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Thinking in action: thought made visible in contemporary dance

Received: 16 June 2005 / Revised: 12 July 2005 / Accepted: 14 July 2005 / Published online: 26 August 2005
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Abstract Contemporary dance—movement deliberately and systematically cultivated for its own sake—is examined in the light of the procedural and declarative view of long-term knowledge. We begin with a description of two settings in which new works of contemporary dance are created and performed. Although non-verbal, contemporary dance can be a language declared through movement and stillness of the body. Ideas for new movement material come from objects, events or imaginings that are spoken, seen, heard, imagined, or felt. Declared through movement, the idea becomes visible. Communication in dance involves general psychological processes such as direct visual perception of motion and force, motor simulation via mirror neurons, and implicit learning of movement vocabularies and grammars. Creating and performing dance appear to involve both procedural and declarative knowledge. The latter includes the role of episodic memory in performance and occasional labelling of movement phrases and sections in rehearsal. Procedural knowledge in dance is augmented by expressive nuance, feeling and communicative intent that is not characteristic of other movement-based procedural tasks. Having delineated lexical and grammatical components in dance, neural mechanisms are identified based on Ullman's (Ullman in *Cognition* 92:231–270, 2004) alignment of lexical knowledge with declarative memory and mental grammar with procedural memory. We conclude with suggestions for

experiments to test these assumptions that concern thought in action in composition, performance and appreciation of contemporary dance.

Keywords Action · Memory · Procedural knowledge · Declarative knowledge · Implicit learning · Non-verbal communication

Thinking in action: thought made visible in contemporary dance

In contemporary dance, the major medium is movement, deliberately and systematically cultivated for its own sake, with the aim of achieving a work of art. Movement material that is created, performed, or observed engages motor and kinaesthetic processes and leads to cognitive and affective reactions. Rich in gesture, expression, and affect, contemporary dance is a heightened form of non-verbal communication. Contemporary dance shares with other art forms the possibility of being viewed either as non-representational, non-symbolic, formalist, or of being representational or symbolic in some sense. At one extreme, contemporary dance comprises movement pure and simple, investigating how weight and force interact with time and space (Cunningham 1968; Gardner 1993; Vaughan 1990) requiring no support from music, no visual background, no plot. At the other extreme, dance has been regarded as the termination, through action, of a certain kind of symbolic transformation of experience (Hanna 1979), or “an image of dynamic life” (Langer 1953, p 175). Across the gamut, dancers and choreographers use the body's motion and stillness to sculpt shapes and patterns in space and time.

What are the cognitive processes that underpin creating, performing or responding to contemporary dance? In this paper we examine candidate processes and consider whether they are unique to dance or shared by musical and athletic performance and response. Complex dance vocabularies challenge the view of memory as

Communicated by John Sutton

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a storehouse of linguistic propositions. We argue that some aspects of dance draw on procedural, implicit knowledge but dance is also intentionally communicative and expressive; feelings and personal experience of dancers and choreographers brought to the work in the studio imbue the work in performance. Examples provided suggest that creating and performing dance involves both procedural and declarative knowledge. Although non-verbal, contemporary dance can be a language declared not in words but through movement of the body. The inspiration for phrases of dance material may be a concept, feeling(s), a space, texture, rhythm, lilt or sound. Declared through movement, the idea becomes a visible thought.

In the next section, we will briefly describe two settings in which new movement material was created in the dance studio and subsequently performed. The material illustrates ways in which choreographer and dancer communicate and create (for detailed accounts see Grove et al. 2005; McKechnie 1999, 2001, 2002, 2005; McKechnie and Grove 2000; Stevens et al. 2003). Multimodal thinking, memory for complex movement, and response to dance are then examined in the light of direct perception, neural mirroring, and procedural and declarative knowledge. Hypotheses that capture our assumptions about processes in composition, performance and appreciation of contemporary dance are discussed.

Two examples of choreographic processes

“Eternity”: the Quantum Leap Youth choreographic ensemble

The Quantum Leap Youth Choreographic Ensemble at the Australian Choreographic Centre in Canberra involves over 50 young and inexperienced dancers in an intensive out-of-school ‘dance enrichment program’. In 2004, the Quantum Leap process focussed on the Eternity Exhibition at the National Museum of Australia. The exhibition provided a basis for the themes that were to inspire the development of the year’s work and performance. Several visits to the museum led to ongoing studio discussions about the individual experiences that made up the exhibition.

