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Systematic review: Factors influencing creativity in the design discipline and assessment criteria

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ABSTRACT

Using psychological instrument to measure creativity is getting popular in design research. However, unlike quantifying general creativity using divergent thinking, the complexity and interdisciplinarity of the design discipline have made it difficult to explore research on design creativity. Therefore, to better quantify and measure design creativity, 31 relevant studies were retrieved by Google Scholar and the University of London Common Research in this article. This study summarizes the factors that influence design creativity in different design disciplines, the rules for setting the internal dimensions, and the valid instruments for measuring design creativity. The factors affecting design creativity can be divided into internal factors (aesthetic, spatial ability, and ambiguity tolerance) and external factors (environment and visual stimulation). Among these factors, different instruments and evaluation criteria considerably impact the result, while the measurement of design creativity is still not mature enough. A single scale evaluation or creative task evaluation cannot comprehensively evaluate the design creativity, which consists of aesthetic, functional, and technical aspects. In addition, the reference value of ordinary creativity remains to be further discussed in design. Under some professional design fields, the effect of widely recognized factors closely related to creativity, such as divergent thinking, imagination, and personality, is insignificant.

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1. INTRODUCTION

Creative thinking is the bridge between art and science, and design is in the middle of this bridge, which includes aesthetic appeal and scientific creativity [1], [2]. Creativity is one of the important personal abilities of designers, and it is also the embodiment of divergent thinking and high-level cognition of students in design programmers [3]. There is no standardized guide to how to measure design creativity because of the huge diversity of specialties within the design field [4]. Moreover, the output of the design (solution, product) is a combination of multiple functions and aesthetics [5]. This leads to different aspects of design creativity. Therefore, a large number of scholars began to use psychological measures to study design creativity [6]. Through a review of previous studies, we summarize some common factors that influence design creativity, and provide advice on setting internal standards and dimensions for measurement, as well as guidance on how to select instruments.

2. RESEARCH METHOD

The paper was searched by two academic search engines, namely Google Scholar and University of London Common Research. Elsevier, Taylor & Francis Online, and Springer are selected as the focused research databases. These three databases contain a large number of journals related to creativity, and all of them have high impact factors. In order to retrieve literature related to design creativity, the keywords searched include: Creativity OR creative design OR design creativity OR creative ability OR creative product OR designer creativity. In order to narrow down further, "impact" OR "influence" OR "affect" OR "related" OR "improve" OR "foster" were also added as key words. There were 59 papers initially found, and 31 papers were remained after excluding studies on general creativity, which were not closely related to design, according to their titles and abstracts. After careful reading and summary of each paper, the paper classified and sorted out according to the three themes, which is the influence factor, the measure instrument and the assessment criteria, and summarized the correlation of research results under the three categories, the detail is shown in Table 1.

Table 1. Research themes

Items	Interpretation	Example
Influence factor	Factors related to design creativity, or factors that can influence creative performance	Imagination/spatial ability/aesthetic/environment/teaching method
Instrument	The methods for assessing or quantifying creativity	CPSS, CAT, TTCT
Assessment criterion	Internal details and criteria for measuring creativity	Novelty/usefully/neatness/originality/appropriateness

Note: Creative product semantic scale (CPSS); Consensual assessment technique (CAT); Torrance tests of creative thinking (TTCT)

3. FACTORS INFLUENCING DESIGN CREATIVITY

Related research is divided into six disciplines: architecture, industry design, engineer design, interior design, graphic design, and fashion design. Among them, industry design is the discipline with the largest number of articles on creativity research, with a total of 31 articles, most of which are related to teaching methods and teaching environment. Both architecture and graphic design tend to explore the relationship between creativity and personal ability, such as personality, aesthetic and spatial ability. Engineer design is mature in its research on creativity measurement tools, and unlike most majors, it has relatively stable and clear functional evaluation criteria [7], [8]. Interior design currently studies the relationship between knowledge and skills in its field and creativity [9]. Fashion design research includes the relationship between environmental impact, professional knowledge, tolerance of ambiguity and creativity [10].

