she could not accomplish without him.
This entails that she is not actually treated as a strong, independent character. Rather, she is passively displayed, presented as an object of manipulation and voyeuristic regard by a male choreographer. Against this art critical backdrop, the numbed neutrality of Carolyn Brown’s modernist performance in Septer is deeply expressive: it portrays the emotional retreat of a powerless participant in a coerced activity. A similar kind of story can be told about T releases. Interpreted against the overweening metaphysical and psychological weight of abstract expressionism and modern dance, the pedestrian playfulness of Yvonne Ruizer’s movement in the piece is expressive of the mischievous collective irreverence that defined early conceptual art. Seen against the conceptual backdrop of Balanchine’s modern ballet, this irreverence can, in turn, be interpreted as an expressive act that wrests the strong individuality of the dancer away (or maybe better back) from the dance.

These examples illustrate a functionalist account of artistic form (Carroll 1999, Carroll & Tanes 1982). How do we delineate artistically salient features from the range of formal features and compositional relations present in a work? We ask ourselves why the work was made: the way it was, what its purpose is, how the formal choices made by the artist contribute to its context. In difficult cases we may have to engage in explicit interpretive activities in order to tease these out of the work. But in the vast majority of cases a tacit understanding of the general practices that define common categories of art, the stylistic conventions and productive practices that define schools of art, artistic movements, or the body of work of an individual artist, will suffice.

A sensorimotor model for audience engagement with dance.

The presence of a heightened focused awareness of the expressive qualities of movement in our engagement with dance does not suffice to explain the artistic salience of the choreographed movements from which they are constructed. What matters is the semantic salience of these features, or how they contribute to the more general context of the work. The semantic salience of an artwork, in turn, is not an intrinsic property of any of its features. Rather it emerges from the context of our engagement with the work, from the range of artistic conventions that define artistic practices and consequently constrain artistic production. The challenge for neuroscience is dance is, therefore, to understand how choreographers and dancers use kinesthetic empathy in the context of artistic conventions to express the content of the work. In what follows I will sketch out a sensorimotor model for audience engagement with dance derived from a diagnostic recognition framework for object recognition and a biased competition model for selective attention. This model can serve as a framework for understanding how dance can communicate the artistic salience of its formal and compositional features.

The sensory inputs to perceptual systems are, as discussed above, replete with information about the local environment. Cognition is, in contrast, a limited capacity resource. Selectivity is, as a result, a critical feature of perceptual processing. This raises a question. How do we assign salience to local environmental features? One way is simple perceptual salience. Some features stand out because they are distinct from their surround, e.g. high colour contrast or sharp differences in the relative motion of a target and its surround. However, it is not always the case that the features salient to our current behavioural context are also the most perceptually salient. This entails that perceptual systems need an independent mechanism to bias perception to the behaviourally salient features of an organism’s local environment. Biased competition models for selective attention demonstrate that cortico-hippocampal attentional networks bias perception by priming sensory systems to the expectation of features diagnostic for the identities, shapes, and affordances of task salient objects and their parts in particular locations, enhancing the perceptual encoding of expected targets and inhibiting the encoding of local distractors. Selective attention is, therefore, a mechanism through which we flexibly bias basic sensory processes to our current behavioural context on the fly relative to our changing needs in a dynamic environment.

Diagnostic features are defined as sets of sensory features sufficient to enable an organism to perceptually recognize the identity, shape, and affordances of objects and events in the local environment (Schyns 1998). Diagonsticity is a task specific notion (Palmer 1999). Altering our behaviour, changing a target task, changes the way we categorise objects and events. Changing the way we categorise objects and events alters the way we assign salience to its parts and features. Given the framework of a biased competition model for selective attention, this entails that changing the way we categorise an object or event quite literally influences the way we perceive it.

How do biased competition models propose that task salience is integrated into sensory information in goal directed behaviour? Feedback projections from prefrontal areas associated with spatial working memory and object recognition, e.g. dorsolateral prefrontal cortex (DLPFC), and premotor areas associated with the implementation of motor programs for motor preparation and planning, e.g. supplemental motor area (SMA) and premotor area (PM), to areas throughout the visual system enhance the firing rates of populations of neurons that would encode for target objects and features at expected locations and inhibit the firing rates of populations of neurons that would encode for task irrelevant distractors (Kastner 2004; Schubotz & Von Cramon 2003). These processes include top
down projections to subcortical areas like the lateral geniculate nucleus (LGN) and pulvinar (PUL) in the thalamus and the superior colliculus (SC). LGN is the primary relay station for sensory information between the retina and the visual system. Pulvinar is reciprocally connected to SC and all areas of the visual system (Pessoa & Adolphs 2010). SC is a multisensory area involved in directing eye movements and the cross-modal integration of visual, auditory, and somatosensory information (Beck & Kastner 2009). Analogous stories can be told about the architecture of attention in auditory and somatosensory processing (Muschamp & Wilson 2010; Stein, Stanford, Wallace, Vaughn & Jung 2004; Wiener 2006). Affective processing influences perceptual processing via a similar cortico-amygdala network that includes reciprocal connectivity between areas associated with assessments of the predictive value and behavioral significance of objects and events, i.e. orbitofrontal cortex (OFC), visceromotor control and gut reactions, i.e. ventromedial prefrontal cortex (vmPFC) and anterior cingulate cortex (ACC), and the amygdala (Duncan & Barrett 2007). Amygdala is reciprocally connected to the visual, auditory, and somatosensory systems. These cortico-thalamic and cortico-amygdala attentional networks are mechanisms through which cognitive assessments of object identity and behavioral context influence sensory processes at their very earliest stages. The result is an integrated, cross-modal biased competition model for perception that is a means to direct attention, encode the mnemonic, task, and emotional salience of objects and events, and facilitate embodied responses to affective and sensorimotor contingencies in the local environment.

