

2017-04-01

Cognitive Innovation: A View From The Bridge

Punt, Michael

<http://hdl.handle.net/10026.1/6693>

10.1162/leon_a_01386

Leonardo

MIT Press - Journals

All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.

Cognitive Innovation: A View From The Bridge

Susan L. Denham. Professor in Cognitive and Computational Neuroscience, School of Psychology and Health, University of Plymouth, Drake Circus, Plymouth, PL4 8AA UK.

Email: Sue.denham@plymouth.ac.uk

Michael Punt. Professor of Art and Technology, Transtechnology Research, School of Art, Design and Architecture, University of Plymouth, Drake Circus, Plymouth, PL4 8AA UK.

Email: mpunt@plymouth.ac.uk

Submitted

Abstract

This paper is about creativity. It proceeds from an understanding of the promise of the concept of cognitive innovation as a focus for collaboration between the sciences, arts and humanities. The value of the concept in this context lies in its approach to creativity as a bootstrapping cognitive process in which the energies that shape the poem are necessarily indistinguishable from those that shape the poet. Keywords: Creativity, Cognitive Innovation, Theoretical Neuroscience, Art, Science, Technology.

Introduction

For the purposes of this paper the exploration of the idea of cognitive innovation embraces an understanding of creativity that is not exclusively concerned with conscious human thought and action but is also intrinsic to our cognitive development. As a consequence, we see the possibility for the idea of cognitive innovation to provide a theoretical and practical platform from which to explore disciplinary differences in our understanding of creativity. In this paper we make suggestions of how two particular concerns; those of theoretical neuroscience and those of the history of art, science and technology might find the concept of cognitive innovation useful. The presentation of this paper has a challenging format in that it comprises a common introduction, two separate papers published in a parallel text and a brief common conclusion. The demands that this makes upon the reader we acknowledge as a cost involved in preserving the intellectual distinctiveness and conventional voices of the disciplinary territories inhabited by the authors. To synthesise and homogenise them into a single style we felt would result in a “voice from nowhere” and undermine the speculative and formative aspects of our thinking. Although the demands may be unusual they are in fact no more unusual than many of the cross cultural exchanges that are the commonplace of most academic conferences, or the normal format of newspapers, commercial television and indeed the experience of most of the mediated information we negotiate in our daily lives. In this we situate an academic discussion of creativity and cognition in the normal (and unselfconscious) operation of our creative capacity to make meaning from experience. From a transdisciplinary perspective our underlying expectation, in an academic context, is that reading the text will ultimately be productive and return critical insight to the primary disciplinary concerns of the reader. In sum, we offer a narrative in which the aggregates of interaction between quite distinct disciplinary methods and voices are made available to the reader as a collage. In this way hope that the text will open up a space which stimulates new insights from unexpected connections between the parallel perspectives.

This essay began life in a series of exchanges over the past five years as a group of us gained experience of each other’s intellectual strategies and practices through research collaboration. As a group comprising theoretical neuroscientists, arts practitioners, cultural anthropologists and critical theorists from the humanities we felt that the interdependence of creativity and cognition was well recognised as significant in our various disciplines but began to suspect that there were some important discrepancies in our (often unstated) assumptions. Like many cross-disciplinary interactions, it took time for the participants to understand the variable nuances of terms they had hitherto thought to have universal meaning – not least because they were also terms in common use. Terms like, ‘value’, ‘novelty’ and ‘creativity’, it turned out, not only meant very different things in the arts, humanities and sciences but also had widely variable current uses in everyday contexts. In addition, reference points that seemed to be shared in the literature that did attempt to cross disciplinary boundaries often turned out to have very different meanings. This was compounded by the way that concepts such as art, and science are mobile and contingent in their general application and in the arts and humanities in particular are a constant topic of revisionist thinking. As an initial response it was tempting to seek common ground in simple metric, and much work that follows this approach, as for example in the coalition between neuroscience and the arts, literature and cinema, has this emphasis.

At first flush the scientific measurement of creativity is seductive, but on closer inspection reveals itself to be something of an oxymoron. In the arts and humanities the measurement of creativity is a vexing problem that sits uncomfortably in auction rooms, private galleries, museum collections and art schools. In this context, in which creativity has resisted definitive valuation, the term has been politically hi-jacked so that it has become a marker of value added (‘creative coffee’, ‘creative industries’) rather than a marker of a quality of interaction with the world as an exceptional subjective combination of cognitive skills and competences. In the sciences, whose truth claims are, in the very best sense, tautologies that allow informed prediction, the frequent disconnect between phenomenological metrics of creative potential and actual creative achievement causes similar discomfort.

These rather obvious observations did not seem quite so clear to us until, through considerable effort and a little luck, we had the opportunity to work with a large group of researchers from a dozen or so disciplines (and as many countries) all thinking hard about creativity. It became obvious that if the question we shared was ‘how creativity might be measured’ then we would need to agree what it was that we were measuring. Paradoxically, it also became clear that this would not be answered through tighter and tighter definition, but by recognition of the contingency of the concept. At the heart of the conundrum that we needed to resolve was the tension between the quantitative measurement of a property (creativity) manifest in the world and the inner, mostly occult, properties of the creator. Creativity as a concept or quality was (and is) considered in the arts primarily as an externally observable (behavioural) property that can only be understood partially, provisionally and from the standpoint of the present. In the sciences, mostly concerned with internal (structural) properties that give rise to creative behaviour, much of the focus has been on metrics that enable informed prediction of individual creative potential. It was in the attempt to reconcile this conundrum that we turned our attention to the topics of novelty and cognitive innovation, and our method to transdisciplinarity. As this paper attempts to make clear, our claim is that cognitive innovation and creativity are intimately related; the former being to do with the

processes of building the knowledge and behavioural repertoire of the individual, and the latter requiring the explicit generation of something that measurably extends the knowledge and/or behaviours of others. In this way we hope to offer some resolution to the conundrum that stifled progress on the integration of our thinking as well as opening the way to the inclusion of problematic concepts such as phenomenology and consciousness into the scientific exploration of cognition.

The outline above is intended to stress that the paper that follows began life almost in “*media res*” and its contribution is primarily methodological in the sense that both authors (and many of those researchers to whom they owe an intellectual debt) have approached this problem as an epistemological challenge that resonates with the intellectual uncertainties that lie at the core of much contemporary academic research. As a transdisciplinary tactic we elected to produce a paper in which the contributing specialisms retain their academic and methodological distinction and voice but position their arguments in such a way as to open up new topics and concerns that can be returned to in their originating disciplines. For this reason, rather than meld our differences, for reasons well developed in post-colonial studies we have retained the contrasting styles of both authors and arranged the contributions side-by-side in two columns. This may be a little unusual, and even frustrating, but we wanted to be sure that each contribution could be self-standing and read independently of the other. At the same time we hoped that in their juxtaposition in the spirit of the collage or flea market (so beloved of the Surrealists) in which the context of presentation offers a minimal coherence they suggest to the reader where they might need to look if the vexing issue of understanding and measuring creativity is to be taken further. Our intention is that we might avoid many misunderstandings by acknowledging that what we are trying to tackle **is**, and also **is not**, necessarily the same thing. In what follows the two authors have maintained their disciplinary perspectives.

