The Shifting Sands of Creative Thinking: Connections to Dual Process Theory

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Abstract

Dual process models of cognition suggest that there are two types of thought: (1) autonomous *Type 1* processes, and (2) working memory dependent *Type 2* processes that support hypothetical thinking. Models of creative thinking also distinguish between two sets of thinking processes: those involved in the generation of ideas, and those involved with their refinement, evaluation and/or selection. Here we review dual process models in both these literatures and delineate the similarities and differences. Both generative and evaluative creative processing involve elements that have been attributed to each of the dual processes of cognition. We explore the notion that creative thinking may rest upon the nature of a shifting process between Type 1 & 2 dual processes. We suggest that a synthesis of the evidence bases on dual process models of cognition and of creative thinking, together with developing time-based approaches to explore the shifting process, could better inform the development of interventions to facilitate creativity.

Keywords: creativity, dual process model, associative thought, analytic thought, Type 1 and Type 2 thinking

Dual Process Models of Cognition

The notion that there are different types of thought processes extends at least back to the Ancient Greeks who distinguished between intellectual intuition and knowledge received by the senses. The nature of intuition and the distinction between sensory knowledge and reasoning also preoccupied later philosophers such as Descartes, Locke, Kant, Bergeson, and Russell (see Frankish, 2010). More recently, Cognitive Psychology has provided increasing evidence of two kinds of thinking processes and has made significant progress towards understanding their nature and operation (Evans, 2008; Evans & Stanovich, 2013; Frankish, 2010; Stanovich & Toplak, 2012). In one early formulation, Stanovich (1999) distinguished between 'System 1' and 'System 2' thinking. System 1 was conceptualised as corresponding to intuitive processing whilst System 2 was viewed as reflective. However, use of the terms Systems 1 and 2 has been discouraged (e.g. Evans, 2008) because they imply singular entities that are not supported by research (e.g. Glöckner and Witteman, 2010). Moreover, Stanovich (2004, 2009) subsequently decomposed System 1 into The Autonomous Set of Systems (TASS) that have in common their fast, automatic, unconscious nature, but which differ in their diverse foci, and decomposed System 2 into the reflective and algorithmic minds.

Later accounts speak in terms of 'Type 1' and 'Type 2' thinking processes (e.g. Evans, 2008; 2009). As theorists attempted to synthesise the work of different authors (e.g. Evans, 2003, 2008; Smith and DeCoster, 2000; Stanovich, 1999) an increasingly elaborated set of features was associated with each type of thinking. Type 1 processes were described as rapid, nonconscious, automatic, and associative in nature, corresponding to our gut reactions and intuitions. They were seen as high capacity, able to rapidly combine (or associate) information

that has been implicitly stored in memory, over long time periods, with sensory information from the current context without effortful thinking and intervention; that is, they are reflexive. Type 1 processes have been regarded as contributing to experience-based decision making and have been considered as largely independent of cognitive ability. They are often thought to lead to biased responses. In contrast, Type 2 processes have been described as slow, controlled, effortful, conscious, and analytic. Thinking using these processes has been seen as capacity limited and rule based, applying these rules explicitly to current information; that is, it is reflective. Responses based on Type 2 processes are often regarded as normative and rational, as contributing to consequential decision making, and as correlated with cognitive ability.

However, the burgeoning list of features associated with Type 1 and 2 processes has led to a range of criticisms of dual process accounts including that the range of features ascribed to each type of thinking process are imperfectly aligned to each other and the overarching processes (Keren & Schul, 2009) and that an alternative rule-based, unisystem model can explain human judgement (Kruglanski & Gigerenzer, 2011). In response to these criticisms, Evans and Stanovich (2013) suggested that there are just a few characteristics that differentiate Type 1 and Type 2 thought: Type 1 processes are autonomous and do not require working memory, whilst Type 2 processes require working memory and are 'cognitively decoupled' to prevent real world representations from becoming confused with mental simulations, thereby supporting hypothetical thinking (see also Stanovich & Toplak, 2012). They suggested that the larger feature sets previously associated with Type 1 vs 2 thought should be regarded as frequent correlates, not defining characteristics; that is they are neither necessary nor sufficient (Evans & Stanovich, 2013; Stanovich & Toplak, 2012).

