JCB

Publication of the Creative Education Foundation ®

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Implicit Theories of Creativity in Computer Science in the United States and China

ABSTRACT

To study implicit concepts of creativity in computer science in the United States and mainland China, we first asked 308 Chinese computer scientists for adjectives that would describe a creative computer scientist. Computer scientists and non-computer scientists from China (N = 1069) and the United States (N = 971) then rated how well those adjectives described creative computer scientists using a 5-point Likert Scale. Factor analysis revealed that the concept of a creative computer scientist had four dimensions: (1) smart/effective, (2) outgoing, (3) creative thinking and (4) unsociable. Differences in the implicit concepts across disciplines, ethnicity, gender, age, and working experience were analyzed. We discuss the implications of these findings for our understanding of the domain specificity of creativity.

Keywords: creativity, implicit theory, computer science, domain-specific.

The controversy about whether creativity is a general ability that transcends domains or a range of domain-specific abilities that vary from domain to domain came to the forefront in the creativity research and theory literature in the 1990s (Baer, 1993, 1998; Kaufman & Baer, 2005a, 2005b; Plucker, 1999; Plucker & Zabelina, 2009; Silvia, Kaufman & Pretz, 2009; Sternberg & Lubart, 1999). This debate brought with it much evidence regarding differences in creative thinking and performance in different domains and much speculation about the origins and causes of such differences. The different abilities that underlie creative performance in different domains may have their roots in the different modes of operation and ways of thinking used in different disciplines (Gardner, 1993), in different "intelligences" (Sternberg, Kaufman, & Grigorenko, 2008), or in different physical and mental abilities important in different domains (Kaufman, 2007). Different domains might require specific kinds of knowledge or performances (Baer, 1999) or a diverse set of facts, concepts, techniques, heuristics, themes, questions, goals, and criteria (Csikszentmihalyi, 1990, 1999). A domain-specific approach to creativity must consider whether or not different fields (or even tasks within a field) require the same cognitive skills and/or the same profiles of personality traits for creative work and the relative importance of these abilities and

 The Journal of Creative Behavior, Vol. 0, Iss. 0, pp. 1–21 DOI: 10.1002/jocb.61

traits in different fields. The goal of the research reported here was to elucidate the abilities and traits that might be of special importance for creativity in computer science and to examine how those abilities and traits might be viewed differently by people with different academic and cultural backgrounds.

Many researchers have examined the similarities and differences in creative performances by subjects in varying domains (e.g., story-writing, poem composition, collage-making, drawing, advertisements). The general finding has been that creativity varies widely across domains, with correlations ranging from low to non-existent and that within-domain correlations of creative performance are significantly larger and vary depending on how similar the tasks are (Baer, 1993, 1994a,b,c, 1996; Conti, Coon & Amabile, 1996; Han, 2003; Han & Marvin, 2002; Kaufman & Baer, 2002a, 2004a,b, 2005a, 2005b; Lubart & Sternberg, 1995; Runco, 1989; Ruscio, Whitney & Amabile, 1998). The boundary lines demarcating what constitutes a domain are not clearly drawn, however (Sternberg, 2005). Feist (2004) posited seven "domains of mind": psychology, physics, biology, linguistics, math, art, and music (Feist, 2004). Gardner (1999) argued for eight intelligences: interpersonal, intrapersonal, spatial, naturalistic, language, logical-mathematical, bodily-kinesthetic, and musical. Kaufman and Baer (2004c; see also Baer & Kaufman, 2005a) offered a hierarchy of domains and subdomains and proposed seven general thematic areas based on self-reported creativity in a wide range of activities: Artistic-Verbal, Artistic-Visual, Entrepreneur, Interpersonal, Math/Science, Performance, and Problem-Solving (Kaufman, Cole & Baer, 2009). Kaufman (2012) later found evidence for five factors (Everyday, Scholarly, Performance, Science, and Art).

Researchers in creativity sometimes compare scientists and artists, such as Einstein and Picasso (Simonton, 2009) or Heisenberg and Emily Dickinson (Kaufman & Baer, 2004b). Because the essence of both creative scientific and artistic activities is to do novel work (Feist, 1998), their basis for creativity is problem solving, but their problem-solving processes may nonetheless take very different forms (Weisberg, 2006) and creative scientists and artists also have different personality profiles (Charyton, 2005; Charyton & Snelbecker, 2007; Feist, 1998, 1999; Snow, 1964). For these reasons, science and art activities have been frequently contrasted in domain generality/specificity studies (Charyton & Snelbecker, 2007; Kaufman & Baer, 2004b; Kaufman et al., 2009). Art and science obviously belong to different domains, but we also believe it's important to compare different science disciplines to learn how creativity may be different in different areas of the domain of science (just as studies have shown how creative writers of different kinds, such as poets, fiction writers, and journalists, differ from one another; Kaufman, 2002; Kaufman & Baer, 2002a,b).

Creative processes used by scientists are many and diverse, ranging from the logical, objective, formal, and conventional to the intuitive, subjective, emotional, and individualistic (Simonton, 2009). Simonton argued that different creative processes were associated with different scientific disciplines and ranked five science disciplines in the following order based on the characteristics of their creative processes (with "hard sciences" at one end of the extreme, "soft sciences" in the middle, and arts and humanities at the other extreme): physics, chemistry, biology, psychology, and sociology. Although squeezing all variety of scientific creativity into a single dimension might be too ambitious, Simonton's goal of comparing different science disciplines in terms of the domain-specific kinds of thinking necessary for creativity in each is an intriguing one.

Some theorists have argued for a hybrid approach that combines features of both domain specificity and domain generality (Plucker & Beghetto, 2004). One such theory is the Amusement Park Theoretical (APT) model (Baer & Kaufman, 2005a; Kaufman & Baer, 2004a; Kaufman et al., 2009), which includes a few domain-general skills and dispositions as initial requirements for creative performance in most domains (e.g., intelligence, an appropriate environment, and the motivation to create something new). The next level of this hierarchical model becomes more specific, positing several general thematic areas (such as artistic-verbal, artistic-visual, entrepreneur, interpersonal, math/science, performance, and problem solving). The next level gets even more specific because, within each general thematic area, there are a variety of domains (such as poetry, fiction writing, and journalism in the general thematic area of writing). Finally there are microdomains (such as clinical, social, and cognitive psychology within the domain of psychology—which in turn is part of the math/science general thematic area.) Each microdomain has a somewhat distinct knowledge base and its own modes of thinking and analysis.

Culture also impacts how people conceptualize creativity. Nisbett and colleagues (Nisbett, 2003; Nisbett, Peng, Choi & Norenzayan, 2001; Norenzayan & Nisbett, 2000; Peng & Nisbett, 1999) have demonstrated a strong and pervasive cultural influence on human cognition. Culture, they argue, influences even our most basic cognitive processes. East Asians tend to use a more holistic approach to reasoning that emphasizes similarity and connections between objects and the field, an approach that is rooted more in intuition and experience than in formal logic. Westerners follow a more analytical and decontextualized approach to reasoning. Niu, Zhang and Yang (2004) extended this work by examining cultural influences on creative performance as well as on deductive reasoning. They found only weak correlations between deductive reasoning and creativity on a creative writing task, but they reported statistically significant cultural influences on the creative writing task.

