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REVIEW ARTICLE

Gender and creativity: an overview of psychological and neuroscientific literature

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Abstract The topic of gender differences in creativity is one that generates substantial scientific and public interest, but also courts considerable controversy. Owing to the heterogeneous nature of the findings associated with this line of research, the general picture often appears puzzling or obscure. This article presents a selective overview of psychological and neuroscientific literature that has a relevant bearing on the theme of gender and creativity. Topics that are explored include the definition and methods of assessing creativity, a summary of behavioral investigations on gender in relation to creativity, postulations that have been put forward to understand gender differences in creative achievement, gender-based differences in the structure and function of the brain, gender-related differences in behavioral performance on tasks of normative cognition, and neuroscientific studies of gender and creativity. The article ends with a detailed discussion of the idea that differences between men and women in creative cognition are best explained with reference to the gender-dependent adopted strategies or cognitive style when faced with generative tasks.

Keywords Gender differences · Sex differences · Cognition and behavior · Creative cognition · Creative thinking · Divergent thinking · Neuroimaging · Cognitive neuroscience · Cognitive style · Cognitive strategy · Brain basis

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Creativity refers to the singularly complex human capacity to produce novel ideas, generate new solutions, and express oneself in a unique manner. Although astounding works of art and groundbreaking scientific discoveries are the customary associations that are readily evoked when we consider the concept of creativity, our capacity to be creative is evident in virtually all aspects of human life when engaged in language and communication, choice and decision making, as well as planning and organization (Runco and Pritzker 2011; Sawyer 2012). While the potential to be creative exists within each person, there is considerable individual variability in both the type and amount of creative output that is produced over a lifetime. A substantial proportion of the empirical investigations on creativity are directed at uncovering which variables have a positive or negative impact on creativity. Gender is one factor that has been explored in this regard within psychological research.

This paper provides a general overview of psychological and neuroscientific research that has a direct or indirect bearing on the topic of gender and creativity. The first part is devoted to understanding what is meant by creativity in terms of definition and methods of assessment. This is followed by a summary of behavioral findings on gender-related differences in creative thinking, and a discussion of the explanations that have been forwarded to account for such differences. Current knowledge concerning gender-based behavioral and neurobiological differences in other (non-creative) aspects of cognition is then explored. In the final section, implications of recent findings from neuroscientific studies of gender differences in creative thinking are discussed.

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Defining and assessing creativity

A creative response or product is one that is determined to be both original and relevant (Runco and Jaeger 2012; Stein 1953). The level of originality of a given response is defined in terms of its novelty, uniqueness or statistical rarity, whereas relevance is assessed in terms of the functionality, usefulness or fit of the response to a particular end or within a specific context. The importance of both these defining components of creativity can be illustrated with an example from one of the most widely used tasks in creativity research, namely the alternate uses task (Wallach and Kogan 1965). When performing this task, participants are instructed to generate as many uses as they can for a common object beyond its customary use. When contemplating potential alternate uses for a shoe, for instance, almost all the participants will report that you can use a shoe to kill an insect. While such a use is certainly relevant in that it serves that particular instrumental function successfully, it would not be considered as highly original because it is not a unique or statistically rare use for a shoe. Occasionally, a participant might report an invalid use, such as using a shoe to staple things together. While this particular use could be deemed highly original in that it is unusual and statistically rare, it is also considered to be irrelevant because a shoe cannot be used effectively for that purpose. Using a shoe as an ashtray, on the other hand, is an example of a use that is, relatively speaking, both original (or novel) as well as relevant (or fitting) given the task at hand.