A further issue is how the two types of processes interact. According to what Evans (2008) terms a "default interventionist" theory, Type 1 processes provide fast, preconscious information to working memory that is used to guide behaviour by default, unless analytic reasoning intervenes (e.g. Evans, 2006; Kahneman & Frederick, 2002). According to what Evans terms a "parallel-competitive" theory, implicit knowledge from Type 1 processes and explicit knowledge from Type 2 processes compete to control behaviour (e.g., Sloman, 1996; Smith & DeCoster, 2000). A third process may control the shift between Type 1 and Type 2 thinking (Evans, 2009; Stanovich, 2009). Use of type 1 and 2 thought may vary as a function of disposition, such that some individuals are more inclined to use Type 1 processes and others Type 2 processes (e.g., Epstein, 2003; Stanovich, 1999). We contend that the nature of the interaction between Type 1 and 2 processes may be a key source of individual differences in creative thinking ability and of variation in creative thinking across time by a given individual. Before we consider how this interaction might influence creative thinking we consider the relationship between dual process models of cognition in general and dual process models of creativity specifically.

Dual Processes in Creative Thinking

Allen and Thomas (2011) illustrated that both Type 1 and 2 processes are implicated at each of a five-stage model of creative thinking, the origins of which can be seen in Wallas' (1926) four-stage description of the creative process. Here we draw back from Allen and Thomas' five stages to focus on just two fundamental processes of creative thinking emphasised in many recent models: developing ideas and evaluating them. This allows us to

survey the wide range of theories of creative thinking that incorporate these two processes and thereby to explore the extent to which they map onto Type 1 and 2 thinking processes.

Our emphasis on idea generation and evaluation in creative thinking can be traced to contemporary definitions of creativity. Kaufman and Sternberg (2010, p. *xiii*) focus on the creative outcome and suggest that a creative response must be "*novel, good, and relevant*". Others add that creative responses should also be surprising (Boden, 2004; Simonton, 2012). Further definitions of creativity include emphasis on the internal creative process (Plucker, Beghetto & Dow, 2004, Gabora, 2010a) and the external social context (Csikszentmihalyi, 1996, Plucker, Beghetto & Dow, 2004). Despite these varying views, most contemporary researchers agree on a generic definition that creative outcomes must be both original and of value within a given domain. Whilst, generative processes are required to formulate original ideas, evaluative processes are required to select and/or refine those ideas into a form that is of value (see also Howard-Jones & Murray, 2003)

The evaluative phase may incorporate convergent thinking, the process of homing in on a single solution. However, an assumption underlying several measures of creativity (e.g. the Alternate Uses Test and the Torrance Tests of Creative Thinking) is that creativity requires only divergent thinking; the generation of many different ideas. In addition, Epstein (2003) located creativity in just one type of thinking process in his Cognitive-Experiential Self Theory (CEST) of personality. This posits two information-processing systems: an experiential system that maps onto Type 1 processes, and a rational system that maps onto Type 2 processes. Epstein suggests that creativity is a product of the experiential system because it can use associations to generate ideas while a linear-processing rational system cannot. In support, an experiential

thinking style was positively correlated with performance on divergent thinking tests (Norris & Epstein, 2011). However, scoring of these tests focused on fluency—how many creative ideas are generated—whilst neglecting assessment of the extent to which the responses were of value, even though scoring of divergent thinking tests can be readily adapted to include measurement of the value of ideas (see Silvia, 2008). To produce responses that are valuable, it seems reasonable that analytic Type 2 processes would be required emphasising the need for dual process models of creativity.

Most other models of creative thinking do include the dual processes of generation and evaluation and we next review key models, starting with the work of Guilford (1950, 1956), to examine their relationship to each other and to dual process models of cognition. While dual process models of creativity frequently appeal to the language of dual process models of cognition (e.g. Gabora & Aerts, 2009; Howard-Jones & Murray, 2003; Kaufman, 2011) these two sets of dual processes cannot always be straightforwardly mapped onto each other.

Guilford's (1956) Structure of Intellect Model, distinguished between *divergent* and *convergent* thinking processes and can be viewed as an initial, contemporary dual process model of creative thinking. Several authors have suggested that divergent processes are associative in character, such that items encoded in memory are combined with information from the current context in a state of defocused attention (Gabora, 2010a; Martindale, 1999). Conversely, convergent processes are seen as analytic in character, and thought to predominate in the refinement and evaluation of solutions. Thus, in some respects divergent and convergent thinking appear to map neatly onto typical correlates of Type 1 and 2 processes. However, there are important differences. Although divergent thinking may be

spontaneous and associative in nature, with solutions sometimes appearing in a flash of insight, performance on divergent thinking tasks can involve processes that are effortful and deliberate (e.g., Ward, 1994). This could imply that divergent thinking does not map neatly onto Type 1 processes (Frankish, 2010). Furthermore, experiencing a flash of insight indicates convergence on an initial idea or solution that is ripe for testing and/or development but this may arrive during an autonomous incubation process (see Wallas, 1926) logically implying that convergent thinking can arise from Type 1 as well as Type 2 processes. Thus, a simple mapping of divergent thinking onto Type 1 and convergent thinking onto Type 2 processes is not possible.