Our understanding of creativity will of necessity be influenced by the field, discipline, or domain that we wish to understand. Just as different domains have different knowledge bases and modes of thinking and analysis, so too can we expect that creative people working in those domains will have different traits and dispositions (Feist, 1999; Simonton, 2005, 2009). It is these differing traits and dispositions that were the focus of our research. We selected computer science and psychology as the domains to be compared. Both disciplines belong to the larger general thematic area of math/science, but the content, skills, and modes of analysis, important in the two domains are markedly different. Our goal was to examine differences in the personality traits and dispositions associated with creativity in one of those domains (computer science) by people working in these two related, and yet very different, domains.

CREATIVITY IN COMPUTER SCIENCE AND PSYCHOLOGY

Creativity is the ability to produce work both new and appropriate to the task (Beghetto & Kaufman, 2007). There are different ways to be creative, such as reiterating a known idea in a new way, moving a field forward along its current trajectory, or integrating diverse trends in a field (Sternberg, Kaufman & Pretz, 2002). Both computer science and psychology need creativity (Saunders & Thagard, 2005; Simonton, 2005), but the characteristics of creativity in the two fields exhibit some important differences.

Computer science was established as a field in the 1950s (Fein, 1959). A computer scientist specializes in the theory of computation and the design of computational systems. Computer science is a kind of applied science. In contrast, psychology is an academic and applied discipline that involves the scientific study of mental functions and behaviors. Psychology has been thought of as a science since 1879 when German physician Wilhelm Wundt founded the first psychological laboratory at Leipzig University. It includes theoretical psychology and applied psychology.

Compared with psychology, research in computer science is more constrained by a given paradigm (Kuhn, 1970) because the development of the computer industry has been driven by the development of semiconductor technology: transistors (1950s), integrated circuits (1960s), and microprocessors (1970s).

Creativity in computer science is stimulated by technological tasks rather than by naturally observed phenomena or theoretical (Why?) questions (Saunders & Thagard, 2005). It may involve entering into a new market, improving an existing product, solving problems that have been identified in existing systems, or envisioning and developing new systems and structures. The basic organizational unit in computer science is the team.

Psychology is a broad field with several areas of specialization (Cronbach, 1957). Psychology can be very theoretical or very empirically driven and has nearly boundless applications in everyday life. There are many ways to become a creative psychologist, and the approaches to creating new knowledge in psychology are less limited than in computer science; in fact, it has been argued that "psychology is among the most creative of sciences" (Simonton, 2005, p. 147). In contrast to the team approach common in computer science, "psychology tends to be a more personal enterprise than the other sciences" (Simonton, 2005, p.139).

THE CREATIVE PERSON

Creative people may have special personality traits, distinct cognitive abilities, or high general intelligence (Barron & Harrington, 1981; Feist, 1998; Getzels & Jackson, 1962; Gough, 1979; Guilford, 1986; MacKinnon, 1962; Simonton, 1988; Sternberg & Lubart, 1996; Tardiff & Sternberg, 1988; Torrance, 1962; Treffinger, Young, Selby & Shepardson, 2002). Some authors hold that scientists share certain personality traits such as dominance, arrogance, hostility, high self-confidence, esthetic taste, and a lack of conventionality (Galton, 1874; Feist, 1998, 1999; Silvia, Kaufman, Reiter-Palmon & Wigert, 2011; Sternberg, 1986). It has also been presumed that some cognitive abilities, such as divergent thinking, could foster creativity across many domains (Plucker, 1999).

Recent studies, however, have found that personality as well as cognitive and dispositional profiles of highly creative people might not be the same across domains (Feist, 1999; Simonton, 1999). Mumford and his colleagues found that creative problem-solving skills have cross-field differences (Mumford, Antes, Caughron, Connelly & Beeler, 2010). Even motivation, which might seem like something any creator would need, is not a domain-general trait; as Baer (2012) pointed out, "motivation is not fungible" and one cannot "turn one's love of writing sonnets into love of balancing one's checkbook, doing one's math homework, or working out at the gym" (p. 18). Creativity may be more like expertise, which is very domain-specific:

Although we may use the term "expertise" without reference to a specific type of expertise, expertise is in fact very much domain specific. No one is an all-around expert. A person may have no expertise in any area, expertise in one or a few areas, or even expertise in several areas, but no one assumes that acquiring expertise in one field will give one expertise in all fields (or in *any* other field, for that matter). We don't assume that if a person studies and practices playing the guitar she will, as a result, gain expertise in economics, cooking, biology, or weather forecasting. (Baer, 2011, p. 81).

Kaufman and Baer (2004a,b,c) challenged the idea of a general creative personality and asked, "Does it make sense to call someone 'creative,' or should attributions of creativity always be qualified in some way (e.g., 'a creative storyteller' or 'a creative mathematician,' but not 'a creative person')?" (p. 14).

Context also plays an important role in definitions of creativity (Plucker & Beghetto, 2004) and highlights the qualitative differences we observe in levels of creativity (such as mini-c, little-c, Pro-C, and Big-C creativity; Kaufman & Beghetto, 2009, 2013). There are even many different kinds of creativity even within a given domain, as outlined in the Propulsion Model, which posits eight types of possible creative contributions to a domain including both, those that reject and replace current paradigms in a domain and those that use and modify existing paradigms (Sternberg et al., 2002).

Studies that have considered differences in the personalities of creative people in different domains have often been based on explicit theories of creativity (Davis, Kaufman & McClure, 2011; Kaufman, 2006; Mumford et al., 2010; Silvia et al., 2009), but explicit theories of creativity may neglect some valuable contextual information that a more implicit approach can uncover (Sternberg, 1985). The focus of this study was on implicit theories of creativity held by people working in the domains of computer science and psychology.

IMPLICIT THEORIES OF CREATIVITY

An implicit theory is "about people's views of what [something] is" (Sternberg, 1985, p. 39). Implicit theories help us formulate and make explicit often unstated but nonetheless foundational views that dominate thinking about a given psychological construct.

Beginning with Sternberg's (1985) research on implicit theories of intelligence, this method has been frequently used to study the concept of creativity (see, e.g., Paletz & Peng, 2008; Rudowicz & Yue, 2000; Runco & Johnson, 2002) and traits associated with creativity (e.g., Runco & Bahleda, 1986). The main purpose of these studies was to find those things that facilitate or inhibit creative behaviors or characteristics (Runco, Johnson, & Bear, 1993), especially when investigating creativity cross-culturally (Paletza, Peng & Lic, 2011; Runco & Johnson, 2002).