In her paper, Denham starts from a consideration of Chalmers' (1995) analysis of easy and hard problems in consciousness and argues for adopting a similar functional approach to theorising about creativity. She shows that cognitive innovation, the recursive process of exploration, exploitation and synthesis, can be expressed in the form of a recursive function that usefully abstracts the process of developing the self. It also clarifies the multifaceted role of novelty as a boundary marker of the known and bearer of new information. Creativity in this context is argued to be an evolutionary exaptation of cognitive innovation, amplified by cultural and societal resonances. Creativity can also be expressed in a recursive functional form by including terms reflecting the broader societal context within which individuals live and work. Ultimately, this analysis leads to a new, more precise, more nuanced definition of creativity (and non-creativity) that it is hoped will have wider resonance across many fields.

Punt proceeds from Metz' suggestion that the cinema is a technological experience in which the viewer engages with their perception in action and from that draws a line through an historical account of art and technology to argue that the aesthetic and material forms of both are externalisations of some of the tendencies and properties of human cognition that neuroscience has identified, while others are the consequence of cultural determinants and choices that themselves function in collaboration with the various processes of human cognition. This he argues can be seen at work in the way that science, art and technology have changed in the past. From this he proposes that the concept of cognitive innovation may help us

recover a particularity to the idea of artistic creativity that distinguishes it from the broader use of the term to identify an economic niche.

Conclusion

The bold claim that we make is that cognitive innovation is a fundamental strategy that has evolved in living organisms, driven by the need to flexibly adapt to the changing pressures on existence. Creativity is a generative exaptation of this life-force which feeds on the rewards triggered by the internal recognition of novelty and the cultural and social linkages between individuals. Expressing both cognitive innovation and creativity in the form of recursive equations has helped us to start unpacking the implications of these claims. Cognitive innovation involves a recursive process of exploration, exploitation and synthesis which confers (some degree of) autonomy on the individual. Creativity is distinguished from cognitive innovation by requiring the explicit generation of something that measurably extends the knowledge and/or behaviours of the individual and ultimately others. As such the concept of cognitive innovation invites us as cognitive neuroscientists to review the considerable literature on consciousness in our consideration of new metrics for creativity, and secondly suggests to the humanities, another resource to add to its armoury when considering the social, political and economic determinants of technological change. We hope this new way to think about creativity may provide a useful broad consensus across a range of disciplines, which recognises the recursive and multi-faceted nature of creativity, and the fundamental importance of understanding the explicit and implicit subjective and societal perspectives. We also hope that it paves the way for further steps in the understanding of creativity by addressing novelty as a complex multifaceted feature of cognitive and socio-cultural systems.

Post Script

One thing has become abundantly clear to us as we ponder creativity in the twenty first century: this is not a problem that can be resolved without generosity and collegiate collaboration. This means that although there are two distinct voices in this paper the intellectual ownership of the thoughts that they articulate are shared between the authors as well as the network of colleagues who have enriched the discussion with support and criticism. We hope in this way that the paper articulates the problems with greater clarity and, as a social manifestation, is simultaneously suggestive of creativity in action.

The Creativity Function

Susan Denham

Creativity, the ability to think or act creatively, is a highly valued quality that nevertheless remains rather ill defined. The currently popular operational definition which forms the basis for countless studies in the cognitive (neuro-) sciences (the generation of something both novel and useful), says little about creative practice or the sense of creativity felt by the creator. In this sense, creativity is rather like consciousness; we all know what we mean but both terms are difficult to define. Here I argue that creativity may be better understood as an exaptation¹ of generic processes of exploration, selection and synthesis. Inspired by Jack Mackay Fletcher's argument² that Chalmers' approach to breaking down theoretical considerations of consciousness into qualitatively different classes of problems could profitably be applied to creativity, I similarly draw on mathematical functional forms to clarify the discussion. This approach suggests a new way of thinking about creativity, which provides pointers towards more holistic objective measures of creative potential.

Easy and Hard Problems

The idea that the easy problems of consciousness are ones that can be expressed in a functional form was originally proposed by Chalmers (1995). For example, $y = F(x)$ could represent the identity, y , of the face in image, x , as determined by the function, F . From a cognitive science perspective we can think of F as a process which acts on a set of objects, x , including, for example, facts, memories and perceptions. Although not necessarily solved, Chalmers regarded explaining conscious phenomena of this type as a relatively easy problem in comparison with the hard problem which he argued is to explain the sense of conscious experience. Explaining conscious experience is clearly a qualitatively different problem from explaining face recognition (although both involve awareness). What we are asking is how it *feels* to experience the world as some other system. This requires something more even than recording the unobservable internal processes of another because what we are asking is what it feels like to be in the place of that system. In this sense, thinking about creativity is similar to thinking about consciousness. Creativity also offers easy problems accessible to objective measurement (e.g. generating innovative solutions in a given task), and it also poses more fundamental problems involving the subjective experiential perspective; what does the process of creativity *feel* like, why is being creative apparently so compelling?

Returning to consciousness, if we simply epitomise the experiential problem of consciousness as one of qualia ('what is

Creativity in Action: Pulling Things Together Michael Punt

In the cinema ... I know that I am really perceiving, that my sense organs are physically affected, ... and I also know that it is I who am perceiving all this, that is the perceived – imaginary material is deposited in me as if on a screen, that it is in me that it forms up into an organised sequence, that therefore I am the place where this really perceived imaginary accedes to the symbolic by its inauguration as the signifier of a certain type of institutional social activity called 'cinema'.

In other words, the spectator identifies with himself, with himself as a pure act of perception (as wakefulness, alertness): as the condition of possibility of the perceived and hence as a kind of transcendent subject, which comes before every there is.

Metz, C. 1997. *The Imaginary Signifier Psychoanalysis and the Cinema*. Bloomington: Indiana University Press. p.49

A Short History of Creativity

In the trajectory of human biological, social and cognitive history, creativity has marked out a watershed that has allowed us to register a profound potential in antiquity that can offer guidance and quality to the present. In this respect the present concept of creativity has its firmest foundation in the various manifestations across the world of what we like to call the Renaissance.

However we may now feel about the adequacy of the historical category of the Renaissance, our current understanding and valorisation of the human quality of creativity is defined by the interventions of individuals who considered the world around them and thought that through material and critical practices they could better reflect the material and spiritual needs of the individual. Those moved to action in this context had to do two things that hitherto had been thought of quite separately: (i) they had to dig deep within themselves to explore what it was that, at the experiential and phenomenological level, drew perception and representation into a coherent gesture, and at the same time (ii) they had to find ways of representing those aspects of human experience that were valuable in ways that had meaning for other humans. The migration of these imperatives from established institutions to the individual precipitated new opportunities for understanding and shaping the world. So much so that creatively marking divergence from orthodoxy (as for example in the depiction of space) became a formalist trope for human insight. In this way creativity became inextricably entwined with the individual and this detached the absolute authority of quality from the history and norms of

¹ Exaptation, a term introduced by Gould and Vrba (1982), denotes a shift in the function of a trait from that for which it originally evolved. For example, bird feathers originally evolved for heat regulation but were later co-opted for flight.

² The ideas expressed here were inspired by the 'Off the Lip' keynote presentation of Sundar Sarukkai in which he pointed out the significance of the bracket in mathematics, and the talk given by Jack Mackay Fletcher in which he discussed the *Pretty Hard Problem of Creativity* and the use of the functional form to distinguish easy from hard problems. Jack argued that within Chalmers' framework creativity is a 'pretty hard' problem. It is pretty hard because it cannot be expressed in simple functional terms. Off the Lip: Transdisciplinary Approaches to Cognitive Innovation. Plymouth, 7-11 September, 2015.

it like to see red'), then the question is ill-posed; there can be no one answer to this question even from the subjective perspective. What it's like to see red depends on what else is around at the time, e.g. see (Purves, Lotto, Williams, Nundy, & Yang, 2001). And, even if the stimulus and context are the same, in the face of unchanging stimulation, the viewer can, and generally will, perceive a number of different interpretations of the scene, as documented in the extensive studies of perceptual multistability; for a review see (Leopold & Logothetis, 1999). In sum, the scientific literature relevant to discussions of qualia reveals that there is no one-to-one mapping between the physical world and perceptual experience. This lack of obligatory correspondence between physical and mental worlds means that conscious experience is essentially idiosyncratic (Noë, 2010); so even if we know what it is like to see red for system A, there is no guarantee that it tells us what it's like for system B. Something similar is clearly likely to apply in the case of creativity; what counts as creative for one individual or one situation may be very different for another individual, or the same individual in a different time or place.

