Review Article

Neuroscience, the Bodymind and the Actor

- Reflections on consciousness, learning, memory and the actor in the post-Grotowski era.

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NOTE: *Launched in February 1995, xHCA is an interdisciplinary research programme seeking interstices between contemporary theatre research and the Cognitive Neurosciences. It brings the intsruments and the reflection of the Cognitive Neurosciences to bear on events taking place in the performer (a) as he works upon himself within the parameters of the contemporary theatre's rigorous training regimens and (b) as he engages in the performative act. xHCA was founded by the world-famous theatre pedagogue and director Ingemar Lindh (xHCA Director until his death in Malta in June 1997), Dr. Richard Muscat (Director, Laboratory of Behavioural Neuroscience), Herr Bernhard Plassmann (Administrator) and Dr. John Schranz (Vice-Director). In June 1998, its directorship was entrusted conjointly to the latter and Dr. Glyn Goddall, Cognitive Scientist at the University Victor Segalen, Bordeaux 2. Current research is directed to the fields of memory, attention and kinaesthesia.*

Introduction

The following reflections have a number of characteristics which represent both their strength and their weakness: it is the paradox inherent in any exercise that attempts to be simultaneously factual and impressionistic. Factual, because neuroscientific data, insofar as they have been tested and have yielded positive results, constantly offer new insights on the nature of the human being. Impressionistic, because, in the past three years, the former has been involved in theatre praxis, which means that a lot of what will be said on the nature of the actor is a result of the *sketch* - preliminary at best - of oneself that one is able to form after this (admittedly short) period of time of involvement in what is, in itself, a research process.

At another level, we will try to relate neuroscientific findings to the implicit assumptions and observations that seem to underlie the writings of the late Jerzy Grotowski, and these observations are the fruit of a lifetime of research. Why should a theatre practitioner feature in any form of scientific discourse? Throughout his work, Gortowski insisted that he was not a scientist. Yet, any discipline whose focus is the human being as a conscious, behaving organism, with a capacity to learn and undergo change may be interested in the techniques and methods of an art in which the performer is engaged in a constant discovery which is also a learning process. Attempts to discuss the biological and cognitive foundations of performance are nothing new. Diderot proposed a biological theory of the actor, Evreinov linked theatre to human and animal behavioural science, while Meyerhold was fascinated by Pavlov's experiments (Pradier 1998). Meanwhile, the twentieth century has witnessed an entire reinterpretation of the heritage of masters such as Stanislavski and Meyerhold. Gortowski is one who set out to redefine theatre in terms of its barest essentials, that is, in terms of the organism of the actor and his/her relationship with the spectator (Grotowski 1968a). The research to date on the nature of the body's impulses and the basic resistance which must be overcome in the process of working upon oneself, that is, the *via negativa*, are essentially a learning process.

On the other hand, the sketch presented here is complicated by the fact that the numerous systems underlying human cognitive processes are multiplexed and often defy simplification (see Fentress 1991 for a discussion). For the present purposes, the discussion will take place on three levels: the molecular/biochemical, the organic, and the level of the organism as a conscious being. In short, in a discussion such as this one, molecular and genetic considerations, anatomical data and ethological observation will be of equal essence. Indeed, theatre praxis - as the work of the performer upon himself - is a research process which is reflected at each of these levels, and the very concept of a learning organism implies the possibility of change at each level. An operational definition of learning is therefore vital at this early stage:

Learning is a process whereby an input - behavioural, sensory or somatosensory - results in a change in an organism's state and/or behaviour, requiring the mediation of encoding (memory) mechanisms that lead to the relative permanence of this change, within the architectural constraints imposed by the nature of the organism itself.

Subjectivity and imagery

The Problem of Models

Various times, throughout his extant writings and speeches, Grotowski makes references to the personal associations of the performer. The research he proposes seems to be a thoughtless process; thinking is the arch-nemesis of creativity. The performer does not think, but what he does is given "meaning" in the personal, highly individual tangle of associations that make up the subjective state of the organism. What is subjectivity?

The question is inherently tied to the question of consciousness, of which more later. The point at issue is, at present, whether or not we can speak of subjectivity at all, without enmeshing ourselves in phenomenological and volitional fallacies (on which see Ryle 1949).