Because the creativity-relevant processes and contexts commonly used in computer science and psychology are not the same, it is likely that people coming from these two disciplines hold different concepts of what a creative person in computer science would be like. They would likely have different conceptions of what traits or attributes would be found in creative computer scientists because, although computer scientists have an inside view, psychologists have an outsider's view of computer scientists. By comparing the difference in their concepts, we might hope to find the effect each discipline's context has on their understanding of the creative person. In this study, we also selected two countries (the United States and China) to do a comparative analysis.

The primary purpose of this paper, then, was to study how these two disciplines' different contexts and understandings affect their implicit concepts of the creative person, with secondary goals of looking at this comparison cross-culturally and examining how age and gender might affect such implicit concepts. We asked: (a) What is the implicit concept of the creative person in computer science?; (b) What similarities and differences in this concept will be found among participants from computer science and psychology?; and (c) How might ethnicity, age, and gender influence these concepts?

METHOD

DEVELOPING THE MEASURE

A pilot study was conducted to develop the measure. The first step was to collect adjectives about possible characteristics of a creative computer scientist. There were 308 participants for this pilot study, including 142 computer science graduate students (89 males, 53 females, average age was 24.3) and 166 employees and managers from computer science-related companies (110 males, 56 females, average age was 31.5). The data were collected during weekend courses at the University of Chinese Academy of Sciences. Participants were asked to answer an open-ended question: "What do you think are the characteristics of a creative person in computer science? Please list as many appropriate adjectives as possible." A total of 1,480 words were collected; the average participant listed 4.8 words.

The second step was to code the words. One associate professor and four master degree students of organizational behavior coded the words. All repeated or very similar words were dropped, resulting in a total of 261 words. In order to organize the coding process, four coders categorized all adjective words into the following groups based on the contents of all words: intrapersonality, interpersonality, intelligence, competency, experience, and others. After completing this step they clustered all related words with similar meanings into subgroups and selected one adjective to represent the meaning of each subgroup. They finished this step independently. In all, they created 68 groups using this process. Their results were then compared with each other. Four coders got the same adjective words in 51 groups (75.00%) and three coders got the same adjective words in 14 groups (20.59%). For the remaining 3 groups, only two coders had chosen the same adjective words (4.41% of the total). At that point, they decided to select the 65 groups with which at least three coders had independently reached the agreement. The words that had been used to represent these categories were compared and the most appropriate words were chosen. A total of 65 adjectives and descriptors were chosen based on the categorizations. This initial Creativity in Computer Science Checklist is presented in Table 1.

PARTICIPANTS

There were a total of 2,040 participants in this study, with 971 from the United States and 1,069 from China.

The sample from the United States was comprised of undergraduate and graduate students. There were 300 computer science majors (248 males) and 654 students (primarily psychology majors) who were taking a psychology class (99 males). Students participated in the study on-line for extra credit at their instructors' discretion.

The sample from China included 690 computer science students and professionals (500 males) and 381 students who were taking a psychology class (46 males). Students were recruited through class and took the survey in the classroom. Professionals were tested either in person when taking a weekend class or on-line (a request for volunteers was forwarded via their human resource managers).

The average age of the American college sample was 23.74 years old (with ages ranging from 17 to 57). The Chinese sample mean age was 24.49 years old (with ages ranging from 17 to 52). All of the American college student participants and 929 of the Chinese college student participants had little or no professional work experience, but all had been studying computer science for more than 1 year.

MEASURES

Participants were presented with the Creativity in Computer Science Checklist with the following instructions: "Do the following descriptors describe a creative person in the field of Computer Science? For each descriptor, please indicate your level of agreement over whether it describes creativity in Computer Science." They were then presented with a Likert Scale from 1.0 to 5.0, with "1" standing for "strongly disagree" and "5" standing for "strongly agree." They then completed a basic demographic measure.

DATA ANALYSIS AND RESULTS

Principal component factor analysis with Varimax Normalized Rotation method was carried out. Adjective words with all the loadings below .35 or with cross loadings higher than .35 were dropped. The remaining adjectives were reexamined, and

TABLE 1. Descriptors of a Creative Person in Computer Science

Creative person categories	The samples of corresponding Chinese adjectives (in Putonghua)
Unique	ge xing, du te, ge xing hua, ge ren feng ge, qiang diao ge xing.
Energetic	jing li cong pei, jing li wang sheng, hao jing li, you neng liang, sheng ti hao.
Persistent	jian ren, chi xu, jian chi, jian chi bu xie, bu fang qi, wan qiang, you nai li.
Independent	du li, zi wo bu yi kao bier en.
Focused	tou ru, ru mi, quan xing tou qu, re zhong, dui gong zuo zhao mi, wang wo jing jie.
Innovative	chuang xin, chuang zao, chuang xin jing sheng, shan chuang xing.
Imaginative	Xiang xiang li, hui xiang xiang.
Flexible thinker	Si wei ling huo, shan cong bu tong jiao du ti fang an, hui ling huo gong zuo.
Proud	jiao ao, zi hao, zi gao zi da, wu zhong wu ren.
Indomitable	hao sheng, zheng qian hao sheng, bu fu shu.
Able to make leaps of thought	tiao yue xing si wei, si wei tiao yue.
Broad thinker	si wei you guang du, si wei kua du da.
Simple/naïve	jian dian, tian zheng, you zhi, bu fu za, dan cun.
Unpredictable	ge xing yi bian, shan bian, ge xing zuo mo bu ding.
Romantic	rang man, ruo man ti ke.
Likes nature	zi lan, re ai da zi ran.
Leisurely/unhurried	bu jing bu man, you ran zi de, dan ding, bu huang ruan.
Lonely	gu du, gu ji, ji mo.
Industrious	qing feng, qing lao, chi ku nai lao.
Arrogant	zi da, mu zhong wu ren, gao ao, zi gao zi da.
Insightful	dong cha, you dong cha li, wu xing hao.
Explorative	tan suo wei zhi, fu yu tan suo, cha geng wen di.
Humorous	you mou.
Striving for perfection	Zui qiu zhuo yu, jin shan jin mei, wan mei zhu yi, wan mei zhe.
Self improving	Zi wo ti gao, zi wo chao yue, zi mo geng xing, zi wo wan shan.
Odd	Gu guai, guai ren.
Passionate	Re qing, ji qing.
Self-confident	Zi xing, xiang xing zi ji.
Curious	Hao qi, hao qi xin qiang.