Eternity is a single 90-min dance work with many parts and sections. Much like a book, it has chapters, pages and paragraphs. Within this book-like structure, the creative team considered the ten emotions that give structure to the *Eternity* exhibition. The poems that accompany each emotion were written by local writer, Francesca Rendle-Short (in Stell 2001). The programme for the performance of *Eternity* notes that ‘these poems provide a profound basis for the imaginative journey of contemplating and owning our own intimate experiences of these states of being.’ ‘The mystery of these states of being’ weaves itself through the choreographic journey, maybe never to be fully revealed. ‘The mes-

senger in the form of a letter, brings us news and sculpts our journey. Good news or bad news, it brings us messages of separation, mystery, hope, joy, loneliness, thrill, devotion, fear, chance and passion. These messages challenge our daily life and colour our journey to its conclusion.’

The girls and boys of Quantum Leap meet with the choreographers and begin work in the studio in small groups. For example, a group of 11 boys and young men work with the choreographer, Darren Green. Their theme is ‘fear’. They have wondered at the stories of fearful episodes told by the subjects of the Eternity exhibition.

Feel fear? Be very afraid.

Perhaps the strongest of all emotions, fear can crucify your body. Faced with impending danger, your hair stands on end. Blood runs cold. Flesh creeps. Adrenalin pumps as you flinch, shake or quiver, even petrify. Terrors by their nature must be faced alone. But in retelling the horror, fear *can* unite. (Rendle-Short in Stell 2001.)

They talk about it in the studio, tell their own stories, listen to the experiences of others in the group. They improvise to find movement ideas while the stories still grip the imagination. These are the strategies used by actors too but the dancers at this stage have only words and images in the mind; now their bodies must find images powerful enough to convey all this without words. The choreographer demonstrates a slow sustained crawl across the floor; he encourages Charlie to find a similar quality; ‘disembodied tortoise fluid’ he says earnestly as he concentrates on the young dancer’s effort. Nobody finds this funny. The absorption in the group is intense as Charlie, now the subject of their entire focus, melts his body into the floor, slows the pace of the backwards motion, mysteriously finds a quality of creepiness and fluidity. ‘That’s great’ says the choreographer. Everyone relaxes.

They have all learned something, just by observing the process. It is repeated many times. They build a pyramid of bodies: bigger stronger bodies supporting the younger, lighter ones (Fig. 1). ‘Wider and longer’ urges the choreographer as a group advances menacingly, ‘keep it muscular, keep it tense’. And then, when the boys are encouraged to recall what it is like to be truly intimidated he asks them to find the postures of intimidation in their own bodies. ‘What does it look like? Show me.’ Two 14-year-olds struggle to find it. We observe that this is difficult; shoulders lift and chins jut, small chests struggle to expand. No words can easily convey the endearing quality of the effort to find the threatening stance they have often observed in the schoolyard (see Healey 2005a). We suggest that the boys experience an unspoken, felt, bodily knowledge—possi-

Fig. 1 Boys from the Quantum Leap Youth choreographic ensemble at the Australian Choreographic Centre in the early stages of developing the work, “Fear”. Choreographer Darren Green is shown in the right of the photo. Photo by Sue Healey



bly a precursor to an embodiment that can be observed, and ‘felt’ by others.

“Red Rain”: Anna Smith (1999)

Was the creative process observed in the Quantum Leap group different from that practised by the professional dance artists we had studied over the previous 5 years (see Grove et al. 2005)? We think not. Emotional and intellectual engagement with an idea or image was central to the processes pursued by both groups. The key to this engagement was often provided by a choreographer who could find gestures or words that bridged the distance between the intellectually understood and the range of feelings this elicited. Sometimes this process worked in reverse: the choreographer recognising in a dancer the kinaesthetic subtlety and refinement that illuminated the idea.

The dance work *Red Rain* was created for the *Unspoken Knowledges* research project, involving choreographer Anna Smith and seven dancers over a period of 9 months in 1999 (Smith 1999). It won Melbourne’s Green Room Award for original choreography in that year.