In 1949, Gilbert Ryle put paid to the conceptual fallacies that plague any discourse that treats such concepts as "will", "knowledge", etc. as anything more than conceptually useful items with little validity when grounded in the facts. Yet, the subject seems to be his own agent. What drives the performer? Why must he not think? (we will never forget a seminar with Ingemar Lindh, back in 1997, in which, every day after the work was over, he would insist that "there was something to understand", but "without too much wanting, without too much thinking". The problem is certainly very real: we find we cannot "improvise" unless there is something resembling perfect silence and privacy. The director rarely interrupts this process, not, at any rate, until some action sequence is formalised and can finally be said to be "learned" and therefore open to dissection (improvisation is an exercise in what is not there yet and thus is hardly open to dissection, analysis, conceptualisation).

In actual fact, the more suitable question seems to be, "Does the subject/performer *need* to think at all?". There seems to be little doubt that there is such a thing as subjectivity, but what constitutes the subjective?

A contribution from Minsky

Marvin Minsky (1968) posed the problem of subjective agency quite succinctly when he pointed out that, while attributing volition to any organism or automaton is merely a dead give-away for the lack of knowledge about that organism, "all such questions are pointed at explaining the complicated interactions between parts of the self-model". A man's or machine's strength of conviction about such things tells us nothing about the man or about the machine except what it tells us about his model of himself". The problem is further posed by Dennett (1991): Is there a picture in the mind? If so, does the mind have a picture of the picture? And a picture of the picture of the picture?

Talking about agency is more than vaguely reminiscent of Moliere's comic notion of *virtus dormitiva*: opium puts people to sleep because it has the virtue of putting people to sleep. (People have will - and are often wilful - because.....well.) But there is also the risk of infinite regression. Minsky's (1968) talk of models is grounded in the assumption that a human being, or machine, has a model of the world and a model of himself, and models of these models. Where does it all stop? Presumably, it doesn't, and the real answer does not lie in any arbitrary splitting up of subjectivity into models; the notion of "subjectivity" may well become nothing more than that - a notion or a reified construct - unless one can talk of the complex systems underlying the phenomenon as completely as possible (cf. Fentress 1991 on the problem of reification of constructs in ethology and neuroscience).

The impressionist club:
Dennett's phenomenological garden

Dennett (1991) pays a "visit to the phenomenological garden" and asks some pertinent questions. The implicit argument is that we cannot talk of pictures in the brain, nor can we extrapolate the argument to any form of mental imagery, including that pertaining to other modalities such as audition. Similarly, emotions are not explainable by the self-defeating arguments such as " something is painful and I can imagine it so, because that particular something is painful".

What are impressions? What is mental imagery? They are not models - at least, not static models - and they are more than static memories. Imagery and subjectivity is a process. Otherwise, associations in the performer are simply vivid pictures, subject to intellectualistic analysis, and this is *not* the case (see above). Grotowski (1968) gives the example of the performer who's playing Macbeth. You don't have to be a killer, but it helps, he seems to be saying. Yet, killing, or the subjective impression of being a killer would certainly not be possible if this impression were merely an association with the actual act of killing a person, that is, if one were to succumb to the phenomenological argument. Yet, any performer who has had at least a week's experience of normal living is highly likely to have killed a fly. This is not murder, but it too helps.

Imagology: the process and the Process

Imagery

It appears that mental imagery of motor activity is subject to the same constraints as the activity itself. Crammond (1997) argued that the act of imaging a simple motor activon takes the same time, and is subject to the same constraints of speed and accuracy. Fitt's Law, a fundamental tenet of biomechanics and motor activity studies, states that there is a speed-accuracy trade-off in any action. A related finding is reported in Fentress (1991), to the effect that, a movement - such as grooming in rodents - is carried out oblivious of interruption and/or environmental stimuli the faster it is executed.