If we only consider the qualia of conscious experience then our thoughts turn towards a rather passive conceptualisation of a conscious being as a viewer of the world. Clearly this is not sufficient; it overlooks the fundamental need to understand the 'viewer' more holistically as an autonomous active being and the essential life force of agency³ (Noë, 2010); the creation, development, maintenance and intentionality of the self through engagement with the world. It is precisely in issues of contingency and agency that consciousness and creativity become intricately linked.

Cognitive Innovation

To establish a basis for discussing creativity I would like first to consider a more generic process, namely cognitive innovation⁴. Cognitive innovation is conceptualised as a recursive process in which an individual probes its boundaries to seek out new knowledge, selects promising avenues for more extensive exploitation, and synthesizes what it learns within its growing body of knowledge, which includes knowledge of how to act in the world and how to interact with other individuals. Agency is inherent in this definition of cognitive innovation, and innovations emerge in some way from the possibilities afforded by changing relationships between the individual and its environment (including other individuals), and changing knowledge structures within the individual itself.

Does cognitive innovation offer an easier problem, a possible route into understanding creativity? Might cognitive innovation be expressed in a functional form? The answer is not immediately obvious, but there are possibilities suggested by the notion of recursion (Pickering, 2010). If F represents the mental processing of an individual, and x the set of things it knows about, then we can capture cognitive innovation in a functional form if we allow F to operate on itself; i.e. F is a recursive process (or set of processes) that is changed in the course of acquiring

antiquity that had prevailed. The triumph of observational representation over pictorial convention became a marker of the autonomy of the individual that the Renaissance promised more generally. The radicalism and personal liberation that this engendered has resonated for six centuries. As a consequence the various attempts at institutional repression appear to only have stoked the fires of individual expression to the extent that novelty and creativity (in the arts) have become synonymous with a modernist avant-garde. The benchmark of creativity in the arts then is the manifestation of a novel perception that diverges from the norm. The fact that this is also manifest in economic activity has not gone unnoticed by scholars.

For some, the cultural determinism of creativity is perhaps a step too far, and the insight and driver of this paper (and our collaboration) is to ask if the spurs of creativity might not also derive from those aspects of biology, and cognition fundamental to all living organisms that are (for whatever reason) amplified in the human. We have been led to ask whether creativity in the social and economic realm might be also understood as a legible manifestation of a cognitive habit that fuels an intrinsic exploratory drive. This leads us to ask to what extent the history of secessionist movements, the likes of which have shaped the story of art, science and culture for the last 600 years, can be understood as an opportune narrative of progress that is in fact driven by the apparently inexorable lure of novelty. This points to the compelling fascination of thinking about creativity and cognition as a systemic and representational dyad in that it touches (and challenges) both our knowledge and assumptions about our cognitive capacities, and the cultural valorisation of creativity as a criterion of representational competence.

Cognitive Innovation

The coalition of creativity and cognition as a theoretical platform on which to build theories of aesthetics, interpretation or form has been a significant concern in critical theory. In the past four decades it has provided both valuable insight and methodological paradigms for interdisciplinary research as it has enriched our understanding of creative practice. Reflection on this foundation has opened the way for the development of the more totalising concept of cognitive innovation that Denham develops in her parallel paper. Her discussion of the recursive process in the context (and language) of theoretical neuroscience is suggestive of Metz' thoughts on the cinema experience. The claim underpinning cognitive innovation is that in humans and animals there is an irresistible attraction to the novel, and this is mirrored by internal cognitive processes that privilege new events. Such a tantalizing double reflection of apparatus and context can, however, only be perceived through externalization (at both world and system levels) which, wherever one stands in the debate about representation, is simultaneously the outcome of, and trigger for, novelty perception. The cultural

³ Agency here is used rather loosely to mean an entity that is able to perceive, think, learn and make choices about its actions (a human being for the purposes of most of the discussion).

⁴ Cognitive innovation is the focus of the CogNovo programme (cognovo.eu)

new knowledge and skills.

$$F_{t+dt}, x_{t+dt} \leftarrow F_t(F_t, x_t, s_t)$$

where F_t represents all internal (mental) processes, x_t is the set of ideas, facts, words, and so on that are known by the individual and can be exchanged with others, s_t are things in the world perceptually accessible to the individual and t is an index of time. Cognitive innovation refers to changes in F and x as the individual builds its knowledge, x , and processing capabilities and skills, represented by F .

Implicit and Explicit Knowledge

This formulation may throw some light on why it is we have conscious access to some knowledge (generally termed declarative or explicit knowledge) while we do not have access to other types of knowledge (non-declarative, procedural or implicit knowledge) (Squire & Dede, 2015). Although x is by definition known, F can never be explicitly known as it is a process (or complex set of processes). We can never have direct access to F , only to the results of its operations, x . However, although we can define the set x as the set of what is known, this does not mean that the entirety of x can occupy consciousness at the same time. The point of consciousness is perhaps rather that it can (temporarily) confer a privileged position to selected subsets of x which can be manipulated in the process of thinking, or exchanged with others in communicative acts.

In the brain, both facts and procedures are thought to be stored in the form of changes in network connectivity. As a consequence both forms of knowledge alter the processing of the system in some way. The rather glib distinction I have just made between explicit and implicit knowledge therefore needs to be further considered. In the case of explicit knowledge the information can be held as an item in working memory within the conscious present. Implicit knowledge is somehow different. For example, when we read we gain access to words and ideas, but we cannot say much about *how* we read (the process of reading). Perhaps the difference is also one of time. Implicit knowledge cannot be brought into working memory as a unit as it has (sometimes considerable) temporal extent. Consider, for example, the concert pianist who 'knows' a Beethoven sonata; what the pianist actually knows is the processes necessary to generate the actions that produce the sequence of notes that make up the sonata. While fragments or static structural views (e.g. in the metaphor of a spatial map) can be accessed consciously, the entirety of the work as it exists in time is only accessible in time. Consciousness has temporary access to the products of the process of playing the sonata, and this is true even if the process is imagined. So, the remainder of this article is based on the assumptions that a distinction can be made between explicit (declarative) knowledge and implicit (process) knowledge, even if both are instantiated in some way in the connectivity and activity in the brain, and that consciousness can sample explicit knowledge (only).

Development of the Self

Expressing cognitive innovation as a recursive, self-modifying function makes clear an essential drive at the heart of living

acknowledgement of external representation also significantly modifies what would be, in effect (and possibly is in lower organisms), a closed system of stimulus and apparatus. In the context of creativity described here, representation is less concerned with its most familiar function - communication - and more to do with self-recognition and resistance to intellectual stasis. As a consequence the action that leads to representation externalizes the system's proclivity for novelty, (in a social manifestation such as a painting) and the system is further stimulated by the recognition of an external novelty.