The alternate uses task falls under the classification of *divergent thinking tasks* that are widely used to assess creativity. Such tasks assess single or multiple facets of creative thinking (Abraham and Windmann 2007), and potentially allow for an unlimited number of ideas or solutions to be generated. This is in contrast to *convergent thinking tasks* where there is only one solution to be reached, such as in the remote associates task. Here the novelty factor come into play with a fundamental perspective shift or overcoming of functional fixedness which allows one to solve the problem (Bowden and Jung-Beeman 2003). Convergent thinking tasks are used to assess specific aspects of creative cognition, such as insight in analytical problem solving (Bowden and Jung-Beeman 2007). Just as in the case of intelligence, executive function and other mental abilities, there are also test batteries for creativity in which a range of divergent thinking tasks are collectively scored to obtain an index of the creative ability of a person. A prominent example of a *divergent test battery* is the Torrance Test of Creative Thinking (TTCT: Torrance 1974). Another means of assessing creativity is via the *consensual assessment technique* (CAT: Amabile 1982), where a product is generated and then evaluated by experts in terms of the level of associated creativity. These four methodologies (divergent tasks, convergent tasks, divergent test batteries, and CAT) include verbal and/or nonverbal tasks, and often more than one response measure/index within each task. Together, they are the most widely used assessment tools to gauge creative ability or potential. The latter reflects the terminology used when referring to the six Ps of creativity, or the theoretical approaches that are adopted when investigating creativity. These are in terms of process, product, person, place, persuasion and potential (Kozbelt et al. 2010).

In contrast, self-report forms, like the Creative Achievement Questionnaire (CAQ: Carson et al. 2005), are commonly employed to assess intermediary factors, such as personality traits, perceived self-efficacy and indices of achievement, that are associated with creativity. A notable issue that arises in the context of how the methods are chosen and applied is that diversity across and within methodologies (owing to variability in the tasks and response measures of focus) renders it difficult to relate and integrate the resulting findings across studies (Arden et al. 2010). For instance, in the case of the alternate uses task, some studies find differences in creativity based on the fluency measure (number of ideas generated), whereas others find differences on the originality measure (uniqueness of the ideas generated). However, even when significant findings are specific to a particular response measure, authors tend to generalize and discuss their implications in terms of overall creativity. So the vast heterogeneity in the available methodologies often leads to unspecific and generic claims or conclusions. And this is a significant deterrent to progress being made in the field.

Several factors have an impact on the choice of creativity assessment, such as type of creativity being tested (Simonton 2012), creativity in different age groups (Torrance and Haensly 2003), and creativity across different applied settings (Kaufman et al. 2008). For instance, a researcher might opt for a divergent test battery if her aim is to obtain a general creativity index as it provides a composite score across several tasks, whereas she would opt for a convergent thinking task if her objective is to target the specific process of insight in creative problem solving, or a nonverbal divergent thinking task if her objective is to make cross-cultural comparisons of creative potential in children or adults. The following section presents a summary of the behavioral findings on gender and creativity using these different methods.

Gender and creativity: behavioral findings

The role of gender in creativity has been explored to determine not only if males and females differ in terms of creative ability (potential) or output (product), but also what factors contribute to the likely differences and whether these manifest differentially over the course of the lifetime, as suggested by recent studies (Bender et al. 2013; Cheung and Lau 2010; He and Wong 2011; Hong and Milgram 2010; Karwowski et al. 2013; Kaufman et al. 2010; Sayed and Mohamed 2013; Stoltzfus et al. 2011). Three astute reviews have been published on this theme (Baer and Kaufman 2008; Pagnani 2011; Runco et al. 2010), the insights of which are integrated and summarized below.

The following approaches have been mainly employed in this line of research: (a) empirical studies of differences in creative potential in children and adults, (b) prevalence based studies on high levels of creative achievement across life domains in adulthood, and (c) prevalence based studies on eminence or attaining the highest levels of achievement in different domains in adulthood.

Empirical investigations on creative ability among children and adults are inconclusive with reference to the impact of gender differences (Baer and Kaufman 2008; Pagnani 2011; Runco et al. 2010). Approximately half of the investigations reported no significant differences between males and females, whereas the other half were characterized by mixed findings that, on average, was suggestive of superior creative abilities in females. Potential age and domain related differences in creativity have also been explored in relation to gender. Even when clustering the findings by age group, the slight advantage displayed females over males holds true across preschool and elementary school, middle school and high school, and college. Despite the intuitive appeal of the idea that females are more creative at verbal and artistic domains whereas males are more creative at mechanical and scientific domains, there is little empirical evidence to support such notions of domain-general advantages as a function of gender. For instance, when performance on several verbal and nonverbal divergent thinking tasks were evaluated as a function of gender in adults, both genders scored higher on one of the two verbal and one of the two nonverbal tasks (Ruth and Birren 1985).

