5 Neurocognitive mechanisms underlying creative thinking: indications from studies of mental illness

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> Creative people who can't but help explore other mental territories are at greater risk, just as someone who climbs a mountain is more at risk than someone who just walks along a village lane.
>
> – R. D. Laing

> One must still have chaos in oneself to be able to give birth to a dancing star.
>
> – Friedrich Nietzsche

The magnetic appeal of the nexus between madness and creativity has persevered over centuries. The ubiquity of this fascinating idea is no doubt primarily due to the greater incidence of mental illness associated with professions that purportedly involve a high degree of creativity (e.g., Post, 1994). However, its remarkable persistence can be attributed, at least in part, to the shared characteristics of mental illness and creativity. Both are associated with a high tolerance for ambiguity, the ability to go beyond generic conceptual connections, and the adoption of alternative perspectives. Despite the considerable interest in this theme and concerted efforts to demystify the ineffability surrounding it, the precise manner in which enhanced creative abilities can be related to mental illness has remained a difficult one to pin down.

There are several reasons for this. One is that creativity itself is an extremely multifaceted and heterogeneous construct for which few comprehensive or unifying information-processing frameworks have been proposed (Dietrich, 2004). In addition, while several measures have been developed to assess creative thinking, most do not specify which particular facets of creativity are assessed within the tasks because related psychometric work is lacking (Arden *et al.*, 2010). For example, clarifications about the manner in which any creativity measure is comparable to or differentiable from other creativity tasks are usually absent. Moreover, unlike in the case of personality tests, for instance, the lack of comprehensive reliability or validity indices accompanying creativity tests makes it difficult to estimate the efficacy of, not just the measures in question, but also their associated concepts. So making clear claims about creative thinking in relation to almost any variable is extremely challenging.

This picture is further complicated by the fact that critical issues also surface when investigating information-processing biases in mental illness. Several ideas are in circulation about which specific types of mental illness are associated with enhanced creative abilities. Mood disorders and schizophrenia spectrum disorders have received the bulk of the focus so far (e.g., Abraham *et al.*, 2007; Andreasen and Powers, 1975; Dykes and McGhie, 1976; Soeiro-de-Souza *et al.*, 2011). But other psychiatric disorders, such as autism spectrum disorders and attention-deficit/hyperactivity disorder (ADHD), have also been discussed in relation to enhanced creativity skills (Abraham *et al.*, 2006; Healey, this volume; Healey and Rucklidge, 2006; Pring *et al.*, 2012).

What still remains largely unknown, however, is the nature of these information-processing differences between the disorders. Do such widely varied clinical conditions overlap in some way with regard to creative cognition? Given their rather distinct cognitive and behavioral profiles, is it at all possible to argue for an underlying cognitive bias that is common to all of these disorders? In what manner is the cognitive bias during creative thinking in bipolar disorder related to that of ADHD, for instance? Can information-processing biases during creative cognition be predicted from the well-documented biases in normative cognition that are associated with each of the mental disorders? These are some of the many questions that need to be explored to be able to gain precise insights about the dynamics of the relation between creativity and mental illness.

Can information-processing biases lead to advantages in creativity?

The core idea behind investigations on creativity and mental illness is that each of the psychiatric conditions in question is associated with one or more insufficiencies in information processing during normative cognition (negative biases) that may be advantageous in the context of creative cognition (positive biases). Factors such as reduced top-down control, defocused attention, flat associative hierarchies, and cognitive disinhibition have been proposed as underlying the roots of such information-processing biases (Carson, 2011; Eysenck, 1995; Kasof, 1997; Mednick, 1962; Mendelsohn, 1974; Snyder, 2009; Thompson-Schill *et al.*, 2009).

The relevance of defocused attention in creative thinking, for instance, was highlighted by Mendelsohn (1974). Defocused attention refers to a widened attentional capacity and can best be understood with reference to the metaphor of the attentional spotlight. To arrive at a creative idea, conceptual elements that are available within one's attentional focus need to be combined. From a statistical standpoint, an increase in the number of elements present within one's attentional stream would result in an exponential surge in the number of potential combinations of elements. For instance, if one's attention spotlight is extremely focused and one is only able to attend to two conceptual elements (A, B) at the same time, only one combination would arise (AB). If, however, one's attentional focus is comparatively less focused and there are three elements within one's attentional stream (A, B, C), then four permutations would be possible (AB, BC, AC, ABC). So, according to this view, the manner in which information from one's conceptual networks can be accessed (focused versus defocused) has a direct effect on the amount of information available within one's stream of attention, and, consequently, the number of potential conceptual combinations that can be generated. This has a crucial impact on creative output because the greater the number of conceptual combinations available in one's attentional focus, the higher the likelihood of unique combinations occurring.

