The ‘H’ in HCI

Enhancing perception of interaction through the performative

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Abstract. Motion sensing technologies are well developed at the bio-mechanical (motion capture) and geo-locative (GPS) scales. However, there are many degrees of scale between these extremes and there have been few attempts to seek the integration of systems that were designed for distinct contexts and tasks. The proposition that motivated the Scale project team was that through such systems integration it would be possible to create an enhanced perception of interaction between human participants who might be co-located or remotely engaged, separated in either (or both) time or space. A further aim was to examine how the use of these technologies might inform current discourse on the performative.

Keywords. multi-modal, scaleable, interactive environments, interdisciplinary research, perception

1 Introduction

CIRCLE is a group engaged in **C**reative **I**nterdisciplinary **R**esearch into **C**o**l**laborative **E**nvironments. CIRCLE's members work at Edinburgh College of Art and the University of Edinburgh in the visual and media arts, dance and performance, architecture and sound, informatics and social sciences. They seek to undertake collaborative research at the juncture of the creative arts and sciences and across disciplines. The CIRCLE website is at http://www.eca.ac.uk/circle/

The Scale research laboratory was designed as a prototype research laboratory. In this paper we describe the undertaking and outcomes of some of the laboratory sessions. The intention is that having successfully completed the laboratory and arrived at some initial outcomes this work will serve as the basis for a more ambitious and rigorously framed research project.

2 Context

The Scale research laboratory was undertaken at a juncture of a number of research areas. These include research into choreography and cognition, interactive environments, dance education and motion capture in performance and animation. However, what bound these research foci together was a shared interest in how the perception of interaction, across interactive systems and medial modes, might be enhanced. The mix of disciplines might have been seen as a challenge but, as we found, was advantageous in addressing this overall aim.

Since the 1990’s there have been attempts to employ digital multimedia and imaging technologies in the recording, analysis and enhancement of physical performance. William Forsythe’s Improvisation Technologies interactive CD-ROM [1] allowed users to navigate a non-linear database of the choreographer’s work, learning choreographic and dance material, illustrated by the choreographer and his dancers. Scenes could be selected employing various angles of view. The dynamic use of graphical elements allowed the choreographer to visually illustrate the dynamics and character of particular movement sequences.

Fundamental work informing research in visual motion analysis was undertaken by Gunnar Johansson [2] at Uppsala University. This work employed video recording of light points attached to moving bodies that is strikingly similar in effect to contemporary motion capture systems.

Scott deLahunta is a key researcher inquiring into physical performance, choreography and cognition. His most recent work in this area has evolved out of a working relationship he has developed with choreographer Wayne McGregor and researchers at the University of Cambridge [3]. Recently he has been furthering this work with Forsythe and choreographers Emio Greco and Siobhan Davies on the development of ‘interactive choreographic sketchbooks’ and other digital tools for the analysis and creation of dance [4].

Kate Stevens' [5] work seeks to elucidate dance, from a psychological perspective, as a domain of knowledge and signification. Her research focuses on how communication operates in dance and information is apprehended in a non-verbal environment. Similar to deLahunta, Stevens' work employs both conventional and digital notational and analytical systems in the analysis of physical performance, the objective being to comprehend how movement is perceived as meaningful.

Significant artistic work has been undertaken with systems involving full-body interaction. David Rokeby [6] has worked with real-time video based motion analysis since the 1980's and his Very Nervous System software has been employed by numerous creative practitioners. Mark Coniglio, of dance company Troika Ranch, similarly works with self-authored tools to create interactive stage environments for the performers to inhabit and interact with. Coniglio's system Isadora [7] is used by numerous creative practitioners.

Biggs has worked with unencumbered sensing systems in artist designed interactive environments for some years, developing his first 3D motion analysis system whilst artist fellow at the Commonwealth Scientific and Industrial Research Organisation's National Measurement Laboratories, Sydney in 1984 [8]. Currently he works with and contributes to the development of Myron [9], an open source video tracking system, primarily authored by Josh Nimoy and used by other artists and developers.