Basadur, Graen and Green (1982; see also Basadur, 1995) propose the notion of ideation-evaluation cycles. They distinguish between three major stages in the creative thinking process — problem finding, problem solving, and solution implementation — and suggest that ideation and evaluation are involved at each stage in varying degree according to the domain. For instance, domains that emphasise problem finding have a high ratio of ideation to evaluation, whereas domains that emphasise solution implementation show the converse. Their emphasis on cycling between ideation and evaluation has parallels with the proposal of Allen and Thomas (2011) that Type 1 and 2 processes are involved at each stage of creative thinking. Basadur *et al's* work begs the question of how successfully individuals can cycle between ideation and evaluation but is not framed at a level that helps us understand the fundamental mechanisms of ideation and evaluation or their relationship to dual process models of cognition.

An early, more mechanistic, conception of the dual processes of creative thinking is the "Blind-Variation-and-Selective-Retention" model (BVSR; Campball, 1960). Simonton (1999,

2007, 2010, 2011, 2012, in press) elaborated this into a *Darwinian theory of creativity*. BVSR proposes that we generate new ideas through a trial-and-error process involving *'blind'* generation of ideational *variants* followed by *selective retention* of the fittest variants for development into a final product. The variants are referred to as 'blind' because the creator has no subjective certainty about whether they are a step in the direction of the final creative result. Further, they are viewed as independent of the environment, each other, and of their likelihood of selection.

There is an intuitive appeal to BVSR; as do biological species, creative ideas exhibit the kind of complexity and adaptation over time that is indicative of an evolutionary process, both when they are expressed to others, and in the mind of a single creator (Gabora, 1997; Terrell, Hunt & Gosden, 1997; Thagard, 1980; Tomasello 1996). However, numerous problems have been identified with BVSR as a conceptual framework for creativity (Dasgupta, 2004; Eysenck, 1995; Gabora, 2005, 2007, 2010b, 2011; Sternberg, 1998; Weisberg, 2004).

Nevertheless, BVSR has interesting features such as Campbell's conception that selection operates through "*exploration of a substitute representation of the environment the solution being selected from the multifarious exploratory thought trials"*. This conception clearly relates to the 'cognitive decoupling' of Type 2 thinking (Stanovich & Toplak, 2012). However, Campbell's discounting of the role of the environment in idea generation does not sit well with findings that Type 1 processes often combine current contextual information with prior knowledge (Evans, 2008). Further, the assumption of BVSR that successively generated ideas are unrelated is contradicted by empirical studies. For instance, Nijstad & Stroebe (2006) show that when participants generate ideas for problems, such as "*what can everybody do to*

improve or maintain one's own health", temporal clusters of semantically related ideas occur (see also Feinstein, 2006).

A dual process theory of creativity that is consistent with these findings is Finke, Ward and Smith's (1992) Genoplore model, which divides creative thinking into two overarching stages of idea generation and *exploration*. These are further subdivided into smaller stages with multiple operations available at each stage. For instance, generation can involve retrieval of items from memory, formation of associations between items, and synthesis and transformation of the resultant 'pre-inventive' structures. Exploration can involve identifying the attributes of these pre-inventive structures and considering their potential function in different contexts. Evidence for this model comes from findings that when people generate ideas they appear to make use of exemplars from the same or a related domain and they endow the new idea with many of the attributes of the previous exemplar. For instance, participants endow imaginary alien creatures from a planet very different to earth with typical features of animals on earth, such as arms and/or legs (Ward, 1994). Ward refers to this process as *the path of least resistance* (see also Ward & Kolomyts, 2010).

The Genoplore model can be partially mapped onto dual process models of cognition, with the generative phase corresponding to Type 1 processes and the exploration of pre-inventive structures corresponding to Type 2 processes. However, analytic processes may give rise to new ideas and insights (Finke, 1996). Thus, the generation phase appears to involve both Type 1 and 2 processes whereas the exploration phase is consistent with Type 2 processes alone.