This idea can be readily aligned to other prominent hypotheses, such as that of cognitive disinhibition (Carson, 2011), that link enhanced creative abilities with insufficiencies in select aspects of information processing. Notwithstanding their differences, each of these hypotheses has been proposed as the missing link that would allow one to align the greater incidences of mental illness among practitioners of ostensibly creative professions (such as artists and poets) with the presence of cognitive and behavioral deficits that typify the very same mental illnesses. Such ideas set the stage for a number of debates about the "upside" of having a mental illness including the proposal that the propensity for mental illness must confer some evolutionary advantage for humankind or else it would have been weeded out through processes such as natural selection. This evolutionary advantage has been posited to take the form of enhanced creative potential (Crespi *et al.*, 2007; Karlsson, 1970).

So there are several influential ideas that postulate the presence of some kind of positive bias in creative thinking in association with certain mental illnesses. While the general thrust of such hypotheses carries considerable intuitive appeal, they have received only limited direct or indirect support (e.g., Andreasen and Powers, 1975; Carson *et al.*, 2011; Soeiro-de-Souza *et al.*, 2011). In some of the earliest empirical work on this topic, in comparison to healthy control participants, a group of patients with schizophrenia and a group of highly creative individuals were both found to exhibit poor performance on a divided attention task along with superior performance on a creative thinking task (Dykes and McGhie, 1976). Almost four decades later, in investigations of subclinical populations with a high degree of schizotypal traits, Carson and her colleagues (2003) reported related evidence that showcased advantages in creative output in association with a higher propensity for mental illness alongside concurrent disadvantages in cognitive inhibition.

In addition to schizophrenia, mood disorders and specific childhood disorders have also been linked empirically and theoretically to superior creative abilities (Abraham *et al.*, 2006; Andreasen, 2008). However, as mentioned earlier, few studies have explicitly addressed key issues such as what aspects of creative thinking would be positively affected by information-processing biases typical of any disorder, and which other facets of creativity would be unaffected or negatively influenced by the very same biases. The fact that no mental disorder is known to be unequivocally associated with greater creativity is a clear sign that any potential bias in information processing that hampers some distinctive aspect of normative cognition is likely to be extremely specific in terms of which particular facet of creative cognition would be enhanced as a result.

How is creative cognition related to normative cognition?

In order to estimate the specificity associated with positive versus negative consequences of information-processing biases, it is necessary to first understand how creative and normative cognition are linked to one another. Surprisingly, this issue has only seldom been explicitly addressed in the literature. Most cognitive-based investigations of creativity attempt to characterize what differentiates high and low creative individuals. Within the domain of cognitive neuroscience, for instance, neuroimaging investigations mainly seek to clarify the neural basis for individual differences in creative thinking (Dietrich and Kanso, 2010). However, most studies do not openly address in what manner creative thinking is similar to or distinguishable from non-creative or normative thinking. In fact, there is a latent assumption that creative thinking is somehow qualitatively different from normative thinking (Panels A and B of Figure 5.1). But are we correct in making such an assumption?

The only researchers to have broached this issue head on were the proponents of the Geneplore model who adopted the creative cognition approach (Abraham and Windmann, 2007; Finke *et al.*, 1996; Ward *et al.*, 1995). According to this framework, it is unlikely that there are mental operations that are exclusively in place for creative cognition. The information-processing "toolboxes" would be expected to be one and

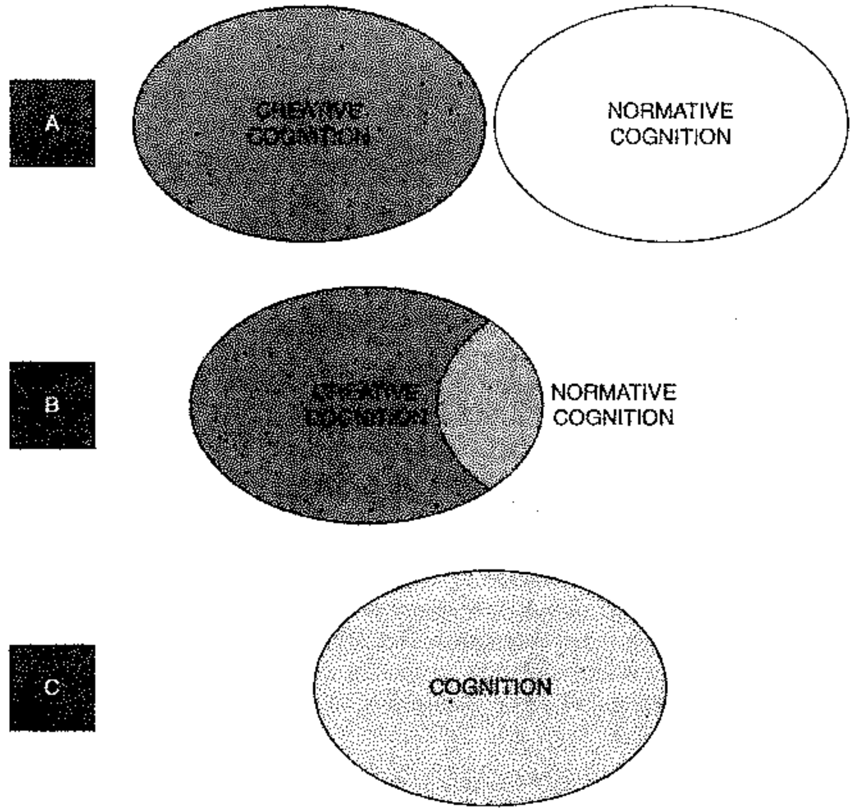

Figure 5.1 The relationship between information-processing toolboxes of creative cognition and normative cognition can be conceived of as mutually exclusive (A), partially overlapping (B), or undifferentiated (C) (adapted from figure as originally published in Abraham [2013])

