CONCEPTS AND AFFECTS IN COMPUTATIONAL & COGNITIVE MODELS OF DESIGNING

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Abstract. *This paper addresses two aspects of theory foundations relating to computational models of creative design cognition based on human designing. It proposes definitions of core concepts to address problems of terminology and epistemological coherency in this area. The paper argues that neurological findings and a greater understanding of the roles of closure activities imply that benefits can be gained from increased emphasis on the roles of physiologically based somato sensory activities in human designing and cognition. A code is introduced to separate the different representations of affects found in computational and cognitive modelling of human processes.*

Cite as: Love, T. (2001). Concepts and Affects in Computational and Cognitive Models of Designing. In J. S. Gero & M. L. Maher (Eds.), *Computational and Cognitive Models of Creative Design* (pp. 3-23). Sydney: University of Sydney.

1. Introduction

This paper proposes changes to the theoretical foundations of computational and cognitive theories and models of creative designing. It:

- Describes definitions of foundational concepts for computational and cognitive theories of designing developed to minimise epistemological problems in this area and to facilitate discourse across disciplines
- Explores how the foundations of cognitive and computational theories of designing are impacted by differences in the ways that cognitively related somato-sensory processes (affect) are included in human design thinking especially in relation to ***closure*** processes.

Gero (2000) has suggested that there are three main categories of research into computational models of design cognition:

- Empirically-based research
- Axiomatic theory building
- Theories founded on conjectures about processes viewed as analogical to human cognition and designing.

The first part of this paper aligns with Gero's second and third categories. The second part of the paper is aligns with the first and third categories. Much of the paper, however, sits largely outside of Gero's categories because the paper combines an epistemologically based approach to theory, the findings of biological/neurological/psychological research relating to humans' sensory processes whilst designing, and recent structural theories about the functioning of human brains. This contrasts with more traditional approaches that focus on design problems, the characteristics of designs for solutions, and the infomatic aspects of designers' conscious thinking of about problems and solutions. The approach used here follows Ostanello (1996) who argued, in relation to research into Multi-Criteria Decision Aids (an area with a similar focus and technological approach to computationally and cognitively modelling designing), that it is necessary to go beyond 'convenience hypotheses' (e.g. hypotheses and assumptions such as 'affect is not included in modelling cognition' and 'it is not necessary to comprehensively define key terms') that researchers have used to rationalise human processes in ways that facilitate their analyses.

Research undertaken by the author into combining qualitative and quantitative aspects of design theory (Love, 1996, Love, 1998a) showed that two key problematic factors in this area are the lack of coherent and well chosen epistemological foundations for making theory about designing and designs, and inadequate models of human designing that include all aspects of human functioning. Both of these factors remain substantially unaddressed in the literature and both are relevant to building computational and cognitive models of creative design cognition.

Definitions of core concepts need to differentiate them from similar concepts used in other disciplines whilst facilitating the integration of theories and research across disciplines. In the different fields associated with designing, theoretical discourse has been terminologically and conceptually problematic since the inception of modern design research (see, for example, French, 1985, Jones, 1970, Hollins, 1994, Lewis, 1964, O'Doherty, 1964, Reich, 1994b, Reich, 1994a, Ullman, 1992, Wray, 1992, Hubka and Eder, 1988, Hubka and Eder, 1996). Unlike disciplines such as Engineering and Physics, there are no widely accepted definitions of core concepts, and, across the myriad sub-fields of design research, even small variations in definition frequently result in significant differences in meaning (Love, 1998b, Hubka and Eder, 1988, Hubka and Eder, 1996, Cross, 1993). Reviewing the research literature about designing and designs (human and AI) indicates that in most texts, key concepts such as 'designing', 'designs', 'design process', 'creativity', and 'cognition' have not been defined in sufficient detail to differentiate them from different meanings in the literature (Love, 1998b).

This widespread lack of definition of concepts is associated with their different meanings being confused and conflated by researchers and results in problems of conceptual indeterminacy that reach deep into theory making about designing and designs. The contradictions inherent in the differing ways that the core concepts are used reduce, and in some cases negate, the validity and usefulness of theory and research findings. The problems of terminology are at root a problem of epistemological neglect. The combination of epistemological and terminological weaknesses means that researchers' findings are questionable unless they have made explicit how the different epistemological implications of the concepts they have used align with their analyses. For example, a statement such as 'The research results in a finding Y in relation to X aspect of design' (substitute for X and Y as appropriate) is relatively meaningless unless the term 'design' is defined carefully and explicitly and with sufficient detail.