It seems that motor imagery utilises the same networks of connectivity as actual motor movements, with the exception of the efferent stimulation of the muscular effectors. The reason seems to be related to the efference copy, or corollary discharge, that is communicated to brain regions other than the effectors, resulting in a copy of the movement being synthesised and evaluated. The site for this evaluation is probably the parietal cortex. The discovery has a number of implications, among which, as Fuster (1992) observed, the brain never processes anything exclusively in serial mode, but reconciles serial and parallel. A similar hypothesis was put forward by Rumelhart, McClelland and Sejnowski (1987), who claimed that sequential thought processes are probably the result of the sequencing of multiple parallel processes. Their observation may however, be too simplistic, as it is based on the assumption that the processes which are placed sequentially are in themselves exclusively processed in parallel.

Images are therefore extant in the brain, and not only *motor* images at that. It seems possible therefore, to live in virtual reality, with the obvious trade-off that, if one were only to image walking, nothing would get done, which might be why one sometimes "resigns from not doing".

Motor activity and the evaluation thereof is also dependent on reafferent activity and kinaesthetic feedback. Gandevia and Burke (1992) reviewed the research on both active and passive movement and posture, particularly on the hand. The argument presented was that the motor system depends in part on kinaesthetic feedback to execute commands: knowledge of the "self" is vital. In this context, a small excerpt from Grotowski's Skara Speech probably speaks for itself:

What is an association in our profession? It is something that springs not only from the mind but also from the body. It is a return towards a precise memory. [...] Memories are always physical reactions. It is our skin which has not forgotten, our eyes which have not forgotten.

(Grotowski 1968: 225-226)

This then, is what is meant by "associations" and "contact". If the theatre is to be a process of uncovering "the truth", at least insofar as it avoids to be a contrived series of gymnastic activities, then the intention of the performer is one of constant self-assessment, and this is not an intellectualistic activity.

Images and plasticity

Perception and image-formation may well lead to the creation of large-scale topographical representations that are strengthened/weakened according to the amount of practise/learning. This has major implications for plasticity: strengthening of neuronal groups that represent images in any sensory modality, aided both by the highly ordered gating of inputs to early sensory cortices via topographically arranged thalamic nuclei and by practice may result in changes in representation (Merzenich and De Charms 1996).

Plasticity is a major factor in determining individuality, adding further weight to Grotowski's constant insistence that the first and major task of the performer is to determine the association (image) that the action holds for him/her. The task of delivering is relegated to a place of secondary importance. As regards individuality, Johnson (1997) concludes that, while the laminar and topological arrangement of the cortex is a given predetermined factor, epigenesis is probabilistic in the sense that, to a large extent, what determines the make-up and the structure of topological representations is experience, coupled with innate (genetic) mechanisms. In other words, the individual is a result of a dynamic interplay and interplay which Merzenich and de Charms (1996) view in terms of the strengthening of connections that are related to specific images via the constant reappraisal of the said images, through such processes as training. It is important to note that the "image" is hardly a picture as this would otherwise leave us open to Dennett's criticism (see above). Rather, the term image is to be understood as any form of representation. This also now invokes the "use it or lose it" principle inherent in such theory's as Edelman's *Neural Darwinism* in which connections and representations that are not strengthened tend to be weakened and/or lost. Furthermore, neurontogeny may well be an iterative process, influenced by a number of variables that determine the outcome in much the same way as "attractors" that determine an oscillation's chaotic activity. In this connection, it is worth noting that were one to view the topographical structure of the cortex from a fractal geometric viewpoint, its topography is practically infinite.

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These changes in representation may occur as a result of environmental stimulation, which creates an image that, juxtaposed against pre-existing images, may cause a change or perturbation in the pre-existent image of the self. Images seem be stored topographically or otherwise in the early sensory cortices (including V1 and S1), but are somehow juxtaposed or otherwise interpolated in higher sensory cortices (Damasio and Damasio 1996). The hypothesis put forward by Damasio (1994) and Damasio and Damasio (1996) is that there is such a thing as dispositional representations that are activated and cause a distributed reactivation of images in sensory cortices. The fact that these images are distributed implies that there must be some kind of convergence zone and moreover, that some process of attentional orientation is required. Damasio (1994) hypothesises that the convergence zones may lie in the temporal and frontal cortices. In the temporal lobe, the hippocampus has long since been identified as a substrate for memory. Yet, the actual role of the hippocampus may well be more complex than simply that of a storage site for engrams. Eichenbaum et al. (1994), in an extensive literature review, propose *pattern-formation* as one of the functional components of the hippocampal memory system: while engrams may be encoded in the perirhinal and parahippocampal tissue, the hippocampus per se is probably a convergence site. Some more insight is provided by studies carried out by two groups of researchers on the nictitating membrane reflex in the rabbit. Thompson and colleagues identified the site of the engram for the (procedural) learned reflex in the cerebellum, but a parallel finding by the Disterhoff group identified a functional role of the hippocampus using a different conditioning paradigm - trace conditioning - in which the time window is such that the conditioned and unconditioned stimuli do not co-occur in time. If this is indeed a functional role of the hippocampus, it highlights the importance of convergence *in time* (see also Merzenich and de Charms 1996 for a discussion of temporal contiguity in the formation of images).

