Title

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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 20(0)

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Publication Date

1998

The Variation of Ideational Productivity over Short Timescales and the Influence of an Instructional Strategy to Defocus Attention

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Abstract

This paper describes psychometric investigations that have been carried out as a prelude to developing new approaches to learning structures within education, based on connectionist concepts. In Experiment A, the ability of 15 subjects to produce different interpretations of an image formed from abstract geometric shapes was studied over a 30 minute period of observing the diagram. The rate at which these subject produced ideas was shown to initially decline and then become constant. Experiment B investigated the effect of a strategy that encouraged 16 subjects to defocus their thinking before attempting to find another new interpretation. On returning to the problem, the average time taken to produce another interpretation was significantly reduced. Both sets of results are discussed in terms of connectionist modelling, the need to broaden one's attention during creative problem-solving and the neural mechanism of 'lateral inhibition'. Further evidence for the potential effectiveness of 'chance' strategies is also referenced in the work, techniques and philosophy of well-known and recognised artists.

Introduction

The generation of ideas through the combination of elements has been emphasised as an essential part of creative problem solving. Campbell (1960) proposed that underlying this ability is a process of 'blind variation and selective retention'. He argued that a spontaneous construction of ideational combinations takes place in a more or less unpredictable fashion, a small proportion of which are selected for further elaboration. Others have successfully used this theory to model the career trajectories of creative geniuses (Simonton, 1997) and scientific communities (Kantorovich, 1993).

Finke , Ward and Smith (1992) have developed a model which suggests that there is alternation between a generative phase in which 'pre-inventive' structures are produced through combining elements, and an exploration phase in which these structures are interpreted. In this 'geneplore model', constraints may be involved at both stages. Based on empirical evidence Finke et al. (1992) suggest that broadening the focus of attention may improve creativity.

The ability to access a large number of elements for possible combination inevitably involves elements which may be only remotely associated with the problem. Mednick (1962) investigated the associative strength of different words in individuals. He considered a non-creative person as being characterized as possessing steep associative hierarchies of ideas. In other words, such an individual could at first respond quickly with 2 - 3 stereotyped associations to a particular stimulus word. Thereafter, however, the strength of their associations would rapidly diminish and, although a few further responses might be produced with difficulty, these individuals would then quickly dry up. A creative individual, Mednick explained, has much flatter associative hierarchies. Their behaviour in word association tasks is characterized by a slower but more continuous rate of production. Since a flatter associative hierarchy means that the relative strengths of association between close and remote associations are less, such individuals are more able to produce associations which are less stereotyped. It can be argued that to combine remotely associated elements requires one's attention to be unfocused, and that a wide focus of attention increases the probability of finding a novel and useful combination. In terms of Mednick's ideas, it is easier to widen the focus of attention if one has a flat associative hierarchy, since the first and more obvious associations are weaker and less distracting.

As early as 1926, Wallas labelled the stages of creative problem-solving with the terms *preparation*, *incubation*, *illumination* and *insight*. This sequence has often been referred to by later writers and researchers who have been struck by the need for a period of incubation, and also by the apparently effortless, sometimes inspirational, arrival of illumination with a solution that often involves knowledge only remotely associated with original problem. The phenomenon of fixation (eg Jansson & Smith, 1991) can be explained in terms of difficulty in broadening the focus of attention away from a particular area to discover new associations for combination. Finke et al (1992) describe incubation as merely the 'dissipation of fixation', suggesting that a broadening of the focus of attention may play some part in all creative problem-solving.

There appears, then, to be a general agreement that the defocusing or broadening of attention is an essential part of the creative process. In contrast, critical analytical thinking is considered to benefit from sharply focused attention. Reflection upon a possible dichotomy of 'reasoning' led the psychoanalytic theorist Ernst Kris (1952) to propose that there are two modes of thinking: primary process and secondary process. Whereas secondary process thinking is concerned with conscious, focused and logical analysis, primary process thinking is more concerned with defocused, unconscious, more freely associative thinking. He suggested that the two formed a continuum along which consciousness varies. This concept is strongly allied with Wundt's (1896) associative versus intellectual, and Werner's (1948) dedifferentiated versus differentiated thinking. Secondary process thinking may be essential for the critical exploration and validation of novel combinations of elements (corresponding to Wallas's insight, or Finke's exploration phase), but the initial production of ideas through the combination of remote associates would also require primary process cognition. Thus, creativity may be characterized by an ability to move freely between the two modes of thought.