To address these issues, a meta-theoretical position has been used to focus on theories as theories, and on the best ways of defining and assembling theory and concepts. Definitions of concepts, theories and terminology are chosen so as to differentiate them from similar concepts, and be epistemologically coherent with other bodies of theory and knowledge. This contrasts with more conventional approaches that take definitions of concepts as given, and focus on the information content of theories using these concepts: difficult to justify where core concepts have a large number of contradictory meanings.

The specific definitions of terms such as 'creativity', 'design', 'affect' and 'cognition' described later in this paper have emerged from research by Love and others in relation to building sound epistemological foundations for theory making (see, for example, Love, 1999, Love, 2001 (accepted), Love, 2000f, Spink, 2000, Love, 2000c, Love, 2000e, Byrne, 2000, Hubka and Eder, 1996, Stegmüller, 1976, Love, 2000b, Love, 2000d). The proposed definitions were shaped by the following criteria, all of which are relevant to building computational and cognitive models of designing. Definitions should:

- Align with common usage of the terms (as defined in major dictionaries)
- Reduce the multiplicity of meanings attributed to the concepts by excluding meanings that are epistemologically problematic
- Locate concepts and the discipline of design research in a unique space not occupied by other concepts or disciplines
- Facilitate the integration of research and theory making about designing and designs with theories and findings of a wide range of other disciplines

- Offer the basis for a single core of concepts across the several hundred sub-disciplines that involve designing and designs.

The second part of the paper builds on the definitions proposed in the first part to draw attention to the key roles cognitively-related somato-sensory and physiological changes, feelings and affect play in designing, and in theorising about designing and designs. It extends earlier work by Love (2000a), suggesting advantages in focusing on somato-sensory processes, *feelings*, rather than *emotions*. There are several reasons for going down this path:

- Many designers and researchers insist on the importance of 'feelings', intuition and human values in designing (see, for example, Akin and Akin, 1996, Cross, 1989, Cross, 1990, Davies and Talbot, 1987, Galle and Kovács, 1996, Glegg, 1971, Kolodner and Wills, 1996, Lawson, 1990, Lawson, 1993, Lawson, 1994, Liu, 1996, Love, 1998a, Lera, 1983, Tovey, 1997, Love, 1996).
- The role of feelings and the neurology of affect in cognition have been relatively neglected. The study of affect in formal computational and cognitive theories has been mainly restricted to a psychological focus on *emotions*, especially 'emotions as physiological expression of cognition' rather than exploring the underlying neurological phenomena and its relationship to information models of brain activities (see, for example, topic areas in Picard, 1997, ISRE, 2001, Sloman, 2001).
- Cognition-related somato-sensory processes, feelings, and to a much lesser extent, emotions and moods, physiologically underpin the moment to moment interplay of human *closure* processes in cognition. Their roles are important because closure processes are crucial elements of cognition, and explaining closure requires going beyond theories of cognition based on information transformations and analysis (see, for example, Rosen, 1980, Bastick, 1982, Hamlyn, 1990, Dewey, 1959) (Ryle, 1990, Fleckenstein, 1992).
- There is increasing neurological evidence that affect, as physiologically-based somato-sensory processes, is an important element of all human functioning as well as cognition (see, for example, Kiehl et al., 2000, Fleckenstein, 1992).
- Understanding the role of human somato-sensory processes is significant to creating computational models of creative cognition because it offers a conceptual basis for a more sophisticated working model for the creation of new concepts and the identification of solutions based on integrated optimisation processes that are error checked against complex criteria (Love, 2000a, Davis, 2001, Davis, 2000).

- The role of affect in human processes is a key issue in the distribution of requisite variety in cybernetic analyses of systems models of organisational and individual processes (not addressed in this paper) (Love, 2001).