TABLE 1. (Continued)

Creative person categories	The samples of corresponding Chinese adjectives (in Putonghua)
Sensitive	Ming gan.
Hands-on	Shan xing dong, xing dong li qiang, shan zhi xing.
Good at observation	Shan guan cha, guan cha ming rui, hui guan chua.
Good at reasoning	Shan tui li, shan cha chu yi you.
Ambitious	You ye xin, you bao fu, you zui qiu.
Intelligent	You zhi neng, zhi li chao qun, gao zhi shang.
Good at learning	Shang yu xue xi, xue xi neng li qiang, hui xue.
Good at interpersonal relationships	Ren ji guan xi hao, shan yu ren jiao wang, dong jiao ji, hui xiang chu.
Enterprising	Qi ye jia jing sheng, you chuang ye jing sheng.
Good leader	You ling dao li, shan ling dao ta ren.
Far-sighted	Chang yuan mu guang, you yuan jian, ba wo wei lai.
Knowledgeable	Bo xue duo shi, zhi shi feng fu, zhi shi mian guang.
Logical	luo ji xing qiang, you luo ji, si lu qing xi, tui li yan jin.
Serious	Yan jin.
Shares ideas	shang yu feng xiang guan dian, chuang yi jiao tiu.
Loves work	gong zuo kuang, re ai gong zuo, xi huan gong zuo, gong zuo di yi
Well organized	you zhu zhi, shan zhu zhi, jing jing you tiao, you tiao li
Open-minded	Kai fang, xing tai kai fang, dui wai jie chi kai fang tai du
Keeps up with the times	yu shi ju jing, shi dai gan, geng shang shi dai,
Brave	yong gan, you yong qi, bu wei ju
Experienced	jing yan feng fu, you jing yan, jing yan lao dao, fu you jing yan
Good at collecting information	shang chang xin xi shou ji, xing xi shou ji neng li qian
Has faith	you xing yang, you xing nian, you xing yang zhui qiu
Positive	le guan, xiang shang, yang guang
Unfaithful/not monogamous	yi bian, shan bian, duo bian, bian hua bu din
Lazy	lan duo, you jie jing, shan yu tou lan
Sentimental	ming han, xi ni, duo chou shan gan
Has clear goals	mu biao ming que, fang xiang xing qiang, you mu biao
Unselfish	bu zi si, wu si
Friendly	you hao, you san, you san yi, cong ban san yi

TABLE 1. (Continued)

Creative person categories	The samples of corresponding Chinese adjectives (in Putonghua)
Active	ji ji, zhu dong,
Diligent	ren zheng, qing fen,
Artistic	yi shu xiu yang qian, dong yi shu, you shu qi zhi, you yi shu caihua
Asks questions	hao wen, xi huan ti wen ti, shan yu zhi yi
Outgoing	wai xiang, kai fang, kai lang
Communicative	gou tong, shan yu gou tong, hui ren ji gou tong, dong gou tong

they were grouped into four factors with an accumulated explanation of variance of 40.44%. Studying the content of each adjective, we found factor 1 represented "smart/effective," factor 2 represented "outgoing," factor 3 represented "creative thinking," and factor 4 represented "unsociable" (see Table 2).

Before comparing the mean score of each factor among the comparison groups, it was necessary to make sure the structural validity of the creative personality in each of the four subgroups (American and Chinese, Computer Science and Psychology) was acceptable. Confirmatory factor analyses were carried out. According to the usual conventions, the RMSEA should smaller than 0.06; $\chi 2/df$ ranged from 1 to 3; GFI, IFI, TLI, and CFI were above 0.9) (Hu & Bentler, 1999). The structural validity of each group was acceptable, as shown in Table 3.

The mean scores and the rankings from the two disciplines and two ethnicities are presented in Table 3. Ethnicity influenced the priority of the four factors more than discipline. The two least important factors for both ethnicities were "friendly/ interpersonal" and "dark side." Interestingly, Chinese participants selected "creative thinking" as the most important factor, while American participants chose "smart effective" as the most important.

In order to see more clearly the disciplines' effects, two-way multiple analysis of variance (MANOVA) was calculated with the Bonferroni adjustment examining the effect of discipline (computer science and psychology) by ethnicity (Chinese and American) on four factors. It turned out that the mean differences (MD) of Chinese participants on "creative thinking" in both disciplines were significantly higher than those of their American counterparts ($p < .01$). The MD of Chinese psychology participants was significantly higher than that of Chinese computer science participants ($p < .01$). Chinese computer science participants rated "smart/effective" higher than Chinese psychology participants. The MDs of American participants in both disciplines were significantly higher than their Chinese counterparts ($p < .01$). American computer science participants and Chinese psychology participants both rated "dark side" higher than Chinese computer science participants (both $p < .01$; see Table 4).

TABLE 2. Principal Components Factor Analysis and Varimax Normalized Rotation

Adjective words	Factors			
	1	2	3	4
Intelligent	.65	.04	.18	.00
Well organized	.65	.17	.01	−.10
Striving for perfection	.50	.18	.07	.16
Good at learning	.64	.02	.30	−.08
Persistent	.55	.00	.13	.06
Explorative	.57	.17	.26	−.01
Keeps up with the times	.55	.17	.21	.03
Focused	.62	−.05	.15	−.03
Diligent	.65	.11	.08	−.08
Passionate	.48	.26	.28	−.07
Enterprising	.52	.28	.07	.03
Experienced	.61	.20	−.03	.02
Good at collecting information	.65	.11	.14	−.06
Asks questions	.37	.18	.23	−.00
Far-sighted	.36	.18	.22	.04
Knowledgeable	.61	.10	.20	−.04
Industrious	.58	.15	−.07	−.13
Hands-on	.59	.16	.20	−.11
Logical	.68	.00	.16	−.05
Serious	.56	.03	.02	.08
Good at observation	.53	.21	.33	−.10
Shares ideas	.55	.33	.07	−.06
Good at reasoning	.60	.01	.31	−.08
Loves work	.52	.32	.14	−.07
Has clear goals	.61	.25	−.05	−.17
Humorous	.12	.61	.20	.13
Active	.26	.53	.26	−.03
Romantic	−.09	.61	.17	.21
Unselfish	.23	.46	−.05	.10
Friendly	.31	.71	−.06	.01
Likes nature	.13	.55	.09	.08
Outgoing	.12	.70	.10	.03
Good at interpersonal	.26	.70	.03	−.03
Brave	.26	.48	.29	.08
Unique	.14	.16	.50	.16
Imaginative	.25	.05	.75	−.04
Innovative	.18	.18	.63	−.03
Curious	.35	.10	.58	.07

TABLE 2. (Continued)

Adjective words	Factors			
	1	2	3	4
Able to make leaps of thought	.06	.08	.62	.04
Broad thinker	.30	.02	.67	−.01
Simple/naive	−.12	.14	.02	.47
Unpredictable	−.07	.25	−.03	.51
Odd	.02	−.14	.09	.61
Unfaithful/not monogamous	−.16	.13	.18	.52
Proud	.16	.18	.03	.48
Lonely	.03	−.16	−.04	.67
Indomitable	.20	.28	.03	.35
Arrogant	−.04	−.15	−.03	.72
Lazy	−.07	.06	−.02	.49
Sentimental	−.13	.10	−.06	.57

Note. Extraction method was maximum likelihood; rotation method was Varimax with Kaiser Normalization.