Advances in connectionist modelling have suggested ways in which primary process thinking can occur in terms of the type of massively parallel architectures associated with the mind. Artificial neural networks consist of large numbers of nodes interconnected with each other. Connections between adjacent nodes are strengthened when they are active simultaneously (Hull,1943). Martindale (1995) divides consciousness into attention (most activated nodes) and short-term memory (nodes that are activated but less so than those in the focus of attention). During preparation, attention becomes highly focused and just a few nodes dominate consciousness. These highly active nodes exert strong lateral inhibition (see Anderson and Spellman, 1995 for a review of this mechanism) on other nodes, preventing them from becoming more active. As attention is gradually defocused, inhibition caused by the previously highly-active nodes that encoded the problem is decreased and those other nodes which were only primed by remote association with the problem become more active. If, at some stage during this incubation period, one of these partially active nodes is related to the nodes that encoded the problem then the latter become fully active, providing the experience of illumination. Attention becomes focused again during the verification stage when the idea is being analysed for suitability.

Martindale (1995) has also used neural network models developed by Hopfield (1982) to account for how transitions between primary and secondary process thinking may take place. The weighting of the connections varies symmetrically so that the strength of the connection from one node to another is the same in both directions. The extent to which nodes are activated varies according to a probabalistic function, and the term 'temperature' is used to describe the degree of randomness of this function. Thus, at low temperature, nodes are almost always activated, and to a predictable extent, when adjacent nodes are activated. At high temperature, nodes behave more randomly.

Hopfield borrowed concepts derived from analogous physical systems to suggest that such networks may operate so as to minimise what he called 'energy'. Energy is minimized for any one node when the constraints placed on it by other nodes are satisfied. Thus, for two nodes which are positively connected, energy is minimal if both are on. For two nodes which are negatively connected, one should be on and the other off for minimum energy. A large variety of combinations must be investigated to determine a 'global' energy minimum. Thus, a network which has been trained, by self-adjustment of its connection strengths, to recognise certain patterns will recognise new or partial patterns by updating the activation of its nodes one at a time and moving towards the best solution - identified as the one which minimizes energy. Interestingly, Hopfield's network occasionally suffered from getting caught in local minima - which could be considered as a type of fixation. These local minima are configurations of activity which provide some, but not the greatest, minimizing of energy but which discourage the network from searching further. Hopfield continued drawing on the analogy of such neural systems with physical systems, by applying a process of simulated 'annealing' to dissipate the problem. To simulate annealing, the temperature of the network is increased producing quasi-random nodal activity, allowing the system to crawl out of local minima. The temperature is then slowly reduced, allowing the activity to become increasingly more 'rational' and less random, until the global minimum is found. Martindale (1995) has suggested that the oscillation between high and low temperatures during simulated annealing is analogous to the oscillation between primary and secondary process thinking.

The experimental evidence and models of creative problem-solving discussed above suggest that broadening of the focus of attention is an essential part of all creative problem-solving. The experiments described below attempted to investigate whether such concepts may provide the basis of classroom strategies to improve creative thinking. Experiment A investigated how ideational productivity varies over time and Experiment B attempted to explore the hypothesis that defocusing can be encouraged by an instructional strategy.

Methodology for Experiment A

16 volunteer subjects in the age range 18- 40 were asked to perform a task involving the interpretation of a diagram. The experiment was run on a PC workstation. A simple image was created from randomly-selected geometric shapes (see Fig 1:a) and subjects were asked to identify what 'invention or artifact, real or imaginary' the picture might represent. Subjects were told that their ideas could be 'as wild as you like and do not have to be realistic'. Subjects were requested to enter their ideas for the image via the keyboard as soon as they occurred to them, by typing 1 - 2 words. Having entered their response, the same image would reappear and subjects were required to think up another idea, and so the test continued. Subjects were asked not to repeat any ideas or words during the test session. The time spent by the subject observing the image before they began typing the response was recorded for each response. Both the response and the time taken for the response to begin was recorded by the computer. The time taken for the subjects to enter their response was not included in the response time. The test for each subject was halted when their response times totalled 30 minutes. Training, involving the use of a different pattern to the one used in the test, was provided prior to the test.