the same for both creative and normative cognition (Panel C of Figure 5.1). The essential difference between creative and normative cognition, though, lies in the kind of situations in which our information-processing toolboxes need to be applied. The situational factors during creative cognition are open-ended or unclear, whereas the situational factors during normative cognition are concrete or predictable. A situation that is open-ended and involves the generation of novel responses to reach a solution would necessitate creative cognition.

The creative cognition framework has only been explored to a limited extent so far using neuroscientific techniques (Abraham *et al.*, 2012;

Kröger *et al.*, 2012; Rutter *et al.*, 2012). The relation between normative and creative cognition in terms of brain function has mainly been informed through behavioral investigations of psychiatric (Abraham *et al.*, 2006, 2007) and subclinical populations (Abraham and Windmann, 2008; Abraham *et al.*, 2005; Karimi *et al.*, 2007). In each of these studies, diverse aspects of creative cognition were assessed including the ability to extend conceptual boundaries when forming new ideas (conceptual expansion task) (Ward, 1994) or when generating new uses for common objects (alternate uses task) (Wallach and Kogan, 1965), originality and practicality when generating new objects within a predetermined category (creative imagery task) (Finke, 1990), the ability to overcome constraints imposed by recently activated knowledge (constraints of examples task) (Smith *et al.*, 1993), and overcoming functional fixedness during analytical reasoning (insight problem-solving tasks) (Weisberg, 1995). Adopting a comprehensive creative cognition approach enables one to establish not only whether there is evidence of cognitive biases during creative thinking associated with any clinical or subclinical population, but also allows one to determine which aspects of creative cognition these biases are restricted to, and how the biases in one population (e.g., ADHD) parallel and/or can be differentiated from another population (e.g., schizophrenia). Indeed, the insights from these studies indicate that information-processing biases associated with a specific mental disorder exert a discerning influence depending on the type of creative operation in question.

Specificity of information-processing biases in creative cognition: attention-deficit/hyperactivity disorder

Diverse aspects of creative cognition were investigated in adolescents with ADHD, for instance, and the findings indicated that, for the most part, the clinical group performed comparably to the matched healthy control group on almost all the tested measures of creativity (conceptual expansion, fluency and originality in the alternate uses task, originality in creative imagery, insight problem solving) (Abraham *et al.*, 2006). Two creative cognition measures were, however, associated with significant and, at first glance, seemingly opposing findings.

On the constraints of examples task, which requires the generation of a novel response (inventing a new toy) following exposure to salient distractors (examples of three novel toys that were engineered to have three core features in common), the ADHD group outperformed the healthy control group in that they were more successful at inventing new toys that did not have features in common with the examples. But their information-processing advantage, which was discussed as the positive consequence of being highly distractible, was only limited to this particular facet of creative cognition. The ADHD adolescents, in fact, concurrently demonstrated a significant disadvantage on an alternate facet of creative thinking. The creative imagery task requires that participants invent objects that fall into a pre-specified category (e.g., transport) using three geometrical figures (e.g., cube, cone, handle). The inventions are assessed in terms of their originality (unusualness or novelty) and practicality (relevance or appropriateness). While the ADHD participants were no different from the control participants in the degree of originality associated with the inventions, they were far less able to generate inventions that were functional, practical, or usable. This finding was attributed to the impulsive tendencies that are characteristic of ADHD. Hasty or erratic responses and the resulting lack of appropriate goal-directed planning in this type of generative situation could have resulted in the creation of inventions that were less functional and practical than otherwise.

These findings showcased the importance of assessing different facets of creativity in the same sample. For instance, had the ADHD group only been assessed on a single creativity task, one would have attained only a limited understanding about the specificities underlying their performance, which may have even led to erroneous conclusions (e.g., generally low creative ability in ADHD based on their poor performance on the creative imagery measure). Including a wide range of tasks that tap different operations associated with creativity allows one to also make more specific claims about which aspects of creativity are affected in a particular group and whether these can be related to the cognitive insufficiencies associated with that population.