The 'Honing Theory' of creativity (Gabora, 2005, in prep.) also posits that people draw on past knowledge when generating new possibilities, expanding on Mednick's (1962) work on flat associative hierarchies. Mednick found that whereas most people have rather steep associative hierarchies (i.e., a given stimulus evokes only highly related items in memory), creative people have flat associative hierarchies (i.e., a given stimulus evokes not just highly related but also remotely related items). Gabora proposes that creative people spontaneously enter a state of flattened associative hierarchies during idea generation (Gabora 2010a; see also Martindale, 1995), and that refinement of an idea occurs through iterative interaction between the current conception of the idea and the individual's internal model of the world, or 'worldview'. Creativity then arises through the joint effects of associative and analytic types of thought and the process of shifting between them in response to task demands (for related views see also Howard-Jones, 2002; Martindale, 1999; Vartanian, Martindale & Kwiatkowski, 2007). In this view, the activation of flattened associative hierarchies, when presented with a task requiring a creative response, facilitates the forging of connections between more remote attributes of ideas and concepts in a contextually bounded way that contrasts with the BVSR view that creative generation is independent of context. The ideas that result from the associative process described by Gabora are then honed by an analytic process characterised by 'spiky' neural activation functions. Thinking becomes more focused on core aspects of the idea and can involve logically testing and elaborating the idea into a final solution, which is likely to require the cognitive decoupling of Type 2 processes.

Gabora's theory of creativity addresses criticisms of BVSR by accounting for observed effects of context and expertise on creative thinking (e.g., Howard-Jones & Murray, 2003;

Vincent, Decker & Mumford, 2002) and gets us closer to an understanding of the fundamental mechanisms underlying creative thought, but there are still aspects to work out. The theory emphasises the importance of the ability to shift from an analytic to an associative type of thought when stuck in a rut, and from an associative to an analytic process following insight, and computer models have shown this shifting to be effective (DiPaola & Gabora, 2007, 2009; Gabora, Chia & Firouzi, 2013; Gabora & DiPaola, 2012). However, there has been little empirical investigation of this shifting in humans.

Further, whilst associative and analytic thinking processes appear to be closely related to Type 1 and 2 thinking, their recruitment may be different. In dual process models of cognition, Type 1 processes either govern behaviour by default or in competition with Type 2 processes. However, the nature of the relationship between these types of process in creative thinking may be different. For example, creative thinking may be characterised by shifting from analytic to associative thinking as suggested in Howard-Jones' (2002) Dual-State model of creative cognition. Howard-Jones suggests that a key barrier to creativity is the notion of 'fixation' (the tendency to rely on previous ideas when generating new ones; cf. Maier, 1931), and proposes strategies to help shift individuals from secondary process, analytical thinking to primary process associative thinking. At present, Gabora's theory is uncommitted to where on the spectrum from associative to analytic the 'default' starting point falls when thinking creatively, and acknowledges that the default point may vary across individuals (see also Basadur *et al.* 1982; Basadur, 1995; Epstein, 2003; Stanovich, 1999). It seems likely that work on dual process models of cognition could usefully contribute to exploring the process of shifting between Type 1 and 2 thinking processes in the context of creative thinking.

Another recent dual process theory of creative thinking, proposed by Nijstad, De Dreu, Rietzschel and Baas (2010), suggests that creativity can arise through two pathways: a *flexibility* pathway and a *persistence* pathway. Greater cognitive flexibility is viewed as generating more categories of ideas, and as more frequent shifting between them, which Nijstad *et al.* argue can lead to greater originality. Thus, the flexibility pathway appears to relate to dual-process models of creativity, such as BVSR, that have suggested that multiple idea variants are generated. However, they argue that exploring a few content categories in depth may also lead to increased originality. Given its focus on a few categories of idea, the persistence pathway appears to relate to other models of creativity that focus on developing ideas, such as Honing Theory. However, the flexibility and persistence model is different from these previous models in that it strongly emphasises deliberative processing under conscious executive control. Indeed Nijstad *et al.* (p43) state "*our model is not applicable to situations in which creativity occurs ''spontaneously'' without intentional effort*". In essence, they argue that the creative thinking described by their model is primarily a product of Type 2 processes. However, they note that the degree of executive control differs between their two pathways. The flexibility pathway uses broad and inclusive cognitive categories, flexibly shifts among categories, approaches, and sets, and establishes more remote associations. The authors suggest that, in the case of individuals with high mental ability, this may be helped by reduced latent inhibition, which allows more distant associates and ideas to enter working memory. Such individuals may have the necessary cognitive control to benefit from reduced inhibition because they are also able to evaluate and identify the inevitable proportion of poor solutions that result if more are allowed. The persistence pathway achieves creative outcomes through a systematic and effortful

exploration of possibilities and an in depth exploration of only a few categories or perspectives. These systematic processes are likely to start with readily available solutions. Less obvious, more original, solutions only arrive if the individual persists in generating more ideas within a category. Because systematic search is involved in this pathway they argue that higher levels of executive control are required than for the flexibility pathway. When persisting, individuals will be less distractible, but also less flexible because more distant associates are filtered out.