3 Aims and objectives

The Scale research project sought to inquire into the following:

How do multiple sensing and tracking systems permit the mapping of the human body at multiple simultaneous scales and what effect do such systems have on those being monitored and tracked within artistic installations and performative environments?

What are the artistic possibilities, arising during the laboratory, involving scaleable representation of the human body in systems ranging from the subjective proprioceptive through to location specific human interaction and larger topographic environments?

The subsequent questions specifically addressed in this paper include:

How do different actual, augmented and telematic environments affect inter-actors self-perception and interaction with other inter-actors, interactive systems and the environment?

How do changes in telematic mediation affect inter-actor perception and behaviour (including agency) of themselves and others?

Does co-locating pre-recorded motion capture data with real-time video tracking of an inter-actor enhance the inter-actor's capacity to understand and internalise the recorded movement?

4 Methods

The evaluation of the Scale research laboratory was carried out employing several interpretative practices aimed at gathering data for qualitative analysis. Since the interest was in how the constructed environments affected the inter-actors' behaviour we applied methods, drawing on ethnography, within an action research approach.

Ethnographic research practices permitted direct observation of the inter-actors by the researchers, who were also situated within the research environment as subjects. We sought to apprehend the various physical and emotional states the inter-actors experienced in response to various stimuli (visual, aural, verbal and tactile) and their empathy with one another and reflect upon our actions and responses as engaged artists, researchers and system developers. We sought to identify how the stresses and tensions of multi-tasking, problem-solving and categorising within a complex interactive environment might result in inter-actors and researchers experiencing a heightened awareness and sensitivity of self and others.

This approach was helpful in identifying patterns of meaning creation by the inter-actors that informed our research objectives. In parallel to this data collection we employed hand-written notes and video recordings to record participants' observations derived from their "exhibited moment-by-moment improvised character" [10]. We also engaged with the inter-actors in short informal discussions and more formal interviews (Timmons, Hawksley, Wright, Ekeus), during and after the laboratory sessions, all of which were video recorded. It is proposed that these recordings will be subsequently digitised and annotated employing experimental video annotation tools in development at the University of Edinburgh.

The inter-actors activities in the interactive environments and other systems were documented on video tape (including real-time frame sequence screen grabs of the projections) while photographs were taken throughout all sessions and during the final presentation to an invited audience (Dima, Biggs, Timmons). Video recordings of the researchers engaged in the research process were also made. The gathered material was analysed and coded by a team of informants during and after the research laboratory (Timmons, Hawksley). The team discussed, at each stage, their findings with the rest of the research team in an attempt to identify elements that could serve in designing the next stage. This iterative process allowed outcomes of early experiments to inform the design of the later experiments.

Selected sequences of digitised video material are included with the electronic version of this paper. Documentation of the laboratory sessions is also accessible at http://www.eca.ac.uk/circle/scale1.htm

5 The laboratory

The laboratory was carried out in the British Association of Sport and Exercise Sciences accredited Biomechanics Laboratory within the Physical Education, Sport and Leisure Studies department of the University of Edinburgh and was organised as a week long intensive, following on from several days prior setup and testing of the technologies employed. The laboratory involved a number of members of the CIRCLE group, each bringing their own expertise and disciplinary concerns to the project, as well as four inter-actors who were professional contemporary dancers from the Scottish dance company, Curve Foundation. The dancers were Ross Cooper (Director, Curve), Morgann Runacre-Temple, Ira Siobhan and Lucy Boyes.

As professionals, all the dancers were highly skilled in movement and self-reflection, our reason for working with such professionals. Nevertheless, they each brought to the laboratory different prior experiences of working with set/choreographed and/or improvised material. Choreographic direction was by Hawksley. For some of the dancers adopting the role of inter-actor within a technologically mediated interactive environment was novel, demanding an approach and modality of self-reflection with which they were unfamiliar. This shift in their working patterns and self-awareness is reflected in the interviews conducted with them.