Critical discourse and history as responses to a social manifestation, amplifies the power and visibility of novelty by transcending individual experience as the benchmark of the new. This social amplification comes at a price since it produces a stifling double bind in that although the artist (for example) must dig deep within themselves to seek what is important, the relevance of what they find must extend beyond the individual if it is to respond to the irresistible appetite for material novelty. In short it is the formula for art, (and possibly other modes of knowledge production), that in the case of a representation, the particular is only significant if and when it has general relevance, and only through the most intense and obsessive engagement with the particular can the generality be uncovered and meaningfully invoked.

Creativity and Technology

Plumbing the depths of human history for the origins of art, or other social manifestations of creativity, is possibly less important here than outlining its contemporary function; not least because the material evidence that informs the history of the origination of representation is simply too slight. Without the fullest contextualization of any representation, its function and purpose can only at best comprise informed speculation and this characterises much that is written about cave paintings for example. Thinking about the functions of art in a contemporary context is more sustainable in that there is a wealth of evidence to draw on in the exponential growth in the volume of social manifestations of human endeavour. In the critical engagement with these manifestations creativity is acknowledged as both a cognitive function (probably posited on a cognitively impenetrable impulse to recognise novelty) and a cultural predilection to valorise the new. In this scenario, creative novelties claim attention in as much as they offer a material representation of human cognition and ingenuity in action.

The cultural privilege of creativity as a virtuous human quality filters the arts (in the present and the past) for evidence of a particular class of novelty that has, or has the potential for, a transformative effect. Tracing and narrating this transformative effect is the work of contextual memory, without which the novel becomes undifferentiated from the personally new. Without a narrative each new day is an entirely new beginning. As a consequence the human apparatus is burdened with another task in addition to internal reflection and external representation set out at the start of this paper. Each observation/reflection and representation must be

systems⁵. At birth, the human infant has some rudimentary abilities or basic processes, F , which include instinctive drives such as feeding and sleeping, and the ability to sense and express (communicate) its internal emotional state. At this stage the set of explicit knowledge, x , is more or less empty. But there is something else at work, and that is an active, restless, not necessarily conscious process of extracting information from the world. This process can be demonstrated even in sleeping neonates. For example, differential brain activations in one day old babies are elicited depending on whether a sound can be anticipated or not (Stefanics et al., 2007). This differential activation also reflects contextual influences, so if rather than occurring randomly, a previously unexpected sound forms part of a repeating pattern, it no longer merits (or gets) special mention, even if the probability of its occurrence is the same in both cases. We cannot be sure what is going on but this makes sense from an information perspective, as when something unexpected occurs, it potentially contains new information, while if it forms part of a known pattern, it does not. From the start then, there is an ongoing (mostly non-conscious) process of detecting and representing regularities or patterns in the world, within which framework subsequent perceptions are processed. Pattern representation and novelty detection are equally important flip-sides of the process of information gathering, which together provide the infant with the ability to acquire and internalise knowledge about the world⁶, its structures and its dynamics.

This innate exploratory process is amplified exponentially through action which facilitates experimentation and critical exploration of the quality and reliability of the infant's knowledge. Agency blossoms; actions open up new modes of experience, new ways of knowing, new possibilities for interacting with others, and ultimately the construction of the (shareable concept of the) self. The paradox at the heart of this notion of the self being something that is iteratively constructed and continuously subject to modification, is that one generally has a subjective sense of a singular self despite the enormous changes the self clearly undergoes. It is only under extreme trauma that disconnects, such as phantom limbs or multiple personalities arise. In other words, F remains F even though F_{ti} and F_{tj} may be totally different; as long as F_{tj} was reached from F_{ti} as result of a recursive process it seems we are happy to consider them as being instances of the same self.

Underpinning all of this is a set of intrinsic processes that constantly evaluate the state of the individual and the results of its actions (including internal 'actions' such as thinking) within the context of expected consequences. When something unexpected occurs (e.g. some new object appears on the scene, some behaviour produces unanticipated outcomes, some new idea emerges), differential (novelty) brain responses are

integrated into a personal story of memory as a history of (among other things) novelty. History is a story of significant change told in a way that is consistent with the present. This means that the irresistible attraction of novelty at both cognitive and cultural levels drives perception simultaneously in two directions: the past and the present. What was new then and how does that relate to what is new now: *Laius thought that he had killed his son at birth but a shepherd brought him up and years later when he met his father on a bridge Oedipus killed him and later, married Jocasta unaware that she was his mother.* Here the function of the recollected past can be claimed to be a necessary condition for the perception of the present, and we find ourselves engaging in one of the philosophical debates of the late nineteenth century that shaped both the breach with the Renaissance and the birth of Modernism. The propositions about the nature of the present launched by Marey, Bergson and Curie, (to name just three) over the place of time and memory in perception remained unresolved in their lifetimes as they do to the present day, but the uncertainties about consciousness that they insist upon had a transformative effect on material culture through the arts, sciences and humanities.

Modern Technology

In the wake of this uncertainty a new idea of what technology was for and could do replaced earlier concepts of it as a tactic to alleviate the hardships of nature through muscular amplification. Based on a mechanical physics that was largely driven by the needs of the manufacturing, agricultural, extractive and transportation industries technology meant brute power. Intelligent machines were left to the realms of magic and spectacle. Where the technologies of the eighteenth and early nineteenth century responded to a pre-existing world of hardship and natural obstacles, the new understanding of technology, in contrast, was manifest in devices that originated in an understanding of the affordance of human perception as a defining quality of our species. A perception that was also, in many ways, an instrumental but deficient apparatus in the sense that imagination outstripped that which could be perceived. Built on a discontent with the limitations of sensory range, recall and reproduction, the emergent technological trajectory in the second half of the nineteenth century was concerned not just with the enhancement of perception but also with the development of devices that extended its range to superhuman levels.

While in previous centuries technologists had developed ocular and specular devices through, and with which, to more clearly observe the material world, in the late nineteenth century the amalgamation of scientific instrumentation with a

⁵ As a baseline, there are random mutations, some of which are preserved through natural selection. As animals become more sophisticated, they develop more nuanced exploratory behaviour as they learn about their worlds. This behaviour is driven by intrinsic reward mechanisms, modulated by emotionally-valenced memories. The important point here is that the processes of cognitive innovation are fundamental to the adaptability and autonomy of all living creatures, including humans.

⁶ By world here we mean anything external to the neonate, but it could equally well be argued that something similar must apply to the internal milieu.

triggered⁷. Novelty detection is a pervasive brain function. Unexpected events are given salience through enhanced neural responses in many brain areas⁸, and transient activation of the mesolimbic dopamine system (Schultz, 1998). Activating the dopamine system has two important consequences. Firstly, dopamine facilitates learning (Wise, 2004) and so information about the event's relationships with other events, actions, context and consequential value (Schultz, Carelli, & Wightman, 2015) is internalised, and in this way the individual acquires and refines its knowledge (x) and processes (F). Secondly, transient activation of the dopamine system is also linked to feelings of pleasure. So in some way, dopamine also provides an incentive for exploratory behaviour, driving the quest for new experiences and ideas; the *lure of the new*.