The choreographer chose the words ‘blood’ and ‘red’ as a starting point for her ideas. She offered brief snatches of imagery from some remembered readings; perhaps from some personal experience of loss (for a full case study of *Red Rain* see Stevens et al. 2003). Here is a summary of extracts from choreographer Anna Smith’s (unpublished data) journal and from recordings of discussions with the dancers.

‘soaking the high air scarlet’; ‘blood silently burning’; blood knotted to life and death. These words engender imagery that is textural, sensuous, provocative;

images which have their roots in the legends of many cultures. The single word ‘blood’ provides a rich and eloquent source for movement invention. Red wax drips onto bare skin; it is like blood ebbing slowly. Red wax on white paper; blood on white snow. The legendary lantern fuelled by burning blood was called ‘the lantern of life and death’.

Many ideas give birth to the movement material: a torrent flows, a visceral relationship with images and light suggests ‘blood red’. The movement through the space is sometimes chaotic, sometimes stilled. Tensions are dynamic and urgent, at other times structured to suggest a sensual flow. Movement combines with text, molten wax, drifting paper and other elements to create a richly layered and contemplative work. In its final form *Red Rain* is suggestive of the cycles of experience in which rituals of birth and death, isolation and community, mark the passing of women’s lives.

Like the young dancers in *Eternity*, these highly skilled and experienced dance artists have found the movement material via an exploration of their own thoughts and feelings, their observations and discussions with one another, and the guidance of the choreographer. She is the final arbiter of the work’s overall form and shape.

Cognitive processes in creating, performing and responding to contemporary dance

Mixed modalities in creating a dance

The two case studies affirm that creativity in contemporary dance is movement-based and material evolves from experimentation and exploration in the medium itself (Foster 1976; Hanna 1979; Healey 2005b; Hum-

Fig. 2 Members of the Quantum Leap Youth Choreographic Ensemble in rehearsal 2004 at the Australian Choreographic Centre. The flying boy is Jason Franks with Paddy Quiggin ready to catch him. Photo by Sue Healey



phrey 1959; Limón 1955; Vaughan 1990). The source of an idea in a new work may be drawn from any modality—word, concept, visual image or space, music, heard or felt rhythm, beat, texture, visual, auditory, muscular, or psychological tension, emotion or feeling (Foster 1986; McKechnie 2002; Stevens et al. 2001, 2003). The idea is then made visible being expressed through movement subtleties and qualities, contrasts between tension and relaxation, and between high degrees of physicality and absolute stillness.

Communication through movement and dance

Communication between dancers, choreographer and dancers, and dancers and audience can occur in at least three compatible ways¹: (a) direct perception of motion, force and dynamics (see Fig. 2); (b) perception through neural mirroring and sympathetic kinaesthesia, particularly among experts; and (c) recognition of patterns and structure similar to implicit learning of artificial grammars—within a single work or across a body of works from a particular choreographic tradition.

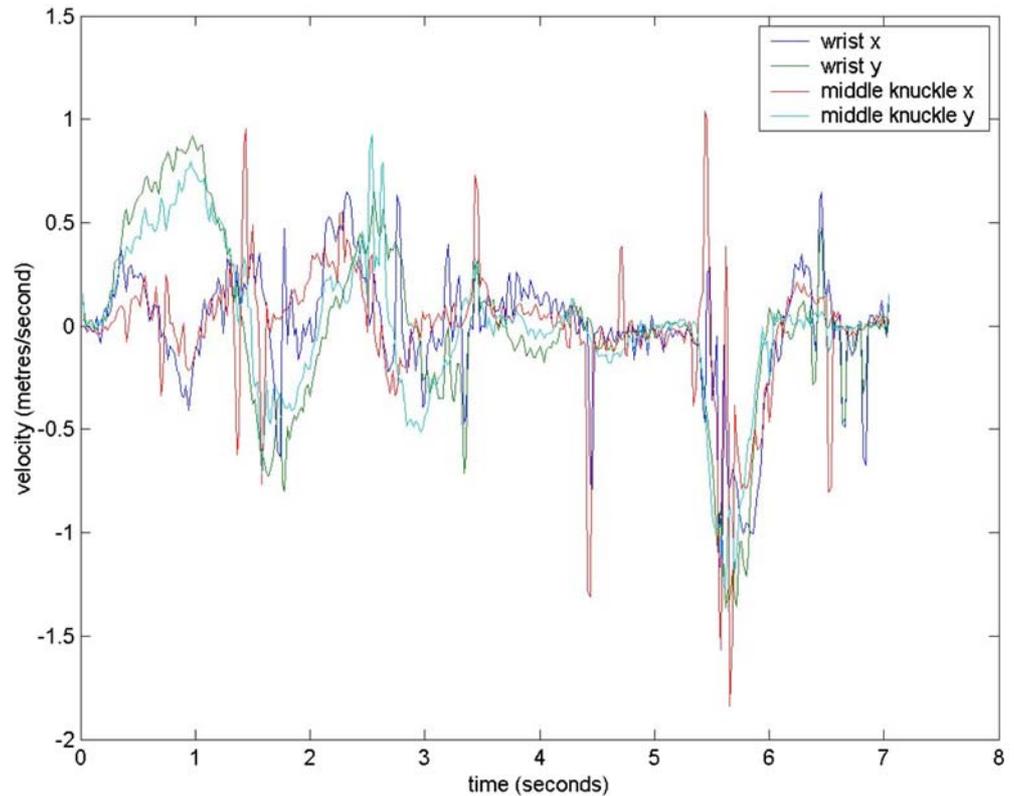
¹It is important to note that dance and music performed separately from each other and observed passively is a largely Western and relatively recent phenomenon (Cross 2003). The mechanisms discussed have been informed by our analysis of contemporary dance in a Western setting. As perceptual mechanisms they are likely to apply to a range of stylistic and cultural contexts.