As the proportion of studies that reported a lack of gender based differences in relation to creativity is larger than those that found otherwise, the conclusion that can be derived from this body of work is that there are no firm grounds from which to presume systematic differences between the sexes across child development and young adulthood in terms of creative ability or potential.

Some data, however, suggests that certain external factors can exert a gender-specific effect on creativity. For instance, introducing an extrinsic motivator, like rewards (bonus points added to their art grade) or evaluations (their degree of creativity would be graded), had no discernible effect, as determined by the consensual assessment technique (CAT), on the creative output of boys when creating collages, but negatively impacts girls (Baer 1997, 1998). Recent evidence has in fact revealed gender differences in the neurophysiology of reward processing (Volf and Tarasova 2013). Such findings are intriguing given what we know about the relationship between creativity and motivation. It is well-known that creativity is fuelled by intrinsic motivation and that increases in extrinsic motivation can be counterproductive to creativity (Amabile 1993; Pink 2011). The differential impact of motivators and other (many as yet untested) factors on creativity as a function of gender may account for the findings of some contentious longitudinal studies, which suggest that individual differences on divergent creativity tasks are predictive of creative accomplishment in boys, but not girls (Howieson 1981; Subotnik and Arnold 1994).

Nonetheless, when taken together though, what the findings suggest is that human beings commence their creative development on a roughly even footing, or at least on one that is not significantly skewed solely as a function of gender. But differences in creative accomplishment begin to surface in young adulthood and are manifest in real world achievements throughout the adult lifespan.

With regard to high levels of creative achievement, the prevalence of men and women in expressive domains such as writing, musical performance, dance and drama is comparable. However, more men than women pursue domains of invention, such as science, musical composition and painting (Chan 2005; Kaufman 2006; Runco 1986). These differences are inflated at the highest levels of creative achievement where far more men than women attain eminence across various domains in the arts and sciences (Cole and Zuckerman 1987; Piirto 1991).

The critical question then is why men go on to achieve higher levels of creativity than women despite the fact that they are not developmentally predisposed to do so. Indeed, the literature demonstrates that any gender-dependent advantage, if it can be posited at all with respect to enhanced creative potential, should marginally favor women. So what changes over the course of development that tilts the balance in favor of men? Some of the dominant ideas that have been explored in relation to this question are summarized in the next section.

Explanations: biological versus sociocultural

The explanations that have been put forward to justify the ostensible gap between the sexes in both creative and non-creative output and achievement fall into two categories: biological and sociocultural (Baer and Kaufman 2008; Halpern 2011; Kimura 2000; Miller and Halpern 2013; Pinker and Spelke 2005).

The most commonly discussed gender-dependent biological variations that are held to underlie cognitive differences between men and women include genetic differences, hormonal differences, and brain differences in terms of overall size, size variability and organization. The genetic variability between men and women, for instance, is substantial at 2–3 % (Carrel and Willard 2005). Animal research indicates that the exposure to different sex hormones in the early developmental phase is one of the most important factors in the differentiation of males and females (Lentini et al. 2013). Among human beings, even after correcting for body size differences, men have slightly larger brains than women and are also more variable in brain size. The proportion of gray-to-white matter in the brain also appears to vary as a function of gender, although the direction of such differences is often inconsistent between studies (Luders and Toga 2010). While such biological explanations may seem to offer compelling grounds from which to explain how gender differences in cognition and behavior surface, what is entirely unclear is how such gross distinctions in terms of physiological factors could give rise to specific biases in information processing that influence creative or non-creative cognition.

Sociocultural explanations have therefore been more widely discussed in the context of accounting for gender differences in behavioral performance, particularly in the context of creativity (Baer and Kaufman 2008; Pagnani 2011; Runco et al. 2010). Societal, cultural and socialization factors have been put forward to explain why men demonstrate higher levels of creative achievement than women.

Societal constraints include different standards of success for men and women, women not being allowed to participate to the same degree as men in different spheres of life, and active discrimination which negatively impacts access to resources that are essential for achievement in certain fields (Simonton 1994). For instance, even in the oldest university in the English-speaking world, the University of Oxford, women were only allowed entry from the 1870s and were not allowed to matriculate or graduate till 1920. Although the academic opportunities were slightly better in the US, it was only in 1849 that Elizabeth Blackwell became the first woman to obtain a medical degree (Wilson 1970).