Creativity

Mapping out cognitive innovation as an inseparable amalgam of knowledge and process helps to position creativity. Creativity is the term in common usage. It is a term that in our time seems to deliver an implicit value judgement (creative = good, non-creative = mundane, bad), a term that has become muddled and ill-defined in trying to encompass everything from the profound act of creating a new scientific theory ('CREATIVITY') to the everyday resourcefulness displayed by people as they try to overcome daily challenges ('small creativity'). The definition most commonly used in psychological studies is that creativity is the production of 'something that is novel (original) and useful (valuable, appropriate)'; for a review of its provenance see (Runco & Jaeger, 2012). This definition has spawned an array of tests, often focussed in practice on people's ability to think up multiple solutions to some problem, with creativity being equated to the number and novelty of the solutions they provide. In this scenario, novelty is judged by the experimenter (in relation to some norm) rather than the individual, and little emphasis is placed on measuring the 'value' or relevance of the solutions to the individual, or their ability to synthesize knowledge gained through the creative process. In sum, these objective 'divergent thinking' measures of creativity take little account of the role of agency or the component processes involved in creativity, and, in attempting to create an 'objective' measure of creativity, end up by substituting the subjectivity of the creator with the subjectivity of the experimenter.

Might considering creativity in terms of the cognitive innovation framework outlined above provide pointers to more meaningful measures of creativity? Let us take each of the component processes of cognitive innovation in turn; exploration, exploitation, synthesis. Exploration implies an active intentional process of probing current boundaries to go beyond the known, identifying gaps in knowledge, posing new questions. Of all the definitions of creativity, the concept of 'forming something from nothing'⁹ is arguably the most misleading. Exploration is only

sophisticated enquiry into human perception that mapped the flaws and restrictions of the senses spawned devices that described an alternative (and parallel) world that was discontinuous with the human sensibility. Many of these devices were developed as autonomous sensors that extended human sensibility in much the same way as pumps, presses, drills, engines and cranes extended muscular potential, but others delivered credible data - confirmed theoretically - that was acquired from beyond the sensory spectrum available to humans. The most direct example of this trend that springs to mind is the nineteenth century approach to what was later called photography and particularly chronophotography. The photograph delivered images of events that humans could understand but were only accessible through the machines. Although there were many competing vectors driving the enterprise that was eventually stabilized into the photograph as the instrumental device that we might recognize today, a key determinant of the appeal was a dissatisfaction with existing systems of capturing visual data (and impressions). This was particularly the case in the context of an evidence based perception that used photography as an augmented 'eye' to underpin the very idea of fact that was detached from human perception. Etienne Jules Marey and his teams of researchers at the Physiological Station in Paris for example were driven by fundamentally pragmatic 'real world' questions about blood-stock, fatigue and movement while at the same time they struggled with the philosophical problem of exactly what version of reality their instruments revealed.

Creating Reality

Marey and his team's technological approach to the conundrums of time and movement embraced the sensory apparatus of the human in the same way that Renaissance artists responded to the collapse of Byzantine conventions: they dug deep within the human apparatus to discover its functionality and replicated its sensory mechanism through an observable effect. In the case of chronophotography or high speed photography for example, this was achieved not simply by amplifying human perception as though it were a muscle, but in revealing things that only the camera could 'see'. In this they exceeded the possibilities in ways that resituated the human as an alien form in a parallel instrumental reality. In much the same way as the microscope did when its powers of magnification exceeded any possibility of touch or any other human physical engagement. Put allegorically; the imaginary muscular giant of the steam hammer and locomotive was pitted against crafty gods who re-envisioned the world in ways that were beyond the giants reach - they may have been able to walk through the telescope to infinitely far but could never pass through the microscope to touch the infinitely small without changing their form. These gods saw things moving at speeds only accessible to the instruments they used to observe

⁷ From this list of possibilities it is clear that novelty can vary qualitatively from the rather passive or reactive (e.g. some new object appears on the scene unexpectedly) to the more intentional or active novelty that arises when a new idea is generated, for example. Whether the mechanisms for signalling novelty in these different cases are the same is not clear, but here I will assume some commonality.

⁸ For example, as demonstrated in the mismatch negativity paradigm; for a review see (Naatanen, Paavilainen, Rinne, & Alho, 2007).

⁹ Shorter Oxford Dictionary, 1986

meaningful within the context of the known. The truly creative individual is one who is able to draw on a comprehensive understanding of what is known, to ask the questions others have not thought to ask, to find the paths others have not investigated. These explorations are not randomly plucked from the ether; they are situated, and acquire meaning, within the context of current knowledge, practice and sanctioned methodologies, driven by an internal reward system that is triggered by personal (subjective) measures of novelty. It is important to note that although knowledge can be both individual and collective, the exploratory processes described here are essentially made in relation to personal knowledge. In other words the individual must have internalised the relevant collective knowledge in order to find those new pathways that are interestingly new to others too. Novelty detection in this context can be seen to provide a subjective contextual indicator of passing through some boundary of the known¹⁰.

Creativity is generative, i.e. some new thing (artefact, idea, etc) is forged. In contrast to cognitive innovation, which is focussed on the development of the individual and does not necessarily require the generation of explicitly (consciously) accessible representations or products, creativity does¹¹. This aspect of creativity is associated with exploitation and notions of selection, elaboration, and value. From all of the possible questions to think about or artefacts to create, some choice has to be made. It is here that intuition¹² and value judgement play a crucial role. No-one knows what the future holds, but somehow judgements are made about the potential value of the options. In the first instance, this selective process is subjective, based on the intrinsic (not necessarily conscious) value-judgements of the creator. The initial 'externalisation' of the product is an internal one, which occurs as novel concepts, or even accidental discoveries, are consciously considered and evaluated within the subjective realm of the creator. Of course individuals are situated within communities so these internal processes may also be influenced by (actual or anticipated) external feedback from others.

Finally, the knowledge and processing skills gained through these explorations are incorporated within existing (personal and collective) knowledge structures and processes, the implications and ramifications explored and consolidated. This account of creativity differs from other models in the stress it places on knowledge consolidation, and modifications to internal processes which are honed through practice. From this viewpoint we can see that creative novelty (valuable novelty) is not simply something new, it is something new in relationship to existing (internal and external) frameworks of knowledge. The most useful novelty, therefore, is one which is positioned not too far from (known) boundaries so that it can be incorporated within existing frameworks (reified in the academic practice of identifying and acknowledging antecedents to one's current

them and constructed a version of the world superior to humans dependent on the amplified perception afforded by a new idea of technology

Cognisant Machines

The very idea of technology as it developed in the closing decades of the nineteenth century precipitated a formalistic problem of understanding experience. Devices such as the phonograph or photographic camera represented real world perceptions mechanically or chemically with uncanny similarity to the dominant modes of simulating experience. These modalities were indebted to conventions that were primarily established in the arts through sound instruments, paintings and prints. However, as technologies diverged from earlier forms they revealed aspects of the world that were theoretically consistent with scientific laws but only evidenced through the device's own descriptive apparatus. Through the apparently higher truth of objectivity they gained an authority that challenged and modified the representational aspects of the artist's project of self-realization. The tensions that this created are expressed in the conflicting responses to chronophotographic images of movement that contradicted the established conventions of representation. Most famously this is found in the disputes that Marey and Muybridge became embroiled in over instrumental truths of the horse's movement that were considered 'ugly' and therefore untrue. Nonetheless the apparent autonomy of the technologies yielded what was ultimately considered a higher truth that, in virtue of its special particularity, trumped any experiential or phenomenological evidence that was drawn from within the individual. In contrast human evidence was recognized as individually powerful but universally irrelevant except in special circumstances. In the Romantic and Expressive paradigm, the reservoir of the soul, (suitably detached from rationality), held such experience as an idiosyncratic feature of individual sensibility that was not reproducible as a relevant universal truth in any meaningful way. Art and the kind of creativity that was associated with it, was effectively detached from technology and science.