As regards the frontal region, dorsolateral prefrontal cortex is one site that seems to serve as a neural substrate for working memory, while the frontal cortex itself is involved, by and large, in decision-making and preparatory set for motor activity (see Fuster 1996). This planning and execution function is also coupled with the high connectivity of the frontal lobe, whose resources for aiding decision making are, among other things, emotional, since connections exist to the basal ganglia among other areas. Latash (1998) claims that, while a motor program that is learned after repetition and automated is probably relegated to subcortical brain structures for the purpose of reducing redundancy, it is nevertheless liable to subtle changes due to the active nature of what is known as the *orienting response* (OR), which has been found to have an emotional value, in the performance situation or just prior to initiation of action.

Creativity

An important proviso should be added at this point. While it is possible to image a movement - or anything prelearned for that matter - the emphasis must be placed on *learned*. The movement studies reported by Crammond (1997) indicate that the movement as imaged is subjected to the same constraints *as the movement when it has been learned and carried out*. Put another way, without actually doing anything there would be no corollary discharge and thus no reafferent input to create images from. If researchers such as Fuster (1992) are correct in their judgements, there is very little that we actually do which is ever completely new: walking is not learned by the child out of nothing. Thus, we are not talking about an imaginative process, nor are we creating something out of nothing. The process of making images is therefore the result of learning: subjectivity is the result of ontogenetic development, plasticity and that infinitesimally subtle process called learning. And learning is a progression.

What, then, is creativity? In theatre research, the performer is engaged in various physical activities - exercises - which serve the research (Grotowski 1968). Creativity may well be a process of combination and interpolation of what is essentially part of oneself. Theatre research is a corroboration of what one knows, an exploration of its associations and derivations, and an elimination of all that is superfluous, the *via negativa*.

The implication for the performer is that thinking about doing is different from doing. Indeed, the possibility of actually thinking about doing is merely the result of doing, or having done. Once doing is in progress, the formation of images and the action itself are quasi-indistinguishable phenomena, a corollary of the observation by Fentress (1991) that it is often difficult to subdivide a process into its component parts without ignoring the fact that the components may be doing more than one thing at a time: the same neural substrates are used, by and large, for the formation of motor images and the execution of movements (Crammond 1997).

The performer is therefore left with the option of only executing the task and making the association in the Process. At first glance, the process called improvisation seems to be an unwieldy exercise in anarchic self-stimulation. The research that Grotowski makes reference to at every stage, from start to finish, in the description of the exercises carried out by the Theatre Laboratory constitutes a substantial denial of such a claim. What the actor is doing is forming associative images in the Process of doing, and since doing is never a complete novelty, training is a learning process, and improvisation is the culmination of such learning.

Concluding remarks: orienting, learning and being-in-the-act

The picture sketched above is one of a self-conscious individual with the capacity to react in a specific time window to input that causes psychosomatic and behavioural changes. The Orienting Response - itself bearing emotional value - coupled with the decision-making capacity of the performer, as well as the integrative process of bringing together distributed representations in convergence zones, via the mediation of dispositional representations, are all factors that bear on this point. In accordance with the operational definition of learning given in Section 1, it is possible to surmise as to the nature of the performance itself: given that the performer is not a solipsistic automaton, but has the capacity to orient and react *actively*, then the execution of a program of action - even if it is stored in subcortical regions (such as the reticular formation and the basal ganglia) for the purposes of reducing redundancy (Latash 1998) - may very well be in a state of constant flux. Damasio's (1994) somatic marker hypothesis, highlighting the interplay of environment, memory and current organismic state, gives us the picture of a conscious subject whose self-image is under constant perturbation. Moreover, if the act of creation in action (and improvisation) is viewed as a syntactic process of re-ordering of what is there already and what is new in terms of input, then, for the performer:

