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A New look at Design Thinking: Research in Progress

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Social Significance Of Design And Designers

Substantial funding over several years has been attracted from multiple sources for both basic and applied elements of this programme of research into design thinking, as a result of recognition that design is an essential ingredient of civilisation, providing orderly satisfaction of human needs, at all levels from the individual to societal, and in the senses of utility (utensils, artefacts), comfort and security (built environment, infrastructure), and the abstract sense of worthiness (aesthetics, achievement, fashion). "Design", here, refers to the creative unification of multiple functional and aesthetic solutions into a single comprehensive satisfaction of a need (Ostwald, 1994).

Design, in the context of this research, encompasses much more than the mathematical or algorithmic solution to engineering problems. It is intricately connected to social, cultural and political factors (De Jong, 1992; Michialino, 2005). Design in a progressive culture must contribute to the advancement of society not only at a utilitarian level satisfying new needs as they arise (reactively), but also at the higher level of anticipating new needs and satisfying them before they arise (proactively, pre-emptively) (Cowdroy and DeGraaff, 2005). At the highest level, "inspired design" not only anticipates and satisfies new needs, but also achieves a break-through to a new way of thinking about design in that field. That is, "inspired design" refers to pre-emptive design at the highest level of creative "finesse" that anticipates needs and transcends multiple conflicting parameters to produce new design precedents (Crick & Cowdroy, 1998; Cowdroy & DeGraaff, 2005).

Designers achieving this inspired level of design are recognised by society as elite designers through prestigious awards, exhibitions and publications. However, their exceptional ability to design at this level is *not understood*, and there are no educational structures that can provide for the expansion of the ranks of this elite group that is required to meet the needs of accelerating development of society (Ostwald, 1994; Crick & Cowdroy, 1998; Cowdroy & DeGraaff, 2005).

Theoretical Framework Of The Research Programme

The research programme addresses the problem of loss of intellectual content in design, particularly in team design and computer aided design environments, by developing a new understanding of the intellectual processes at key levels of creativity in design, at key stages in design development, and in three key design environments. At a more general but no less important level, the research addresses the problem of confusion about how creative thinking works (Eckert et al, 2004) by studying the thinking processes of elite designers *at work* in their working environments.

This research is nationally and internationally innovative in several respects: no comparable previous empirical studies on this scale are evident from the literature. The project moves away from current world-wide preoccupations with reductivist theoretical approaches to design processes such as computer-aided design (CAD) and artificial intelligence (AI) that presuppose design processes to be sequential and rational (Broadbent and Cross, 2002) and discount multi-lateral and emotional/intuitive design thinking. This research also moves away from world-wide philosophical debate about thinking (Deleuzian, Kantian, etc) and from neuroscience's "multi-locating" of various thinking (dys)functions in the brain, and from associations between creativity and dysfunction (autism, Asperger's syndrome, brain damage, etc) (Domasio, 1995; Fitzgerald, 2005). Instead, this research returns to a composite empirical approach to the (normal, healthy) human intellectual process of design at its highest level, using empirical methods from the social and behavioural sciences that have only recently been adapted to the purpose of design research.

This re-focus is based on a conviction that the rhetoric and dialectic of computer sciences, neurosciences, psychiatry and philosophy of thought show little sign of converging towards a shared understanding of the creative processes of the mind, including design, particularly at their highest levels (Grabowski et al 1998). Very little empirical research addressing creative individuals and their normal, healthy mental processes has been undertaken, particularly at the elite level on this scale.

This research introduces established methods from other research areas into new applications in design research. Use of cross-cultural and cross-validation methods for studies of individual designers in this programme are widely used in psychology and psychiatry, but are highly innovative in the present context. Similarly, use of interaction and discourse analysis methods for studies of groups and teams of designers in this programme are widely used in sociology and social anthropology, but are also innovative in the context of studies of design processes. Also, use of digital video recording, sampling and mixing techniques and of Noldus analysis system in conjunction with interaction and discourse analysis in team design studies are technically highly innovative in this context.

This research programme therefore breaks new ground and promises to provide a basis for a new dialectic that tests the validity of philosophical and reductivist models of design processes. The research programme also promises to provide a methodological basis for more general modelling of high-level creative processes.