TABLE 3. Confirmatory Factor Analysis

	χ^2	*df*	*p*-value	χ^2/df	RMSEA	GFI	IFI	TLI	CFI
American	1592.31	556	0.00	2.86	0.05	0.91	0.92	0.91	0.92
Chinese	1504.19	510	0.00	2.95	0.04	0.93	0.93	0.92	0.93
Computer Science	1368.89	502	0.00	2.73	0.04	0.93	0.94	0.92	0.94
Psychology	1444.08	538	0.00	2.68	0.04	0.92	0.92	0.91	0.92

One-way ANOVAs with the Bonferroni adjustment were calculated examining the differences between disciplines and between ethnicities (see Table 5). Disciplines had a significant effect on “smart/effective” (F (1, 1860) = 34.05, $p < .01$), “friendly interpersonal” (F (1, 1860) = 5.41, $p < .05$), and “creative thinking” (F (1, 1860) = 57.55, $p < .01$). Computer science participants gave higher ratings to “smart/effective” and “outgoing” than psychology participants (for “smart/effective,” $MD_{computer\ science} = .15$, $MD_{psychology} = -.16$; for “friendly interpersonal,” $MD_{computer\ science} = .05$, $MD_{psychology} = -.08$), but rated “creative thinking” lower ($MD_{computer\ science} = -.10$, $MD_{psychology} = .28$). No significant effect was found for “unsociable.”

Significant differences between ethnic groups were found for “smart/effective” (F (1, 1875) = 149.36, $p < .01$), “outgoing” (F (1, 1875) = 42.96, $p < .01$), and “creative thinking” (F (1, 1875) = 348.17, $p < .01$). American participants’ mean ratings (MD = .32) were higher than those of Chinese participants (MD = −.32) on “smart/effective” and on “outgoing” ($MD_{American} = .17$, $MD_{Chinese} = -.20$), but

TABLE 4. Mean, SD, and Rank of the Ratings for Each Factor

Factor	China						America						*M*
	Computer sciences			Psychology			Computer sciences			Psychology			
	M	*SD*	Rank	*M*	*SD*	Rank	*M*	*SD*	Rank	*M*	*SD*	Rank	
Smart/Effective	3.8	0.6	2nd	3.7	0.5	2nd	4.0	0.5	1st	3.9	0.6	1st	3.8
Friendly/Interpersonal	3.1	0.6	3rd	3.1	0.5	3rd	3.4	0.7	3rd	3.3	0.7	3rd	3.2
Creative thinking	3.96	0.75	1st	4.39	0.49	1st	3.82	0.56	2nd	3.73	0.66	2nd	3.91
Dark side	2.55	0.77	4th	2.77	0.69	4th	2.81	0.6	4th	2.7	0.62	4th	2.66

TABLE 5. Mean Differences in Factor Scores by (A) Country X Major (B) Country and Major (Separately)

Factor	America		China	
	Computer science	Psychology	Computer science	Psychology
(A)				
Smart/Effective	.43[cd]	.22[cd]	−.12[d]	−.53
Outgoing	.24[cd]	.09[cd]	−.15	−.25
Creative thinking	−.33	−.42	.13[ab]	.98[abc]
Dark Side	.16[c]	.03	−.12	.14[c]

Factor	Computer science	Psychology		America	China
(B)					
Smart/Effective**	.15	−.16	Smart/Effective**	.32	−.32
Outgoing**	.05	−.08	Outgoing*	.17	−20
Creative Thinking**	−.10	.28	Creative Thinking**	−.38	.56
Dark Side**	.02	.08	Dark Side	.09	.01

Note.
[a]The mean difference is higher than American Computer Science majors at $p < .01$.
[b]The mean difference is higher than American Psychology majors at $p < .01$.
[c]The mean difference is higher than Chinese Computer Science majors at $p < .01$.
[d]The mean difference is higher than Chinese Psychology majors at $p < .01$.
$^*p < .05$, $^{**}p < .01$.

lower on "creative thinking" ($MD_{American} = -.38$, $MD_{Chinese} = .56$). No significant effect was found for "unsociable." No significant differences were found between female and male participants' ratings, which is consistent with other studies (Baer & Kaufman, 2006, 2008).

DISCUSSION

IMPLICIT CONCEPTS OF CREATIVE COMPUTER SCIENTISTS

Implicit concepts of creative computer scientists were comprised of four primary factors: smart/effective, outgoing, creative thinking, and dark side. This result was somewhat different from that reported by Rudowicz and Yue (2000), who conducted a study on implicit conceptions of creativity in China (Beijing, Guangzhou, Hong Kong, and Taipei). Their participants were undergraduate students, and they found three factors: innovative abilities (creative, imaginative, observant, inventive, etc.), dynamism (assertive, independent, self-confident, etc.), and intellectual (wise, flexible, good thinking). Their study did not focus on a specific discipline, however. One cannot know what kind of creative person their subjects were imagining when they made their responses—creative painters? creative musicians? creative scientists in some field?—but it seems likely that the concept of creativity and a creative person in a specific discipline is not the same as conceptions of creativity and a creative person more generally.

In the United States, when people think of a creative person they are more likely to think of someone in the arts than someone in the sciences, (Kaufman & Baer, 2004b; Silvia et al., 2008); so if asked simply to describe a creative person, respondents are more likely to think of a creative artist than a creative mathematician. Implicit conceptions of creativity vary by domain, even within the same cultural context, as demonstrated by the differences between the implicit conceptions of creative computer scientists given by Chinese participants in this study and the culturally similar participants in the Rudowicz and Yue (2000) study, who were simply asked to describe a creative person in general. Just as the personalities, attributes, and skills associated with creative performance vary widely across domains (Baer, 1993, 2010; Charyton, 2005; Charyton & Snelbecker, 2007; Feist, 1998, 1999; Simonton, 2009; Snow, 1964), so do implicit theories of creativity and creative people. Taking a domain-general approach to building implicit theories by asking participants what a creative person is like without specifying the field of creativity would be like asking people what experts are like without specifying the area of expertise. No one would expect that experts in chess, expert chefs, experts in yoga, and expert masons would be very similar. Neither should one expect that implicit theories of creative people in the visual arts, in cosmology, in cosmetology, in poetry, and in computer science (to name just a few domains) would result in similar profiles.