(a) Direct perception of motion and force

Dance as the motion of bodies through space and time embodies dynamical principles of the physical environment and, we contend, can be understood by direct visual perception. Contemporary dance can be considered as an exemplary instance of human movement that brings movement relations into relief from which general principles may be uncovered. We have suggested elsewhere that Dynamical Systems Theory (Stevens et al. 2000, 2002; Stevens and McKechnie 2005) may be used to analyse and quantify many timescales and dynamics of human movement and bring to the surface certain fundamental patterns that humans enjoy and understand. Hagendoorn (2004) proposes that watching dance involves motor imagery (p 95) and that the brain predicts motion trajectory and dynamics (p 97). Pleasure, he argues, arises from (1) increased allocation of attention and a general state of arousal if a movement deviates from its predicted path, and (2) rewarding correct prediction of the motion trajectory. Hagendoorn's theory assumes enjoyment through direct perception of dynamics and forces acting on a dancer moving through space and time.

If observers are, quite literally, moved by watching contemporary dance then there will be significant correlations between dynamics of velocity and force and the rate of change of engagement (an attentional reaction) and/or rate of change in emotional response. As an example, Fig. 3 shows velocity recorded in the x and y dimensions of two points on the right arm of a dancer as she generated a new phrase of movement. Using on-line, continuous recording techniques (e.g. Schubert 2001) we

Fig. 3 Plot of velocity recorded in the x and y dimensions of two points on a dancer's right arm (wrist, middle knuckle). The dancer had been asked to generate a new phrase of movement in response to the spoken concept "freedom"



can closely compare time series data of dancer motion, and continuous emotional responses recorded from observers as they watch a performance of dance (Stevens 2005).

(b) Mirror neurons and action recognition

A second mechanism that underpins reaction to contemporary dance is neural mirroring. Evidence is accumulating to support the hypothesis that *observing* an action involves the same repertoire of motor representations that are used to *produce* the action (Castiello 2003; Fadiga et al. 1995; Gallese et al. 1999; Murata et al. 1997). For example, stimulation of motor cortex of human subjects observing hand actions made by an experimenter led to activity in the observers of those muscular groups used by the experimenter in executing the actions (Fadiga et al. 1995). Motor simulation then is a candidate mechanism in non-verbal communication between dancers, dancers and choreographer, and underpinning the empathy reported by observers of dance (Foster 1976; Glass 2005; Malloch 2005).