Nijstad *et al.* note that because the persistence pathway reduces flexibility it might appear to be negatively related to the flexibility pathway. However, they argue that this is not the case because individuals can shift from a flexible mode, where they discover new and promising approaches to a task, to a systematic, persistent mode where they further explore these approaches. In describing this shifting process the distinction from previous 'generate and explore' models is somewhat lost. It again appears that creativity may most likely result from the joint operation of both pathways such that the flexibility pathway helps with the development of originality and the persistence pathway with the elaboration of ideas into those that will prove useful. As such the pathways might not appear conceptually to be independent 'dual-routes' but necessarily coupled stages in a creative thinking process, much as proposed in other work. However, arguing against this, Nijstad *et al* (pers. com.) find that the correlation between their measure of flexibility – the number of categories generated – and their measure of persistence - the within category fluency (average number of ideas per category/total number of ideas generated) – decreases over time. This might suggest that on a given task, rather than shifting between pathways individuals become increasingly entrenched in the processing associated with one pathway over time.

Nijstad *et al.* provide a meta-analysis of the relationship between their measures of flexibility and persistence on the originality and feasibility of creative ideas. They find a correlation of 0.36 between flexibility and originality that is much stronger than the correlation of 0.12 between within-category-fluency (persistence) and originality. This suggests that the flexibility pathway is more strongly implicated in the overall originality of ideas, although Nijstad et al cite evidence that the relationship between within-category-fluency and originality increases for the originality of ideas within a particular category (Rietzschel, 2005; Rietzschel, Nijstad & Stroebe, 2007). This latter finding somewhat strengthens the argument that persistence can indeed increase originality, but still overall originality is much more strongly related to flexibility than to persistence. In addition, Nijstad *et al* find no factors that significantly correlate with feasibility of ideas other than originality, which is negatively correlated. This, coupled with a greater emphasis on measures of originality, leaves somewhat unaddressed in their model the question of how creative ideas that are both original and of value come about. One possibility arises from examination of the effects of mood state on creativity. De Dreu, Baas & Nijstad (2008) find that negative activating mood states enhance persistence, which they argue should benefit within category fluency. However, another possibility is that negative activating mood states also improve the evaluation of creative ideas as observed by Sowden & Dawson (2011) thereby enhancing their value.

In summary, Nijstad *et al* provide strong evidence for a flexibility pathway that promotes creativity through increasing the originality of ideas, but the evidence for the impact of a second persistence pathway on originality is weaker, nor does persistence relate to the feasibility (value) of ideas. The factors predicting the latter are largely unexplained by their

model. Thus again, whilst dual process models of cognition clearly relate to Nijstad *et al*'s ideas, the mapping is not straightforward. There appears to be a clear relationship between correlates of Type 1 processes and the flexibility pathway in that both may be associative in character, but the flexibility pathway also involves deliberative processing, a Type 2 process, and evaluation of ideas by an "*idea monitor*" to keep them on track. Monitoring and cognitive control are viewed as one component of Type 2 processing (e.g. the '*reflective mind*' of Stanovich, 2009), as a separate Type 3 process (Evans, 2009) or as a product of metacognitive processes (Thompson, 2009). Further, although both Type 2 processes and the persistence pathway are hypothesised to make strong use of working memory, the persistence pathway does not appear to contribute to the feasibility of creative ideas whereas a key function associated with Type 2 processes is evaluation facilitated by cognitive decoupling.

In summary, we have looked at two sets of dual process models: general cognitive models and models of creative thinking. Table 1 summarizes the various elements of these models and the relationships between them.

[Insert Table 1 about here]

It is clear that both idea generation and evaluation may recruit Type 1 and 2 processes, and this might suggest the possibility of a four-component model of creative thinking. Although this cannot be ruled out, some recent models of creative thinking do align quite parsimoniously with Dual Process models of cognition, particularly Howard Jones' Dual State model (2002) and Gabora's Honing Theory (2005, in prep.). Nevertheless, the question of how Type 1 and 2

processes interact in creative thinking remains largely unanswered. Although there is general agreement that shifting between the different processes is required for creative ideas to develop (e.g. Basadur, 1982; Basadur *et al.*, 1985; Finke *et al.*, 1992; Gabora & Ranjan, 2013; Howard-Jones 2002; Nijstad *et al.*, 2010), it is not known whether this is different when thinking creatively, how it varies across individuals, and whether it could be trained. These issues are discussed in the next sections.