DIFFERENCES BASED ON DOMAINS OF EXPERIENCE OF IMPLICIT CONCEPTS OF A CREATIVE COMPUTER SCIENTIST

Participants with a background in computer science rated creative computer scientists as being more likely to fit a description of "smart/effective" than did participants with a background in psychology, who rated creative computer scientists less likely to be "smart/effective." We should note that the participants that we have described as having a background in psychology may have only limited expertise in psychology—they are not psychologists in the same way that the computer science participants have significant levels of expertise and experience in the field of computer science. They have at least some (in many cases very limited) experience in psychology—they have taken at least one course in the field—but more to the point, they do not have backgrounds in computer science, so they can also be thought of as novices vis-à-vis the field of computer science, which is the domain about which we have probed their implicit theories of creative people. One explanation for this difference in the ways that computer scientists and non-computer scientists have described what it takes for a person to be creative in computer science is that work in computer science is not done primarily by individuals, but is instead usually carried out in the form of team projects that have limited time frames—one must work quickly and effectively with teams. Hence, computer scientists (who are more likely to be aware of this) may be more likely to see the need for a creative computer scientist to be smart and effective than someone from another field (such as psychology, where the work one does is less restricted by project constraints and individuals therefore have more freedom to select both what kinds of projects they will work on and the research approaches they will use). Non-computer scientists (such as students of psychology), who may be less aware of these kinds of constraints within which computer scientists must work, may therefore regard creative thinking as more important (and being smart and effective relatively less important) for creativity than computer scientists. This is speculative, of course, one cannot know why participants from different backgrounds have different implicit concepts of what it means to be a creative worker in any given discipline but whatever the explanation, this difference supports our argument that disciplinary backgrounds are likely to influence conceptions of creativity. Implicit theories of what it takes to be creative will vary from domain to domain and will also vary depending on one's experience in the domain in question.

CREATIVE THINKING RATED HIGHER IN CHINA THAN THE U.S.

Chinese participants rated "creative thinking" as more important for creativity in computer science than did American participants. It is not clear why this might be the case or whether this result would remain true if researchers asked about creativity in other domains. One possibility is that the Chinese participants viewed computer science in China as lagging behind that of the U.S. and therefore creative thinking is more strongly required during this "catching-up" period, but this is speculation. The results show a significant difference between the two groups but cannot provide clear support for any particular hypothesis about why this difference was observed.

This result of ethnic group differences on the importance of creative thinking is especially interesting because it is in marked contrast with the idea that creativity is relatively undesirable for Chinese (Rudowicz & Yue, 2000). In comparing cultural values, researchers have pointed out that different cultures may have different emphases on what types of activities are considered most prototypically creative due to cultural values, such as conformity and independence (Niu & Sternberg, 2002; Paletza et al., 2011). This line of thinking would lead one to expect that Chinese should be less likely to rate creativity so highly in their implicit conceptions of what it means to be a creative computer scientist. Some studies have suggested that more mixed or controversial results might be expected, however. For example, Hui and Rudowicz (1997) suggested that Hong Kong Chinese valued creativity more, and Paletz and Peng (2008), who asked students from Japan, China, and the United States to rate products (either a meal or a textbook), reported that Chinese students were more influenced by novelty and less by appropriateness in their desirability ratings than both Japanese and American students. It seems that cultural values may be more complex than assumed and might not all point in a uniform direction when it comes to concepts of creativity.

The results of this study of implicit theories of creativity suggest that the context of domain or discipline—both the target domain or discipline being considered and the disciplinary background of those whose implicit conceptions are being probed—should be taken into consideration when thinking about conceptions of creativity and the creative person. Scholars have pointed out that creativity requires synthetic abilities to define and represent problems in new ways, analytic abilities to recognize which ideas are worth pursuing, and practical abilities to "sell" one's work to others (Sternberg & Lubart, 1995). The results of this study suggest that the concept of the creative person in computer science cannot be fully expressed by looking only at cognitive or personality variables. To understand creativity in a particular discipline, participants belonging to that discipline might be more qualified to explain what kinds of cognitive abilities, motivation, and personality are needed for creative performance in that field than participants from other fields. One possible approach in the future should be to compare creative and uncreative people in a variety of disciplines with the goal of understanding what key factors explain their differences.

This study suggests that a domain-specific understanding of creativity in different science disciplines might be more complex than current understanding suggests. Simonton (2004) distinguished "hard" natural sciences and "soft" social sciences based on such criteria as disciplinary consensus, knowledge obsolescence rate, anticipation frequency, theories-to-laws ratio, lecture disfluency, and age at recognition. This model provides insight as we try to understand differences among science disciplines, but this single dimension of difference is insufficient to understand fully how creativity is different in the various sciences. Implicit conceptions characterized the computer scientist as smart/effective, friendly, using creative thinking, and featuring a dark side, which is much more complex than a single hard-soft dimension might allow. It will be interesting to observe how these dimensions differ from and overlap with implicit conceptions of the creative person in other sciences, something future research should explore.

LIMITATIONS

Several caveats should be considered in the interpretation of our study's results. All of the initial work of developing the list of descriptors (in the pilot study) was conducted using only Chinese participants, and the participants in the main study were asked only to describe creative people working in computer science, not other fields. For these reasons, even though the structural validity was acceptable in all subgroup samples (American, Chinese, Computer Science, and Psychology), collecting adjective words of creative people only in computer science and only in Chinese might have generated a bias in describing the creative person. In future research, descriptors should be collected from a more diverse group of participants and descriptions of creative people in multiple fields should be assessed. In addition, the sample selectiveness in the two countries was not completely comparable, and the amount of work experience of the samples was not strictly controlled. Despite these important caveats, this study still gives us interesting suggestions about implicit theories of the creative personality from both domain-specific and culture-specific perspectives.

REFERENCES

Baer, J. (1993). *Creativity and divergent thinking: A task-specific approach*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Baer, J. (1994a). Divergent thinking is not a general trait: A multi-domain training experiment. *Creativity Research Journal*, *7*, 35–46.

Baer, J. (1994b). Generality of creativity across performance domains: A replication. *Perceptual and Motor Skills*, *79*, 1217–1218.

Baer, J. (1994c). Performance assessments of creativity: Do they have long-term stability? *Roeper Review*, *7*, 7–11.

Baer, J. (1996). The effects of task-specific divergent-thinking training. *Journal of Creative Behavior*, *30*, 183–187.

Baer, J. (1998). The case for domain specificity of creativity. *Creativity Research Journal*, *11*, 173–177.

Baer, J. (1999). *Domains of creativity*. Encyclopedia of creativity (vol. 1), San Diego, CA: Academic Press.

Baer, J. (2010). Is creativity domain specific? In J.C. Kaufman, & R.J. Sternberg (Eds.), *Cambridge handbook of creativity* (pp. 321–341). New York: Cambridge University Press.

Baer, J. (2011). Why grand theories of creativity distort, distract, and disappoint. *International Journal of Creativity and Problem Solving*, *21*, 73–100.

Baer, J. (2012). Domain specificity and the limits of creativity theory. *Journal of Creative Behavior*, *46*, 16–29.

Baer, J., & Kaufman, J.C. (2005). Bridging generality and specificity: The Amusement Park Theoretical (APT) model of creativity. *Roeper Review*, *27*, 158–163.

Baer, J., & Kaufman, J.C. (2006). Creativity research in English speaking countries. In J.C. Kaufman & R.J. Sternberg (Eds.), *The international handbook of creativity* (pp. 10–38). Cambridge, United Kingdom: Cambridge University Press.