The hardware and software systems developed for and employed during the research intensive laboratory were composed of three primary elements, as follows:

5.1 The motion capture system

The 3D motion of the inter-actors was captured using a Motion Analysis Corporation system, operated by Wright. Spherical reflective markers where attached, using Velcro, to worn motion capture suits. Eight infra-red cameras, with ring-array red LED lights, were used to illuminate and record the motion of the markers. The 3D position of the markers was calculated and recorded as an x, y, z coordinate set in each frame at 60 frames per second. The system was not real time and had a maximum capture time of approximately one minute. Individual dancers were initially recorded with a full 32 marker set. Further recordings were taken of multiple dancers employing reduced marker sets. The motion capture data was used in two ways. Firstly, it was viewed as point data within the motion capture system so as to permit evaluation of the inter-actors ability to recognise individuals from the data set. Secondly, the 3D data was transferred and parsed for use in the real-time interactive video environment.

Dancer Ross Cooper within the motion capture environment.

5.2 Interactive video environment

Software and hardware systems were employed that allowed for the real-time playback of 3D motion capture data acquired from the motion capture system, combined with real-time video acquisition and image analysis. The software was composed of custom C++ code (Nimoy and Biggs) along with higher level Lingo (Adobe Director) code (Biggs). The system permitted full resolution acquisition of digital video which could be analysed in real-time to determine moving points of interest. Live acquired video bitmaps were encapsulated with corresponding 3D motion capture data-sets, allowing the isomorphic mapping of live acquired video to recorded 3D motion capture data and their object-oriented manipulation. Given real-time motion capture technology and appropriate interfacing this could be achieved with real-time motion capture data with little more development work.

The resulting composite digital video image was video projected life-size and co-located with the inter-actors who were the live subjects of the video acquisition system. The resulting effect was not unlike a digital mirror. The inter-actor would see elements of themselves, in real-time, mapped onto the recorded motion capture data. So long as the inter-actor closely mimicked the movements of the motion capture data then they could ensure that the corresponding anatomical elements would be synchronised with the corresponding motion capture points and thus each part could be graphically mapped to create a full image of themselves. In practice, the inter-actors rarely achieved perfect correspondence between their real-time and motion captured actions. The resulting asynchronous activity led to the emergence of a far richer visual effect than if the correspondence had been perfect. Indeed, to exploit this the software was modified such that a perfect spatial correspondence would not be possible. The image acquisition and motion capture tracking capability were designed to have a degree of spatial overlap. The visual effect caused by this was like a fragmenting tessellated mirror. The greater the asynchronicity of the inter-actor with the motion capture data the greater the fragmentation. When no synchronous activity was occurring the video would not be mapped to the motion capture data, causing elements of the inter-actor (at times, all elements) not to be mapped and thus for the live graphic image to be partial or blank. The greater the synchronicity the more data that would be visible and the more complete the mirroring effect achieved.


Image sequence generated within interactive video environment.

5.3 Visual temporal differencing system

This system was developed by Ekeus using Cycling 74's Max/MSP/Jitter development environment. A digital video feed of the inter-actors was acquired in real-time and a running average of the most recent frames calculated. The 'absolute difference' between this running average and the current image was calculated and output as a life-size projection. The effect was that stationary objects, including the floor and walls, 'disappeared', the projection showing only what had changed. If an inter-actor stood still, the running average of the frames would gradually match the current image seen by the camera and they would seem to ‘disappear’. Similarly, when individuals who were rendered ‘invisible’ moved they seemed to re-appear and also leave a 'shadow' at their former position. This shadow would also fade away over the time-span of the running average.

The effect was that the system would show a 'memory' of movement in the space and the inter-actors could effectively interact with their earlier movements. Different temporal scales were used, ranging from 10 seconds down to 1 second. This related to similar temporal effects achieved with the interactive video environment system. It was found that shorter time spans tended towards the inter-actors making faster, more sudden gestures, and the longer spans towards slower, smoother movements.