Cognitive mechanisms of shifting between creative thinking processes

Dual-process models of creative thinking make different predictions concerning the extent to which creative thinking processes operate in series or in parallel. The dual-stage models of Basadur (1995), Howard-Jones (2002), Finke *et al.* (1992) and the theory of the emergence of a creative insight proposed by Gabora and Ranjan (2013) suggest shifting between types of thinking occurs in series. However, Nijstad *et al's* (2010) dual-pathway model suggests that an 'idea monitor', a mechanism that evaluates ideas, continually checks the outputs of idea generation processes in a similar fashion to type 2 processes in default-interventionist dual-process accounts of cognition (Evans, 2008; Stanovich, 2009; Frankish, 2010) or Type 3 processes in Evans' (2009) hybrid model. This suggests that individuals have the mode (or Type) of thinking supporting evaluation available ''on tap' and can apply it to keep idea generation in check. While not necessarily implying that the two types of thinking operate in parallel, Nijstad *et al.'s* (2010) model does suggest that generation and evaluation work more in unison than in the aforementioned serial models. Serial models can be interpreted as implying that it is necessary to disengage one type of thought prior to engaging the other, or to shift along the continuum between analytic to associative thinking (Gabora & Ranjan, 2013).

Different models also propose different mechanisms that enable shifting between types of thinking. Nijstad *et al.* (2010) propose that executive control underlies thinking within both pathways but lower cognitive control is applied in the flexibility pathway when broadening one's attention, while higher cognitive control is applied in the persistence pathway to support systematic search. It has also been suggested that shifting between types of thinking involves differentially adjusting the focus of attention based on the demands of the task at hand (Gabora, 2003; Vartanian, Martindale & Matthews, 2009).

Further, there may be a link between the mechanism responsible for adjustments in cognitive control and the mechanism responsible for adjusting attentional focus. For instance, Kaufman (2011) suggests that, during generative thinking, unconscious cognitive processes activated through defocused attention are more prevalent, whereas, during exploratory thinking, controlled cognition activated by focused attention becomes more prevalent. There is evidence that creative individuals are better able to alter this focus of attention in response to task demands by modulating cognitive inhibition (Ansburg & Hill, 2003; Bristol & Viskontas, 2006; Dorfman, Martindale, Gassimova & Vartanian, 2008; Gabora, 2000, 2003; Vartanian, Martindale & Kwiatkowski, 2007). In addition, shifting between these processes may be more effectively applied by creative individuals over the course of a creative task (Gilhooly, Fiortou, Anthony & Wynn, 2007; Vartanian, Martindale & Kwiatkowski, 2003). However, there is debate about whether shifting happens automatically or under top-down control (Vartanian, Martindale & Matthews, 2009). Perhaps, as Vartanian, Martindale & Matthews (2009) suggest, both top-down and automatic bottom-up processes drive adjustments in the focus of attention,

and whether this mechanism is under conscious control or not, depends on what stage of the task one is at.

Neurobiological mechanisms of shifting between thinking processes

Moving to a neurobiological level of explanation, one potential candidate for a shifting mechanism is the 'salience network' proposed by Menon & Uddin (2010). The salience network incorporates the Anterior Insula and the Anterior Cingulate Cortex (ACC). The ACC has been shown to become active shortly before an insightful solution is reached (Kounios & Beeman, 2009) consistent with it playing a role in the shift from autonomous generative processing to conscious validation. Menon & Uddin (2010) propose that this network serves to shift between a Default Mode Network (DMN) and a Central Executive Network (CEN; see also Raichle, MacLeod, Snyder, Powers, Gusnard & Shulman, 2001; Fox, Snyder, Vincent, Corbetta, Van Essen & Raichle, 2005). They summarise evidence that the DMN shows decreases in activity during cognitively demanding tasks and includes brain regions involved in self-referential and social-cognitive processing, and in processing episodic and autobiographical memory. It has been further suggested that this retrieval of information from memory, both personal and general may facilitate solving problems and developing future plans (Greicius, Krasnow, Reiss & Menon, 2003). Thus, the function of the DMN might appear to bear some relationship to the associative processes involved in the generation of creative ideas (see Buckner, Andrews-Hanna & Schacter, 2008). Conversely, CEN activity increases during cognitively demanding tasks and has been linked to maintaining and manipulating information in working memory and making judgements and decisions. Thus, the CEN may play a role in the analysis and evaluation of creative ideas and Type 2 thinking processes. Further, the CEN is closely aligned anatomically