It is a logical step to investigate heightened sympathetic response in individuals observing specialised or complex actions that they themselves have performed. In the domain of music, magnetoencephalography (MEG) has shown that pianists, when listening to piano music, exhibit involuntary motor activity in unilateral motor cortex (Haueisen and Knösche 2001 in Hagendoorn 2004). Calvo-Merino et al. (2004) using fMRI have

demonstrated neural mirroring and an effect of specialist expertise when dancers observed dance movement that they had learned to do (either classical ballet or capoeira) compared with movement that they had not learned to do (either classical ballet or capoeira). The results show an effect of acquired motor skills on brain activity during action observation—brain activity was affected by whether observers could do the action or not. Calvo-Merino et al. conclude that the brain understands actions by motor simulation. Importantly, neural mirroring appears to be distinct from direct perception in that the former is influenced by expertise and experience performing an action whereas direct perception involves visual perception of movement without requiring knowledge of the motor skills to perform such a movement.

Interpreting fMRI scans, Lee et al. (2001) suggest that novice observers perceive dance simply as movement whereas professional choreographers analyse movement with knowledge of choreography and the extraction of symbolic units that activate a semantic network associated with the meaning of particular gestures and actions. Calvo-Merino et al. too, noted some (non-significant) activity in middle temporal areas suggesting semantic categorisation of dance movement by experts. This is plausible given the labelled vocabularies of "steps" that constitute classical ballet and capoeira repertoires. We will return later to the interplay or competition between procedural and declarative memory (Poldrack and Packard 2003) that is implied in these brain imaging studies.

(c) Implicit learning of movement vocabulary and grammar

Classical ballet consists of a vocabulary of discrete, named steps such as *arabesque*, *attitude*, *plie*. Most contemporary dance has no single vocabulary or readily accessible system of notation. (Some choreographers have devised formal vocabularies of movement, e.g. Martha Graham, Cunningham, Lester Horton, José Limón. All dance and movement can be notated graphically via Labanotation. The ballet usually uses the system known as Benesh Notation. Benesh uses figurative symbols on a musical staff. Labanotation is an abstract representation with time depicted vertically and a different part of the body represented on distinct vertical lines. Video recording has, in many cases, replaced written notation although commercial ballet companies often employ trained notators particularly for archival purposes.) Many choreographers during the course of a single work or across a series of works may develop their own movement lexicon to which onlookers may become attuned. This is most likely to occur in the case of particular choreographers or in established choreographic traditions (e.g. Cunningham 1968; Graham 1973). A movement lexicon refers to phrases of movement with distinctive features of a choreographic tradition. For example, an emphasis on material involving leg work, or a particular athleticism, or distinctive, fine, subtle movement of limb extremities.

In those instances where there is an identifiable movement lexicon it is possible to liken contemporary dance to language², albeit non-verbal. It consists of vocabularies of movement and a grammar comprising a system of structuring patterns of movement—permissible combinations based on sound anatomical knowledge and the imperatives of training in a particular style. The latter accords with Snyder's (2000) deliberately broad notion of syntax in music. Syntax, to Snyder, refers both to traditions of rules for the use of particular kinds of functional patterns in particular musical styles (or schematic expectancies according to Bharucha 1994), and relations between patterns that are developed in (and unique to) particular pieces (or veridical expectancies according to Bharucha 1994).

Composers of dance or music use techniques such as repetition, redundancy, hierarchy, succession, and association to facilitate perception, comprehension, and retention of a particular work. It is proposed that while watching a performance of contemporary dance observers learn implicitly features of a particular choreographer's movement vocabulary, as well as the grammar or relations between identifiable patterns—the systematic way patterns are structured, sequenced, and related to one another in a piece. If this is the case then it

should be possible to demonstrate learning during a performance that is akin to the implicit and long-lasting learning of complex, artificial grammars, as studied by Reber (1967, 1993; see also Brooks and Vokey 1991).

Reber (1967) had participants either learn sequences of letters generated by an artificial grammar where certain forms were permissible and others not, or learn random sequences. Both groups then categorised a new set of 44 sequences wherein half had been generated by the grammar and half were ungrammatical. Those participants with experience of learning grammatical sequences averaged 79% correct categorisation, significantly greater than the level expected by chance, and significantly greater than the level of performance achieved by the other group. Participants in such experiments are generally unable to report any knowledge of the underlying rules or grammar—the knowledge appears to be implicit³.