4. MEASUREMENT OF DESIGN CREATIVITY

4.1. Measuring instruments

Among these 31 studies, except for one qualitative study using observation method, two studies using self-evaluation, and three studies using experts grading, there are altogether nine tools to test creativity. According to the evaluation methods and basic theories, they can be divided into three categories: i) Subjective evaluation; ii) Scale evaluation; and iii) Creative task evaluation. The details are shown in Table 2.

Table 2. The category of instruments for measuring creativity

Category	Instruments
Subjective assessment	Consensual Assessment Technique (CAT), Design Rating Survey (DRS), The Iowa Inventiveness Inventory (III)
Scale assessment	Creative Product Semantic Scale (CPSS), Cropley and Cropley scale (CCS), Metrics for Measuring Ideation Effectiveness (MMIE)
Creative task assessment	Torrance Tests of Creative Thinking (TTCT), the Remote Associates Test (RAT), Abbreviated Torrance Test for Adults (ATTA)

4.2. Subjective assessment

Subjective assessment includes Consensual Assessment Technique (CAT), Design Rating Survey (DRS), and The Iowa Inventiveness Inventory (III). The main feature of this type of evaluation is that the judges' subjective judgment basically determines the creativity score. The judges have little or no interference. The dimensions of creativity evaluation are not overly complex, and there are no strict scales or rubrics to guide the judges' scoring. Therefore, the professional level of the judges and the consistency of the scoring determine the reliability of the evaluation.

Table 3. Factors influencing design creativity

Discipline	Influence factor		Instrument	Correlation	Source
Graphic design	The form of examples		Observe	√	[11]
	Aesthetic		CAT	√	[12]
			RAT	×	[13]
	Contextual teaching learning method		Self-evaluation	√	[14]
	Co-creative virtual learning		CPSS	×	[15]
	Mind Mapping		CAT	√	[16]
Architecture	Abstract thinking		TTCT	√	[17]
	Visual cognitive style			√	
	Spatial ability			×	
	Personality			√	
			CAT	√	[18]
	Virtual reality (VR): Virtual body		Self-evaluation	√	[19]
	Ambiguity tolerance		TTCT	×	[20]
Interior design	Spatial ability		CAT	×	[21]
			CAT	√	[22]
	Visual stimulation: Image type		CAT	√	[22]
Industrial design	Aesthetic		CPSS	√	[23]
	Virtual reality (VR): Virtual environment		CCS	√	[24]
	Work environment	Light and music	CPSS	√	[25]
		Online collaborative design system	ATTA	√	[26]
	Graphics software: three-dimensional computer-aided design		CPSS	√	[27]
	Communication	Brainstorming	Experts grading	√	[28]
		Design thinking	CAT	√	[29]
	Visual stimulation	Sketches and picture	Experts grading	√	[30]
		Full and partial	CAT	√	[31]
		Images with/without text	CAT	√	
		Ambiguous or definite image	TTCT	√	[32]
Fashion design	Ambiguity tolerance		III	√	[33]
	Virtual reality (VR): Virtual environment		Experts grading	√	[34]
	Family environment		III	×	[35]
	Imagination		CAT	√	[36]
Engineering design	Personality	Openness	DRS	√	[37]
		Conscientiousness		×	
		Extraversion		√	
		Agreeableness		×	
		Neuroticism		√	
	Virtual reality (VR): Teaching application		CPSS	√	[38]
			CPSS	√	[39]
	Designer-product interaction		MMIE	×	[40]

CAT occurrences the highest, with a total of 9. In Amabile [41] and the followers in hundreds of trials, it is found that experts in different fields have a high degree of consistency in their subjective ratings of professional creativity. There are three ways to test the consistency of CAT: i) Winer proposed the reliability coefficient obtained by analyzing internal and external variation (1); ii) Spearman-brown prediction formula, consistency coefficient (2); and iii) Cronbach coefficient in SPSS software (3).

$$\propto= 1 - \frac{MS_{Within-Raters}}{MS_{Between-Raters}} \quad (1)$$

$$\alpha = \frac{nr}{1+(n-1)r} \quad (2)$$

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum S_i^2}{S_x^2}\right) \quad (3)$$

Moreover, studies have found that in some fields, raters who are not experts can still achieve high levels of agreement. Since the end result of design is the product, and targeting the product is the most direct way to evaluate a designer's creativity. CAT is the gold standard for this creativity test.