Cultural factors also have an enormous impact on creativity as cultures differ considerably with regard to gender-based rules, roles and assumptions. Not only are cross-cultural differences reflected in the pattern of gender-related creative achievement, even transformations within a culture accompany changes in gender-related differences in creative achievement (Simonton 1992). For instance, when evaluating gender differences in creativity within the Middle East (Mar'i and Karayanni 1983), gender-based creativity differences were found to be modulated by the level of modernization in the country whereby an increase in gender equality was accompanied by an increase in creativity among women.

Socialization differences have also been put forward to explain gender differences in creativity (Baer 1999; Piirto 1991). These include gender labeling, different perceptions and expectations for daughters compared to sons, variation in schooling and other important resources as a function of gender, and over-socialization of girls in traditional cultures. All of these factors restrict the development of creative thinking skills. The fact that women do not exhibit lower levels of creative achievement until after college suggests that this is a critical period where crucial life choices are made that directly affect the drive for creative accomplishment (Piirto 1991). There are more conflicts between one's own goals and the expectations of others in the case of women than men. Men are both expected and encouraged to actively pursue a professional career and attain high levels of achievement. Women are not encouraged to the same extent and are often dissuaded from following an ambitious career path. Moreover, they deal with the added expectancies of pursuing marriage and family life in parallel. So a key factor that accounts for gender differences in creative achievement is that "young women are pulled by their society away from the kind of intense commitment necessary for creative accomplishment" (Baer 1999, p. 758).

To date, no study has systematically investigated what proportion of the gender-dependent variance in creative achievement is attributable to biological or sociocultural factors. This is unsurprising given the sheer complexity of the challenge involved in undertaking such a research venture. Scientific investigations of gender differences in cognition and behavior have not been conducted thus far with a view to determine the causes of potential variability.

Gender and cognition: behavioral findings

Several studies have addressed the issue of gender based differences in cognition, particularly with respect to mathematical performance, spatial abilities, verbal skills and memory-related functions. Much of the focus emerged from early evidence that suggested that although boys and girls were no different in general intelligence, boys performed better on tasks of mathematical reasoning whereas girls performed better on tasks of verbal comprehension (Terman 1916). Decades of empirical work in the meantime has indeed confirmed that differences in general intelligence are not modulated by gender (Flynn and Rossi-Casé 2011). But the idea that there is a gender-specific advantage which is domain general: verbal in the case of females and spatial or quantitative in the case of males, has not been clearly corroborated.

This is not to say that there are no differences between males and females in terms of their cognitive skills (Baer and Kaufman 2008; Halpern 2011; Kimura 2000; Miller and Halpern 2013). Differences certainly exist, but these are not global or generalizable across domains. For instance, girls display an advantage on tasks that necessitate verbal fluency, rapid math calculations, and memory of spatial position of objects, whereas boys demonstrate an advantage on tasks that assess verbal analogy, rapid math reasoning, mental rotation and memory for layout geometry (Pinker and Spelke 2005). This shows that gender based differences in cognition are more subtle and process based than domain-general hypotheses would lead one to believe. More importantly though, the notion that "cognitive differences" translate to "cognitive deficiencies" (Halpern 1989) is an erroneous one and needs to be done away with in order to arrive at a genuine understanding of what these variations reflect. One could speculate that what might instead be the case is that these differences reflect variable strategies or approaches that are automatically adopted in a gender-specific manner when engaging in complex cognition. Does the evidence of gender differences in brain structure and function support such a notion?

Gender and the brain: structural and functional differences

Although gender based differences in terms of brain structure and function have long been a subject of study dating back at least 50–60 years (McCarthy and Konkle 2005), there has of late been renewed interest in this theme (Cahill 2006; Gong et al. 2011; McCarthy et al. 2012; Ruigrok et al. 2014). A rapidly increasing multitude of gender differences have been documented as a result. Structural brain differences that have been reported include, for instance, greater cortical thickness in anterior temporal and orbitofrontal areas in men, and greater cortical convolution and complexity across the neocortex in women (Luders and Toga 2010). Sex differences in brain function are also routinely explored, such as in the field of emotion processing, where enhanced left amygdala activity, for example, was demonstrated in response to negative emotions in women but positive emotions in men (Stevens and Hamann 2012).