The paper takes the position that:

- Feelings are epistemologically, conceptually and physically more foundational than emotions.
- Cognition and associated physiologically-based somato-sensory activities (affects and feelings) are closely interwoven and interdependent, and better regarded as aspects of the same function.
- Feelings are an *ongoing* element of cognition rather than an occasional addition to it.

This approach differs significantly from the way that affect is commonly conceived in the literatures of affective computing and cognition. It emphasises the active and often initiatory partnership that human somato-sensory processes have with brain activities in the process of human cognition (Fleckenstein, 1992, Davis, 2001). It contradicts the trend over the 1990s for viewing affects almost exclusively in terms of 'emotions' with their properties regarded as 'James-Lange' byproducts of informatically-based cognition. This alternative perspective relocates the emphasis on to the neurobiological representation of somato-sensory 'feelings' and away from the rather remote and abstracted cognitive conceptual constructs used in the discourse of emotion and cognition.

In relation to computational models of creative cognition in designing, this shift in perspective is significant. Research and theory making in the AI and design literature relating to affective cognition, creativity and designing leans heavily on theories described by Ortony, Clore and Collins (1988) in *The Cognitive Structure of Emotions*. The approach suggested here contrasts with that of Ortony, Clore and Collins theories in the depth of participation of somato-sensory processes in human thinking and action. In this paper, the role of somato-sensory aspects of human thinking and conation is extended to areas of cognition theory in ways that Ortony, Clore and Collins did not address because of the delimitations they put on their analyses (Ortony et al., 1988, p.11). This is an alternative viewpoint to their description of *emotions* as 'extras' on top of a non-emotional modality. In this paper, somato-sensory activity and informatic transformation are regarded as essentially commingled elements of a single complex process of cognition, perception, intuition and conation. This supersedes Ortony, Clore and Collins' claim there is a need to provide an explanation of cognition in emotion that parallels earlier explanations of the role of emotion in cognition. It replaces it with a requirement to identify interactions between somato-sensory and informatic aspects of cognition.

It is emphasised that the approach presented in this paper is not intended to replace or challenge existing research in emotion and cognition. From the perspective presented here, emotions as a public representation of interior human states have an important role in designing because, like words, language and other symbols, they offer a fast, superficial, and widely understood means of communication of the underlying somato-sensory aspects of an individual's cognition and bodily functioning similar to the *style* attributes of artefacts described by Eno (1996).

2. Defining an Epistemologically Useful Basis for Research & Theory Making

Research aimed at bringing qualitative and quantitative factors involved in designing into a single epistemologically coherent theoretical frame (Love, 1998b) pointed to the need for improved definitions of core concepts for theory making about designing and designs that are epistemologically sound and useable across disciplines. The multiplicity of meanings given to core terms in the literature means that identifying appropriate definitions is mainly a pruning process of choosing which characteristics are best included, which are best excluded, and then shaping the identified characteristics into a straightforward description. In essence the approach asks, for example,

'What characteristics are best given to the concept 'creativity' (or 'design', 'design process', etc) that are epistemologically most useful for building coherent theory about designing and designs across disciplines?'

This contrast with approaches in which definition of core concepts are assumed and incompletely defined, and where the focus is redirected to situations, objects or processes, leading to questions such as,

'Is activity X ' designing?' or *'Can computers design?'*

The difference between the two approaches is profound. The first is aimed at identifying the basis for building coherent and epistemologically justifiable theory. The second is aimed at associating 'activity X' with a core concept such as 'design' so as to either apply properties associated with the core concept *to* activity X, or to infer something about creativity *from* characteristics previously designated to activity X. Alternatively, and further from coherent theory, the aim may be to bestow on activity X 'reified' status associated with the core concept to gain casuistic support.

Another purpose in defining the core concepts below is the identification of a unique epistemological territory for research. The following definitions have been chosen to shape a theoretical foundation for research and theory making about designing and designs that differentiates theories specific to these areas from theories that clearly belong to other disciplines. They identify a distinct space for a discipline relating to designing and designs, and they align the discourses and theory foundations of this discipline (as expressed in much of the existing design literature) with those of other disciplines (Love, 2001 (accepted), Love, 2000d). As would be expected, they also align with definitions of major dictionaries and many aspects of definitions used by other researchers (see, for example, Gero, 2000).