The consistency between architectural experts as CAT judges was achieved 0.8, it is also found that the correlation between CAT index and divergent thinking was not as high as expected (R=0.226, P<0.006), its relationship between openness is also far lower than that of other design majors [18]. Further, Saad *et al*. [42] subdivided CAT evaluation dimension, and novelty is divided into three subsets: innovated, surprising, unexpected. The creativity of function and technology is applied to concrete factors such as walls, space, lighting, materials and intelligence. In contrast, three interior design studies applied CAT without setting too many evaluation criteria, among which Suh and Cho [22] found that the CAT index also achieves considerable

reliability and validity without interfering with the experts' judgment on the creativity of works. The research results show that, in graphic design, the internal consistency of CAT experts as judges is above 0.7, in which Type Task has the highest consistency (r=.82) and the image task has the lowest consistency (r=.62) [43]. Later, Jeffries applied the improved CAT model of Baer [44] and Kaufman *et al*. [45], which standardized guidance to judges, with internal agreement between a floating difference of 0.05 and 0.09. It is concluded that to count or discount technical execution does not have a great impact on graphic design creativity.

It can be seen that, despite numerous studies demonstrating a high degree of consistency among quasi-experts, practitioners, and even students as CAT judges, but in studies, the judges tend to be experts, and because CAT is not mandatory, the researchers' criteria are more flexible. It is worth noting that four of the nine articles only take creativity as the sole criterion of CAT. Whether setting standards will mislead the judges is also one of the controversies in design creativity research.

4.3. Scale assessment

CPSS, CCS, and MMIE classified as scale assessment. The biggest difference from subjective evaluation is that it has more strict limits on evaluation criteria or evaluation process. Although this kind of method is not as flexible as subjective evaluation, the evaluation process is more standardized and the results are more stable. This helps to disentangle the creative attributes of different aspects of the product and facilitate the horizontal comparison between different evaluation groups. CPSS is the most representative scale evaluation instrument, it was also invented specifically for design creativity. Like CAT, CPSS is also product-oriented, so it is very popular in the study of design creativity. Different versions of CPSS have different dimensions, but they basically to assess novelty, resolution, and elaboration and synthesis.

However, García-García *et al.* [25] conducted the study and defined the assess standard of CPSS as novelty (novelty of the product), resolution (project coherence), style (pattern of design). Lin *et al.* [38] defined the assess standard of CPSS as process, form, function, this takes into account both the creative process and the evaluation of the results. Believed that aesthetic expressiveness must be based on function, so they decided to use novelty, expressiveness, and functionality as the evaluation criteria. In terms of engineering design, a study on the relationship between Spital ability and creativity omitted aesthetic and artistic evaluation, and identified novelty [7], [8], resolution and elaboration as CPSS evaluation dimensions.

It can be seen that although CPSS has stipulated the evaluation standards and procedures, scholars have still modified it. Perhaps, as a new interdisciplinary subject integrating technology and art, the standardized evaluation method is not suitable for design. Since the design product contains many aspects of creativity such as technology, aesthetics and function, the process and standard of scale evaluation should also be improved according to the research direction when selecting tools to evaluate design creativity.

4.4. Creative task assessment

TTCT, RAT, ATTA and the similar tools guide participants through different creative tasks and serve as a basis for assessing creativity. They are also the most commonly used tools in psychology to measure universal creativity. TTCT is the most widely used tool for general creativity, and it has two basic tasks: Verbal and Figural, divergent thinking in language and image was measured respectively by TTCT. This method is mainly to allow the subjects to produce as many creative solutions as possible in a limited time. A large number of studies have proved that divergent thinking test has good validity in predicting creative performance, and it has been shown to cross cultural, personality, language and other barriers. However, among these 31 articles, only 2 studies applied TTCT, and RAT and ATTA only appeared once. It seems that creative task evaluation is not very popular in the studies of design disciplines.