Baer, J., & Kaufman, J.C. (2008). Gender differences in creativity. *Journal of Creative Behavior*, *42*, 75–106.

Barron, F.X., & Harrington, D.M. (1981). Creativity, intelligence, and personality. *Annual Review of Psychology*, *32*, 439–476.

Beghetto, R.A., & Kaufman, J.C. (2007). Toward a broader conception of creativity: A case for "mini-c" creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *2007*, 73–79.

Charyton, C. (2005). *Creativity (scientific, artistic, general) and Risk Tolerance among Engineering and Music Students*. Doctoral dissertation, Temple University.

Charyton, C., & Snelbecker, G.E. (2007). General, artistic and scientific creativity attributes of engineering and music students. *Creativity Research Journal*, *2007*, 213–225.

Conti, R., Coon, H., & Amabile, T.M. (1996). Evidence to support the componential model of creativity: Secondary analyses of three studies. *Creativity Research Journal*, *9*, 385–389.

Cronbach, L.J. (1957). The two disciplines of scientific psychology. *American Psychologist*, *12*, 671–684.

Csikszentmihalyi, M. (1990). The domains of creativity. In M.A. Runco & R.S. Albert (Eds.), *Theories of creativity* (pp. 190–214). London: Sage.

Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 313–335). Cambridge: Cambridge University Press.

Davis, C., Kaufman, J.C., & McClure, F. (2011). Non-cognitive constructs and self-reported creativity by domain. *Journal of Creative Behavior*, *45*, 188–202.

Fein, L. (1959). *The Role of the University in Computers, Data Process*ing*, and Related Fields* 119–126. Proceedings of the Western Joint Computer Conference. New York: Association for Computing Machinery.

Feist, G.J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review*, *2*, 290–309.

Feist, G.J. (1999). The influence of personality on artistic and scientific creativity. In R.J. Sternberg (Ed.), *Handbook of creativity* (pp. 273–296). Cambridge, United Kingdom: Cambridge University Press.

Feist, G.J. (2004). The evolved fluid specificity of human creative talent. In R.J. Sternberg, E.L. Grigorenko & J.L. Singer (Eds.), *Creativity: From potential to realization* (pp. 57–82). Washington, DC: American Psychological Association.

Galton, F. (1874). On men of science: Their nature and their nurture. *Nature*, 9, 344–345.

Gardner, H. (1993). *Creating minds*. New York: BasicBooks.

Gardner, H. (1999). *Intelligence reframed: Multiple intelligences for the 21st century*. New York: Basic Books.

Getzels, J.W., & Jackson, P.W. (1962). *Creativity and intelligence*. New York: Wiley.

Gough, H.G. (1979). A creative personality scale for the adjective check list. *Journal of Personality and Social Psychology*, *37*, 1398–1405.

Guilford, J.P. (1986). *Creative talents: Their nature, uses, and development*. Buffalo, NY: Bearly Limited.

Han, K.S. (2003). Domain specificity of creativity in young children: How quantitative and qualitative data support it. *Journal of Creative Behavior*, *37*, 117–142.

Han, K.S., & Marvin, C. (2002). Multiple creativeness? Investigating domain-specificity of creativity in young children. *Gifted Child Quarterly*, *46*, 98–109.

Hu, L.T., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*, 1–55.

Hui, A., & Rudowicz, E. (1997). Creative personality versus Chinese personality: How distinctive are these two personality factors? *An International Journal of Psychology in the Orient*, *40*, 277–285.

Kaufman, J.C. (2002). Narrative and Paradigmatic thinking styles in creative writing and journalism students. *Journal of Creative Behavior*, *36*, 201–220.

Kaufman, J.C. (2006). Self-reported differences in creativity by ethnicity and gender. *Applied Cognitive Psychology*, *20*, 1065–1082.

Kaufman, J.C. (2012). Counting the muses: Development of the Kaufman-Domains of Creativity Scale (K-DOCS). *Psychology of Aesthetics, Creativity, and the Arts*, *6*, 298–308.

Kaufman, J.C., & Baer, J. (2002a). Could Steven Spielberg manage the Yankees? Creative thinking in different domains. *The Korean Journal of Thinking & Problem Solving*, *12*, 5–14.

Kaufman, J.C., & Baer, J. (2002b). I bask in dreams of suicide: Mental illness, poetry, and women. *Review of General Psychology*, *6*, 271–286.

Kaufman, J.C., & Baer, J. (2004a). Hawking's haiku, Madonna's math: Why it is hard to be creative in every room of the house. In R.J. Sternberg, E.L. Grigorenko & J.L. Singer (Eds.), *Creativity: From potential to realization* (pp. 3–19). Washington, DC: American Psychological Association.

Kaufman, J.C., & Baer, J. (2004b). Sure, I'm creative – but not in math!: Self-reported creativity in diverse domains. *Empirical Studies of the Arts*, *22*, 143–155.

Kaufman, J.C., & Baer, J. (2004c). The Amusement Park Theoretical (APT) model of creativity. *The Korean Journal of Thinking & Problem Solving*, *14*, 15–25.

Kaufman, J.C., & Baer, J., (2005a). *The Amusement Park Theory of Creativity*. In J.C. Kaufman & J. Baer (Eds.), *Creativity across domains: Faces of the muse* (pp. 321–328). Mahwah, NJ: Lawrence Erlbaum.

Kaufman, J.C., & Baer, J. (Eds.) (2005b). *Creativity across domains: Faces of the muse*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kaufman, J.C., & Beghetto, R.A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology*, *13*, 1–12.

Kaufman, J.C., & Beghetto, R.A. (2013). In praise of Clark Kent: Creative metacognition and the importance of teaching kids when (not) to be creative. *Roeper Review*, *35*, 155–165.

Kaufman, J.C., Cole, J.C., & Baer, J. (2009). The construct of creativity: A structural model for self-reported creativity ratings. *Journal of Creative Behavior*, *43*, 119–134.

Kaufman, S.B. (2007). Investigating the role of domain general mechanisms in the acquisition of domain specific expertise. *High Ability Studies*, *18*, 71–73.

Kuhn, T.S. (1970). *The structure of scientific revolutions* (2nd edn). Chicago: University of Chicago Press.

Lubart, T.I., & Sternberg, R.J. (1995). An investment approach to creativity: Theory and data. In S.M. Smith, T.B. Ward & R.A. Finke (Eds.), *The creative cognition approach* (pp. 269–302). Cambridge, MA: MIT Press.

MacKinnon, D.W. (1962). The nature and nurture of creative talent. *American Psychologist*, *17*, 484–495.

Mumford, M.D., Antes, A.L., Caughron, J.J., Connelly, S., & Beeler, C. (2010). Cross-field differences in creative problem-solving skills: A comparison of health, biological, and social sciences. *Creative Research Journal*, *22*, 14–26.

Nisbett, R.E. (2003). *The geography of thought: How Asians and Westerners think differently and why*. New York: Free Press.