Embodied thought: procedural and declarative knowledge in performing and responding to contemporary dance

The form of knowledge manifested in creating, remembering and performing contemporary dance presents a conundrum for cognitive psychology. Is the knowledge declarative, i.e., explicit knowledge of various facts? Or is it procedural, i.e., knowledge of how to perform various tasks? Explicit memory is flexible, and implicated in evolution of spoken and written language, conscious awareness, and evolutionarily newer parts of the human brain. Implicit learning is slow, rigid, unconscious, and evident in other animals in the form of reflexes and conditioning. In the next section, we argue that dance involves both procedural and declarative knowledge. Nuance, intention to communicate, and expression distinguish dance (and music) performance from other movement-based behaviours that rely on procedural knowledge (e.g. gymnastics, athletics). Finally, we apply Ullman's (2004) model of declarative/procedural knowledge to dance and posit that a dancer's knowledge of a work consists of declarative knowledge of the movement vocabulary and procedural knowledge of its syntax or sets of relations between identifiable patterns in the work. Such a model generates a number of testable hypotheses.

Dancing, like running or skiing, is procedural knowledge—implicit, unconscious knowledge of how to move one's body so as to generate, in the case of dance,

²According to the *New Shorter Oxford English Dictionary* (Brown 1993) language can refer to "a non verbal method of human communication, as gesture or facial expression, hand-signing, etc.; as a means of artistic expression, as dance, music, or painting".

³Speculating, there is an intriguing possibility that a rule common to all forms of dance is for movement to be biomechanically possible. Experiments have demonstrated that biomechanically impossible motion reduces, for example, accurate pursuit of two-dimensional targets (Viviani et al. 1987), and recognition of emotion in point-light displays (Dittrich et al. 1996). Further experiments are needed to determine whether this is an example of slow, ungrammatical sequence learning, whether it relates to the role of acquired motor skills in action perception, or whether these two postulates are both correct and linked

aesthetically appealing shapes, patterns, forms and motion trajectories. However, as well as expert contemporary dancers having procedural knowledge of general ways to move and to dance, we posit that through rehearsal and experiences in the studio they also have declarative knowledge of movement phrases and vocabulary that constitute a specific dance work. Calvo-Merino et al. (2004) reported activation of cingulate, retrosplenial and parahippocampal areas consistent with episodic memory. They proffered that familiarity of experts with their own movement style may lead to activation of brain mechanisms of episodic memory even when watching another person.

Dancers declare or make visible, thoughts, ideas, and images through patterns of movement and stillness of their body. Earlier, we discussed the multimodal inspiration for new phrases of movement. This knowledge too can be declarative with dancers in the studio consciously recollecting thoughts and ideas from their experience, general knowledge, visual or auditory imagery, emotional history, and feelings of fear, as in the example from the Quantum Leap ensemble. It is possible that, during performance, a dancer re-experiences an episode in which a phrase of movement emerged and became refined in the studio. While not semantic or referential for the *observer*, the *dancer's* knowledge of that phrase of movement has an episodic, autobiographical component and in performance may be accompanied by the feelings and recollections in the dancer that had been elicited by the choreographer or other dancers in the studio.

The affective and expressive components in creating and performing phrases of dance movement, e.g. expressing fear through the body described in the example from Quantum Leap, distinguishes knowledge in contemporary dance from procedural knowledge in other not-easily-verbalised areas of expertise such as athletics, gymnastics, maths, and physics. Feeling or expressive nuance (Snyder 2000) is likely to distinguish an *accurate*, effective physical action or movement in sport, music, or dance from an *expressive* performance in music or dance.

Verbal encoding, said to be the first stage in acquisition of expert skills (Anderson 1983; Fitts and Posner 1967) is not a necessary condition in contemporary dance. Verbal labels such as “D’s wrists”, “K’s shoulders”, “hangs” are used in the studio where dancers and choreographers name phrases or sections to cue and communicate in words (Stevens et al. 2003; Stevens 2005). The dancers working with choreographer Anna Smith commented on the extraordinary amount of information they needed to retain while working with the new and demanding movement material. On a particular occasion, a dancer watched herself perform a slow and intricate move on video but had little recollection of performing it or how she made her body move in a particular way. The dancer’s journal comments on the difference between producing movement after looking at the image on screen (*feeling* it in the body) and

reacting to a verbal prompt (Stevens et al. 2003). Comparing the dance of children and adults, McKechnie (1984) noted an apparent lack of ‘movement intelligence’ among adults who came late to the dance experience. Damasio (1999) has argued that once language is learned it is impossible to not use it as everything is named and this tends to take over. The children’s superior ability in being able to ‘look and do’ as described by McKechnie supports the notion that kinaesthetic perception and knowledge precedes verbal coding. Kinaesthetic perception appears to be a skill retained by those who dance.