However, design is not a single social science or science, nor can it be considered as fine art. As a comprehensive discipline intersecting multiple fields, it has various creative performances. TTCT, RAT, ATTA and other scales measure creative potential, not creativity itself. Therefore, TTCT and ATTA scores of participants only reflect their divergent thinking, RAT is simply an expression of convergent thinking. Whether this can effectively predict design creativity, which is composed of multiple factors, is questionable. For example, in a study on the relationship between tolerance of ambiguity and creativity, the author used TTCT and actual architectural design tasks as reference bases to evaluate participants' creativity. However, there was no correlation between TTCT and creative task performance, and tolerance of ambiguity was only related to TTCT results. Therefore, researchers need to further explore how to use creativity as a reference for creative performance in design.

5. RESULTS AND DISCUSSION

In 31 articles, a total of 29 evaluation criteria for creativity appeared. According the interpretation of the evaluation criteria, they are roughly classified into four categories: i) Creative expression; ii) Practical cluster; iii) Quality and quantity; and iv) Aesthetic performance. The detail is presented in Tables 4 and 5.

Table 4. Categories of creativity assessment criteria

Categories	Instrument
Creative expression	Novelty 12, Originality 8, Surprise, Unexpectedness, Genesis
Practical cluster	Feasibility 5, Appropriate 4, Functionality 4, Practicality 3, Usefulness 3, Resolution, Suitability, Function
Quality and quantity	Fluency 4, Quality 4, Elaboration 3, Variety 2, Quantity 2, Process, Complexity, Technical quality, Flexibility, Insolubility,
Aesthetic performance	Aesthetics, Elegance, Form, Expressiveness, Style

Table 5. Criteria for design creativity assessment

Creativity criteria	Instrument	Source
Novelty, Appropriateness	CAT	[21]
Novelty, Usefulness, Functionality, Surprise	CAT	[23]
Novelty, Usefully, Appropriate	CAT	[18]
Novelty, Complexity, Insolubility	III	[33]
Novelty, Unexpectedness, Feasibility	Experts grading	[28]
Novelty, Resolution, Style	CPSS	[15]
Novelty, Elaboration, Resolution	CPSS	[39]
Novelty, Variety, Quantity, Quality	MMIE	[40]
Novelty, Expressiveness, Functionality	CPSS	[27]
Novelty, Functional, Appropriate	Self-evaluation	[19]
Novelty, Style	CPSS	[15]
Novelty, Elegance, Genesis	CCS	[24]
Originality, Fluency, Elaboration	TTCT	[17]
Originality, Appropriateness	CAT	[16]
Originality, Practicality, Quality	Experts grading	[30]
Originality, Practicality, Aesthetics, Technical Quality	CAT	[31]
Originality, Fluency, Elaboration	TTCT	[32]
Originality, Flexibility, Fluency	Experts grading	[34]
Originality, Feasibility, Usability,	CAT	[29]
Originality, Fluency, Elaboration	ATTA	[26]
Originality, Fluency, Flexibility, Practicality, Suitability	RAT	[13]
Process, Form, Function	CPSS	[38]
Creativity only	CAT	[22]
Creativity only	CAT	[12]
Creativity only	TTCT	[20]
Creativity only	CAT	[36]
Creativity only	III	[35]
Creativity only	Observe	[11]
Creativity only	DRS	[37]
Creativity only	Self-evaluation	[14]
Creativity only	CAT	[22]

5.1. Creative expression

Creative expression appears in different forms in almost all studies. Novelty and originality were the main expression forms, see Table 5. Novelty was recognized the highest, and novelty was regarded as one of the evaluation criteria for 12 papers, followed by originality for 8 times. While surprise, unexpectedness, and genesis each occur one time. It can be seen that novelty and originality are the high generalization of creative expression, and their meanings also have overlapping relationship. For instant, Han *et al*. [23] explained novelty as originality and newness, and simply defined the creativity formula: Creativity (C)=Novelty (N)×Usefulness (U). Whereas Chang [39] explained novelty as originality and initiative. Therefore, it is not difficult to understand that originality is hardly set as the standard when novelty was set as the standard in studies.

5.2. Practical cluster

It can be seen from Figure 1 that practical cluster mainly appeared in the research applied CAT, CPSS, experts grading. It is worth noting that both CAT and CPSS are evaluated on products, and Experts Grading can also be considered as CAT without systematic guidance and consistency evaluation. Therefore, the tool that takes the product as the evaluation object, not only gives consideration to the novelty and originality of the idea, but also ensures the practicality and technical rationality of the idea.