> *Each night's "run" in(-)forms the performer at the same time that the performer forms it. Each night's run is considered to be (and it is indeed seen to be) a "revisiting", a step in the process of the performance's growth, a step in the learning of the possibilities of the performance, a step of the continuous change and flux of the process, night after night.*
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> (Schranz 1997: 2)

The problem of creativity is thus posed in terms of the capacity of the human being to create anew from the old, almost as though a pre-existing grammar were being utilised to string together new sentences. The temporal and co-ordinating function of some possible convergence zones may well be of this sort, further highlighting the conceptual appeal of the term so frequently used in neuroscientific literature: the syntax of action. It is comparable to the musician whose ultimate goal is to create a new semantics from an oid syntax. This is why, in the theatre, "the exercise serves the research" and why, while everyone can walk and raise his hands, the performer can do it beautifully.

Another point that has been made implicitly throughout this section regards the nature of consciousness: the conscious human subject is a self-observer, and the self-observer has the capacity to assess perturbations in his own body proper (his most intimate space) and changes in the environment, the external space. The conscious subject must act upon these possibilities - that is what they are - and collapse the enormous number of possibilities into a single one by a process of conscious decision-making.

Micro phenomena and Macroscopic entanglement

Quantum phenomena and the self-observer

Some decades ago, Schroedinger made history by placing a cat in a box. The cat was accompanied by a radioactive molecule that could, if a certain oscillatory pathway within the molecule were taken and a radioactive energy release occur, break open a cyanide cylinder which would then kill the cat.

The intramolecular dynamics of the molecule are such that each subatomic particle exists in a number of

superposed states - the essence of quantum theory. But these superposed states, which when summed up form the *wave function*, resulted in a corresponding state of indeterminacy in the cat, a phenomenon known as macroscopic entanglement. The cat, once the lid was closed would also exist (to the external observer) in at least two superposed states: dead or alive. The fundamental point is that, once the box is opened - were Schroedinger to peer into the box as it were - the wave function would collapse: the cat would take up one of its two superposed states *via the mediation of the observer.* Are there such microphenomena in the brain and is the conscious (self-)observer constantly collapsing his/her own wave function?

Signaling cascades and knockouts

Most of the ABook explored the possibilities of learning largely in terms of structural changes and constraints imposed by the brain's cytoarchitecture. At a more micro level, the changes occurring at synapses offer a different, if highly related, account of what happens when a process is learnt well enough for the neuronal circuits supporting the process to be facilitated in the long-term. This facilitation, and its counterpart, the actual weakening of the synapse, is the hallmark of long term potentiation (LTP) and long-term depression (LTD) (H.K. Lee et al., 2000). LTP is one way of increasing the brain's efficacy for storage.

A plausible site for LTP is, of course, the hippocampus. There are signaling cascades occurring in this region, specifically, the binding of glutamate to NMDA (N-methyl D-aspartate) receptors that causes the concomitant opening of calcium channels in the cell membrane. Calcium activates a number of enzymes, among them CAMKII, which influence the transcription of immediate early genes, and whose influence at the micro level has repercussions throughout the learning process. Indeed, genetic knockouts have highlighted the importance of this process: take a laboratory rat, knock out the relevant CAMKII gene, and the rat becomes incapable of learning the position of a submerged platform within the Morris water maze (see the report by Seife 1997).