- 'Design' - a noun referring to a *specification* for making a particular artefact or for undertaking a particular activity. A distinction is drawn here between a *design* and an artefact - the design is the basis for and precursor to the making of the artefact. In this sense, this distinguishes the outcomes of designing from the outputs of craft or art alone.
- 'Designing' - non-routine human internal activity leading to the production of a *design*.
- 'Designer' - someone who is, has been, or will be *designing*. Someone who creates *designs*
- 'Design process' - any process or activity that includes at least one act of 'designing' alongside other activities such as, calculating, drawing, information collection many of which are, or can be, routine or automated.
- 'Create' – A verb meaning to make or produce. The noun form 'creativity' is often defined as the *attribute* of being able to produce 'original' work (see, for example, Marckwardt et al., 1986). In building theories, this is problematic because it implied that creativity is an attribute of both activities and objects: epistemologically different categories.

The above definition of designing includes only non-routine human internal actions. The definition does not carry into repetition: it attributes the concept of designing only to the initial event. In this sense, the attribute of designing does not apply to an individual's repetition of an act of designing, or its automation.

This definition of designing offers the basis for an epistemologically more coherent foundation for concepts, theories and terminology about designing and designs. The fact that there are currently many, and often subtly different, definitions of designing in the literature means that the above definition aligns with some, contradicts others, and frequently aligns with, and contradicts, different aspects of single definitions.

For example, the definition of ‘designing’ above aligns with Gero’s (2000) observation that human ‘designing is situated’ because the activity is different, in different times and situations - even for the same designer. The definition also aligns with Sargent’s description of people designing:

‘People have intuitive feelings that a set of ideas have some relationship, then a new way of looking at the problem (a new space) yields an ‘Aha!’’

The new definition contrasts, however, with other work in the same paper where Sargent focuses on ‘the generation and evaluation of new design spaces’ and implies that if a new design space is identified then ‘designing’ must have occurred. The contrast is between a definition of designing as a human activity and ‘designing’ as an inferred prerequisite for any*thing* new. The latter implies that if an automatic process can produce new things then this process must be ‘designing’. In terms of building coherent and differentiated concepts and theory this is problematic. Countless activities, many of them with no purpose to produce designs, result in new things, for example, a few repetitions of coin tossing is likely to result in different sequences of heads and tails. There is already useful terminology and concepts to describe most of these activities.

Similar contradictions are evident in regard to definitions of ‘design process’. The version proposed here aligns with Sargent's (n.d.) thesis that ‘individual ‘creative actions’ appear to be separately amenable, in principle, to automation’, but conflicts with Sargent's later analyses in which he continues to refer to the now automated processes as ‘design’.

To conclude, the definition of ‘designing’, proposed in this paper refers only to non-routine human internal creative process, a human internal cognito-affective activity. From the perspectives of this paper, the phrases ‘human creative design cognition’ and ‘designing’ are essentially identical. The proposed definitions imply that phrases such as ‘automated designing’ and ‘routine designing’ are perhaps better replaced by phrases that reflect other forms of practice. This confusion between designing and other forms of practice is evident where for example; definitions of concepts do not differentiate designing form engineering. One of the core purposes of the field of Engineering is to derive methods that deterministically and accurately identify the technical specification of solutions from problem definitions. Confusion between designing and engineering occurs when designing is loosely defined as ‘identifying solutions that satisfy problem criteria’. Where this is done, the activity of designing (including fashion design, graphics, music designing, social systems designing etc) is defined as epistemologically identical to engineering, and by implication one of them is a redundant and unnecessary concept.

The proposed definition above differentiates designing from engineering and other forms of practice through defining designing in terms of human activities that result in the identification of solutions where there is no routine deterministic method to generate solution specifications from problem definitions. This defines the activity of designing independently of other, more routine, activities or forms of practice.

To summarise, the proposed definition contains most of the factors with which designers accord. It reflects much of the literature, and retains both designing and engineering as concepts. But, this differentiation then implies that once a means has been found to identify, automate or computerise a particular relationship between a set of problem definitions and solution specifications, then it is epistemologically and terminologically more sensible to no longer regard (or define) such an automated or routine process as 'designing'.