The main criteria for feasibility evaluation are feasibility, appropriate, and functionality, and the three criteria mainly focus on technical creativity, technical creativity, and validity of idea. Such as: Casakin and Georgiev [29] explained the feasibility as the rationality and innovation of technology and materials. Cropley defined appropriate as solution fits within task constraints. Hong *et al*. [19] considered appropriate as the creative point is called usability in the project, and functionality is set to technical rationality in design solution. Han *et al.* [23] defined functionality as the performance of a product.

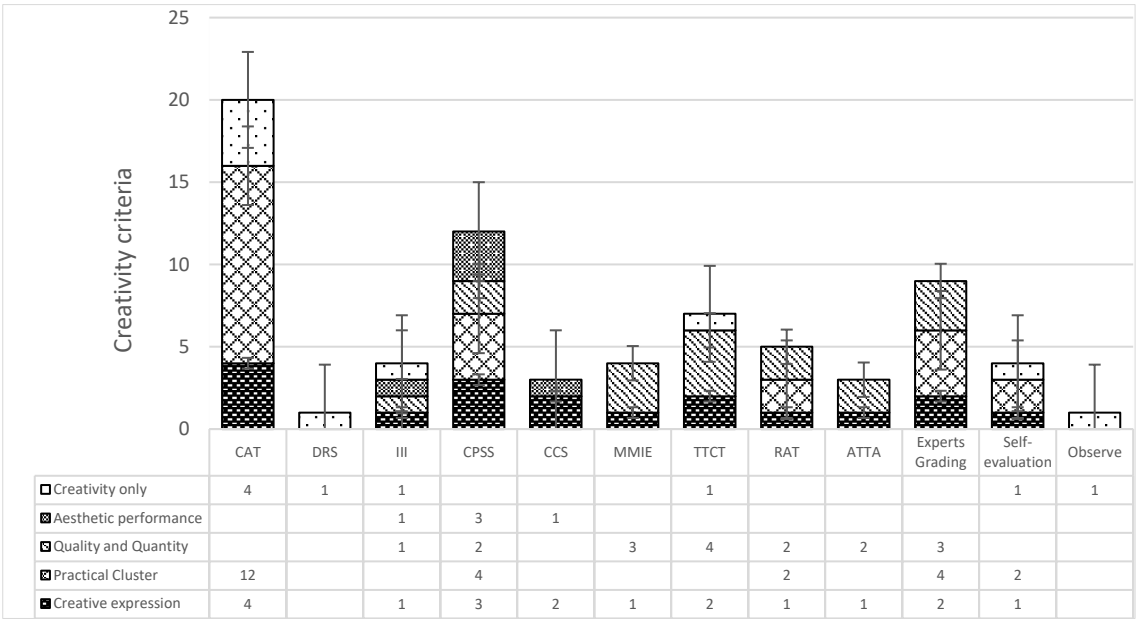

Figure 1. Frequency of occurrence of standard categories in creativity measurement instruments

5.3. Quality and quantity

The product attributes of the design output and the numbers of ideas are reflected in criteria such as quality and quantity. In Figure 2, we find that there are a large number of descriptors occupying this assessment standard, of which fluency, quality, and elaboration are the most representative. In Figure 1, in addition to CCS, scale assessment and creative task use them as evaluation criteria. All, most scholars agree that production fluency is an expression of design creativity.

