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INFORMATION AS AN INPUT INTO THE CREATIVE PROCESS

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1. Introduction

Creativity is an integral and essential part of the engineering design process. One of the under researched areas associated with creativity is the role that information plays in enhancing or even inhibiting creative design activities.
This paper gives an overview of the literature on creativity as it relates to information and knowledge use in design and innovation processes. The overall aim of the research associated with this paper is to better understand the **effects of the inputs into a creative process** rather than more common research that focuses solely on the outputs from creative processes. The paper presents: a definition of creative ideas; a model of the creative process from psychology; and two new cognitive models of idea generation. These are part of a longer term study to decipher and identify both stimulating and suppressive information in design processes.

1.1 Defining Creativity

For any study regarding creativity, a definition is essential. A broad definition might be that it concerns the production of novel ideas that are in some sense useful or an advance beyond previous conceptions [Eysenck et al. 2000]. However, there are a wide variety of definitions, over 200 in the literature alone [Goldenberg et al. 2001]. It is rarely useful to generically define creativity, instead creativity must be more specifically defined to suit the particular study and domain. In particular, the typology of research in the engineering design field has been categorised by Ullman [Ullman 1997] into; Person, Process, Output and Environment. This paper uses elements of both the creative process and the creative output to form a definition that links to the information used as an input to idea generation.

2. The Creative Output

In psychology 'the creative output' is commonly referred to as 'the creative product'. This can cause confusion between domains, as product in engineering is associated with a complete solution or an artefact. For this research the creative output is defined as in idea rather than a solution, an approach more common in psychology than engineering sciences. In this research an idea is classified as a creative idea when it has the following three attributes; Originality, Appropriateness and Obviousness. This research has brought together these three attributes to provide a robust measure of the creative output from design activities.

2.1 Originality

It is very difficult to asses how original an idea is. It is argued that while the information processed is known and unoriginal, it is in the original combination and association of this information that leads to

a creative idea. Boden [Boden 1990] defines creativity around this aspect of originality. She distinguishes between an idea that is an original idea for the beholder (P-Creative) and an idea that is original historically (H-Creative). A good example of this differentiation in reality is in the gyroscope patent. In the 1920's the gyroscope was awarded a patent for its designers proud and original invention, unbeknown that its details could be found in Leonardo da Vinci's notebook dated back to the sixteenth century. This differentiation divides the perception of creativity between domains. Social scientists are more concerned with the creative process of the individuals involved so therefore prefer the P-Creative definition. Conversely, engineers are more concerned with innovation (adding commercial value), focusing on creative outputs and therefore find the H-Creative definition more useful.
In undefined and unconstrained tasks and problems, typically the arts, it is relatively easy to obtain idea originality. As the problem becomes more defined and constrained with a known goal state (solution) and known legal moves or operators, thus moving from creative problem solving towards logic, original ideas become rarer.

2.2 Appropriateness (Context)

In 1978 the Nobel Prize for Physics went to Robert Woodrow Wilson and Arno Penzias who discovered background radiation thought to be left behind by the 'Big Bang'. Although they were not looking for this radiation when they stumbled across it they were acknowledged for their ability to add context to this information and realise its appropriateness and relevance.
Relating ideas to the context plays a large role in problem solving, where the desired solution or result is known. This is common in the sciences and engineering where understanding appropriateness and harnessing is directly linked to the implementation of a creative idea thus innovation.

2.3 Obviousness

In some definitions [Goldenberg et al. 2001], a creative idea is described as an 'unobvious' idea, this is less common and less recognised than the previous two properties. This has been introduced so an idea cannot be creative if for example a large percentage of commercial competitors facing the same problem or task independently came up with the same appropriate idea. In terms of information, this can be viewed as obviously relevant information (leading to obvious outputs), or unobviously relevant information (leading to creative outputs).
This element is neither easy to quantify or qualify but its effective measure and understanding may lead to an increase in the ratio of H-Creative ideas to P-Creative ideas. This research is based on the premise that it is possible to improve creative output in design, thereby contradicting theories that there is a constant proportion between creative and routine ideas [Buhl 1960].