Born of novelty detection, one of the key drivers of creativity in the form of the Renaissance, the technological imaginary of the late nineteenth century appropriated the primary imperative of self-reflection by offering a novel world that was defined as an instrumental reality. The technologies that had promised to serve so well to reveal the invisible manifestations of elemental truths passed over the individual in favour of their own autonomous universe. While steam engines, drills, presses, looms and pumps could be inventively combined to deliver new processes and products, by virtue of their apparent capacity to reflect upon their own capacities, late nineteenth century technologies existed in a relational grid

¹⁰ It should be noted that novelty detection is not necessarily always attractive. Under some circumstances, uncertainty can evoke feelings of discomfort (fear of the unknown), and so novelty in a way also signals moving outside the safe boundaries of the known.

¹¹ The generative nature of creativity is implicit within most definitions, and self-evident within the arts and humanities; how else can anyone know that something has been created? But it is an important point to articulate here in order to distinguish cognitive innovation from creativity.

¹² Intuition or gut-feelings may arise from emotional tagging as suggested by Damasio in his somatic marker hypothesis [Damasio, A.R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philos Trans R Soc Lond B Biol Sci.*;351(1346):1413-20].

thinking). In practice, it is probably misleading to think in terms of the continuously incremental cycle described here for reasons of simplicity. The process of creativity is undoubtedly a multiscale one; big new ideas require multiple iterations of smaller scale explorations and selections to fully work them out. At the macro scale this may give rise to step-like advances, as observed at personal as well as cultural scales.

First and Second Order Effects

From the account above, it becomes clear that the externalisation of the creative output has both first and second order effects. By first order I mean the subjective perspective of the creator. The creator is initially the only one with access to the newly generated thing (artefact, idea, and so on); it is their knowledge that sets the scene for questions and explorations and determines novelty, it their judgement of value that influences selection and decisions about what to exploit, and their knowledge base, thinking processes and skills that are first to be refined and influenced. Second order effects occur as others engage with the new thing, as it impinges on their own thought processes and behaviours. In reality, there are of course complex interactions between the two levels and they cannot be so neatly separated; external forces can strongly influence internal processing and explicit knowledge (though not implicit processes) can be fluidly transferred between individuals.

It is not necessarily the case that individuals are driven by a conscious drive to produce novel outcomes; but an intrinsic reward system that activates in response to unexpected events creates a bias for generating outcomes that the individual perceives as novel. This is important. In life most creative practice requires sustained effort, so an intrinsic reward system that is able to generate what are essentially self-motivational signals provides the fuel needed to maintain the demanding multiscale processes of creativity without the need for (immediate) external reward that in any event must be delayed relative to the effort. The social context introduces an extra layer of reward and another potential source of motivation. In addition to intrinsic reward mechanisms, recognition by others can confer esteem, adulation, monetary incentive and power, which may (or may not) drive and influence the individual creative process.

The Creativity Function

The creativity function is a natural expansion of the cognitive innovation function, extended to include the social context within which individuals are situated. Externalisation of the outputs of the creative process makes them accessible to others. So it is not only the knowledge base and skill set of the individual that may be changed, the processes of exploration, selection and synthesis can now involve others. If, in addition, we allow G to represent cultural and societal processes, and γ the set of communally known things, then we can approach a functional definition of creativity by generalising the cognitive innovation function to include the communal context:

$$F_{t+dt}, X_{t+dt}, G_{t+dt}, Y_{t+dt}, S_{t+dt} \leq F_t(F_t, X_t, G_t, \gamma_t, S_t)$$

This formulation expresses the potential for the creativity of the individual to affect the wider community in some measurable way; i.e. the individual creates something that makes a measurable difference in γ (communal knowledge) or G (the way the community 'thinks' or acts). It also captures the notion of a

of value that replicated the ambitions of those who earlier had sought to represent their own perceptual engagement with the world around them. The human idea that the world was there to be experienced became the *causa sui* of the nineteenth century idea of technology whose truths were only fully accessible through the internal scrutiny of the device. In high speed photography, for example, what an image meant became conflated with how it was made.

Having appropriated the artistic project of the Renaissance in the late nineteenth century as the technological imaginary, the question of how to make something that has meaning to humans (and only to humans) had to be reformulated in ways that privileged novelty detection over the 'perceptual' consistency of the device. It is not surprising then to find that the social manifestations of human creativity in this period became progressively detached from precedents that had served so well for four centuries. In western painting and sculpture, figuration and veridical representation gave way to a preoccupation with images of the perceptual apparatus in process - whether in Impressionism, Post Impressionism, Futurism, Rayonism, Vorticism or even Surrealism, the human apparatus in action became the topic of the image, displacing sacred and secular mythologies as the primary address of the art work. This vision of technology, arguably both the hand maiden and driver of modern science, has continued to shape the technological imaginary into a form that simulates the double action of the cognitive system and its realization in the external world.

Cinema and the Mechanisation of Cognition

This particular account of creativity as multidisciplinary, malleable and as historically contingent suggests a special place for the cinematographe and its passage to its institutional form as cinema. There are many full accounts of its provenance in arts as well as descriptions of the vectors of science, technology and entertainment that shaped it. What might be added to these accounts is a consideration of the coalition of chronophotography as a technological response to the Renaissance project - not as an extension of a realist imperative by the addition of movement, nor as a natural consequence of the industrialization of the image - but the product of a modern technological imaginary that privileged instrumental perception over muscular amplification. The cinema delivered its hermetic logic both technologically, and affectively through the incorporation of the cognitively impenetrable effect of projecting images interspersed with a blank screen at a rapid rate. The industrial form of this quickly founded its own institutions and architectural presence in cities and towns across the world based exclusively on an instrument of perceptual consistency that simultaneously satisfied the appetite for novelty. In this institutional guise the cinema as the spectacular gave way to a predominantly narrative entertainment form driven by internal forces such as character traits, psychological motivation, and sex drive that were partially revealed through allegories of human cognitive operation.

In a rapid evolutionary process of variation, adaptation, mutation and survival; through ticket sales, fanzines, and sell-through of associated products, ranging from clothing to make-up, the cultural form of cinema that survives and

recursive self-modifying process that is influenced by (and in turn has the potential to modify) communal processes and knowledge. However, it is important to note that G actually represents the set of F's that make up society and it is not homogeneous; each F is different, and there are complex (multiscale) linkages between the F's, from tightly coupled small social groups to communities, cultures and nations. G may thus respond very differently in different places across the network to a novel artefact or idea. Time too becomes a crucial factor, as neither knowledge (y) nor cultural or social processes (G) can change instantaneously. Propagation through the communal network takes time, and in this process, information relating to the new creation, and even the new creation itself, may be transformed as individuals engage with it. The creation can capture the creative processes of others and in some sense acquire a life of its own that reaches far beyond the lifespan and immediate community of the creator.

This definition of creativity provides an elegant way of capturing notions of novelty and value that prevail more generally, including in the arts. For an individual to *feel* creative they must produce something that is perceived by themselves as novel and valuable. For an individual to be *recognised* as creative they must produce something that is perceived by others as novel and valuable; i.e. the new thing should make a measurable change to y or G. In other words, the creativity of an individual is a multi-layered quality which has both subjective and objectively observable aspects, and in analogy with consciousness, offers both hard and easy problems.