Considerable debate accompanies the publication of such findings, not only because of the implications of such research, but also with regard to the generalizability of the findings. This can be demonstrated with the example of a recently published article on the human structural connectome of the brain (Ingalhalikar et al. 2014). This study reported significantly greater connectivity within the hemispheres among men (intrahemispheric) and significantly greater connectivity between the hemispheres (interhemispheric) for women. While one prominent advocate for brain research on gender differences strongly endorsed this study and averred that it held the promise of a "landmark paper" (Cahill 2014), others questioned the very basis on which the strong conclusions were derived (Joel and Tarrasch 2014). This case is illustrative of the divisive nature of such research.

A comprehensive meta-analysis on sex differences in brain structure was recently published where of the total 5625 records that were screened, 167 studies satisfying all the eligibility criteria were included in the meta-analysis (Ruigrok et al. 2014). Males were found to have larger grey matter (GM) volume in a range of regions that included the amygdala, hippocampal formation, posterior cingulate, putamen, temporal poles, and parts of the cerebellum. Females, in contrast, had larger GM volumes in regions such as the frontal pole, inferior frontal gyrus, middle frontal gyrus, parietal operculum, insular cortex, Heschl's gyrus, thalamus and lateral occipital cortex. Some of these regions were also implicated in the analyses of GM density where males showed greater GM density in the regions such as the amygdala, hippocampus, insular cortex, pallidum, putamen and claustrum, whereas women displayed higher GM density in the frontal pole. How such structural differences would precisely translate to functional differences in terms of task dependent brain activity, cognition and behavior remains to be determined.

Gender, creativity and the brain

Gender differences in creativity have been extensively explored in behavioral studies whereas it has rarely been the subject of neuroscientific investigations, although some studies have taken gender differences into account as a covariate or interaction factor in interpreting the link between creativity and brain structure or function (e.g., Takeuchi et al. 2012, 2015). To date, only two EEG studies (Fink and Neubauer 2006; Razumnikova 2004), one structural neuroimaging study (Ryman et al. 2014), and one functional neuroimaging study (Abraham et al. 2014) have been published which specifically addressed the question of gender based brain-related differences in creativity.

Fink and Neubauer (2006) found that although no behavioral differences emerged between the sexes on a measure of originality, males and females of different verbal ability significantly differed with respect to task-related synchronization of EEG alpha activity in anterior regions of the cortex. Females in the high ability group demonstrated stronger synchronization with originality than those of average verbal intelligence, whereas the opposite pattern was seen among males. Razumnikova (2004), in contrast, suggested that gender differences are instantiated in terms of the hemispheric organization of brain activity during creative thinking. This conclusion was derived from results showing that, when engaged in a divergent thinking task, gender differences surfaced in the beta2 band of brain activity. While men who were classified as highly creative displayed increases in beta2 amplitude and interhemispheric coherence, creative women showed local increases of the beta2 power and coherence. The corresponding behavioral findings from this study however, cannot be evaluated with reference to the EEG data as information regarding the group classification criteria in terms of creative ability as well as the behavioral performance on the task itself were not provided within the article (Razumnikova 2004).

The structural neuroimaging study revealed gender differences in the pattern of white mater connectivity between brain regions, particularly within the default mode and cognitive control networks, as a function of creative ability (Ryman et al. 2014). High creativity in females was correlated with lower connectivity and efficiency together with clustering across several brain areas, whereas high creativity among males was associated with greater connectivity and efficiency alongside clustering in fewer brain regions. These differences were interpreted as reflecting that, at the expense of efficiency owing to greater white matter path lengths, high creativity among females could result from engaging more regions of the brain during creative thinking. High creativity in males, in contrast, potentially stems from greater efficiency and clustering of the brain network as a result of more direct connections between regions as well as an increase in local processing. So the central postulation from the study was that men and women utilize their brains differently when engaged in creative cognition as a function of structural organization and, importantly, that these distinctions may not be necessarily reflected in behavior as no significant difference in creative output was found to result as a function of gender.