Encouraging subjects to ignore the quality of their ideas sensitised the test to detect efficiency differences in primary

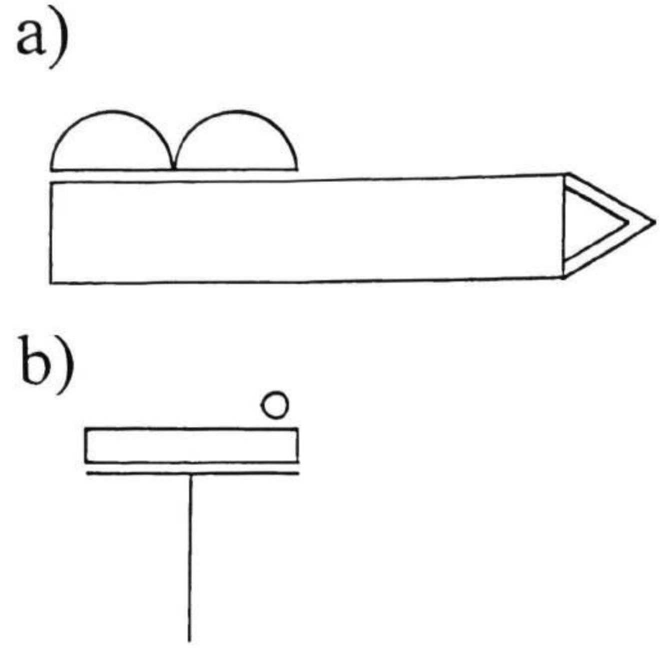

Figure 1: Stimuli for Experiment A (a) and B (a & b)

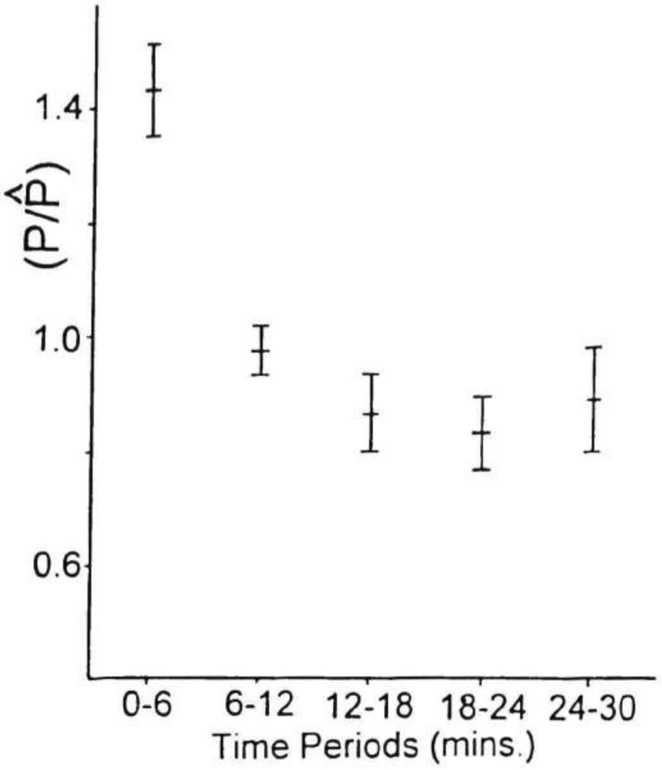

Figure 2: Expt. A: Productivity as $(P/\hat{P})$ over 30 minutes

process thinking, but it can also be argued that a measure of ideational productivity which takes no account of quality is unhelpful when investigating mechanisms of creative problem-solving (Finke et al., 1992). However, while quality, in terms of originality and usefulness, is essential in judging the final outcome of a creative problem, it is generally considered that fluency or the ability to produce a large number of initial ideas is essentially related to the quality of the final outcome. Thus, productivity has formed the basis for many tests of creativity (eg Torrance, 1974). Furthermore, it can be argued, based on the combinatory mechanisms already discussed, that the odds of producing a quality idea should be a positive function of the total number of ideas generated. Historical studies of quality suggest that it is a probabalistic function of quantity (Simonton, 1997). Indeed, experimental evidence confirms such a strong correlation between quantity and quality that the costly effort of quality ratings is difficult to justify (Diehl and Stroebe, 1987). Nevertheless, the procedure described here should be considered more accurately as a test of 'ideational productivity', than of general creativity, where productivity refers to rate of production of ideas irrespective of quality.