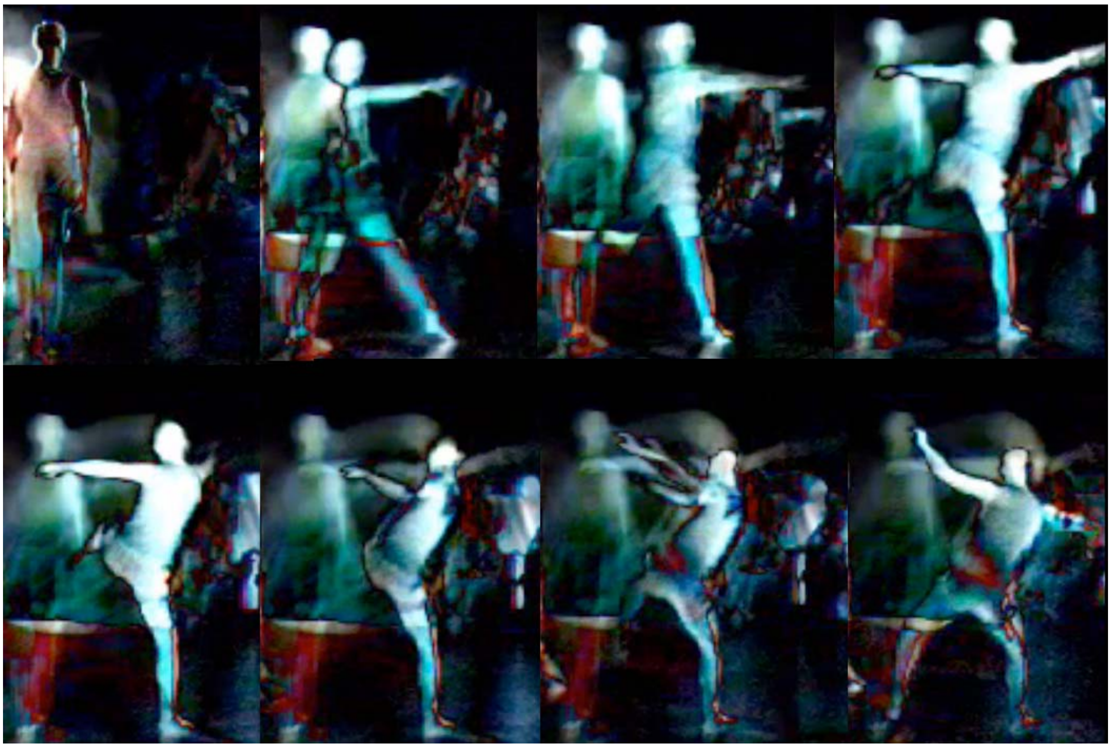

Image sequence generated by the visual temporal differencing system.

6 The experimental sessions

An intention of the laboratory was to explore and exploit the diverse disciplines and skill sets of the team members. One method was for the researchers to shift roles within the team, and to rapidly test out of a range of ideas, with a view to maximizing opportunities for unforeseen convergences and outcomes. Most interview sessions with the inter-actors were held informally, within the studio space, as they cooled down, emphasizing an ethnographic rather than analytical approach.

In the initial laboratory session three of the four inter-actors learned two set/choreographed dance phrases, comprising easily assimilated, codified material; one static, one travelling. The inter-actors also created short personal 'signature' phrases of movements that they felt in some way represented themselves. These phrases were recorded as full 32 point marker sets of 3D motion capture data, the phrases being executed by the inter-actors individually, in duets and in trios. The inter-actors had not previously seen the motion capture suits or the floor space. The only constraint they were given was that their phrases were to be of no more than one minute in length, this relating to the 1 minute capacity of the motion capture system. The physical size of the capture space was a cubic volume of approximately 4 x 3 x 3 metres in a laboratory space of roughly 10 x 10 x 6 metres. The researchers observed how the inter-actors adapted the phrases to accommodate the constraints of the system, with consequent effects on the use of space and timing as the suits restricted the inter-actors' movements. They needed to move more slowly to avoid the Velcro marker attachments sticking, relocating or detaching and also limiting points of body contact with the floor in floor-work to avoid pain from rolling on the markers.