and functionally with a reflective C network proposed by Lieberman, Gaunt, Gilbert, and Trope (2002; see also Lieberman, Jarcho & Satpute, 2004) whilst the DMN shares some overlap in brain regions with a reflexive, X network proposed by Lieberman *et al*. (2002; 2004). However, the latter are not perfectly aligned anatomically and whether they are functionally aligned is not yet clear in the literature. The X-network is linked with associative learning that occurs without conscious intention and with intuition-based self-knowledge (Lieberman *et al*., 2002, 2004), which bears some relation to conceptions of the DMN. However, whereas episodic memory retrieval is seen as part of the DMN it is seen as a key aspect of the C network by Lieberman *et al.* (2004). Further illustrating the complexity of the relationship between generative and evaluative thinking, and the underlying brain mechanisms, a recent fMRI study by Ellamil, Dobson, Beeman & Christoff (2012) found that the default mode network and the central executive network were both activated during evaluation of creative ideas but not during creative generation. The latter was associated with activation of the medial temporal lobes, which supports memory retrieval during creative generation.

Clearly there is much to be worked out in the mapping between brain networks, the processes of creative thinking and dual process models of cognition. However, the consistent involvement of the ACC in shifting between types of thinking suggests that ACC activation could be a useful marker to identify shifting as participants work on creative problems. This could afford us a way to compare the timing and frequency of shifting between more and less creative problem solvers and solutions.

Exploring the time course of shifting

The possibility that patterns of shifting differ across stages of the creative process (Basadur, 1995) and individuals (Vartanian et al, 2007) suggests that the relationship between creativity and shifting is an important avenue for further research. Factors such as frequency of shifts, the length of using one process before a shift, and differences in patterns or the nature of shifting could be examined. Further, individual differences in trait dispositions to engage in different modes or styles of thinking have also been proposed (Basadur *et al.* 1982; Basadur, 1995; Epstein, 2003; Kaufman, 2011; Norris & Epstein, 2011; Stanovich, 1999). Time based approaches would allow us to compare whether these trait differences affect the timing of the shifting process.

General chronological information can be gained through methods such as think aloud protocols (e.g. Khandwalla, P. N., 1993; Gilhooly *et al.*, 2007; Pringle & Sowden, in prep). However, the identification of neurobiological markers of the shift between Type 1 and 2 processes, such as ACC activation, may afford us the opportunity to develop more powerful chronometric methods that explore the precise time at which shifts occur for, say, more vs less creative respondents. For example, recent advances in EEG speech research that deal with the problem of motor artifacts in the EEG speech signal (De Vos, Riès, Vanderperren, Vanrumster, Alario, Huffel & Burle, 2010) may mean it is now possible to combine EEG (e.g. Martindale & Hasenfus, 1978; Fink & Benedek, in press), fMRI and think aloud approaches to study shifting when thinking creatively. By using these methods conjointly it may be possible to lock events in the creative process to patterns of neural activity exhibited by an individual while they are engaged in a creative act.

Developing an understanding of the chronology and chronometrics of shifting should facilitate the development of methods to help people optimise when to shift in order to maximise creative output.

Implications for training creative thinking

Methods for training creativity have tended to focus on just one component such as divergent thinking (Scott, Leritz & Mumford, 2004). However, given the evidence that creativity involves an interaction between thinking processes (Basadur, 1995; Finke, 1996; Gabora & Ranjan, 2013; Howard-Jones 2002; Nijstad *et al.*, 2010), attempts to stimulate shifting between processes could be more effective. Stimulating shifting between different types of thinking to aid creativity could involve enhancing (1) the timing of shifting or (2) the ability to shift. For instance, an individual who is proficient at rapidly shifting between processes may not know *when* to shift. This is important because evidence suggests that a mismatch between the phase of the creative process and the type of thinking can negatively affect creative output (Jansson & Smith, 1991; Howard-Jones, 2002). Further, cycling too rapidly between thinking processes may result in ideas being prematurely evaluated leading to promising ideas being dismissed (Nijstad, *et al.*, 2010; Zabelina & Beeman, 2013), whereas an individual who has a good understanding of when is the optimal time to shift might be better at allowing time for an idea to be sufficiently worked out before applying evaluative processes.