What is the take home message for neuroscience of dance in this laundry list of neurophysiological processes? Artworks are attentional engines (Carroll, Moore & Secely 2012; Carroll & Secley in press; Rollins 2004). Object recognition is a goal directed task in which perceptual systems parse sensory inputs into salient cues and group them together into objects relative to available perceptual categories. Artworks are communicative devices that are designed to focus attention on minimal sets of perceptual cues diagnostic for their content. How might this work in practice? The conventions governing consumer engagement with artworks within a medium or genre are strong constraints on artists' productive practices. Cues diagnostic for the categorical intentions of an artist, or the category of art an artist intends a work to belong to, e.g. modern dance, modern ballet, or capoeira, shape the attentional strategies adopted by consumers in their engagement with dance—what to look for and where to look for it. These diagnostic cues include sensorimotor cues which trigger the activation of motor programs that encode the kinesthetics and dynamics of everyday actions with knowledge of the formal and compositional conventions governing different types of dance would suffice to bias perception to biological motion cues diagnostic for the expressive content of a particular dance—just as the conjunction of generic motor programs and general world knowledge do when we use sensorimotor processes to track and predict the movements, actions, sounds, and emotions of others in everyday contexts (see Collo-Merino et al. 2008). If so a general knowledge of artistic conventions might suffice to bootstrap embodied responses to artistically salient expressive features of choreographed movements. Dance is a hard medium to understand in part because it is abstract, or, as Sally Barnes argues, constrained on

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6. The neuroscience of dance Redux

The sensorimotor model that I have proposed is not offered as a definition of dance. It is rather offered as a model for how the neuroscience of dance can contribute to our understanding of a range of artistic practices associated with the medium. The model resolves questions about how consumers discriminate artworks from non-artworks in dance contexts. The artistic salience of a dance does not lie in the expressive qualities of choreographed movements per se, but rather in the way these expressive qualities are used as communicative devices to convey the content of the work. e.g. the expressive neutrality of the woman's part in the duet from Septet can be interpreted as a reflection on the relationship between the compositional structure of Balanchine's modern ballets and our perception of gender roles in traditional dance genres, an interpretation suggested by the dancer herself (Atas 2001).

What about questions raised by the observation of expertise effects in our sensorimotor engagement with dance? These are concerns that emerge from the observation that familiarity with the motor skills required to perform an action may be needed to recognize the sensorimotor contingencies constitutive of an embodied response to it. The integrated biased competition model for selective attention sketched above suggests an alternative possibility. Perhaps the pairing of generic motor programs that encode the kinesthetics and dynamics of everyday actions with knowledge of the formal and compositional conventions governing different types of dance would suffice to bias perception to biological motion cues diagnostic for the expressive content of a particular dance—just as the conjunction of generic motor programs and general world knowledge do when we use sensorimotor processes to track and predict the movements, actions, sounds, and emotions of others in everyday contexts (see Collo-Merino et al. 2008). If so a general knowledge of artistic conventions might suffice to bootstrap embodied responses to artistically salient expressive features of choreographed movements. Dance is a hard medium to understand in part because it is abstract, or, as Sally Barnes argues, constrained on
production within the medium limit the clarity with which it can convey ideas. But this is only part of the story. Dance history, the story of the conventions that define categories of dance, is not transparent part of our everyday engagement with public media. In the same way that the history of painting is. This raises the possibility that non-dancers may simply have lacked sufficient contextual information to tease out what was shown in what was seen, to recognize the experiential stimuli as exemplars of different categories of dance. Or, it may be the case that the dance stimuli used lacked the compositional depth necessary to carry categorical artistic salience for naive viewers. One means to evaluate these possibilities would be to include a control group of dance critics who were familiar with copoiros and ballet, but were not themselves dancers, in an experiment with the same design. However, independent of the validity of this alternative explanation of the performance of non-dancers in Calvo-Merino's study, the tale home message in the proposed model is that methodological objections to the neuroscience of dance, and neuropsychology of art more generally, can be overcome by paying closer attention to the full range of variables that contribute to our understanding of artistic salience in ordinary contexts.

References

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