ADHD is a disorder that is known to be associated with deficits of the top-down frontostriatal system in the brain that manifest in the form of high levels of distractibility, impulsivity, and poor inhibitory control (Bradshaw and Sheppard, 2000; Cherkasova and Hechtman, 2009; Dickstein *et al.*, 2006). It is not difficult to imagine why such factors have been considered to potentially confer specific advantages during creative thinking. For instance, in a working memory task when salient information must be maintained over time in the service of an active goal, it would be imperative to exert optimal inhibitory control to avoid being misled by distractors. The opposite is true in the case of the constraints of examples task when salient information that is highly relevant to the task at hand must be actively inhibited in order to generate a creative response. Healthy participants have difficulties inhibiting salient information because a functional attentional system is optimized to automatically focus on information that is salient or relevant in a particular context. As a result, these semantic distractors interfere with and exert a strong influence on the ability of the healthy participants to generate a novel idea. The ADHD group would be less affected by the pre-exposure to relevant semantic information because their increased distractibility causes their attention to be readily diverted away from any particular focus. This ordinarily detrimental factor in their overall cognitive functioning translates to an advantage in the constraints of examples task, thereby enabling the ADHD group to outperform healthy participants.

So the constraints of examples task provides a unique context in which the ordinarily negative bias of poor attentional control and increased distractibility associated with ADHD can be advantageous. While this finding is interesting in itself, the next step that can be, or indeed must be, explored at such a juncture is to determine why this advantage is only specific to this particular task. What sets the constraints of examples task apart from the other tasks of creativity? The creative cognition approach would emphasize a consideration of the contextual factors to determine the differences. To follow from that perspective then, in what manner is the context within the constraints of examples task different from that of other creativity tasks, such as the conceptual expansion task? To abet the discussion of the issue of context further, it will be useful to first briefly explore other findings in association with the constraints of examples task in comparison to other creative cognitive measures.

Specificity of information-processing biases in creative cognition: schizophrenia

Following the study on adolescents with ADHD, a more extensive investigation of creative cognition was carried out on adults with chronic schizophrenia relative to healthy matched control participants (Abraham *et al.*, 2007). Schizophrenia is an exceedingly heterogeneous disorder that, like ADHD, is characterized by poor top-down attentional and cognitive control. But the magnitude of the insufficiencies is far more comprehensive in the case of schizophrenia. Hallmark deficits associated with this condition are in the domains of executive function, working memory, inhibitory control, and fluency, particularly in the presence of negative and thought disorder symptoms (Kalkstein *et al.*, 2010; Lesh *et al.*, 2011).

A number of questions were explored in the study. Would the results of the schizophrenia study parallel those of the ADHD study, given that both disorders demonstrate some overlap in the negative information-processing biases particularly in the domain of frontostriatal function that subserves cognitive control? Or was it necessary to take a new factor into account in the equation – namely, the degree of severity of the information-processing biases? For instance, do the predictions concerning directional influence of information-processing biases during creative thinking necessarily vary as a function of the severity of the deficits? In fact, can this be taken one step further to determine to what degree executive dysfunction in schizophrenia modulates performance on the creative cognition variables?

The findings of the study revealed that except for the constraints of examples task, when they fared comparably to the healthy control group, the schizophrenia group performed worse on all other creative cognition measures. So, here again, the constraints of examples task stands out distinctly from the other creativity tasks. Moreover, a high degree of thought disorder symptoms among the schizophrenics was associated with poorer performance across all the executive function measures but better performance on the constraints of examples task. The negative bias in this case of executive dysfunction may be the very same grounds for the relative cognitive advantage associated with thought disorder on this task. Thought disorder is characterized by conceptual disorganization and the tendency to be continually diverted from an intended direction in thinking (Payne, 1973). This kind of disorderly "digressive" thinking, or the inability to stick to a logical train of thought because of involuntary access to irrelevant conceptual representations, would more easily enable the overriding of the conceptual restrictions actively posed by the constraints of examples task. A similar logic was applied earlier to explain the ADHD group's superior performance on the same task.

The next issue was to determine to what degree the schizophrenics' poor performance on the creativity measures could be explained by their deficits on frontal lobe measures of top-down executive function and cognitive control. The findings revealed a most fascinating dissociation in that a partial or full mediation by executive function measures was found only on some measures of creative cognition (insight problem solving, practicality in creative imagery, fluency in the alternative uses task) but not on others (conceptual expansion, originality in creative imagery, originality measure in the alternate uses task).

An ad hoc examination of the contextual differences between the tasks was carried out with a view to dissociate the creativity measures in terms of the extent to which they draw on the defining components of creativity such as originality and relevance. A response is customarily defined to be creative in the extent that it is original (novel/unique) as well as relevant (appropriate/fitting) to a given end (Hennessey and Amabile, 2010; Runco, 2004). While the schizophrenics exhibited suboptimal function across almost all facets of creativity, performance differences on the creativity measures that assessed the originality of generated responses were not linearly modulated by performance on the executive function tasks. The opposite was true of measures that assessed the relevance and fluency components of creativity, such as the propensity to make functional responses (practicality – creative imagery), generate a large number of responses (fluency – alternate uses), or employ effective strategies to overcome functional fixedness (insight – problem solving).