3. Affect, Feelings, Emotions and Designing

The second part of this paper focuses on the roles of somatic and affective aspects of human creative design cognition for building improved computational and cognitive models. The importance of human somato-sensory processes in designing is indicated by recent neurological studies, and through the identification of *closure* processes as key elements in design-related cognition.

Exploring the somatic aspects of human thinking and mind processes requires a more precise definition of 'cognition' that separates out the different human processes necessary to explain human thinking, mentation, designing, reflection and creative activity. This paper follows the example of Harpaz (1994) and using the term 'cognition' to refer to *brain-based* processing of conceptual information, excluding somatic consequences or reflective bodily perceptions.

The physiologically-based, somato-sensory processes and affects associated with cognition are important in modelling human internal processes of designing because not including them potentially results in an insufficiency in computational theories and models. Human trauma research relating to damage to the prefrontal cortex implies such potential weaknesses in computational modeling of creative design cognition. The pre-frontal cortex is significant because it is associated with cognitive control, the use of prior experience and goal setting behaviours – all essential aspects of cognition and designing. Neurologically, the pre-frontal cortex is significant because it consists of 'an inter connected set of neocortical areas that have a unique, but overlapping pattern of connectivity with virtually all sensory neocortical and motor systems' and is also indirectly connect to the 'reward' processes in the limbic parts of the brain (Miller, 2000). In cybernetic terms, the prefrontal cortex has a key location in brain processes associated with designing.

Miller (2000) describes patients with pre-frontal cortex damage as apparently normal but fundamentally dysfunctional. Miller reports that 'humans with prefrontal damage can seem strikingly normal upon superficial examination. They can carry on a conversation, often have normal IQ scores and can perform familiar routines without difficulty'. In essence, it appears that individuals with prefrontal damage are normal. Miller continues, however, that 'their ability to organise their lives is profoundly impaired', that a serious consequence (of damage to this part of the brain) is that subject's behaviours are 'stimulus-bound' based on ' cues that reflectively elicit strong associated actions'.

If brain areas associated with the affective aspects of cognition are damaged then the result is usually the appearance of dysfunctions such as schizophrenia, behavioural problems, or manic-depressive disorders. It might be expected that equivalent computational malaises might ensue from a similar cybernetic shortfall where computational models of cognition do not appropriately include equivalent 'affective' processes. Miller's description of compromised human functioning in the above paragraph reads like some descriptions of developments in the fields of AI and computationally based models of designing. This suggests that models (computational, creative, cognitive or otherwise) of human designing are likely to benefit from a broader picture of human psycho-neuro-physiological functioning. It also implies that many aspects of computational and cognitive models of designing may be more easily conceptualized and addressed if account is taken of the reality that humans manage their thought processes, decision-making, precognitive processes, and actions with close reference to physiologically based somato-sensory states and processes.

The existence of significant roles for physiologically-based somato-sensory processes in human cognition is widely supported by the neurological literature; for example, by Kiehl, Liddle & Hopfinger (2000) on the functions of the anterior cingulate cortex, Badgaiyan (2000) on executive control and nonconscious processing, and Miller (2000) on the role of the pre-frontal cortex in the cognitive control that allows humans to override reflexive reactions to organize behaviour to achieve distant or time removed goals. A significant support for the argument that human thinking involves all of the body not just brain-based informatic cognition is the way that prefrontal cortex, the area of the brain central to gathering experience for use in later circumstances, is comprehensively linked with sensory neocortical and *motor* systems in both top down and bottom up arrangements (Miller, 2000). Reilly (1997) concluded that processes from the *sensory motor-domain* form the neurological foundations for computation in higher-level human cognition and creative cognition. In terms of action, Reilly argues that the perception-action process requires reflexivity between *sensory* and *motor* regions in the cortex, and that thinking about an object or situation causes much of the same cortical affects as actual perception of the same. He predicts that cognitive computation in the cortex will *usually* involve the sensory motor regions.

