Cognitive Phenomena of Style and Creativity

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Abstract

This paper explains a cognitive notion of style and creativity approached from reviewing the general concepts of design thinking and cognition, exploring patterns of cognitive operations conducted in the design processes, elaborating how style and creativity are coming from executing these cognitive operations. In fact, style and creativity are the resulting phenomena, or byproducts, coming from design cognition. Thus, based on the concept of resulting phenomena from cognition as the premise, this paper itemized the theories of "changing or modifying our ways of executing our design cognition, our style and creativity would be improved." Especially, style and creativity, as defined by features appearing in design products, should be treated as physical entities that they could be identified, recognized, and measured instead of abstract notions of intangible elements. Finally, the correlations between style and creativity are summarized to conclude the impact of design cognition. Hopefully, this paper will provide an outline for the ways to improve our style and creativity in design.

Keywords: Design Cognition, Design Problem-Solving, Design Thinking, Style and Creativity.

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COGNITIVE PHENOMENA OF STYLE AND CREATIVITY

Design is to intentionally develop means to meet the desired ends and is a problem-solving activity. There are many operational variables involved in each design project, and a designer would think through variables methodically to find a satisfactory solution. From an operational perspective, while solving different design problems/projects, designers might think differently, resulting in different "creative" forms, or think similarly that resulting in "stylistically" produced forms. Such thinking activities are unique in nature and different thinkers have different patterns of thinking on designing that deserve academic study.

This research explains the resulting phenomenon of designing from a human cognition point of view. Laid out in logical questioning sequences, the general concepts of design thinking, design cognition, patterns of cognitive operations applied in designing are reviewed; how style and creativity arise from executing these operations are discussed. A theory on "changing/modifying the ways of executing design cognition to improve individual style/creativity" is elaborated. These concepts will be of interest to readers in many design professions.

WHAT IS THINKING?

Thinking is a part of human intelligence, which occurs when a person is processing some knowledge in the mind to handle things that happened in front of him or her. When peoples think, they usually apply some kind of logical reasoning to achieve certain intended task; for instance, to ideate a concept, to formulate a creation, to make a judgement, or to solve a problem. Thus, thinking is, in fact, the activities of processing some "information or knowledge" in the brain managed by consciousness (or some mechanisms) in the mind. We could also say that the brain is the hardware and the consciousness in the mind is the software. It is the software that controls the entire processes of all information either stored in the brain or obtained externally through senses. Yet, we should also recognize that the consciousness in the mind is a part of the brain (Penfield, 2015).

WHAT IS COGNITION?

If we explain thinking as ways of processing information in the mind, then it is attributed to the human nature of cognition. Cognition relates to the mental processes of how humans perceive information in the world, selectively capture the attended information, imagine and convert the information into graphic representation (if it is needed in graphic related tasks), conceive and interpret the information to make it into knowledge, apply the information tactically to fulfil the intended missions, make judgements with reasoning on whether the situation has been satisfied, then develop a knowledge scheme of the case and store the scheme in memory for later use, and even fetch the information embedded in previous schemes from memory for re-use. Therefore, thinking is a part of human cognition in the mind on perceiving, interpreting, memorizing, retrieving, and reasoning information. This utilization of pieces of information to turn them into human knowledge, and the application of cognitive operations (or cognitive mechanisms) are the abilities of human intelligence. It is the cognitive operations that drive human thinking.

WHAT IS DESIGN THINKING?

Design thinking is the general human thinking process with additional attribute of design aspect. Here design is defined as intentions, plans, and plots for generating an abstract or physical thing that has functional and aesthetical value. Thus, if thinking is intentionally processed for purposefully generating certain things that are functional, valuable, and beautiful; then such thinking

is design thinking. Generally speaking, design thinking is how human beings work on arranging daily routines, developing intentions for creating artifacts, or managing operational processes for business purposes (Brown, 2009).

As a matter of fact, such thinking processes should be seen as problem solving processes. Then, what is a problem? A problem is when we face a task and don't know immediately what to do; then we have a problem. As such, thinking is the processes of figuring out what to do by utilizing internal and external information to solve various problems we are facing in all aspects, and design thinking is the process of solving problems with particular cognitive operations and intentional actions. Thus, design thinking is not only a kind of problem solving activity, but also a special kind of cognitive process.

Operational wise, design thinking could have been applied for solving everyday life routines to make a better life, to solve architectural design problems for generating a functional and buildable building, to solve business problems for creating elegant product designs, to solve engineering problems for manufacturing industrial designs, to solve aesthetical problems for creating a beautiful painting or sculpture, or even solving some learning problems in teaching to achieve the best learning effects, to name just a few.

WHAT IS DESIGN COGNITION?

If cognition is seen as the mental processes of getting, developing and utilizing knowledge from learning, perceiving, imaging, conceiving, remembering, and reasoning; then design cognition should be explained broadly as how human beings process cognition in some special ways to achieve beauty, function, and market value for what they want to do. Particularly, it is critical in design professions, for instance, in the fields of architectural, landscape architectural, engineering, graphic, interior, and product design, etc., some design related cognition should be utilized for design creation. This article concentrates mainly on the cognitive operations that would be applied in the design processes, which are the mental tasks of design cognition.