So the findings suggested that impairments at the level of executive function are accountable for deficits on select facets of creative cognition such as fluency and relevance, which require functional goal-directed thinking for optimal responses, but not in contexts that require originality. The issue of context and its effects on the influence of information-processing biases surfaces once again here and it is one that will be explored in more detail within the next section.

Contexts: types and influences

The modulatory role played by different types of contexts in the top-down control on information processing has yet to be comprehensively addressed in cognitive psychology. David Hemsley (2005) highlighted a number of distinctions that beg clarification in addressing the issue of context due to the sheer variety in the types of contextual input: temporal or spatial, tonic or phasic, inhibitory or facilitatory, and arising due to contextual priming or executive control. The last category bears some parallels to the concept of cognitive contexts in contrast to socioaffective or perceptual contexts in an alternative classification of contexts (Park *et al.*, 2003). One type of cognitive context includes contextual effects provided by stored representations in long-term memory, and which can be direct or indirect and explicit or implicit. An example of the workings within this kind of context would be in a semantic priming task when past experience and associations between stored representations in memory would influence the readiness to respond on a lexical decision task. Another type of cognitive context is the kind provided by task-relevant information that is actively held in working memory. An example for the effects of this type of context is the AX-type continuous performance task, in which the subject is presented with a series of letters and is required to respond to an X only if an A preceded it.

In order to understand the contextual differences between the creative cognitive measures tested in the aforementioned studies, it would be useful to relate the operations involved in the tasks using the general framework of Park *et al.* (2003). For instance, the conceptual expansion task and the constraints of examples task are similar in that both assess the

degree to which people are constrained in their responses when explicitly instructed to create something novel. However, the essential difference between the tasks lies in the kind of contextual processing that both necessitate. By providing examples of novel toys with common fundamental elements before allowing participants to generate a novel toy, the constraints in the examples task are highly salient and actively interfere with the ability to generate a new toy. This is because it is difficult to overcome or inhibit explicitly pertinent information that is directly relevant to the task at hand. This kind of active inhibition of concrete and relevant information that is called for within the constraints of examples task gives rise to qualitatively different contextual processing demands compared with the conceptual expansion task.

In the latter, the contextual constraints are imposed by the extent to which one's existing knowledge in the form of stored conceptual structures (e.g., concept of an animal) influence the capacity to generate an original response (e.g., create a novel kind of animal). So the contexts that are implicated in the conceptual expansion task are those generated from long-term memory information retrieval. Although the activated schemas regulate and delimit the extent to which one can expand concepts, the contextual effects do not actively impinge on one's ability to widen conceptual structures to the extent that it does during the constraints of examples task. So while the constraints of examples task is primarily influenced by "active" or explicitly salient contexts in short-term memory, the conceptual expansion task appears to be mainly influenced by implicit or "passive" contextual effects in the form of stored representations of concepts in memory.

Just as in the case of the conceptual expansion task, passive contexts also exert a modulatory influence on other measures of creativity such as the creative imagery and alternate uses tasks. There is an underlying commonality between these three measures. All assess the capacity to make original or unusual responses albeit in different generative situations and with differing degrees of abstraction. There is far less active intrusion of interfering, salient, and recently activated representations in any of the tasks. In the case of the creative imagery task, the passive contextual processing is directed by the predetermined categories that limit the nature of the conceptual structures that are activated. Within the alternate uses task, passive contextual constraints are posed not only by the prepotent use for the objects, but also by the properties of the objects themselves, such as their weight, shape, size, flexibility, and so on. Indeed, performance on the conceptual expansion task is positively correlated with performance on the originality dimensions of the creative

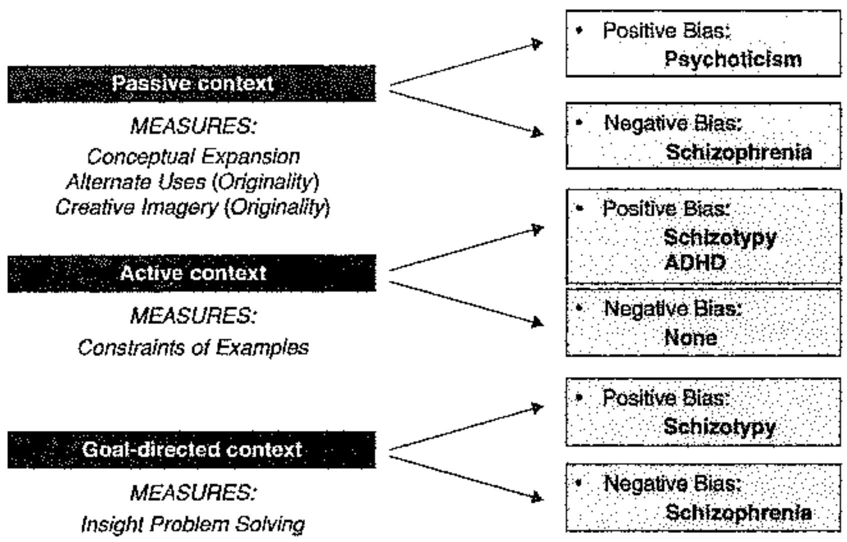

Figure 5.2 Types of top-down or contextual influences on information processing during creative idea generation and their associated findings related to positive versus negative biases

imagery task and the alternate uses task (Abraham *et al.*, 2005, 2006, 2007). This is indicative of underlying similarities between the cognitive operations that are employed when performing these tasks.