The research programme recognises that individual designers characteristically work in one or more of three dominant design environments (after Lawson,1997):

- alone, autonomously,
- in multidisciplinary teams, and
- as "partners" with computers in computer-aided design (CAD) interfaces.

Pilot studies underpinning the present research within the programme indicate that distinctly differing thinking processes are associated with these three design environments but the propensity of each environment for sustaining high quality complex design is poorly understood (Cowdroy & Williams, 2004). This suggests that there is an *urgent and critical* need to understand how elite designers achieve their "prognostic" approach to design that anticipates future complex needs and provides comprehensive complex solutions.

An initial focus of the programme has been on empirical studies of design thinking of "elite" or "inspired" designers working autonomously. Research within the programme has since moved on to studies of designers in team design and CAD-interface environments.

This research programme is expected to provide the conceptual "break-through" that design researchers seek by developing models of thinking in each of the three creative environments and at different stages in the design process (conceptualisation, schematisation, actualisation). It is anticipated that this research will show that thinking processes differ significantly from one stage to another and from one design environment to another, but that the respective thinking processes at each of these levels and stages, and in each of these environments, are consistent among designers regardless of design discipline.

Precedent Research In Design

Design is traditionally associated with creativity — a higher-order intellectual activity that is essentially human and cerebral (Rowe, 1987; Lawson, 1997). However, Modernist rational approaches to design have emphasised a linear process extrapolating from diagnostic analysis of a need (Pasveer, 1992; Grabowski et al, 1998), thereby relegating design to the lower levels of creativity and lower-order intellectual achievement. Developments in computer technology and artificial intelligence (AI), in attempting to imitate creative thinking, have instead further reduced the innovative and original aspects of design to a series of binary choices (Kurzweil 1990; Ostwald 1994; Crick & Cowdroy, 1998). Developments to date in AI have not reached beyond a model of relatively rudimentary *diagnostic* design processes (Grabowski, 1998; Anderson *et al,* 2003) and are still far from reaching a model of complex *prognosis* that is characteristic of elite designers (Crick and Cowdroy, 1998; Cowdroy & DeGraaff, 2005).

Rapid growth in computer-aided design (CAD) has also displaced traditional processes of design development, including (manual) graphic communication and reflection, by a menu of parts to be assembled (Vandenburgh, 2003). Furthermore, 3D computer graphics has displaced traditional 3D manual prototype modelling by a 2D "look-alike" graphic simulation of prototype modelling that all but eliminates the intellectual development at the heart of high quality design (Broadbent and Cross 2002; Ostwald 2004).

Research into team design is a relatively new field, presently focused on understanding the social and psychological interactions that contribute to complex technical design (Fischer, 2000; Cowdroy and Williams, 2004). At this stage, however, it is clearly evident that team design, particularly multidisciplinary team design, contradicts conventional linear process models and notions of designers as autonomous individuals (Williams. 2005).

Precedent Research In Related Fields

It is widely accepted that thinking involves one or more of three memory systems (Eichenbaum, 2002, Fitzgerald, 2005):

- emotional memory is unconsciously expressed attribution of new meanings to past experience or knowledge;
- declarative memory is conscious recollection of facts and events that can be applied and expressed in ways beyond the limits of original experience or learning;
- procedural memory is a learning ability to adapt networks of brain systems that support skilled performance.

It is also accepted, however, that there is no "fine line" separation between them; that all three memory systems may be engaged in parallel and to some extent interconnectedly; and that some switching from one to another occurs. The switching is associated with environmental stress states that open or close access to one or more of the memory systems (Cowdroy, 1992). More recently it has been accepted that some forms of thinking continue during sleep (unconscious/unaware thinking) and that sleep is able to be switched on and off (Fitzgerald, 2005; Hobson, 2005; Saper et al, 2005).

Theoretical studies underpinning the present research programme have identified three dominant types (or levels) of creativity relevant to the present project (Bergquist 2001; Cowdroy and DeGraaff, 2005):

- Conceptualisation (including inspiration as a special case) which is essentially cerebral, involving generation of ideas at the highest level of creativity, and is directly related to emotional memory;
- Schematisation which is development and testing of ideas against established theories, at an intermediate level of creativity and is closely related to declarative memory;
- Actualisation which is production of a creative "work" or object and at the lowest level of creativity (although often at the highest level of crafting skills) and is related to both declarative and procedural memory.