Results and Discussion for Experiment A

Productivity of the subjects over the 30 minute period is summarised in Fig. 2 (all error bars and errors quoted are estimated standard errors in the mean). To reduce variance due to individual differences in productivity, ideation rates were first normalised with respect to individual productivity as measured over the entire 30 minute period. The graph plots the mean over the group of $(P/\hat{P})$, where P is the productivity of each subject during each of the periods (0-6, 6-12, 12-18, 18-24, 24-30 minutes) and $\hat{P}$ is their mean productivity over the total period.

In this study, no subject produced a stream of nonsense and thus it must be assumed that each was applying their own quality criteria. Whether these criteria were applied consistently is less certain. However, it can be postulated that the rate of production of ideas should be proportional to the number of potential ideational combinations that remain (compare Simonton, 1997). If this figure is very large, as must be considered the case here, one would expect that the rate of productivity should be constant if criteria are being applied consistently.

In fact, productivity appears to fall in an approximately exponential fashion (Bousfield, Sedgewick & Cohen, 1954), towards a non-zero asymptote. The difference between values of $(P/\hat{P})$ measured during the first two periods (0-6 and 6-12 minutes) is significant at the 1% level, whereas no significant change was detected during the last 3 periods

An initial drop in productivity has been discussed (Mednick, 1962) in terms of the difficulties that subjects experience in moving beyond their first strong associations. The activity encoding these associations reduces, through the mechanism of lateral inhibition (Martindale, 1995), the accessibility of other, more remote, associations involving short-term memory encoded as weak initial activity. In connectionist terms, when the diagram is first seen by the subject, the nodes encoding the features of the diagram will become active. Any nodes connected to these and also to others already activated prior to the experiment commencing, will increase their activity and the subject will begin to draw solutions arising from a reservoir of active nodes encoding useful associations. For example, if the subject has just been using a pen, then his/her first solutions may be related to pens, pencils, stationary, etc. These ideas arise from what may be considered a narrowly focused domain of attention. The effect of lateral inhibition by these active nodes will not yet be a problem, because solutions are being produced from these more active nodes. When, however, this initial reservoir starts to become exhausted, more remote associations encoded more weakly in other nodes are required to contribute to solutions. These nodes are suffering inhibition caused by the high levels of activity of the nodes related to the previous solutions, and time is required for this inhibition to subside. From this point on, the arrival of new solutions will be delayed as the lateral inhibition, or fixation, arising from previous solutions dissipates.

Methodology for Experiment B

Experiment B attempted to explore the hypothesis that instruction can encourage the broadening of attention.

By considering Martindale's neural network model, it can be predicted that the impact of such a strategy will be significantly influenced by the type of task involved. In particular, it will depend upon how 'well-defined' the problem is. Reitman (1965) classifies a well-defined problem as having a start, a goal and set of processes by which to get from the start to the goal. In a well-defined problem which has only a few specific answers, solution may rely more critically upon the re-organisation of activity initiated by those few nodes which were partially activated during the focused preparation but which enjoy renewed activity as lateral inhibition subsides. Random stimulus, especially one which arrives with considerable emphasis, may slow down successful reorganisation since, although it may successfully reduce the amount of activity associated with original foci and thus reduce lateral inhibition, it may also influence the state following 'preparation' in an unpredictable and unhelpful fashion. It may break down those trace activities which would have been essential in determining one of the few solutions. In such a situation, a random stimulus may help the thinker defocus from their original thoughts, but will cause distraction away from the few fertile areas of thought that had begun to be touched upon.

However, for an ill-defined problem that can be satisfied by an infinite number of solutions, random stimulus may encourage the release of lateral inhibition without having such a deleterious effect upon the re-organisation of the network,since there is a greater number of potential solutions and range of successful routes that can be taken. Here, the random stimulus may simply encourage the problem-solver to move on from his or her previous thoughts into one of many other areas of potential productivity. Even within such a problem solving context, the way in which the random stimulus is introduced may still prove crucial to its helpfulness. Great emphasis upon the extra stimulus, such as informing the thinker that it is an essential clue, may simply bring about another state of fixation. Thus, in developing the methodology for this experiment, the choice of the problem to be solved, and the type and the manner of presentation of random stimulus were seen as critical.