The distinction between serial vs parallel models of creative thinking processes also has important implications for enhancing creative thinking. If shifting occurs in a serial fashion then creative thinking might be improved by focusing on improving the individual's ability or tendency to shift between and/or to engage the optimal type of thinking for performance in a

particular phase of the creative process. The latter may align with the idea, from dual process theories of cognition, of a pre-emptive conflict resolution model in which the use of Type 1 or 2 thinking processes is chosen at the start of a task (see Evans, 2007). On the other hand, if generation and evaluation occur in a more parallel fashion then it may be best to improve an individual's evaluative ability and ensure that evaluative processes are quickly accessible 'on tap' alongside generative processes. It could be that both parallel and serial accounts are correct but that there are individual differences in the shifting mechanism. For example, more creative individuals may have evaluative processes 'on tap' and/or less creative individuals may shift more slowly between different processes in a serial fashion.

There are also various ways by which shifting ability might be influenced. For instance, the creative thinking literature suggests that cues to environmental safety such as mood state or colour can influence the use of different thinking processes (De Dreu *et al.*, 2008; Mehta & Zhu, 2009; Sowden & Dawson, 2011). Further, with different pathways conceptualised as engaging different levels of cognitive control (e.g. Nijstad *et al.*, 2010), a means of aiding shifting between them could take the form of improving a person's ability to flexibly modulate cognitive control as there is some evidence that creative people are better able to modulate cognitive control in response to context (Zabelina & Robinson, 2010). However, further work is needed to determine the extent to which cognitive control can be trained for the purposes of creative thinking. Encouragingly, work from the dual process of cognition framework indicates that instruction can influence the use of Type 2 processes (e.g. Evans, Allen, Newstead, & Pollard, 1994). In addition, work from dual process theories suggests that meta-cognitive factors such as the 'feeling' and 'judgment of rightness' may influence the engagement of Type

2 processes (Thompson, 2009). Work to explore ways to influence these meta-cognitions may benefit the development of methods to assist the ability to shift between types of creative thinking process.

Finally, the direction of shifting between thinking processes may be important. For example, Howard-Jones (2002) argues that individuals evidencing a disposition to think more analytically may benefit from interventions which focus on enabling them to shift to a more associative type of thinking while those evidencing a disposition to think more associatively may benefit from interventions that enable them to shift to a more self-critical, analytical style of thinking (Howard-Jones, 2002). Further research is necessary to examine if such trait differences interact with the process of shifting between types of thinking process.

Summary and Conclusions

There appears to be consensus amongst different dual-process models of creativity on the importance of generative and evaluative processes, and the interaction between them, during creative thinking. However, different models conceptualise this in different ways. The time is ripe to develop an integrated dual-process model of creativity that clearly specifies the nature of this interaction across different points in the creative process, and the mechanisms that underlie shifting between generative and evaluative thinking. An important part of this process will be to incorporate findings from more general dual-process theories of cognition. By understanding the relationship between Type 1 and Type 2 thought on the one hand, and the processes of generation and evaluation in creativity on the other, we can elaborate our understanding of creativity and its underlying biological mechanisms. This is expected to facilitate development of interventions to enhance creative thinking. In future studies it would

be useful to investigate (1) the extent to which creativity is determined by the ability to shift between Type 1 & 2 thinking processes as a function of the circumstances and the stage of the creative process, and (2) whether shifts in generation-evaluation ratios and their timing can be used to enhance creative thinking. Time-based approaches will be essential to explore these patterns of shifting between processes whilst thinking creatively.

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Table 1. Comparison of the characteristics of Type 1 and Type 2 processes with dual process models of creative thought. For instance, the table shows that Type 1 processes may contribute to both convergent and divergent thinking in Guilford's (1956) Structure of Intellect model and that Type 2 processes contribute to both generation and exploration of ideas in Finke *et al.'s* (1992) Genoplore model.

	Dual process models of cognition (Evans, 2008; Frankish, 2010; Stanovich & Toplak, 2012; Evans & Stanovich, 2013)	
Dual process model of creativity	Type 1 (autonomous) processes	Type 2 (working memory based and cognitively decoupled) processes
Cognitive Experiential Self Theory (Epstein, 2003)	Experiential (divergent) thinking	
Structure of Intellect (Guilford, 1956)	Divergent thinking Convergent thinking	Divergent thinking Convergent thinking
Ideation – Evaluation cycles (Basadur *et al.*, 1982; Basadur, 1985)	Mapping unclear	Mapping unclear
Blind Variation and Selective Retention (Campbell, 1960; Simonton, 2011)	Variation (but context effects excluded)	Selection
Genoplore (Finke *et al.*, 1992)	Generation	Exploration Generation
Dual State Model (Howard-Jones, 2002)	Generative	Analytical
Honing Theory (Gabora, 2005)	Associative	Analytic
Dual Pathway Model (Nijstad *et al.*, 2010)		Flexibility Persistence