Novelty is not absolute; what is novel for one individual may not be so for another. The novelty of a particular thing (artefact or idea) may in practice not even register for a particular individual unless it engages some set of knowledge personal to that individual, which activates a relevant representation of the known; novelty too far beyond an individual's 'known' boundaries may simply be incomprehensible. Value too is clearly relative, as it is determined by the processes of the F's in G that engage with the new thing and respond by ignoring, resisting, or changing; i.e. in the individual F's that comprise G there are processes of selection that determine whether the new thing gains traction. This means that the state of each F in G is a crucial factor in determining what influence any particular new idea or artefact has on their intrinsic processes. The real objective measure of creativity then is the extent to which the new thing engages (individuals or communities within) society and changes communal knowledge and behavioural and thought processes.

Non-creativity

What does it mean not to be creative? Non-creativity falls easily from this definition too as the production of novel ideas or products that do not change the thought processes or knowledge of the individual (first order effect). If there is no first order effect, there may or may not be a second order effect since this depends on the state of others; i.e. there is potential for some disconnect here. For example, simply painting something that has not been painted before is new by definition, but may nevertheless not be perceived by the painter as situated beyond any personal boundaries. Therefore, in the terms outlined here it may not engage the painter's intrinsic reward system (even if it does engage the extrinsic one) and so will not *feel* like a creative process. This possibly also offers a reason why non-creativity (often called Mannerism in the arts) is less pleasurable than

flourishes today (at least in Europe, and the USA) developed. Its success was founded on the parasitic incorporation of the perceptual apparatus of the audience to establish an apparently autonomous form of technological creativity that was independent of human agency. As the brief quotation from Metz that opens this essay suggests, the primary identification of the audience in the cinema is not with stars and action but with the apparatus as a surrogate of the self. In this way how something was done, and what something meant, were satisfactorily conflated. It was a truly modern technology that replicated cognition in action.

The cinema was not of course the only technology to satisfy these criteria, but it does epitomize them in a way that prepares the user for a further iteration of the technological imaginary in devices that also exploit perceptual aberrations in the human 'apparatus'. These technologies effectively fully replicate an illusion of creativity by reducing (or disavowing) the contributory function of the user and, more convincingly, simulating autonomous agency and novelty recognition as a property of the machine. The most obvious contemporary example is the text messaging system and its alerts that are the economic core of mobile telephony. This further extension of creativity - at least in the context above - as an historically contingent illusion of the machine, poses questions beyond the bounds of technology studies, media studies and cultural history and leads to the core of the current understanding of human creativity. Creativity is no longer, as it once was, a signifier of personal gift or talent (or indeed direct connection with God) but another contender for attention in the slack water of an economic logic, which at its best, describes a hierarchy of usefulness; a perfect market that in its daily form maximises value for its own sake. In one sense the demise of the earlier concept of creativity, whose meaning we partially inherit from a previous age, is little more than the familiar transmutations attributed to the dynamics of language. However, creativity and novelty recognition are not simply cultural or economic properties of a society but are seen here as crucial structural and micro structural elements in the human cognitive system. For this reason it may be useful to ground our understanding of the socially recognisable manifestations of creativity in the neural processes of cognitive innovation.

The Creative Artwork

Similar accounts to the one above can be woven to give an account of creativity in relation to music, literature, the performing arts and more. They will inevitably be partial, provisional and told from the present as will any account of the past. But it is important to acknowledge, as we address creativity in the present use of the term, that any ahistorical and universalist claims for it in the contexts of high art will also be partial provisional and teleological. Moreover the work of distinguishing the artist's drive from the conditions of production has been a preoccupation of critics and scholars since the early moderns. But distinguishing these elements in an artwork should not be confused with explaining them. Although not formally introduced in to the academy until the nineteenth century, critics have acknowledged a self-conscious awareness of the interpretative responsibility of the external witness to creativity in action in visual, theatrical and musical forms. In literature, for example the endurance of Chaucer,

creativity, even if society continues to confer the desired extrinsic rewards.

Differentiating between first and second order effects has another benefit; the first order effects are generic, and so come into play across all forms and levels of creativity. We do not need to distinguish here between small and big creativity - the subjective sense of novelty, excitement and satisfaction apply to all. This leaves the extent of the second order effects (in time and space) to provide the measure which clearly distinguishes smaller from larger creative acts.

This view of creativity has implications for the measurement of individual creative potential. Simply being able to generate lots of solutions to some specified problem has only a tangential relationship with creativity in practice. In addition to generating novel solutions to some problem, the creative individual needs to be able to find the interesting questions, correctly select promising paths to pursue, modify their internal representations to synthesize their expanding knowledge base and hone their creative skills. Furthermore, their judgements should resonate with those of others if their creations are to have any impact beyond the personal. In essence, the creative individual needs a keen sense of self and an even keener sense of others. Current methods for measuring creativity, even those apparently based on real-life achievements, generally focus on the individual and their products without considering the contributory function of others; something that lies at the core of creativity as an arts practice and is clearly evidenced by publishing practices in the sciences and humanities. The ability to communicate ideas through artworks or other outputs, to engage the imagination and ultimately to leverage the creativity of others of others, is what marks out the exceptionally creative individual.

Further Thoughts

Cultures just like people may be more or less creative, more or less resistant to new ideas. Just as the detection and representation of patterns sets the scene for novelty detection in perception, so too the synthesis of deep knowledge which resists change provides the bedrock for unexpected connections, creative transformations and new breakthroughs. Constant creativity, just like constant novelty, is not only meaningless, it is practically impossible. Cultures can only tolerate (accommodate and make cognitive use of) so much creativity; the consolidation of newly discovered processes and knowledge is equally (possibly more) important and also takes time and practice. There is a balance to be struck then, both at the personal and the cultural level, between novelty and familiarity, innovation and repetition, exploration and exploitation. It is also clear, though not explored here, that familiarity and repetition are equally (perhaps more) compulsive and bring their own pleasures and rewards.

The ideas expressed in this paper suggest a new definition of creativity: *the generation of something that (measurably) changes the knowledge, behaviour and/or thought processes of the creator and (some group of) others.* The hope is that this definition, applicable across many disciplines, may give rise to new more holistic measurements of individual and group creativity that are both personally and culturally meaningful.

There is one final point to note, the component processes of creativity are both conscious and non-conscious, with the latter arguably dominating. This resonates with the earlier distinction between explicit and implicit memory and has similar

Shakespeare, Sterne and Defoe is posited on the explicit invitation to enjoin with the author's creativity on condition that the reader's understanding of it will always be incomplete and in that incompleteness lies its fascination. Literary criticism, art criticism and music criticism along with their handmaiden histories now form established academic pathways based emphatically on the assumption that (i) the fullest account of an externalisation of creative thought (a social manifestation) will never be fully accounted for and will always be open for interpretation, and (ii) that the beholder's share in constructing an account of the cognitive processes of the artist will always tend to envision the springs of creativity in the reader's own image (and time). To this we might add the lessons of reader response criticism; that it does not always follow that the impressions and speculations of the reader are reliable indications of the processes of writing. Indeed there is certainly a case to be made that the virtues and pleasures of the work of art are precisely derived from the threshold and quality of inscrutability that the connoisseur and informed reader encounter.