So this classification of active versus passive contexts in the top-down control of information processing during creative thinking was proposed to explain contextual influences during divergent creative thinking, when active contexts refer to conditionally salient representations in short-term memory, and passive contexts refer to implicitly activated generic representations from long-term memory (Abraham and Windmann, 2007) (Figure 5.2). While this differentiation plausibly explained some of the differences between the contextual factors involved in many of the creative cognition measures, this was not true of all the tasks that were assessed. The process of insight during creative problem solving was a specific exception to this case.

Insight is held to be a phenomenon that goes hand in hand with creativity and it is said to occur when a solution to a problem appears suddenly as a result of a perspective shift or after overcoming functional fixedness. It is typically assessed by means of the remote associates task or problems of analytical reasoning (Bowden and Jung-Beeman, 2003; Weisberg, 1995). What makes insight tasks different from other measures of creative thinking is that insight problems involve convergent thinking given that there is only one ostensibly correct or viable solution to the problem. In contrast, the aforementioned creativity measures involve divergent thinking when the problem is open-ended with an unlimited number of potential solutions to solve it. Unlike the case of the divergent creativity measures, both the means state and the goals state are clear in the case of the insight problems and participants have to work their way through the operations state in order to reach the prescribed goal. As the contextual factors in insight problem-solving tasks are not entirely comparable to the other tasks of creativity cognition, a third kind of context – namely, the goal-directed context – is introduced to explain the contextual factors that exert an influence in this situation. The link between creativity and mental illness will be explored next from the perspective of the influence of different contexts on information-processing biases.

The relationship between mental illness and creativity

In order to determine the accuracy of the idea that the propensity for mental illness confers a specific cognitive advantage in terms of creative ability, it is vital to integrate the findings from the previously discussed neuropsychological findings on the clinical groups (schizophrenia and ADHD) with the findings from related behavioral investigations on subclinical populations (schizotypy and psychoticism). Assessments of subclinical samples are widely carried out in an effort to evaluate whether high-risk healthy populations (e.g., high schizotypy individuals), who exhibit a high degree of psychosis-relevant personality traits, also display the same information-processing biases as their related clinical group (e.g., schizophrenia). Indeed there is evidence of parallels between information-processing biases in the form of reduced negative priming and latent disinhibition seen in clinical groups like schizophrenia and subclinical populations such as high psychoticism or schizotypy groups (e.g., Minas and Park, 2007; Vink *et al.*, 2005).

The constructs of psychoticism and schizotypy are similar in that both concepts stem from a dimensional approach whereby psychosis and normalcy are viewed as two ends of a continuum and varying degrees of each of these personality traits are experienced along this continuum (Claridge, 1997). So the idea is that studying healthy individuals who possess a high degree of such traits, and in doing so display some degree of predisposition for the clinical disorder, allows us to understand the workings of the information-processing biases related to the disorder without the burden of having to control for the kind of variables that can exert major confounding effects in clinical studies such as medication, comorbidity, etc. Schizotypy is explicitly related to traits typically found in the schizophrenia spectrum of disorders, whereas psychoticism, which emerged from H. J. Eysenck's *Einheitpsychose* conception of mental illness, is related to traits typical of psychosis in general. Not only have high psychoticism and high schizotypy trait individuals been reported to exhibit similar, albeit subtler, information-processing biases that have also been reported in schizophrenia, there is abundant evidence to show that they also display superior creativity skills compared with their low trait counterparts (e.g., Carson *et al.*, 2003; Folley and Park, 2005; Gibson *et al.*, 2009; Stavridou and Furnham, 1996).

But the question of specificity also arises in this situation. To which select creative operations are the information-processing biases limited to in the case of psychoticism and schizotypy? Do the differences between the performances of the high psychoticism and schizotypy groups relative to the schizophrenic and ADHD groups reveal hints about the neurocognitive mechanisms underlying these biases? After all, there is considerable variation in the degrees of disruption in top-down information processing that manifests as suboptimal attentional and cognitive control associated with each of these populations. The severity of the cognitive deficits is severe in the case of schizophrenia, moderate in the case of ADHD, and only mild in the case of psychoticism and schizotypy (Figures 5.2 and 5.3). How does this varying degree of top-down dysfunction affect the influence of these information-processing biases during creative thinking? The investigations that have assessed different creative cognition measures as a function of psychoticism and schizotypy indicate that such populations are not associated with any disadvantages in creative thinking. The fact that the ADHD and schizophrenia groups were in fact associated with disadvantages in creative performance on some measures indicates that the "degree" of reduced top-down to executive control has a direct bearing on creative performance.