2.4 Working Definition

Thus for the context of the overall research a Creative Idea is defined as follows:

"A novel idea that is both unobvious and appropriate."

For an idea to be creative and useful in design it must have all three properties: originality, appropriateness and unobviousness. If one element is missing it loses the cutting edge dimension to produce successful innovation. While the presence of the first two elements can be determined by domain experts, the obviousness of the idea can only be determined retrospectively in industrial case studies or after controlled idea generation experiments in research.

3. The Creative Process

A well regarded and recognised creative process in psychology was constructed by Wallas in 1926 and consistes of the four stages: Preparation, Incubation, Illumination, Verification. While this process has since been developed and extended, it is still regarded as a good and clear representation. It is

particularly useful for this research as the incubation stage is a critical part of the cognitive model of idea generation proposed in section 4.2. This section reviews the literature in relation to these four stages and discusses the theories presented in relation to design and information usage.

3.1 Preparation

Preparation is the first stage of the creative process, this is essentially the information gathering stage. All relevant information and knowledge inputs including those incurred through previous experiences and verification phases are added for the purpose of problem definition or task clarification. This is the only phase of the process that develops, increasing in size as the designer progresses through the design process. The author proposes that the creative output is dependant on the information gathered at this stage. It is thus important to understand the types of information inputs involved, how they are used, and where they are stored.

3.1.1 Information Storage

The way by which information is stored, accessed and reused is of great importance when understanding the cognitive process of idea generation. While storing information externally can seem straight forward, the internal storage is far more complex and causes confusion between terminology such as data, information and knowledge. Hicks [Hicks et al. 2002] defines information as data with context. To turn information into knowledge there is a knowledge process, which is the process of understanding the information. The product of this is a knowledge element, which is restructured and stored as information. The understanding process is key to the storage and reuse of knowledge. This understanding is performed relative to other information stored, and allows a network to be formed linking the new information to other knowledge elements via a web of attributes. For design these attributes are function, form and behaviour, and are stored as information themselves [Benami et al. 2002]. Linking information in this way allows designers to form 'chunks' [Miller 1994], which are meaningful groupings of information compressed to enable more space in the working memory. While a personal trait of domain experts is their ability to form these chunks of information, it also explains why experts often do not posses the child-like or novice-like creativity.

3.1.2 Information Inputs

Idea generation and therefore creativity cannot begin without the availability of knowledge and information. This information is used to improve understanding of the problem through descriptive associations and to stimulate associations and solutions.
The types of information used have been categorised against two criteria "Obvious-relevance" and "Location". Obvious-relevance is a criteria that combines the two attributes of obviousness and relevance as defined in section 2.3. Location refers to the position of the information, internal being cognitively stored, external being experienced from outside the human body.

Table 1. Information Categories

		Location	
		Internal	**External**
Obvious - relevance	**High**	Working Memory	Task Information
	Low	Long Term Memory	Surrounding Information

3.1.3 Internal information

Internal information sources are predominantly stored in two locations, the long term memory considered similar to the a computer storage hard drive, and the working memory considered similar to the RAM (Random Access Memory) of a computer. It is in the working memory that the information is processed, creating associations and ideas. During design tasks, obviously relevant information is drawn from the long term memory to the working memory to form meaningful associations. The working memory will therefore be rich in relevant information, where as the long term memory will consist of information that is both irrelevant and 'unobviously' relevant. The

working memory does however have limited capacity said to be between 5 and 9 chunks [Miller 1994], this can be somewhat alleviated by transferring information into long-term memory or externalising the information (e.g. sketching it down on paper).