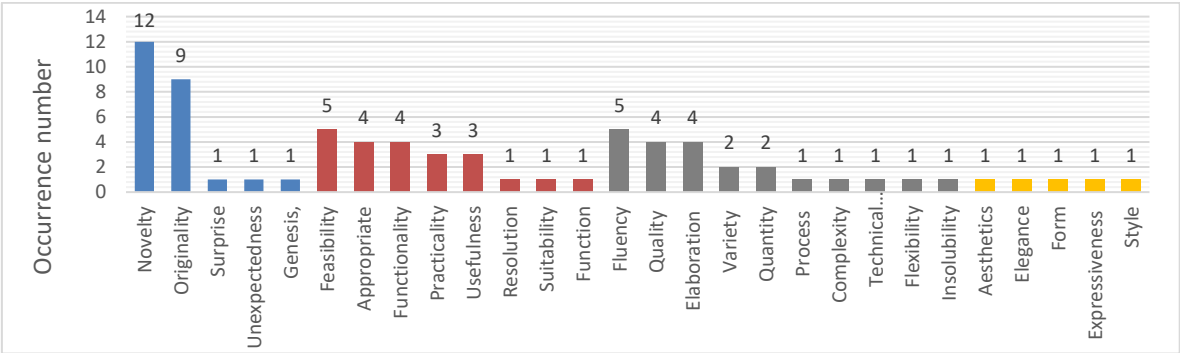

Figure 2. Frequency of occurrence in the creativity criteria

These criteria describe the mental activity of a designer in solving a problem. For example, Hsu *et al*. [26] explained fluency as the ability to generate quantities of ideas. Lee *et al.* [34] described it as fluency in design thinking. Laing and Masoodian [13] concluded it as the number of ideas. Jang *et al.* [32] defined elaboration as the creative quality of the decoration, color, or brightness in your design. In the study of Toh and Miller [37], quality is the complexity and detail of a solution, variety is the solution to a problem, and so on. Fluency is also the addition of other more obscure criteria. Insolubility, for example, is defined as a lack of consistency in different creative points or clues.

5.4. Aesthetic performance

According to Figure 1, dimensions and standards related to aesthetics mainly exist in CPSS. It the initial version of CPSS, O'Quin, and Besemer has set the think of aesthetics as an aspect of creativity. Subsequent researchers using CPSS used many different words (form, expressiveness, style) to describe

aesthetics, but in fact, the details of aesthetics were only supplemented. For example, Han *et al.* [23] defined aesthetics as the ergonomic and visual appeals of a product. García-García *et al.* [15] set style as one of the standards of aesthetics. Chang *et al.* [27] summed up the artistic expression and tension as expressiveness, considered as an evaluation standard. In VR design teaching research, form is the appearance form and type of design. Elegance in CCS is a complement to aesthetics as well, like elegance refers to "the elegance of the product is convincing."

5.5. Creativity only

In addition, there were nine articles, which did not set internal standards and only took creativity as the sole criterion. For example, in a graphic design creativity study, researchers believed that excessive internal standards of creativity (Aesthetic appeal, or technical execution) could easily mislead judges, so creativity was taken as the only standard. Similarly, Toh and Miller's [37] study of personality and creative performance of engineering designers, and the influence of visual stimulation on creativity in interior design, and whether the family background affects the creativity of fashion design students and so on have yet set the criteria.

6. CONCLUSION

The study collected 31 literatures on design creativity and summarized the factors influencing design creativity, appropriate measurement tools, and evaluation criteria for design creativity. In light of this, the following issues remain to be addressed. First, internal-external influencing factors and disciplinary differences. There are differences between various design disciplines regarding the factors that influence creativity, with extrinsic factors having a far less significant impact on creativity than intrinsic factors.

Second, applicability of different measuring instruments. Different instruments can affect the final results, so each design discipline needs to be studied with the appropriate instruments adapted to its characteristics. At the same time, different instruments and evaluation standards in the same field will also affect the results. For example, in Graphic design, students' RAT and Aesthetic scores are not highly correlated, while CAT scores are significantly correlated with Aesthetics. However, this difference was mainly reflected in creative task assessment (TTCT, RAT, ATTA), while the difference between subjective assessment (CAT) and scale assessment (CPSS) was not significant enough.

Third, non-standard evaluation criteria for design creativity. Currently, there are no standardized evaluation criteria for design creativity; researchers set evaluation criteria based on their understanding of the design discipline. In 31 studies, most evaluation criteria have overlapping meanings, which obviously cannot achieve the uniformity as traditional psychological measurements. Interdisciplinarity is the main reason for the broad meaning of design creativity. Therefore, future research on design creativity needs to develop design creativity assessment models based on the characteristics of different design disciplines to allow such research to develop effectively.

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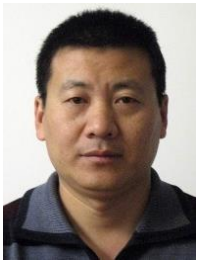

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