16 volunteer subjects in the age range 18- 40 were asked to perform two tasks. The first task was similar to that described in Experiment A, except that subjects were allowed only a total of 6 minutes to observe the figure and determine their responses. The other task in Experiment B again involved interpreting another diagram formed from geometric shapes. This time, however, an instructional strategy to encourage defocusing of attention was employed before each attempt at interpreting the diagram. A partial nonsense sentence appeared on the screen, which subjects were asked to complete by providing the last word. Subjects were told "Don't worry about the sentence making sense - it can't! Choose any word that appeals to you". Having entered the word via the keyboard, the diagram reappeared and subjects were encouraged to "think around ideas associated with the word, and see if any new interpretations of the diagram occur to you" It was also explained that their idea did not have to be related to the word at all, and that the strategy was only there to help them think up more ideas.

It was considered that encouraging the subjects to arrive at a randomly chosen word, rather than choosing it for them, was important both in terms of giving a sense of ownership of the process involved, and in maximising the influence of the task upon the focus of attention. Again, a short training exercise was provided. Order of presentation of the two diagrams (Fig 1:a,b) and the conditions of 'With Instructional Strategy' (WIS) and No Instructional Strategy' (NIS) were permutated, minimising learning and fatigue effects.

Results and Discussion for Experiment B

After returning from the exercise with the nonsense sentence,subjects were, on average, significantly faster at completing the creative task (See Fig 3), with a 31.9 (+/- 6.3) % reduction in response time (significant at the 2% level). Since the time taken to generate a new response was reduced by simply having randomly generated a word prior to each attempt, it would appear that this generation was directly contributing to the ideation process. If the strategy does nothing except encourage the subjects to depart from their previous focus in another (randomly chosen) direction, then it would appear that this encouragement to defocus contributes positively to their performance when they return to the creative task.

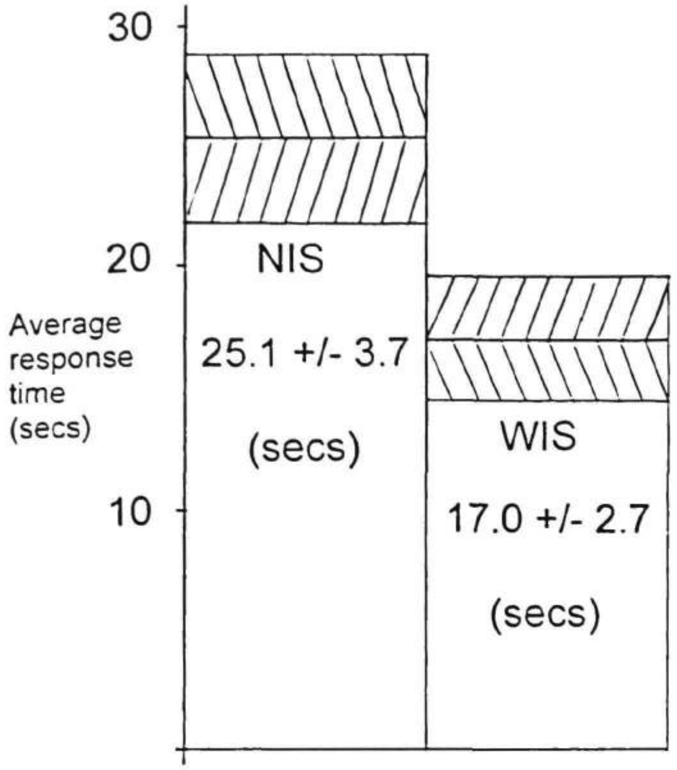

Figure 3: Expt.B: Average response times for NIS (No Instructional Strategy) and WIS (With Instruct. Strategy)

If fixation, caused by lateral inhibition, is not evident in the WIS condition, we should also expect to see no drop in productivity with time. Fig. 4 shows the quantity $(P/\hat{P})$ for the periods 0-2, 2-4 and 4-6 minutes. As expected, there is a significant initial drop in $(P/\hat{P})$ for the NIS condition as lateral inhibition begins to influence productivity, whilst no significant drop can be seen for the WIS condition.

However, a criticism of such an interpretation might be that, by encouraging the subject to stay with the new focus, the strategy goes further than encouraging defocusing, by directing the subject how to approach the rest of the problem solving task ('think around ideas associated with this word'). Is the strategy helpful simply because it 'appears' to provide some extra guidance in solving the problem? This guidance may only serve the purpose of reassuring the subject and reducing the anxiety which some studies and writers have implicated as a negative influence on creative performance (Amabile, 1983). Interestingly, however, many subjects reported that they found the task more difficult when encouraged to use the nonsense sentences as a 'jumping-off point', and felt they performed less well, even though this was clearly not the case. Certainly, if 'placebo' strategies do produce results, they would still have useful applications.