3.1.4 External Information

This is all information external to the designer. Social interaction between the designer and colleagues is viewed as one directional with this approach. The colleague is simply considered as dynamic information, this has been done to allow the authors to focus on the information input and individual creativity rather than social- or team- creativity. The task information is considered highly relevant to the design task. This will be the information stored in the project files as requirements, briefs, specifications, constraints etc. The surrounding information is considered irrelevant or unobviously relevant, encompassing background noise, scenery, smell and other sensory forms of input (e.g. the office environment). This information is usually separated from the design task by either space or time. Spacialy this information is predominantly in the peripheral vision. When the information is in focus it is often differentiated by time from the concentration of the task (e.g. day dreaming, relaxing or working on other projects). The authors hypothesize that it is only when this unobviously relevant information comes into focus, whilst concentrating on the task, that a creative idea can be formed.

3.2 Incubation

This is a relatively unexplained cognitive process where the problem information from the preparation stage is put aside for an unknown period of time until an idea or a solution suddenly emerges. It is proposed that incubation can be divided into two dimensions in terms of cognition and information use, these are Stimulative Incubation and Suppresative Incubation. Stimulative Incubation is a time period where the brain is simply waiting to be stimulated or subjected to the right piece of stimulating information. Suppresative Incubation (mental blocks or fixation) is where the brain is waiting for the creative suppression to pass, enabling new and previously unobtainable connections to be made. In reality it is probable that both types of incubation occur. The authors hypothesise that the addition of this phase is what determines a creative idea from a routine idea. Where routine ideas can be instantly formed from the freely available obvious information, incubation is required to use the unobvious information and thus create novel associations as creative ideas. It is therefore proposed that the incubation period is in fact not determined by the length of time, but by the type of information that the designer is subjected to during this period. If this claim is supported, research into this area may lead to shortened incubation periods providing value to design activities in an industrial context.

3.3 Illumination

This a complex and instantaneous phase where an association is made between two bits of information, commonly called the 'Ah ha' or 'Eureka' moment. The full explanation of illumination is far beyond the realms of this research, however, the information considerations during this phase can be assessed by studying associations, the primary aspect of illumination.

3.3.1 Association

An association is the result of an information processing activity using two or more chunks of information. It is the most recognised process of idea generation *"The building up of solutions is accomplished by associating ideas"* [Buhl 1960].

Aristotle stated three distinct rules of association [Buhl 1960]:

Similarity – finding some sameness of properties in two physical things or situations.
Contrast – an association because of a difference in properties.
Contiguity – associating two objects or ideas by virtue of their physical placement.

Pugh [Pugh 1991] also suggests types of association used to aid idea generation such as analogy, attributes, inversion and combination. Metaphors are also commonly used in design. In simple terms, an association is recognising some relationship between two chunks of information in the working

memory. The more abstract the association is, the more creative the result is deemed to be. Cartoons and joke telling are good example of this. When the punch-line of a joke is too obvious and the audience can see it coming from a mile off it is because the association is not abstract enough. If too abstract the joke may lose it appropriateness and become technically not a joke. It is the association giving surprise that determines the creativity of a joke or cartoon [Mishon 2003].
Some ideas in problem solving and design are complex and the associations are hard to pinpoint. The TRIZ philosophy states that there are no complex problems but simple problems stuck together, likewise, there are no complex associations or ideas just simple ones stuck together. Some more abstract associations are harder to create or recognise. For example the association drawn from emotional response (behaviour) of two design entities is not as easy to recognise as between the appearance (form) of two objects.
The authors have separated these types of associations into two groups, a Descriptive Association (analogy, metaphor, simile etc.) and a Solution Association. Both approaches are described below and illustrated in figures 1 and 2.

3.3.2 Descriptive Association

This is an essential approach for turning information into knowledge. In order to understand or comprehend something, information must be related to, other chunks of information. A descriptive association is when another piece of information is introduced (the descriptor) to further describe and understand the problem/solution. It could be the case that all evaluation and understanding is formed from descriptive associations, although perhaps not as elegant as metaphor.