In the functional magnetic resonance imaging (fMRI) study (Abraham et al. 2014), the influence of gender on creativity was assessed in terms of differences in behavioral performance on a creativity task as well as differences in brain activity during the undertaking of that very task. Engaging in the alternate uses task, regardless of gender (Abraham et al. 2012), was associated with increased activity in the inferior frontal gyrus, frontopolar cortex and temporal pole. These brain structures are known to be involved in the retention, retrieval and integration of semantic information. In contrast, engaging in any kind of divergent thinking (creative or non-creative open-ended reflection), was associated with the additional activation of other brain regions, such as the hippocampal formation, amygdala, posterior cingulate cortex, medial prefrontal cortex and angular gyrus. These are known to be relevant for declarative memory, language processing, hypothetical reasoning, and evaluative judgement.

The question then was whether differences in brain activity as a function of gender would arise within the same network of brain regions (quantitative differences) or whether previously uninvolved brain areas would be recruited (qualitative differences). The evidence showcased both quantitative and qualitative differences in brain activity during creative thinking and divergent thinking as a function of gender despite the fact that they were undifferentiated in terms of their behavioral performance (Abraham et al. 2014). With regard to creative thinking, brain networks associated with semantic memory operations (Binder and Desai 2011), rule learning (Bunge 2004) and outcome-based decision making (Rudebeck and Murray 2011), such as the inferior frontal gyrus, orbitofrontal cortex, and middle/inferior temporal gyrus, were preferentially activated in men. In contrast, women displayed stronger engagement of regions in the superior temporal lobe, which are associated with speech processing (Price 2010) and social perception (Hein and Knight 2008).

When generally engaged in divergent thinking (creative or non-creative), men more strongly activated regions like the hippocampal formation, amygdala, inferior frontal gyrus and retrosplenial cortex, which are involved in autobiographical, episodic, semantic and spatial memory (Binder et al. 2009; Cabeza and St Jacques 2007; Spiers and Maguire 2007). In contrast, regions like the medial prefrontal cortices, posterior cingulate, temporoparietal junction and temporal poles, which were more strongly engaged in women, are implicated during self-referential processing and mental state reasoning (Frith and Frith 2006; Northoff et al. 2006; Saxe et al. 2004).

Taken together, the findings of the functional neuroimaging study (Abraham et al. 2014) showed that although men and women demonstrate comparable performance on the behavioral measures of creative and divergent thinking, the brain activity differences indicated that they may employ different cognitive strategies when performing these tasks. Although, gender-specific strategy differences have rarely been discussed in the context of creativity, they have been more widely explored in other realms of cognition and behavior.

Gender and cognitive strategy

That cognitive or intellectual styles may explain differences in creative output has been the subject of much research particularly with reference to management or business perspectives and pedagogical practices in education (Hartley and Plucker 2012; Miller 2007; Noppe and Gallagher 1977; Puccio et al. 2004). However, cognitive styles have seldom been offered as an explanation to account for gender differences in creativity. Several researchers have postulated that the cognitive style of a person or the adopted cognitive strategy in a situation is influenced by gender. In the empathizing-systemizing (E-S) theory of sex differences in cognitive style, males are held to be characterized by a stronger systemizing or analytical style, whereas female boast a stronger empathizing style (Baron-Cohen et al. 2005). Strategy differences have even been advocated when interpreting gender differences in creative thinking. For instance, women performed better on a divergent thinking task on which performance was positively correlated with openness in personality, whereas men performed better on insight problem solving tasks on which performance was negatively correlated with emotionality in personality (Lin et al. 2012).

Recent proposals have gone a step further in highlighting that gender differences in cognition and behavior may not necessarily be instantiated in actual behavioral outcomes, but may instead be observed in terms of employed strategy differences when performing a task. For instance, sex differences have been documented in the strategies used by rats during spatial learning (McCarthy et al. 2012). While there are no sex differences in terms of the rats' ability to learn the task, the external constraints of the task (e.g., the route to access the platform in the Morris Water Maze) influences the employment of gender-specific strategies (e.g., female rats hug the walls more), which lead to a gender-dependent differences in performance.