Most often, communication in the studio is through movement—“*Show* me what you just did!” (Grove 1999, 2005). In the absence of skilled notation or multi-dimensional, multi-modal recordings and archives of dance works, dancers’ *bodies* are the repositories of dance works that they have performed. The transfer of kinaesthetic knowledge from the body of one dancer to another is unspoken, but declared and learned through movement (McKechnie 2001, 2002; McKechnie and Grove 2000). For expert dancers, it is likely that encoding movement bypasses verbal encoding and is quickly captured in muscles and proprioception (see Meyer and Palmer 2003 for empirical investigation of analogous processes and evidence of motor and non-motor memory in music performance, and Palmer and Pfordresher 2003 for a model of planning in sequence production). In some cases, *procedures* to generate a particular phrase of movement will have been performed previously by a dancer and, we hypothesise, will be available as long-term knowledge that is resistant to change.

In the second “associative” stage of skill acquisition (Anderson 1983; Fitts and Posner 1967), procedural knowledge may replace declarative knowledge, or the two may coexist. Such proceduralisation is familiar to all in the experience of a new task becoming automatic with practice (Anderson 2005). The knowledge of a new dance work of which a dancer may be consciously aware will, with deliberate practice (cf. Ericsson et al. 1993), become automated with retrieval fast and largely unconscious. Chaffin et al. (2002) identify the importance of basic and interpretive performance cues (explicit or conceptual knowledge) to facilitate rapid retrieval of complex actions from long-term memory. An example of the coexistence of the two forms of knowledge in dance is epitomised in the sentence that is needed to verbally describe a *grand changement* in classical ballet compared with its execution in less than a second:

“A *grand changement* is a very small change in the position of the feet. What is unusual, and perhaps ‘grand’ about this little piece of information is that the change is accomplished by an extremely difficult leap into the air while touching the toes of each foot together and simultaneously keeping the knees relentlessly facing in opposite directions” (McKechnie 2004).

From observation (e.g. Stevens et al. 2003) and experience (McKechnie and Grove 2000), the knowledge manifested in composing and performing contemporary dance appears to fluctuate between being procedural and being declarative.

Applying Ullman's model of declarative and procedural memory to dance

Ullman (2004) provides a new conceptualisation of language in relation to procedural and declarative knowledge that resonates with the present description of memory for contemporary dance. He argues that lexical memory depends largely on the declarative memory system whereas aspects of grammar depend on the procedural memory system. As we have proposed that there are counterparts to lexicon and grammar in dance, it is worthwhile to apply to dance (with caution), observations, mechanisms, and neural substrates specified by Ullman.

Double dissociations in humans and animals imply that declarative and procedural systems are largely independent but they also interact in a number of ways (Poldrack and Packard 2003; Ullman 2004). The declarative system is said to be related to the ventral stream system underlying perception of objects and their relations. The procedural system involves parietal cortex and is related to the dorsal stream. It involves the learning of context-dependent stimulus–response, rule-like relations, in the context of real-time sequences; responses are triggered by stimuli rather than being under conscious control; and the procedural system plays a role in learning new sequences. The two systems interact to form a dynamically interacting network that yields both cooperative and competitive learning and processing, such that memory function may be optimised (Poldrack and Packard 2003). For example, procedural memory maintains knowledge in declarative memory (Ullman 2004, p 243). When declarative memory is able to acquire knowledge it may do so initially while the procedural system gradually learns the same or analogous knowledge. Dysfunction in one system can lead to enhanced learning in the other, or learning in one may depress functionality of the other. There appear to be individual differences in relative dependence on the two systems.