Some brain processes act as references and moderators of more primary data driven processes (Miller, 2000, Kiehl et al., 2000). For example, there is evidence that some areas of the brain have comparative functions. An error signal is created resulting in a somatic response (error-related negativity) in an individual if there is a dissonance between ‘what is happening’ and an internally held model of ‘what should be happening’. A day-to-day example of this phenomenon is the conflict between eye perception and balance perception that results in the body sensation and associated physiological reactions of seasickness. The areas of the brain in which comparative functions have been identified are areas centred on the anterior cingulate cortex, and the left lateral frontal cortex. These areas are also closely associated with physiologically based responses that form part of the affective/ emotional/ feeling contexts of an individual’s actions.

These findings from brain research suggest that particular cognitive activities are represented in multiple simultaneous ways in the brain with consistency and comparative processes checking between the representations for similarity and differences (Miller, 2000, Kiehl et al., 2000). In essence, what is appearing from the neurological data is a dynamic model for multiple representations of aspects of a situation to be compared and contrasted and similarities identified, with the state of the comparison checking processes being represented at several levels of granularity:

- Fine/ complex – Physiologically-based somato-sensory changes associated with cognition
- Medium/less complex – emotions and moods
- Coarse/binary - feeling better/worse.

Physiologically-based somato-sensory aspects of human thinking are particularly relevant in building computational models of creative design cognition because of their roles in the *closure* of cognitive activities. Closure is a human *activity* or *process* that has been relatively neglected in modelling cognition. Rosen (1980) has shown that closure processes are often faultily described in terms of object attributes (a category confusion between activity and property). For example, discourse about whether a human is correct to say that 5 is the correct answer to 2+3 usually focuses on the properties of the numbers 2,3 and 5, and implicitly the closure process is assumed to follow the same path. The human closure process, however, involves the internal activities that lead to an individual feeling confidence or otherwise that the answer (5) is correct. This difference between the correctness of relationships between object properties, and the closure activities by which an individual identifies correctness becomes more evident when observing how humans address harder problems such as:

- Manipulating large mathematical equations
- Rearranging large databases
- Spelling difficult words that one almost recognises
- Packing for a holiday

In each of these cases, the problem can reach a level of complexity that can exceed what can be simply held in memory and the individual has to ask himself or herself whether they are confident that the processes have been undertaken. At a certain point, closure happens where the individual's internal state moves from them feeling that 'the process is not complete and fully checked' to feeling that it is and that they can proceed.

The importance of closure in theory building about cognition, however, extends beyond success with equations and holiday preparations. What has been described above is an individual's conscious perception of gross closure processes. At a more subtle level, closure is involved, usually subconsciously, in the stopping, starting, continuation or redirection of any human internal or external process. For example, the particular connections of axons in a developing baby's brain involve closure processes shaped by a wide variety of environmental and intrinsic forces. All human growth and development activities, including cognition, are dependent on closure processes.

In the case of cognition, and especially creative design cognition, physiologically based somato-sensory issues are important because closure in cognition depends on them. In this sense, they are 'where the buck stops' in asking about a cognitive activity. For example, 'The designer chose this solution'…'Why?'… 'Because their internal representation shows the solution satisfied the problem'…'How did it do that?' … 'For these neurological reasons'… 'How did the designer decide that their analysis was correct?' …More explanation . . . 'So what process led them to decide that this amount of designing was sufficient and that they should stop?'… *Closure*.

A description of closure processes is implicit in Rosen's (1980) conclusion that all forms of analysis depend on 'intuition' processes that are functionally independent of an individual's logic (see, also, Walton, 1996). Closure is a core part of primary cognitive processes such as those that underpin the 'human information coordinating behaviour' that Spink (2000) identified as an important element of human information management (as in designing). All these factors point to the human activity of designing being run through with closure-based activities.

When people consciously perceive these closure processes they often describe them in terms of 'feeling' (Bastick, 1982). It is important to include these 'feeling states' into any model of cognition because without them it is difficult or impossible to satisfactorily model all those processes that depend on closure, especially the ways that humans choose, shape and optimize solutions (Badgaiyan, 2000, Kiehl et al., 2000). Simplified descriptions of relationships between physiologically based feeling states; closure and optimization are described in Love (2000a)

In building theoretical models, closure at first glance appears to be almost impossible to model and implausible as a function because it is recursive. It appears that a process requiring closure requires a closure process that requires closure that requires a second closure process ad infinitem. A reality check indicates that closure processes do exist: humans and their activities stop and start. Closure only appears to be reflexive and epistemologically problematic when viewed as an abstract function operating on abstractions (theories, concepts, information and other theoretical representations). Closure processes are not epistemologically problematic because they are physiological phenomena (although they may well be technically difficult to represent). The models below of Bastick, Harpaz, Davis and Love approach this technical difficulty in different ways. Interestingly, they come to structurally similar representations.