Further Thoughts

It cannot be said too often that this account of how creativity and the arts have intertwined in a particular context and period is partial, provisional and told from the author's present. There are many more convincing stories to be told by many other kinds of scholars. But what they will all share is some of the thickness and density of this account. These kinds of discussions about what appears to be a basic and enduring human driver stand in contrast to populist discussions in contemporary journalism and also many of the assumed scenarios that appear in the scientific literature. Given the qualifiers of readership and purpose this too does not present a significant discussion point: departments of journalism and creative writing do sit alongside departments of literature in many universities to great mutual benefit. In the same way many of those trained in the sciences actively engage in the arts as connoisseurs, patrons and practitioners. In the neurosciences, however, there are distinct problems for the study of cognition in as much as its object of study is deeply embedded in the human 'operating system' that controls, recognises, selects and interprets the actions of the human. In parallel this operating system precipitates what we are increasingly calling 'social manifestations' of that system in action that are both individual expressions of creativity and interactive responses to the generality of social manifestations (e.g. the arts) that we might for convenience call cultural glue. In short any observation or engagement with creativity (as a social manifestation or through self-reflection) immediately changes the observed and observer in structural ways. What may be considered unique about neuroscience is that humans studying human cognition never remain the same humans even in the most basic way as for example reading about the brain changes the reader's brain. As a consequence, in the flows of cognition we are simultaneously dealing with an epistemological and an ontological problem. For teachers, practitioners and researchers who share a concern with the cognitive processes of creativity, this presents a conundrum, since approaches that are either solely epistemologically or solely ontologically driven will necessarily always be incomplete. To understand the cognitive aspects of creativity it seems that we need nothing less than a new kind of science. A

consequences; i.e. one does not, and cannot, have conscious access to the entire creative process¹³. Consequently, one lacks (complete) intentional control over it. The best one can do is to lay a groundwork that facilitates the creative processes and then wait patiently for conscious access to the emergence of new ideas and insights that can be further worked out¹⁴.

new science as radical and challenging in its intentions and methodology as that that provoked by Bacon, Galileo, Newton, Boyle, Hooke, Davy, Freud and Bohr all of whom, in their various ways, were intent on recovering the fullest account of the subjectivity of the experience of the world and expressing it in new laws. It is worth recalling that the very foundations of experimental science, analysis and reductive method in the 15th century were developed to recover an Edenic completeness in our understanding of ourselves in the world. This is some way from the current situation in which creativity is frequently defined in reduced behavioural terms that many find difficult to reconcile with the view in the arts and letters that creativity is contingent, and a co-production between social, individual and shared forces in a present that is a product of perception and memory. We hope that the concept of cognitive innovation will help in this debate.

CONTEXTUAL REFERENCES

- Martha Blassnigg, *Time, Memory, Consciousness and the Cinema Experience: Revisiting Ideas on Matter and Spirit* (Amsterdam, NL.: Rodopi Press, 2009).
- Martha Blassnigg, "Revisiting Marey's Applications of Scientific Moving Image Technologies in the Context of Bergson's Philosophy: Audio-Visual Mediation and the Experience of Time." *Medicine Studies* **2**, No.3 (2010) pp. 175-184
- David Chalmers, "The puzzle of conscious experience." *Sci Am*, **6**, No. 273 (1995) pp. 80-86. ,
- Sue Denham, et.al. "Stable individual characteristics in the perception of multiple embedded patterns in multistable auditory stimuli." *Front Neurosci*, **8** No. 25. (2014). doi: 10.3389/fnins.2014.00025
- Josh Ellenbogen, *Reasoned and Unreasoned Images*. (Pennsylvania, U.S.A.: Pennsylvania State University Press, 2012).
- Gaskill. N. and Nocek, A. J. eds. *The Lure of Whitehead*, (Minnesota, U.S.A.: University of Minnesota Press, 2014).
- Lisa Gitleman, *Always Already New: Media History and the Data of Culture*. (Cambridge, U.S.A.: The MIT Press 2006).
- Bruno Latour, B. "Why has critique run out of steam?" *Critical Inquiry - Special issue on the Future of Critique*. **30** No. 2, (2004) pp. 25-248,
- Christine Gallaher and Stephen Greenblatt, *Practicing New Historicism*. (Chicago, U.S.A.: Chicago University Press 2000).
- Michael Gibbons, et. al. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. (London, U.K.: Sage. 1994).
- Stephen J. Gould and Elisabeth S. Vrba, "Exaptation — a missing term in the science of form." *Paleobiology* **8** No.1. (1982). pp. 4–15.
- Jacques Hadamard, (1945). *An essay on the psychology of invention in the mathematical field*. (Mineola, U.S.A.: Dover Publications Inc., 1945).
- S. Kracauer, *The Mass Ornament*. T. Levin, trans. (Cambridge, U.S.A.: Harvard University Press, 1995).
- Christian Metz, *The Imaginary Signifier Psychoanalysis and the Cinema*. (Bloomington U.S.A.: Indiana University Press, 1997.)
- David A. Leopold, and Nicos Logothetis, "Multistable phenomena: changing views in perception." *Trends Cogn Sci*, **3** No.7 (1999). pp. 254-264.
- Phillipe-Allain Michaud, *Aby Warburg and the Images in Motion*. (New York, U.S.A.: Zone Books 2004).
- Risto Naatanen, et.al. "The mismatch negativity (MMN) in basic research of central auditory processing: a review." *Clin Neurophysiol*, **12** No. 118 (2004) pp. 2544-2590.
- Alva Noë, *Out of Our Heads. Why You Are Not Your Brain, and Other Lessons from the Biology of Consciousness*.(New York, U.S.A.: Hill and Wang. 2010).
- Helga Nowotny, Peter Scott, and Michael Gibbons, "Mode 2 Revisited: The New Production of Knowledge". *Minerva* **41** (2003) pp. 179-194.
- Michael Punt, *Early Cinema and the Technological Imaginary*. Chesham, U.K.: The Postdigital Press (2000).
- Dale Paves et.al. Why we see things the way we do: evidence for a wholly empirical strategy of vision. *Philos Trans R Soc Lond B Biol Sci*, **356** No.1407 (2001) pp. 285-297.
- Edward Reed, "From Soul to Mind: The Emergence Of Psychology, From Erasmus Darwin To William James: Emergence of Psychology, Erasmus Darwin to William James." (New Haven, U.S.A.: Yale University Press,1997).
- Mark Runco, Garrett Jaeger, "The Standard Definition of Creativity." *Creativity Research Journal*, **24** (2012) pp. 92-96.
- Wolfram Schultz, "The phasic reward signal of primate dopamine neurons." *Adv Pharmacol*, **42** (1998) pp. 686-690.

¹³ Nietzsche's notion of 'hanging in dreams from the back of a tiger' springs to mind.

¹⁴ This is a common experience, noted by many eminent creative thinkers; e.g. see (Hadamard, 1945)

Wolfram Schultz, Regina M. Carelli, R. Mark Wightman, "Phasic dopamine signals: from subjective reward value to formal economic utility." *Curr Opin Behav Sci*, **5** (2015) pp. 147-154.

Barbara Shapiro, *A Culture of Fact: England 1550-1720*. (Ithaca, U.S.A.: Cornell University Press, 2000)

Stephen Shapin, *The Scientific Revolution*. (Chicago, U.S.A.: University of Chicago Press, 1996).

Larry Squire, Adam Dede, "Conscious and unconscious memory systems." *Cold Spring Harb Perspect Biol*, **7** No. 3, (2015) pp.1-14.

Barbara M Stafford,. *Visual Analogy: Consciousness as the Art of Connecting*. (Cambridge, U.S.A.: MIT Press, 1999).

Garbor Stefanics, et.a. "Auditory temporal grouping in newborn infants." *Psychophysiology*, **44**(No.5 (2007) pp. 697-702.

Andrew Shryock, David Smail, *Deep History: The Architecture of the Past and Present*. (Berkeley, U.S.A.: University of California Press, 2011)

Alfred Whitehead, *The Concept of Nature*. (Cambridge, U.K.: Cambridge University Press, 1922).

Roy Wise, Dopamine, learning and motivation. *Nat Rev Neurosci*, **5** No. 6 (2004) pp.483-494.