In actual fact, there are other sites for calcium activity and the quantum phenomena sketched out in ABook that may actually be occurring in the brain. Miller (1997) made tentative proposals to the effect that signaling cascades in the frontal lobe, among other regions, may lead to the formation of calcium "hot spots", large pools of calcium ions within the cell. Prefrontal cortex, one of the phylogenetically youngest regions of the cortex, is, as has been pointed out above, highly implicated in the processes of decision making - the collapse of possibilities that was hinted at in ABook on Phineas Gage remains the paradigmatic example of what happens when the prefrontal cortex is damaged beyond repair: the capacity to react emotionally, to orient and to make effective decisions is lost (see Damasio 1994; Miller 1997). Phineas Gage is a rather bleak case of a human being who has lost the capacity to act on possibility, mainly because of an apparent deficit in his capacity to act upon perturbations in the self-image.

The Calcium Hot Spot and the small Big Bang

The superposition of possible states of a calcium ion - its wave function - has been estimated to be quite large (Miller 1997); this could imply that the release of neurotransmitter which is calcium-mediated, or intracellular mechanisms that depend on calcium activity are quantum phenomena and may somehow form a possible substrate for the neural, continuous phenomenon called consciousness.

Miller (1997) suggested the possible relevance of calcium "hot spots" in this respect: calcium hot spots occur when as much as a single calcium ion enters the cell, encounters a ryanodine receptor gated pool of calcium and causes the release (by as much as four degrees of magnitude) of a huge cascade of intracellular calcium. The result may have consequences upon the memory processes outlined above as a function of gene transcription in the nucleus, and may also cause the phosphorylation of the cell's calcium channel, altering the consequent flow of calcium into the cell. In short, a small ion may cause a "big bang" in the neuron. Miller further suggested that, if one of these hot spots is viewed as a type of wave function collapse, about 10 trillion hot spot collapses are occurring in the brain every 25 msec. This collapse must be somehow synchronised, given that consciousness is a continuous, uninterrupted phenomenon. Somehow, the shortest period oscillator must be responsible for the eventual synchornisation of these oscillatory mechanisms. If 25 msec is the shortest period, then the oscillation will eventually be synchronised at about 40 Hz which has also been suggested by Crick in his book The Astonishing Hypothesis. This is also the global oscillation that has been recorded in wakeful and rapid eye movement conditions but not in slow-wave (dreamless) sleep. Moreover, these hot spots could behave like a Bose-Einstein condensate during which a population of atoms are forced into the same quantum mechanical state. The process of synchronisation discussed here could be such a mechanism.

In the right cortical areas, such as the prefrontal lobe, these oscillatory mechanisms could be a possible explanation of such theoretical constructs (or Cartesian fallacies) as volition; they moreover fit well into the description of the self-conscious observer. Is the conscious subject a person capable of collapsing his own wave function? (but see Hahnloser et al., 2000). The observer's decision to act is in a sense the culmination of the wave function collapse, the taking of one path out of many. This is subject to all of the constraints discussed. We have often encountered instances - both in our own work and in that reported to us by some colleagues - wherein decisions are taken without the slightest bit of hesitation, *even during performance.* This fact makes it hard to believe that a performance can ever be called a finished work. It is also possible that the decisions taken are instantaneous collapses of a series of possibilities that occur to a performer during the act, resulting in, say, the choice of one action as opposed to another (it is often the case that, at a fixed point in an action sequence, a number of different courses of action have been worked out and are therefore equally possible). This could also be a part of the decision-making process called

improvisation. All of the above is subject to how much one has learned, one's basic grammar and how the action can be strung together in time to produce a syntax of rhythm and melody.

Concluding remarks

The foregoing is mainly the result of personal reactions, both to Grotowski's pedagogy and to our own preliminary explorations in theatre. There is much that remains unsaid, and, it should remain so. Grotowski has not been considered as a research scientist, but rather as one of a number of significant theatre masters who have proposed a methodology, or ways and means of arriving at one such. Some things remains a mystery: how, for instance, can the actor achieve "a state of grace"? We believe these questions, which are often considered with something of a cynical eye - except by a critic who, having witnessed Ryzsard Cieslak's performance of the Constant Prince, found it necessary to make a public confession that he had been ":converted from his cynicism" (see Grotowsky 1968: 97) - are best left unanswered, or put down to experience.

There are a number of possible answers to questions which arise when, having witnessed *results* in the theatre, one asks what are the possible explanation for such. However, most theatrical experience remains beyond rationalisation, and this fact alone is a good enough reason for further exploration.

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