Bastick (1982) derived a physiological/cognitive axiomatic model that gives feedback of somato-sensory tone as the basis for closure. In simple terms, he extended the idea that individuals choose to do what they *feel* pleasantly about and vice versa. At its most essential, Bastick's axiomatic model of intuition and action implies at least three physiologically based affective processes necessary for human cognition:

- A cognitive representation of whatever is the subject of interest for an individual. (In visual terms, 'the picture in the mind's eye'.)
- The mapping of that situation onto the physiologically based somato-sensory structure of the individual. A pattern of physiological changes happen in the individual's body that reflect conscious and subconscious content.

- A reflexive process that relates the above two together so that the cognitive representation elicits physiological changes (some of which are perceived as feelings or emotions), and physiological states cue or prime cognitive representations.

Harpaz (1994) offered an alternative neurological/cognitive model of brain functioning based on the known physical and neurological properties of different forms of neurons and pyramid cells along with the numbers and proportions of different types of neurological elements in human brains. Rather than assuming functional specialisms of brain areas, Harpaz developed a model that explains how a large number of brain functions can be actualised by the different properties of neurons with specialized areas emerging as a natural development of these general-purpose neural functions. Many of Harpaz' hypotheses are supported by Farah's (1994) critique of the locality assumption underlying theories about brain function. Harpaz' model uses the slowdown in episodic recall activity as a closure mechanism. The model offers a neurological basis for some aspects of Bastick's theories, in spite of it being constructed independently of sensory influences.

Davis (2001) cognitively modeled cognition using a computational primitive emotional system as the basis for autonomous 'cellular automata'. In his model, closure is not addressed directly, the automata's actions are driven by rule-based weightings which use parallel computational mechanisms created to represent 'emotions' to provide additional forms of feedback and feed forward on the weightings that influence behaviour. These parallel 'emotional' systems, however, are what provide almost all of the direction and stability to enable the automata's complex behaviours.

Love (2000a) outlined simple models of design process with closure based on simple Bastickian feedback how human affective somato-sensory processes contribute to designing, decision-making, optimization of solutions, the generation of new ideas, and the identification of preferred directions of search.

All of the above illustrate ways that body sensations, or representations of them, provide singular measures for closure, 'scalar aggregate metrics', in situations such as designing that involve many complex variables as a basis for action (Love, 2000a, Sargent, n.d.). These models also help resolve a key issue in modelling 'creative design cognition': how an open-ended process of creativity can emerge from a deterministic computational model of designing that is essentially closed. The somatic aspects of these models of designing enable a resolution of this problem by opening up the possibilities for new designs to be created based on the 'history' or unique pattern of episodic knowledge of the individual as represented in the histories of their somatic sensory states. This is not a completely open-ended process, but it is potentially more effective than models based on purely conceptual representations because it produces maximal possibilities of new designs within the limitations of the physical context (Sargent, n.d., Reilly, 1997).

Finally, this alternative perspective on affect in design cognition points to a linguistic shift of emphasis. In a phrase such as 'The designer uses the vague (intuitive) knowledge to identify where new designs or precise tools should be developed' (Sargent, n.d.), it moves the emphasis of the roles of affect onto 'uses', 'identify', 'should' and 'developed', and away from 'intuitive knowledge'.

4. Discourse of Affect: A Terminology

The term *affect* has been used in this paper in a broad manner that includes individuals' conscious or subconscious perception of their bodily sensations that interrelate with cognitive processes (and the various forms in which these are represented). From this perspective, an individual's 'feelings' are an individual's conscious perceptions of locally-specific physiological states involved in cognitive processes, and 'emotions' are public conceptual constructs of common schema of 'feelings' or 'affects'.