Strategy differences have also been proposed to account for gender differences in other aspects of cognition and behavior (e.g., Hugdahl et al. 2006; Jordan and Wüstenberg 2010; Lipp et al. 2012; Moriguchi et al. 2013). In interpreting differences in the patterns of brain activation during affective experiences, for instance, Moriguchi et al. (2013) held that women are more self-focused whereas men are more world-focused. Hugdahl et al. (2006) classified women as adopting a serial, categorical processing approach during mental rotation relative to the coordinate processing approach employed by men.

Even in applied research domains directly relevant to creativity and divergent thinking, variations in strategy have been put forward to explain gender differences in performance. Take the example of a study on children's free drawings. Compelling gender based differences were found in 5–6 year olds in the motifs they generated (Iijima et al. 2001). More boys (96.4 %) drew moving objects, such as vehicles, trains and aircraft, than girls (4.6 %), whereas more girls drew persons (96.6 %) and flowers (57 %) than boys (26.5 % and 7.2 % respectively). Girls not only use more colors than boys in their drawings, they also use colors more diffusely. While boys prefer to use cold colors like grey and blue more than girls, girls preferentially use warm colors like pink and flesh tones compared to boys.

The authors also presented evidence which suggested that these strategies are likely to be innately determined. They did this by comparing drawings generated by unaffected boys and girls to those by girls with congenital adrenal hyperplasia (CAH). CAH is a genetic disorder that is characterized by an overproduction of adrenal androgen and girls with CAH typically exhibit masculine play behavior and play with boy-preferred toys (Jordan-Young 2012). The free drawings by the CAH girls contained significantly more masculine features (in terms of colors used and motifs) compared to those of unaffected girls. What is more, their drawings were not significantly differentiable from drawings of unaffected boys (Iijima et al. 2001). This constitutes evidence for biologically determined sex-specific strategy differences when engaged in generative tasks.

Evidence for gender-related strategy differences in divergent idea generation also comes from the field of music therapy. In a study on patients with traumatic brain injury, Baker et al. (2005) showed that when given the task of generating lyrics to songs, men expressed adversity and concern for the future more than women, whereas women focused on their relationships with others more than men (Baker et al. 2005).

The mixed picture regarding the behavioral findings associated with gender differences in creativity (Pagnani 2011; Runco et al. 2010) may be partly explained by strategy-based gender differences in creativity. It is impossible as yet to determine whether this is indeed the case as creativity tasks are rarely systematically contrasted in terms of the underlying similarities and differences in the information processing mechanisms (Abraham 2014). It could be the case though that cognitive strategies typically employed by men versus women in generative contexts would selectively enhance performance on specific creativity measures.

All in all, the idea that gender-dependent cognitive strategies could explain gender differences in cognition and behavior is one that has been independently proposed from a number of fields. Further research is essential to verify the manner and the degree to which gender-based strategy differences explain variations in creative (and indeed non-creative) performance. One means by which this can be done is by having participants report what kind of strategies they were explicitly aware of using during the creative idea generation phase. To investigate implicit strategy differences, the consistency of the pattern of brain activity differences during task performance as a function of gender can be compared across different studies. If a reliable pattern can be determined showing a dissociation in the network of brain regions as modulated by gender, creativity tasks could be specifically designed to test for context based differences (e.g., social context based tasks → advantage for women versus hypothetical future context based tasks → advantage for men). This would allow one to evaluate whether gender-related advantages during creative idea generation are context-dependent, as would be predicted if different default cognitive strategies tend to be employed as a function of gender. In any event, great caution and responsibility must be exercised when generalizing any empirical finding of gender differences to the wider context as it can easily lead to the propagation of myths (Eliot 2011; Fine 2010; Rippon et al. 2014).

Conclusions

Assessing gender differences in creativity is a controversial line of research to explore. And for good reason. It is naïve and wrong to suggest either that one gender is more creative than another, or that there are absolutely no differences between the sexes (Pinker 2009). The truth appears to be far more nuanced and complex.

In bringing together diverse bodies of evidence that have explored gender differences in cognition and brain function, the take-home message from this overview is that the sexes do not differ in terms of global or specific intellectual abilities but may do so in the cognitive strategies, functional task sets or cognitive styles that each are physiologically predisposed to adopt. These tentative insights point to novel avenues that beg further exploration in the field of gender differences in creativity.

Conflict of Interest Anna Abraham declares that she has no conflict of interest.

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