If the use of sentences as stimuli were, in themselves, prompting similar answers, it could be argued that the subjects were no longer responding creatively, since our original definition of a creative response includes originality.

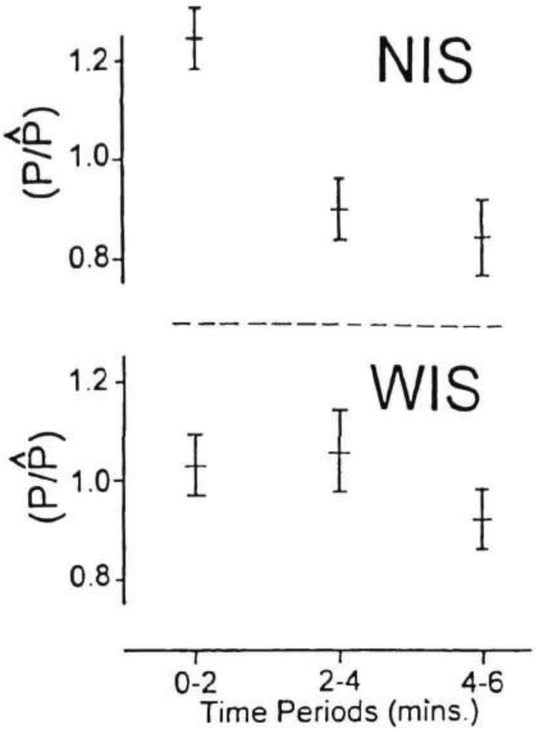

Figure 4. Variation of Productivity as $(P/\hat{P})$ over the 6 minutes during conditions NIS and WIS of Expt. B.

To measure the originality of responses, the numbers of responses that did not contain a noun used by any other subject during the NIS and WIS conditions was calculated.

Condition	Original Responses
NIS	40.0 %
WIS	56.8 %

Table 1: Percentage original responses

Also, on only 2.5% of occasions during the WIS condition did two different subjects use the same noun in a response following the same nonsense sentence. These results tend to imply that originality was not being decreased by use of the same nonsense sentence set for each subject, and provides some evidence for it having been increased. As already discussed above, however, this is primarily an investigation of ideational productivity and has deliberately avoided asking subjects to apply selection criteria such as practicality and originality. Whether releasing fixation in this way influences quality of ideas cannot be determined from this study.

Summary and Applications

The initial drops in rates of ideational productivity observed in Expt A support the concept of fixation occurring even in problems that may be solved over short time-scales. When subjects in Experiment B carried out an additional task intended to draw them away from previous associations, the average time required to arrive at a new solution on returning to the original brief was reduced by about a third. No significant initial drop in productivity was observed when this strategy was employed. These results tend to suggest difficulties in broadening the focus of attention may account for the phenomenon of fixation which has been discussed in terms of a connectionist model of creative cognition.

Although the effectiveness of such strategies may be limited to ill-defined problems with multiple solutions and an assessment of their efficiency would need to include the time taken to carry out the strategy itself, applications suggest themselves in terms of learning structures that may boost productivity within, say, the creative arts.

It is also worth noting that a number of strategies to broaden the focus of attention have already been developed pragmatically. Many distinguished artists (eg Max Ernst, 1948) have succeeded in 'elevating the appeal to chance and accident into a first principle of creation' (Hunter, 1948 on Jackson Pollock). The Surrealist artistic movement is particularly rich with artists attempting to 'liberate the modern consciousness from that terrible fixation mania'. Many of the techniques used by these artists involved chiefly random starting points that were ordered only by a 'disdain for thesis' (Manheim, 1951). Hans Arp developed collages with titles such as 'Objects arranged according to the law of chance' and Kurt Schwitters developed sculptures from the contents of his waste-bin. Max Ernst's 'frottages' were developed from rubbings of various rough surfaces in order to "intensify the irritability of the mental faculties". The successful use of such 'random' strategies tends to infer that they were not, in these instances at least, considered to diminish final quality. However, the influence of strategies involving randomness upon creative quality would be a useful line of future experimental enquiry, both in determining the cognitive mechanisms of creative thought and in developing strategies for its enhancement.

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