Empirical pilot studies into unconscious decision-making (Cowdroy 1992) and the psychological processes of inspiration (Crick and Cowdroy, 1998), forming initial stages of the present programme, have found that:

- conceptualisation (and particularly inspiration) is episodic, of very short duration (< 5 seconds) and occurs in particular sleep states (including day-dreaming);
- the on-set of conceptualisation (and the respective sleep state) depends on the psychological environment of (within) the person;

- the psychological environment of the person is controlled by a particular mix of stressors acting as a gate-keeping mechanism closely aligned with the switching referred to above;
- the gate-keeping mechanism (and therefore also creative block) can be controlled, consciously or unconsciously, by the individual;
- episodes of high-level creative thinking including inspiration, and (importantly for the present project) the psychological environment at the time, can be recalled with high levels of clarity through use of cross-cultural interview techniques combined with memory enhancement techniques;
- episodes of inability to think creatively at a high level, and (also importantly for the present project) the psychological environment at the time, can also be recalled with high levels of clarity through combined use of cross-cultural interview and memory enhancement techniques, allowing creative block mechanisms and the particular mix of stressors to be identified for each individual, and for "un-blocking" strategies to be developed.

The interview processes used in these initial studies therefore allowed identification of the psychological environment of the individual at the time of high level creative thinking and also at the time of inability to think creatively, allowing identification of the stressors in each case, and the gate-keeping and control mechanisms. When results of these initial studies of creativity are compared with literature emerging from research in the wider field of neurosciences world-wide, high levels of alignment are indicated.

Theoretical studies in the present programme also suggest that the gate-keeping mechanisms referred to above, when "closed" and causing creative block at the highest level (conceptualisation), may nevertheless allow creative thinking at a lower level (schematisation or actualisation), and that individuals with high-level creative ability may gravitate to lower levels of creative thinking as a result of long-term adverse stress conditions.

Methodological Approach

The aim of the present research programme is to obtain a comparative picture of individual subjects' thinking processes in differing design activity environments, from which overall models of the thinking process in each respective environment can be obtained. For the purpose of the present stage of the programme, and to address an area of immediate social, economic and political importance, the present research focus is on design fields most closely associated with home environments (the neighbourhood, the home, "homewares" and associated cultural events and rituals). Designers in these fields include architects, engineers, industrial designers, and designers of creative cultural activities (particularly media and cultural events that reinforce a sense of belonging or identity).

The research at this stage is focusing on elite designers identified by:

- a pattern of national or international awards for design excellence;
- a pattern of exhibition or publication

Samples of between fifteen and twenty designers from each of the four categories (Architects, Engineers Industrial designers and Cultural designers) provide a total sample of between 60 and 80 subjects, each of whom will have been studied in one or two distinct design activity environments. These sample sizes are

statistically adequate for present purposes at both the design field and total sample level. Results from both total sample (designers generally) and separate design field samples are of interest, in view of the expected alignment of thinking processes across all fields. The subject mix is moderated to ensure that diversity (gender, age and culture) is achieved and bias avoided.

It is expected that significant differences in thinking processes for each individual in differing design environments will be found, and that differing levels of creativity will be associated with the three environments. This will provide a unique comparison of the relative quality of design to be expected from each environment, and a highly valuable comparison of propensities of individual designers to achieve excellence (as defined through professional recognition, exhibition and publication of design) in one or another design environment.

The Cross-Disciplinary Approach

Three previously distinct fields of research at doctoral and post-doctoral level are drawn together by this programme:

1. empirical studies of the (individual) psychological processes of inspired creativity (Crick & Cowdroy 1998; Cowdroy & Degraaff, 2005) using research methods "imported" from psychology and psychiatry as doctoral and post-doctoral research in the psychological processes of unconscious thinking and decision-making, including particularly the psychological processes of inspiration and creative block;
2. empirical studies of the sociological processes in team design (Cowdroy and Williams; 2004, Williams, 2005) using research methods "imported" from social anthropology through doctoral and post-doctoral research into the communication and sharing of ideas across design teams;
3. theoretical studies of human-machine interaction in virtual and real design environments (Ostwald, 2004).