3.3.3 Solution Association

This is where a chunk of information is associated during problem solving. Rather than describing the result, the descriptor is associated with the problem beforehand to inspire the result.

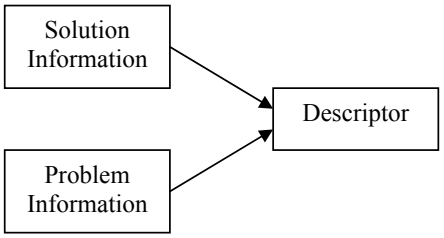

Figure 1. Descriptive Association

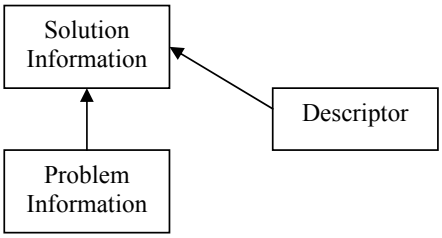

Figure 2. Solution Association

3.4 Verification

This stage is effectively an evaluation stage where and ideas is assessed for its appropriateness. This is an additional phase to idea generation, the information from this phase can be considered as part of the preparation stage for the next idea and so it is not expanded here.

4. Creative idea formulation

Section 3 covered 'creativity' as defined in the literature, highlighting the role of information at the various stages. In this section the authors propose an alternative view of the idea generation process, which builds on the previous definitions and highlights the difference between *routine* idea generation and *creative* idea generation. Unlike routine idea generation where ideas can be forced, creative idea generation relies on the incubation period and the information accessed during this period. For creative problem solving the incubation period is essential. Total immersion in the problem without the incubation period will lead to fixation or lack of stimulation resulting in routine idea generation.

4.1 Routine idea generation

Routine idea generation refers to ideas that are appropriate, and sometimes original, but obvious to an expert in the domain. This type of idea generation requires no incubation phase, it can be forced and depends on concentration levels and previous knowledge. Figure 3 is a proposal to show how the task information is analysed and the obviously relevant chunks of information are drawn into the working memory. These chunks of information are then associated with the task information and other chunks of working memory information to form understanding, knowledge and routine ideas.

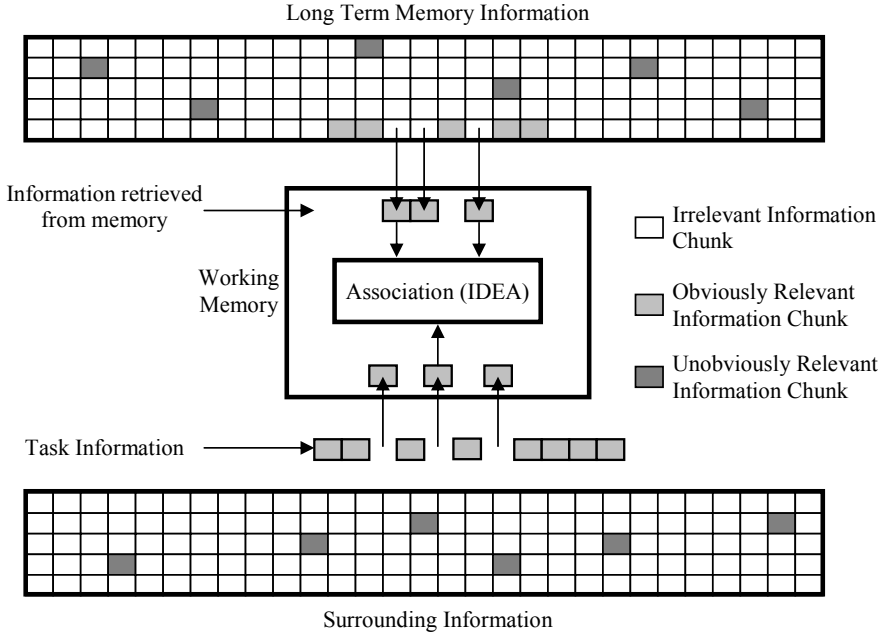

Figure 3. Cognitive model for routine idea generation

4.2 Creative idea generation

Creative idea generation requires the incubation phase. It relies partly upon luck and the ability to associate distinctly different chunks of information.