Building theoretical models of designing that include affect, especially those involving computational representations, is more complex than it first appears because affect and feelings are represented in many different ways. Each of these ways that affects, feelings, or cognition related somato-sensory physiological processes are represented may be functionally, theoretically, or physically different. The analyses in previous sections point to the importance of differentiating between these epistemologically and sometimes physically different elements in discourse about affects. Different aspects of affect include:

- The *perceptions* of others of affect-related *physiological changes* in an individual.
- *Emotions* as public *concepts* that describe *physiological changes* in an individual
- *Emotions* as public *concepts* that describe *relationships between other concepts* associated with bodily changes or perceptions (e.g. 'a sense of maturity')
- *Emotions* as an individual's *subjective conceptualisation* of his or her *own internally perceived states.* (E.g. 'I feel contented' as distinct from 'They appear to be contented').

- *Emotions* as *disturbances* of cognition.
- An individual's *perception* of his or her own physiological states *before conceptualising or categorising them.*
- The *physiological changes* outside the brain associated with cognitive, conatory and other human functions that may or may not be consciously perceived by an individual.
- The physiological states (as states) that an individual perceives and classifies in terms of publicly defined concepts of emotions.
- Physiological states of an individual as objectified or measured by others.
- Representations of any of the above in mentation, theory, or in forms suitable for computational manipulation.

In the literature, these conceptually different aspects of affect are frequently conflated. Theoretical discourse involving affects is easily confused. On one hand, there is poor differentiation between different representations of affect. On the other, is a high level of differentiation between and emotional states such as love, fear, loathing, peace etc. One approach to differentiating the different forms of affect that the author has found useful is to label them:

Labels	Types of affect
F affects	Affects described in terms of *feelings*
E affects	Affects based on *emotions*
P affects	Affects described purely in *Physiological terms*
N affect	The *neurological transmission* mechanisms of affect of
B Affect	Affects described in terms of brain states and processes
C Affects	Affects represented on computer or by computational means
A Affects	Affects *created* by perception of *artefacts*
S affects	The total *system* of affects within an organism, theory, system or computer
R affects	Affects being having an intermediary *representation*
M affects	*Measurements* that are related directly to affects
T affects	*Theoretical* representations of affects
Etc.	

Combining prefixes can be used to usefully extend this prefix model. For example, 'MPFC affects' refer to 'measured physiological aspects of feelings stored in computerized form', and 'CRSE affect' is a 'computational representation of a system of affects defined in terms of emotions'.

5. Conclusions

This paper proposes a change in direction for modelling creative design cognition computationally and cognitively. The proposals that are described have been developed to address weaknesses in regard to epistemological and conceptual coherency, and the lack of attention to the roles of somato-sensory processes in cognition and closure: both key factors in modelling human designing and cognition. The paper first proposes definitions of core concepts in relation to theories of designing and designs that emphasise conceptual differentiation and improving epistemological coherency and validity with respect to other areas of knowledge. The paper outlines reasons for redirecting attention onto the physiologically based somato-sensory aspects of cognition.

To recap, the main points made in this paper are:

1. That affects are an important part of cognition and that an adequate model of human cognition - creative or not - cannot be made without reference to affect.
2. This paper distinguishes between different sorts of affects particularly between affects directly grounded in physiological feelings and affects defined in terms of ‘emotions' as public concepts for objectively perceived states.
3. The paper draws attention to the different roles of closure in processes of cognition and designing, and ways that closure depends on affects and cognito-affective states.
4. The paper moves the focus of creative cognition away from being solely a brain-based activity defined in terms of logical relationships between characteristics of external objects and towards the idea of cognition implicating many parts of an individual's body. This change of focus is in line with recent neurological findings and analyses and theories relating to preconscious 'intuitive' or insight processes.
5. The paper draws attention to the essentially parallel nature of cognito-affective thinking.

The implications of these proposals for building computational models of creative design cognition are a change of focus to whole body models of thinking, designing and decision-making. In terms of the relationship between design research and cognition research, this suggests an increased emphasis on the coordinatory roles of brain functions and neurological systems that relate reflexive somato-sensory and motor aspects of designing with memory-based information processing, and a move away from the dominant focus on information attributes and content of problems, solutions and informatic or brain-based models of information processing.

6. Acknowledgements

Research for this paper was funded by Edith Cowan University through the Schools of Management Information Systems and Justice and Business Law.

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