Previously isolated methodological approaches, also, are drawn together by this programme, as follows:

- Cross-cultural and cross-validation methods from clinical psychology and psychiatry developed for the Inspiration and Creative Block studies in (1) above, are used to track the thinking processes of individuals working alone; of individuals working within a team design process; and of individual human partners in human-machine interactive design processes;
- Interaction and discourse analysis from social anthropology developed for the team design studies in (2) above, are used to track the flow/sharing of ideas from individual designers to other designers and clients, etc, between participants in multidisciplinary design team members, and to track the feedback loops and progression of ideas in individuals in teams;
- Logistical and conceptual analysis from the field of artificial intelligence (AI) and robotics in (3) above, are used to track the progression and development of ideas from individuals to computer-aided design (CAD) environments and back again.

Each of these three methods addresses human design-thinking processes from a distinct perspective. Each method is also robust in terms of scientific validity and reliability, however each has its limitations and careful consideration has been given to avoiding over-use of one method that has been successful for one purpose but is not the most appropriate for another purpose. For instance, the cross-cultural/cross-validation method has been most successful in obtaining highly detailed data on the thinking processes of individual designers including unconscious thinking (with the addition of memory enhancement techniques) and gate-keeping (creative-block) mechanisms and their causes, however this method requires one-to-one interviews using highly trained interviewers, and is therefore labour intensive and relatively expensive and is therefore reserved for studies involving relatively small numbers (eg, 15-25) individuals. This method is also necessarily post-hoc (after the event) and cannot look at individual design processes as they are happening. Nevertheless, this method allows very high-quality and reliable data from relatively small numbers of subjects, and so is very effective and cost effective for this purpose.

For group interaction studies and for human-computer interaction studies, a less intensive and more automated observation method of interaction and discourse analysis has been the most effective and cost-effective. This involves use of digital video and audio surveillance of the whole environment and activities occurring within that environment. Analysis of the activities is undertaken later by observation and coding of the activities, discussion, body language and other non-verbal communication (eg, sketching, reading a diagram) as they occurred together. This method provides excellent data on multiple simultaneous activities and combinations of activities, but provides little data on the individual thinking behind those activities.

The cross-cultural/cross validation method and the interaction and discourse analysis method *in combination*, however, provide a very comprehensive view of both the individual thinking processes and the behavioural processes that constitute the whole complex design process at various stages in both individual and group design environments. Similarly, the combination of these two methods and logistical and conceptual analysis from the field of artificial intelligence and robotics provides a comprehensive view of the whole complex interactive design process where both human and artificial intelligences are interacting. Confidence in these mixes of methodological approaches stems from careful development of each method and successful precedent and pilot studies in which each method has been thoroughly tested.

The Present Stage Of The Programme

The present stage of the programme is being undertaken as a series of overlapping environmental studies: *Study A* involves designers as individuals; *Study B* involves designers as individual members of teams; and *Study C* involves designers as partners in human-machine interactive environments. The research is using cross-cultural/cross-validation methods to identify the psychological environment, gate-keeping mechanisms, and thinking/memory processes in individuals at particular stages in the design process, in each of the three design environments. Discourse analysis is used in team design situations and in human-machine partnerships, to identify progression of ideas in each interactive environment.

Field studies of individual designers at work are being undertaken primarily in Sydney and Melbourne, where appropriate concentrations of award-winning designers in the relevant fields are found, and as follows:

- Study A, of individuals working independently uses cross-cultural interview methods and memory enhancement techniques, structured on prepared questionnaires. These are *post-hoc* interviews of recent design activity. Pilot studies have found that unconscious thinking plays a central role at high levels of creative thinking, and can only be "captured" by means of post-hoc interviews, including memory enhancement techniques. All participating designers are engaged in two contiguous interviews: the first to identify the "jargon", degree of enculturation and work context of the subject; the second to explore the history of a particular design project that exemplifies the subject's *modus operandi*. Each interview is essentially verbal but is video and sound recorded for later analysis of non-verbal communication and content analysis. Data is translated into Noldus software for analysis and cross-study comparisons.
- Study B, of individuals in design team environments, tracks both individual subjects and the whole team participating in team design environments. Real-time digital video and sound recording of meetings are made using multiple cameras and boundary microphones, mixed and exported post-hoc into a laptop for subsequent analysis. Precedent studies have addressed the team as a whole, and progression towards sharing of ideas by the team. The present study addresses the contribution of individuals and shifts in their expectations and achievements as indicated by their verbal and non-verbal communication. The project tracks one design team in each design field in each city. At least five recording sessions of each team (over a period of up to six months) are required to track changes in individual positions as the design develops progressively through successive stages of development of a design (ie, four teams and a total of twenty recording sessions in each city). Digitised data is encoded and translated into Noldus software for analysis and cross-study comparisons.
- Study C, of individuals in human-machine interaction, addresses the particular question of whether individual designers working with machines (CAD, robotics, etc) are in control, in partnership or subservient with respect to the intellectual creative process. These studies use both *in-loco* (real time) recording and post-hoc interviews of designers working in human-machine interface environments. At least five recording and interview sessions are required to adequately model the individual participant's working relationship with the respective machine. Digitised data is encoded and translated into Noldus software for analysis and cross-study comparisons.

Some individual participants in Study A also habitually work in teams and therefore also participate in Study B. Other participants in Study A are also computer oriented and therefore also participate in Study C. Similarly, some participants in Study B also participate in Study C and vice-versa. This multi-participation allows comparisons of individual performances in differing design environments and in relation to other individuals in each environment. The purpose of this multi-participation is to consider the (expected) differing propensities of individuals for particular environments. Multiple participation is restricted, however, to ensure a minimum of fifteen (for statistical consistency) individuals in each Part of the study who habitually work in only one design environment. While the use of the three methods in conjunction is highly innovative, the

researchers are confident that they will provide the multiple perspectives of designers at work necessary to achieve a full picture of the thinking processes in the key environments in which designers work.

Expected Results

The combination of these three fields of research and their respective methods is expected to present far more comprehensive and realistic models of high-level design processes than previously achievable, and to make significant definitive contributions to debate about the nature of highly creative thinking; about the role and importance of creative thinking in various fields of design; and about the role and importance of human thinking in CAD design environments.

In particular, research outcomes from the programme are expected to show that high-level creative thinking underlies the sustained achievement of excellence in all fields of design, regardless of the relative creativity or pragmatic nature of the field and its products. That is, it is expected to show that high-level creative thinking (multilateral, conceptualisation) underlies sustained excellence in generating multiple complex design proposals in architectural design, engineering design, industrial design and cultural design and, by implication, across a broad spectrum of comparable design fields.

This research is also expected to show that distinct thinking processes are associated with particular "levels" and stages of creativity (conceptualisation, schematisation, actualisation), and that each distinct thinking process is engaged by designers (at the respective level or stage) regardless of the design field or discipline of operation. That is, it is expected to show that architects, engineers, industrial designers and cultural designers (among others) engage similar thinking processes at comparable levels of creativity and at comparable design stages of their work.

The more comprehensive models of design thinking processes derived from this programme will provide a basis for more critical evaluation of designers and design outcomes (Crick & Cowdroy, 1998); more effective approaches to management of design processes in industry (Williams, 2005); and more effective means of assessment of design processes and therefore more effective and cost effective approaches to design education (Cowdroy and DeGraaff, 2005).

The products of this research programme are expected to make a significant contribution to reform in design education, challenging stereotypes of designers used as the basis for design curriculum, for example characterisation of architects as "pencil-oriented" creative thinkers who design by sketching, and characterisation of engineers as computer oriented logical thinkers who design by calculating (Jenkins and Martin, 1993). The models developed in this research will provide a more secure basis for curriculum development that will directly address the particular thinking processes that need to be developed in individual design graduates, and especially those needed to support an elite community of designers that can meet society's needs for pre-emptive design.

Expected by-products of these outcomes will be, first, a challenge to current emphasis of neuroscience on associations between high-level creative thinking and mental dysfunction such as Autism and Asperger's syndrome, etc (Eichenbaum, 2002; Fitzgerald, 2005) and, second, connections to contemporary philosophical debate on Deleuzian thinking (conceptualisation, actualisation, etc) and the roles of emotions and memories in "rational" design processes (eg, after Domasio).

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