> "Much of the difficulty in everyday problems may hinge on finding the relevant information in memory or the environment required to solve the problem." [Eysenck et al. 2000] p.408

Figure 4 is a development of the approach, it shows how after the incubation phase, unobviously relevant information may arise from either internal sources (I) from the long term memory or external sources (E) from surrounding information and is used to form new associations.

4.2.1 Internal Source (I)

In this instance, the suppression or block may be lifted during the incubation phase enabling this new chunk of information to form an association. Alternatively, whilst pondering or searching through mental archives, a new unobviously relevant chunk of information may be found and associated.

4.2.2 External Source (E)

During the incubation the designer may come across a surprise result, an interruption or another form of stimulating information to inspire a creative association. This information may have been situated

within sensory distance of designer but was not previously considered relevant or accessed whilst other relevant information was within the working memory.

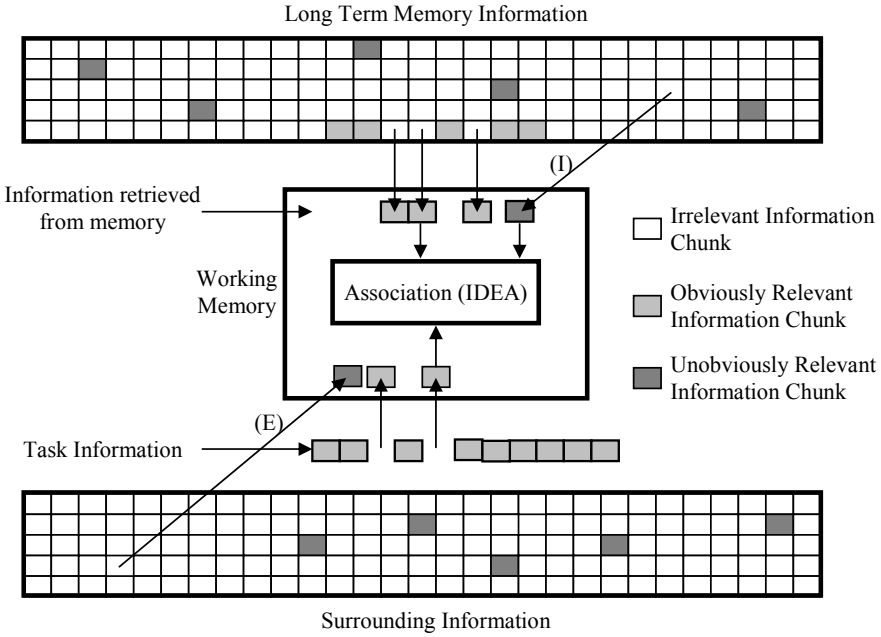

Figure 4. Cognitive model for creative idea generation

"The current favoured account seems to be that any new information introduced into a problem or met in the environment may activate related concepts in memory and result in sudden emergence of solution." [Eysenck et al. 2000]P429

5. Discussion and Conclusions

Sections 2 and 3 show explain the involvement of the information at the various stages of a creative activity. The models presented particularly attempt to highlight the role of information and its relevance. More specifically they show the difference between routine idea generation and creative idea generation. The models created also help define the hypothesis that there are two distinct information sources that must be searched in order to generate creative ideas for design and innovation. The internal source, 'I' type idea, being more complicated, possible improvements may lie in cognitive tools to enable lateral and diverse information scanning of the long term memory. For the external source, 'E' type idea, new models and tools may help capture, store and search for stimulating information depending on the stage of the design process, the domain or nature of problem.

The next stages in this research will develop these models and populate them with exemplars. In particular, the research will investigate the role of 'stimulating' information and 'suppressing' information .

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