That does not explain the whole story though, because the information-processing advantages associated with psychoticism and schizotypy do not overlap with one another (Figure 5.2). While psychoticism was associated with better performance on the conceptual expansion task (passive context) and the originality measure of the creative imagery task (passive context), schizotypy was associated with superior performance on the constraints of examples task (active context) and during insight in problem solving (goal-directed context). So it seems necessary to consider a second factor when interpreting the findings – namely, the "type" of top-down control in terms of the differences in the contextual processing demands of the tasks in question. To briefly recapitulate the findings related to advantages and disadvantages in generating

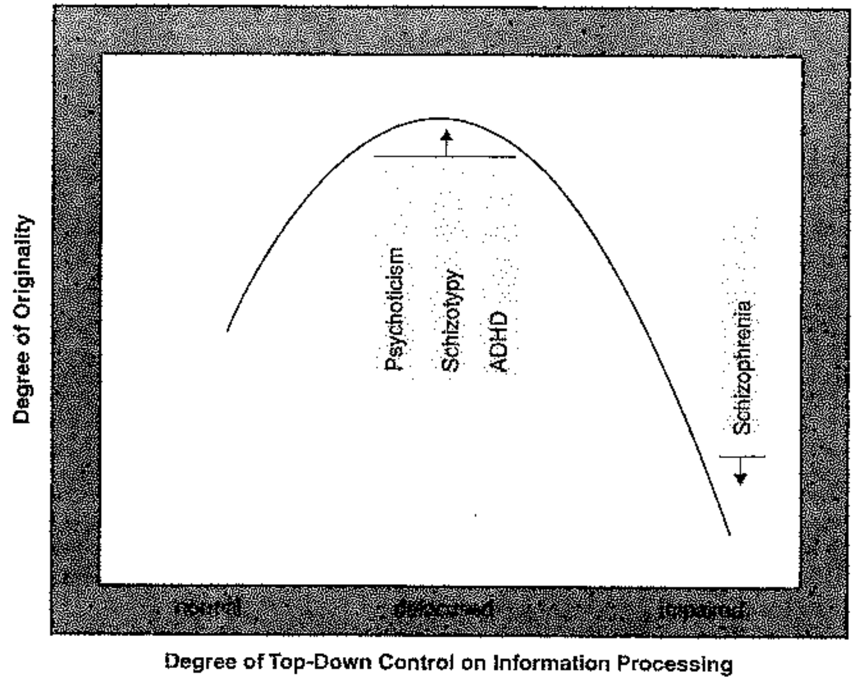

Figure 5.3 The relation between the propensity to generate original responses during creative thinking and the degree of functionality in top-down control of information processing associated with clinical and subclinical populations

original responses during creative idea generation, the ADHD group exhibited only an active contextual processing advantage during creative idea generation. The schizophrenics exhibited goal-related and passive contextual processing deficits but displayed no impairments in active context processing nor advantages otherwise. High levels of schizotypy were associated with advantages in processing involving active contexts and goal-directed contexts, whereas passive contextual processing advantages were related to the presence of high psychoticism traits. Such findings indicate that the constructs of psychoticism and schizotypy indeed appear to represent discrete facets within the dimensional conception of schizophrenia.

So both the "type" of affected top-down context as well as the "degree" of reduced top-down control have an impact on creative performance. The global picture that emerges from the integration of these disparate findings indicates that the simplest way of understanding the effects of alterations in top-down control on creativity is in terms of an inverted-U-shaped function (Figure 5.3). Defective top-down control, as seen in schizophrenia, is accompanied by markedly poor performance across most measures of originality in creativity. On the other hand, defocused top-down processing that is characteristic of a moderately impaired clinical group like ADHD, and is also present to a milder extent in the presence of a high degree of schizotypy and psychoticism traits, is associated with higher originality in creative idea generation. So while diffuse or defocused top-down activation confers some degree of cognitive advantage on select processes of creative cognition, too much top-down control (customary levels) or too little top-down control (completely disrupted or impaired top-down control) may pose a hindrance or even be detrimental to the same.

In demonstrating the role played by both the degree and type of contextual or top-down influences in creative idea generation, the aforementioned findings have not only allowed for a deeper understanding of the relation between creativity and mental illness. They also provide enough fodder to allow for viable predictions to be made regarding the neural underpinnings of creative cognition and individual differences in creative ability. These ideas will be explored in the final section of this chapter.