Some of the motion capture data was rendered as point-figures and projected life-size and deployed so as to manipulate live acquired digital video employing the Myron software. An unexpected outcome of this particular configuration was that in order to maintain a mirror-like video image, the inter-actor is obliged to track the motion captured figure in real-scale time and space.

The three initial inter-actors reported that they felt their task was complicated by the demands of synchronising their actions with the live manipulated video imagery. However, the fourth inter-actor had not been present during the first day of the laboratory and thus we were able to observe her working within the immersive environment with no prior knowledge of how the interactivity worked, nor of the phrases. She was able to decipher some 85% of the movement material and spacing. She reported "finding it easy to follow lines in terms of structure, that was quite clear, but when it got confusing for me was when the movement became circular and things became curved, and the changing in directions, I was just totally lost" [11]. However, she indicated that the life-size scale of the projections were helpful, allowing us to speculate as to how such an experimental prototype could inform the design of a system for movement phrase learning.

The inter-actors also performed more subtle dance improvisations emanating from focussing attention to self and surroundings, more like a 'movement meditation'. Wearing reduced marker sets (as few as 7), to facilitate ease and greater range of movement, the inter-actors freely improvised in the laboratory space. Sometimes they did this as solo activities, sometimes as duos and sometimes as trios. However, they were not informed when recording would start or stop.

Dancers within the interactive environment.

Following these motion capture recordings, the inter-actors were shown data from a range of phrases and improvisations, displayed as point-light figures. They were asked to identify who they thought was performing each phrase and to explain how and why they drew their conclusions. They correctly and confidently identified most of the codified material and their personal 32 marker set phrases. The inter-actors' comments from the interviews indicate the phenomena by which they were able to make these identifications. When two of the inter-actors recognised another in the data sets and were asked why, one stated "the head's like this" [12] (physically demonstrating the movement) whilst another said "because I saw him perform the step and the third count of the second triplet was like how Ira did it" [13]. Ira then said "I think that it is (me) because of the space…" [14]. Further feedback, such as "Mannerisms, character, body shapes…the choice of the movements…there are certain things you can see, like the shape or height of someone's leg, or the line…" [see 12] and "…feet, demi-pointe not high…wider body shape…look at the arms, those arms are big" [see 14], represented typical reflections contained in the recordings with the inter-actors. The latter quote is particularly curious as the point-light figures did not contain explicit data from which a viewer, expert or otherwise, might be able to deduce the volume of an anatomical element, such as the size of an arm. It is possible the inter-actor was referring to the length of the arm but within the context of the recording session and given the physical attributes of the inter-actors we are reasonably confident he was referring to the physical volume of the arm.

Whilst the inter-actors succeeded reasonably well in identifying codified material they struggled to identify any of the 'movement meditations', which used reduced marker sets. They had little recollection of what movement they had done during these improvisations. This suggests that part of their recognition depended on 'somatic memory' of known material as well as a prior knowledge of the material they were observing. Typical feedback collected from the inter-actors evidence this, such as "that is just a mess" [see 13] and "I can't tell what dot is what part of the body" [see 12]. Asking the inter-actors to identify more abstract movement phrases, with which they had less familiarity, echoes Johansson's research, although contrasting with the simple canonical movements, such as walking, of his studies. However, as the different phrases were not presented to the inter-actors as comparable data-sets this aspect of the laboratory will hopefully be explored more thoroughly in the next iteration of the research process.

A further set of experiments sought to explore how the inter-actors interacted with more remote non-visual forms of real-time information. The objective here was to observe how the inter-actors managed to work with interactive data originating at a greater distance and where the spatial envelope was at a scale far greater than the interactive space afforded in the studio environment. This involved some of the inter-actors working in the laboratory, within an immersive interactive audio-visual environment, which was connected by mobile phone to a remote inter-actor.