The difficulty experienced by adults coming late to the dance experience was touched on earlier. Ullman (2004) hypothesises that after puberty, the grammatical/procedural system is less available than lexical/declarative memory, possibly due to an attenuation of procedural memory resulting from increasing oestrogen levels at puberty. Anyone who has attempted as an adult to learn to dance, ski, or play musical arpeggios can take heart in this explanation! Extrapolating from Ullman's thesis, an advantage gained from dancing, playing music

or playing sport in childhood and adolescence stems from cooperative and competitive activity in declarative and procedural memory systems into adulthood. Specific language impairment, according to Ullman and Pierpont (2005), is not specific to language but is the result of abnormal development of brain structures that constitute the procedural memory system. Examples of deficits outlined by the authors provide some support for our assertion that there are lexical and grammatical components to dance. For example, tasks involving complex sequences of movements appear to be particularly difficult for language impaired subjects (Ullman and Pierpont 2005). That is, problems with procedural memory impede sequencing of movement material that is underlain by complex rules of relations between patterns of movement.

Experimental methods to investigate cognitive processes in contemporary dance

There are at least two contentious claims made here that await empirical scrutiny. First, the psychological reality of movement vocabularies and grammars in contemporary dance, beyond mere metaphor, needs to be established. An interference paradigm could be used to demonstrate evidence of rapid acquisition of explicit verbal knowledge among dancers learning a new dance work. Declarative knowledge will be acquired rapidly and procedural knowledge more slowly; once acquired, the latter will be resistant to change. Where there is implicit knowledge of structural rules and which cannot be expressed in words, artificial grammar experiments could be conducted. Such experiments would examine the claim that expert observers and performers implicitly learn relations between phrases and higher order structural systems in dance works. Categorisation of sections from an actual dance work should be superior for those participants who complete a training phase with phrases and sections that conform to the grammar of a dance, compared with a training phase of random sequences of movement material. Second, we proposed that some of the declarative knowledge brought to performance includes autobiographical episodes in which a phrase emerged and was refined in the dance studio. Use of the thinking aloud protocol while a dancer watches a recording of their performance would be one way to examine the validity of this claim.

Questions are also raised by the ways in which contemporary dance communicates. These questions too can be experimentally addressed. If observers are sensitive to the kinematics and dynamics of dance then there will be significant correlations between velocity and force of dance movement, and audience members' continuous measures of emotional response and engagement. If dancers communicate with other dancers and with audience members through a neurophysiological mirror system then brain imaging techniques will illuminate neural mirroring and significantly greater re-

sponses in expert dancers observing phrases of movement from their own movement repertoire. It remains to be seen what areas of the brain are active when the dance material that is observed is, in the case of contemporary dance, not able to be explicitly labelled. Finally, if audience reactions are mediated by direct perception and implicit processes then response to dance may best be measured by gauging the desire of audience members to “join in”, and the recording of changes in physiological arousal such as heart rate and galvanic skin response.

We have argued that creating and performing contemporary dance involves both declarative and procedural knowledge and suggested that Ullman’s (2004) model has explanatory value when applied to the lexical and grammatical aspects of dance. Expressive nuance, affect and intention to communicate distinguish dance and music performance from other movement-based procedural tasks. Movement and concomitantly dance provide insight into one of the earliest forms of communication and memory, (e.g. Corballis 2003; Thelen 1995), both phylogenetically and ontogenetically, where activity is the agency of retention and memories are exemplars rather than linguistic propositions (Crowder 1993). Contemporary dance, communicative yet unspoken, provides a rich and relatively untapped setting for investigating knowledge acquisition and transfer through action, gesture and movement, through multiple codes and modalities, and through exemplars including episodes enriched by personal experience and feeling.

Acknowledgements This research was supported by the Australian Research Council through its Strategic Partnerships with Industry Research & Training (SPIRT) and Linkage research grant schemes (Grant Nos. C59930500 and LP0211991), MARCS Auditory Laboratories at the University of Western Sydney, the School of Dance at the Victorian College of the Arts, and industry partners the Australia Council, Ausdance, and the Australian Choreographic Centre. Our heartfelt thanks to the team at the Australian Choreographic Centre—Mark Gordon, Ruth Osborne, the Quantum Leap Choreographic Youth Ensemble, *Eternity* choreographers and composers, and film-maker Sue Healey; to Agnes Petocz, Shona Erskine, and John Sutton for discussions about art, thinking, and memory; and to Anna Smith, Stephen Malloch, and Rua Haszard Morris for assistance with motion tracking and analysis. Further information: <http://www.ausdance.org.au/unspoken>, <http://www.ausdance.org.au/connections>, <http://marcs.uws.edu.au>. Email: kj.stevens@uws.edu.au

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