Neural correlates of creativity: predictions

Relating creative cognition to brain function has been the subject of electrophysiological research for several decades now, but the recent past has seen a great surge in brain-related investigations on creative thinking in the form of neuroimaging (for a review, see Dietrich and Kanso, 2010) and neuropsychological studies (Reverberi *et al.*, 2005; Shamay-Tsoory *et al.*, 2011). The study of creativity and brain function has primarily focused on issues such as enhanced creative or artistic ability following, or as a function of, brain damage (Miller *et al.*, 1996; Seeley *et al.*, 2008), left versus right brain contributions to creativity (Carlsson *et al.*, 2000; Seger *et al.*, 2000), and the brain basis of high or exceptional creativity in intact brains (Fink *et al.*, 2009; Limb and Braun, 2008). Bringing together the insights from these studies is a highly challenging endeavor. This is because such an undertaking requires making generalizations concerning the neurocognitive mechanisms underlying creative thinking, but what is still lacking in the literature are theoretical frameworks that can guide us in doing so (Abraham, 2012). The problem is compounded by the fact that a wide range of creativity tasks, which are difficult to compare with one another, have been employed in neuroscientific studies on creativity (Arden *et al.*, 2010) and few authors have attempted to

assess the differences and similarities between the employed tasks and the cognitive operations they necessitate.

So can we use the previously discussed insights from the performances of the clinical and subclinical groups on the creative cognition measures to aid us in formulating predictions for the brain basis for creativity? The commonality between the cognitive profile associated with schizophrenia and ADHD is that, although the insufficiencies are far more severe in the case of schizophrenia, the frontostriatal system of executive and cognitive control is compromised in both clinical disorders. The brain areas that are especially relevant for executive function and cognitive control are those that belong to the frontostriatal system and include a network of regions in the lateral prefrontal cortex, anterior cingulate cortex, and the subcortical structures within the basal ganglia (Badre, 2008; Chow and Cummings, 2006). What are the predictions that can be made with regard to the specific role of the frontostriatal system in creative thinking, such as in the case of neurological damage to brain areas within this system?

The findings from the schizophrenia study provide important clues in this context. The results indicated that the degree of intact executive function fully or partially modulated performance on creativity tasks that assessed fluency and relevance, but did not exert a significant influence on tasks that primarily included a strong originality component. So although poor executive function was related to poor performance on relevance- and fluency-based creativity tasks, it did not fully explain poor performance on originality-dominant creativity tasks. Damage to the frontostriatal system could therefore be expected to be accompanied by poorer performance on measures of relevance and fluency, such as practicality in creative imagery and fluency in the alternate uses task, as well as on tasks that require goal-directed thinking, such as in the insight problem-solving tasks. On the other hand, the insights from the findings of the ADHD study suggest that insufficiencies at the level of the frontostriatal system would also be expected to be associated with better performance on creativity tasks that are marked by active contextual demands, such as in the constraints of examples task. This is because the increased distractibility and poor attentional control that result from damage to this neural circuit are the very factors that can abet performance on this task.

Because the capacity to generate original responses, particularly in the case of passive contextual processing tasks, was not fully mediated by executive function, other candidate regions in the brain also need to be considered. Generating an original response requires the activation of distantly or weakly connected conceptual nodes in the semantic knowledge network. The uniqueness of generated responses could therefore depend on how semantic networks are organized in the anterior temporal lobes and accessed through related structures in the semantic cognition system, such as the ventrolateral prefrontal cortex and the superior temporal cortex (Turken and Dronkers, 2011; Wong and Gallate, 2012). Damage to regions belonging to the semantic network of the brain would be expected to compromise the ability to generate original responses during idea generation as well as affect fluency during creativity.

Given that the generation of creative ideas involves not only the access and selection but also the integration of previously unrelated conceptual knowledge, the frontopolar cortex would also be expected to play a critical role. The frontopolar cortex is involved in many aspects of higher-order cognition where its overarching role is to integrate information from two or more separate cognitive operations (Ramnani and Owen, 2004). This brain region, which is located in the anteriormost part of the prefrontal cortex, is singular from the point of view of hominid evolution in that it has increased greatly not only in size but also in connectivity with other higher-order association areas in the brain (Semendeferi *et al.*, 2001). It is no wonder then that this region is purported to exert the highest level of cognitive control at the level of abstract representations (Badre, 2008) and is therefore likely to be extremely relevant in the context of creative thinking.

Conclusions

Studies that have explored the link between creativity and mental illness indicate that the differences between the type of contextual influences as well as the degree of cognitive dysfunction fundamentally influence our capacity to be creative. These insights are particularly valuable because neuroscientific investigations of creative thinking using neuroimaging or electrophysiological techniques are fraught with problems, both conceptual and methodological, that pose considerable limitations on the degree to which hypotheses can be optimally tested (Abraham, 2012; Sawyer, 2011). Investigations of creativity and mental illness therefore not only inform us about the dynamics of this fascinating association, they also offer a unique backstage pass to unravel the cognitive and neurocognitive mechanisms that underlie creative thinking.

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For my brother
David S. Kaufman
(1968–2004)

Of all sad words of tongue or pen,
The saddest are these: "It might have been."
(John Greenleaf Whittier)

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