Using a mobile phone's hands-free set connected to an audio amplification system in the interaction space, an audio link was established between the laboratory and a remote inter-actor. The local inter-actors could talk back to the remote inter-actor. The audio from the phone was fed into the Max/MSP/Jitter patch for the temporal visual differencing system and the amplitude of the incoming audio was mapped to a brightness parameter on the input camera feed. The projection's brightness would thus vary in conjunction with the voice of the remote inter-actor and the sound of their environment.

In trials the remote inter-actor tended to create a demonstrative sound-scape, seeking to translate the auditory characteristics of phenomena and objects back to the laboratory. The inter-actor approached this task almost like a 'gaming' situation. On one occasion the remote inter-actor was not expecting to be called from the laboratory and the resulting spontaneity of the inter-actor's response lent a more vital element to the interaction between them and the other inter-actors. In particular the inter-actors reported a greater feeling of empathy and awareness to the remote inter-actor, each other and their environment. The temporal graphic effects of the system meant that the dancers could purposefully render themselves invisible in the projections, which "gave us a use and a purpose to 'no movement'" [see 13] and allowed us to develop "a sense of becoming quieter … less aware of the situation that we were in and very much involved" (see [11]).

Throughout the laboratory the inter-actors were asked to engage in situations which required highly complex problem-solving and multi-tasking capabilities. The remote audio experiment required a particular interaction with an audio-visual environment in which they were asked to move, watch, listen and talk. Their solutions were creative and they coped by rapidly choosing to respond to only certain information sets. The inter-actors also quickly became adept at juggling multiple tasks and shifting between media, evidencing a visceral sense of medial transliteracy. As one inter-actor observed "I became aware of how listening and how answering Ira on the phone was affecting the group and how we were moving" (see [11]). One inter-actor commented "I didn't think of the movement in the sense of 'dancer making steps'. More relating to the sound…I didn't have a vocabulary" [see 13] and yet another observed "it felt more emotion oriented" [see 12].

Dancers within the interactive environment.

7 Outcomes

The Scale research laboratory allowed the CIRCLE researchers to study how multiple sensing and tracking systems can permit the mapping of the human body at multiple simultaneous scales and to observe the effects such systems have on those being monitored and tracked. A number of different systems, artistic strategies and environments were tested during the laboratory and were subsequently evaluated for their future potential application in artistic projects. Our primary research question, whether an integrated multi-modal approach to designing interactive environments might enhance an inter-actor's perception of interaction, was not definitively resolved. However, the observations and data collected indicate that this is likely the case. The involvement of professional dancers as inter-actors offered an opportunity to collect the qualitative data required to arrive at these outcomes.

The experiments allowed us to observe and evaluate how augmented environments can affect inter-actors self-perception and interaction with other inter-actors. Thus we were able to engage a number of questions, amongst them inquiring into how an inter-actor recognises their own or others movement characteristics. The responses from the inter-actors show that where they were aware of being recorded, and movement material was pre-learned and/or canonical, they were able to identify themselves, whilst when confronted with improvised movement phrases and where they had not been aware they were being recorded, they struggled to do so.

We were also able to observe and analyse how co-locating pre-recorded motion capture data with real-time video tracking of an inter-actor can enhance an inter-actor's capacity to understand and internalise a recorded movement. That one of the inter-actors, who was not present during the first day when many of the movement phrases were developed and recorded, was able to learn sequences with relative ease through physically following and explicitly 'mirroring' the life-size projections of the motion capture data, through the device of having their own video image mapped in real-time and life-size to the 3D data points, is evidence of this. Tantalisingly, there appears to be significant potential value in further exploring this aspect of the research, focusing on variations of how the system might be designed and studying different modes of interaction with the system. However, whilst the inter-actor's perception and recognition of motion capture data, represented as simple motions of individuals, is coherent with

Johansson's classic work complex motions with orientation changes were less successfully recognised, as was the case with the reduced marker sets. Further research will need to more rigorously address these issues.