Nisbett, R.E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review*, *108*, 291–310.

Niu, W., & Sternberg, R.J. (2002). Contemporary studies on the concept of creativity: The East and the West. *Journal of Creative Behavior*, *36*, 269–288.

Niu, W., Zhang, J., & Yang, Y. (July 28th–August 1st, 2004). Cross-cultural comparison of creativity and deductive reasoning. Presented at the reason and creativity in development symposium of the American Psychological Association conference, Hawaii.

Norenzayan, A., & Nisbett, R.E. (2000). Culture and causal cognition. *Current Directions in Psychological Science*, *9*, 132–135.

Paletz, S.B.F., & Peng, K. (2008). Implicit theories of creativity across cultures: Novelty and appropriateness in two product domains. *Journal of Cross-Cultural Psychology*, *39*, 286–302.

Paletza, S.B.F., Peng, K., & Lic, S. (2011). In the world or in the head: External and internal implicit theories of creativity. *Creativity Research Journal*, *23*, 83–98.

Peng, K., & Nisbett, R.E. 1999 Culture, dialectics, and reasoning about contradiction. *American Psychologist*, *54*, 741–754.

Plucker, J.A. (1999). Is the proof in the pudding? Re-analyses of Torrance's (1985 to present) longitudinal data. *Creativity Research Journal*, *12*, 103–114.

Plucker, J.A., & Beghetto, R.A. (2004). Why creativity is domain general, why it looks domain specific, and why the distinction does not matter. In R.J. Sternberg, E.L. Grigorenko & J.L. Singer (Eds.), *Creativity: from potential to realization* (pp. 153–167). Washington, DC: American Psychological Association.

Plucker, J., & Zabelina, D. (2009). Creativity and inter-disciplinarity: One creativity or many creativities? *The International Journal on Mathematics Education*, *41*, 5–11.

Rudowicz, E., & Yue, X. (2000). Concepts of creativity: Similarities and differences among mainland, Hong Kong and Taiwanese Chinese. *The Journal of Creative Behavior*, *34*, 175–192.

Runco, M.A. (1989). The creativity of children's art. *Child Study Journal*, *19*, 177–190.

Runco, M.A., & Bahleda, M.D. (1986). Implicit theories of artistic, scientific, and everyday creativity. *Journal of Creative Behavior*, *20*, 93–98.

Runco, M.A., Johnson, D.J. & Bear, P.K. (1993). Parents' and teachers' implicit theories of children's creativity. *Child Study Journal*, *23*, 91–113.

Runco, M.A., & Johnson, D.J. (2002). Parents' and teachers' implicit theories of children's creativity: A cross-cultural perspective. *Creativity Research Journal*, *14*, 427–438.

Ruscio, J., Whitney, D.M., & Amabile, T.M. (1998). Looking inside the fishbowl of creativity: Verbal and behavioral predictors of creative performance. *Creativity Research Journal*, *11*, 243–263.

Saunders, D., & Thagard, P. (2005). Creativity in computer science. In J.C. Kaufman & J. Baer (Eds.), *Creativity across domains: Faces of the muse* (pp. 153–168). Mahwah, NJ: Lawrence Erlbaum Associates.

Silvia, P.J., Kaufman, J.C., & Pretz, J.E. (2009). Is creativity domain-specific? Latent class models of creative accomplishments and creative self-descriptions. *Psychology of Aesthetics, Creativity and the Arts*, *3*, 139–148.

Silvia, P.J., Kaufman, J.C., Reiter-Palmon, R., & Wigert, B. (2011). Cantankerous creativity: Honesty-humility, agreeableness, and the HEXACO structure of creative achievement. *Personality and Individual Differences*, *51*, 687–689.

Silvia, P.J., Winterstein, B.P., Willse, J.T., Barona, C.M., Cram, J.T., Hess, K.I., Martinez, J.L., & Richard, C.A. (2008). Assessing creativity with divergent thinking tasks: Exploring the reliability and validity of new subjective scoring methods. *Psychology of Aesthetics, Creativity, and the Arts*, *2*, 68–85.

Simonton, D.K. (1988). *Scientific genius: A psychology of science*. Cambridge, England: Cambridge University Press.

Simonton, D.K. (2004). Psychology's status as a scientific discipline: Its empirical placement within an implicit hierarchy of the sciences. *Review of General Psychology*, *8*, 59–67.

Simonton, D.K. (2005). Creativity in psychology: On becoming and being a great psychologist. In J.C. Kaufman & J. Baer (Eds.), *Creativity across domains: Faces of the muse* (pp. 139–152). Mahwah, NJ: Lawrence Erlbaum Associates.

Simonton, D.K. (2009). Varieties of (scientific) creativity: A hierarchical model of disposition, development, and achievement. *Perspectives on Psychological Science*, *4*, 441–452.

Snow, C.P. (1964). *The two cultures and a second look*. New York: Cambridge University Press.

Sternberg, R.J. (1985). Implicit theories of intelligence, creativity, and wisdom. *Journal of Personality and Social Psychology*, *49*, 607–627.

Sternberg, R.J. (1986). Intelligence, wisdom and creativity: Three is better than one. *Educational Psychologist*, *21*, 175–190.

Sternberg, R.J. (2005). The domain generality versus specificity debate: How should it be posed? In J.C. Kaufman & J. Baer (Eds.), *Creativity across domains: Faces of the muse* (pp. 299–306). Mahwah, NJ: Lawrence Erlbaum Associates.

Sternberg, R.J., Kaufman, J.C., & Grigorenko, E.L. (2008). *Applied intelligence*. New York: Cambridge University Press.

Sternberg, R.J., Kaufman, J.C., & Pretz, J.E. (2002). The propulsion model of creative contributions applied to the arts and letters. *Journal of Creative Behavior*, *35*, 75–101.

Sternberg, R.J., & Lubart, T.I. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.

Sternberg, R.J., & Lubart, T.I. (1996). Investing in creativity. *American Psychologist*, *51*, 677–682.

Sternberg, R.J., & Lubart, T.I. (1999). The concept of creativity: Prospects and paradigms. In R.J. Sternberg (Ed.), *Handbook of creativity* (pp. 3–15). New York: Cambridge University Press.

Tardiff, T.Z., & Sternberg, R.J. (1988). What do we know about creativity? In R.J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 429–440). New York: Cambridge University Press.

Torrance, E.P. (1962). *Guiding creative talent*. Englewood Cliffs, NJ: Prentice-Hall.

Treffinger, D., Young, G., Selby, E., & Shepardson, C. (2002). *Assessing creativity: A guide for educators*. Storrs, CT: National Research Center on the Gifted and Talented.

Weisberg, R.W. (2006). *Creativity: Understanding innovation in problem solving, science, invention and the arts*. Hoboken, NJ: Wiley.

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ACKNOWLEDGMENTS

The research in this article is supported by Chinese National Sciences Foundation Projects number: 71173214, 71273256.