Experiments with multi-modal systems employing sound and image that is both co-located with and remote to inter-actors allowed us to evaluate how changes in telematic mediation can affect inter-actor perception and behaviour and, in this instance, choreographic decision making. The evidence acquired during these experiments suggests the quality of the inter-actors experience was not only a function of the level of veracity of a representational system (e.g.: how realistic the presentation of a virtual presence might be) but also of other phenomena that are of a more abstract nature. This experiment also suggested that it is not necessary for an inter-actor to experience phenomena as cohesive or unitary for them to gain an effective apprehension of an event and thus successfully interact with the various elements involved. However, it was also clear from the interviews with the inter-actors that such a situation was more demanding of their concentration and multi-tasking capability as the inter-actors reported experiences of breaks in their sense of presence and agency.

During the research laboratory some initial experiments were attempted that employed geo-locative positioning systems and remote site specific actions, the objective being to engage the inter-actors with information not spatially co-located with them. Due to time constraints these experiments did not lead to any outcomes of value to the questions addressed in this paper. However, the experiment involving the use of the telephone call indicates that this is another area of inquiry that is likely to deliver further valuable insights. The integration of GPS technologies with local sensing and interactive systems was achieved during the laboratory. Successful, but tentative, experiments with synchronised video recording of inter-actors interacting within a large architectural space were also completed. It is the intention to employ telematic, GPS and live video streaming systems in the next iteration of the research, seeking to fully integrate these with the multi-modal interactive systems deployed as well as with real-time motion capture systems.

As the first research project undertaken by the CIRCLE group the Scale laboratory sessions also, perhaps most importantly, allowed us to test whether a group of researchers and practitioners from diverse disciplinary backgrounds could work together constructively, often with diverging aims and objectives, and yet realise outcomes of use in each of our disciplines and which might inform interdisciplinary discourse and research. It is the intention of the CIRCLE group members to further pursue this aspect of our work in order to both facilitate our own effectiveness as a research group and to further inform discourse on what interdisciplinary research might be.

The Scale research laboratory was funded by the University of Edinburgh's Collaborative Research Dean's Fund and Edinburgh College of Art's Research Fund. Many thanks to Simon Coleman, Sports Science, University of Edinburgh.

References

1. Forsythe, W., William Forsythe's Improvisation Technologies, ZKM Karlsruhe and Deutsches Tanzarchiv, Cologne/SK Stiftung Kultur CD-ROM (Mac/PC), ISBN 3-7757-0850-2 (1994)

2. Johansson, G., Visual perception of biological motion and a model for its analysis in perception and psychophysics Vol 14 (2), pp. 201-211 (1973)

3. McCarthy, R., Blackwell, deLahunta, Wing, Hollands, Barnard, Nimmo-Smith, Marcel, Bodies meet minds: choreography and cognition, Leonardo Vol 39 (5), pp. 475-478, MIT Press (2006)

4. deLahunta, S., Choreographic resources agents, archives, scores and installations, Performance Research, Vol 13 (1), Routledge (2008)

5. Stevens, C. & McKechnie, S., Thinking in action: thought made visible in contemporary dance, in Cognitive Processing, Vol 6 (4), pp. 243-252, Springer Berlin/Heidelberg (2005)

6. Rokeby, D., Fondation Langlois, http://www.fondation-langlois.org/html/e/page.php?NumPage=80#n1 accessed January 2, 2009)

7. Coniglio, M., http://www.troikatronix.com/isadora.html (accessed January 2, 2009)

8. Biggs, S., http://hosted.simonbiggs.easynet.co.uk/right/CSIRO/index.htm (accessed January 2, 2009)

9. Nimoy, J., http://webcamxtra.sourceforge.net/ (accessed January 2, 2009)

10. Suchman, L., Plans and Situated Actions: The Problem of Human-Machine Communication. Cambridge: Cambridge University Press (1987)

11. Boyes, L., quoted in interviews (recorded August and December 2008)

12. Runacre-Temple, M., quoted in interviews (recorded August 2008)

13. Cooper R., quoted in interviews (recorded August and December 2008)

14. Siobhan, I., quoted in interviews (recorded August 2008)