WHAT ARE THE OPERATIONS OF DESIGN COGNITION?

Based on the notion that design is problem solving activities, design cognition could be categorized into eight major patterns. These cognitive patterns are the cognitive activities utilized by designers in solving design problems. These patterns have been studied by scholars and discussed in various research publications, which are summarized in short and explained below with major selective citations.

1. Design is goal oriented and bound by design constraints

Design problem solving processes have certain fixed procedures to follow, which represent a series of design steps or sequential goals to accomplish (Chan, 1990). Each goal has its own scope of issues together with certain related constraints associated to consider while achieving these goals. Different goals have different constraints attached, which could be developed before the design starts or during the design processes. These steps of sequential goal procedure on addressing the connected issues and constraints were developed through years of design practices, and are critical on solving complicated design problems.

The resulting phenomena of this cognitive process is that the design processes move along more effectively and efficiently, designers are more aware of handling the sequences that are not goal oriented. On the other hand, the

goal-oriented processes are lineally focused processes; any change or unusual change of goal sequences would change the problem structure, thereby leading to the creation of a new product (Cross & Cross, 1995). Here, the problem structure means the overall layout of the problem framework.

2. Design is making associations

As explained by scholars in developmental psychology and cognitive psychology, human knowledge is built up by association (Anderson, 1980). Making association means to link new experience with what had been previously known in memory through association (Bower, 1970). Associations are formulated either by chronological contiguity, cause and effects, frequency of connection, similarity and contrast, or stimulus and response. After the knowledge is learned, it is also recalled by the same link of association from memory for application (Winner & Shohamy, 2012).

Likewise, design knowledge is also learned and recalled by association for designing. When designers work on a restaurant design, they would make associations with related design cases for reference or find design information on similar restaurant type to aid their design generation. Such kind of association is the concentrate thinking on related information, or convergent thinking type. However, it has been proposed that design problem solving should also involve a divergent, as opposed to a convergent, thinking process (Hatch, 1988). Divergent thinking is to make unrelated connections for design. If unusual associations are linked, its resulting phenomenon would generate an unusual idea.

3. Design is also performed by asking questions

In design, designers might keep asking themselves some hypothetical and "what…if…?" questions to constantly identify their standing point and orient their position in problem solving processes. These activities, depending upon the timing of the questions asked, do have the following multiple purposes. If the questions are asked in the beginning of the design stage, then the purposes are to set up problem constraints for limiting efforts on solution search. If the hypothetical questions are asked at the stage of developing solutions, then the questions are usually posted on simulating reality for evaluating the feasibility, consequences, potential impacts, or values. Resulting phenomena of this cognitive ability are that it is thinking in action (or reflection-in-action, Schon, 1983), and it is the learning in process on accumulating design knowledge. In some cases, unusual questions asked can lead to the generation of surprising results.

4. Design is utilizing knowledge schema stored in memory

In problem solving theory, the characteristic of getting a problem solution is to find a solution through searching for heuristics (Newell & Simon 1972). A heuristic is defined as what was learned from experience and developed into the kind of rule based common knowledge or common sense. For example, in solving one type of problem, the problem solver would search from memory to find a similar type of pre-solved case, and appropriately modify it to fit the current problem context. As long as the correct heuristic is found, a solution is soon to be achieved.

The heuristic stored in memory could also be categorized as a type of knowledge and termed *schema* by cognitive psychologists. A schema has a certain format of rule structure embedded that could be applied to solve similar problems (Anderson & Bower, 1973). Some of these design related knowledge schemata do have the character that there are isomorphic images associated (Kosslyn,

1975). Some images are clear and some are abstract. Designers could apply these images directly for solving design problems. Similar notions of applying previously solved old cases for the current new problem are called case-based reasoning, which were studied in the 1990s by scholars.

Possible phenomena of after utilizing knowledge schemata are that if more of the schemata are developed through practice and stored in memory, then the abundant knowledge information base would provide designers with more chances to recall, apply, and create that certainly would achieve the expert level. More applications of the same schemata might generate more similar design solutions, which would also share similar features across design products.

5. Design is finding, modifying, and building up representations

Representation is to use something to present and represent something else (Echenique, 1972, Chan, 2011). When a design concept is ideated, it must be converted into an image format in the mind (internal representation, Chan, 1997) and present it out to the real world through media of drawings or models (external representation). In the processes of designing, the internal and external representations must be modified from time to time to match together with the conceptual development for completing final form solutions (Eastman, 2001). These are the mental design processes of finding an appropriate representation for showing the concept or establishing an elegant representation of the abstract concept. If an unusual representation is developed, then its resulting phenomenon would have an unusual design product.

6. Design is the process of utilizing some reasoning

Thinking processes are supported or driven by reasoning, which could be deductive, inductive, or abductive. For instances, designers would use some facts or data to ask a particular hypothetical question to find its related specific situation (deductive reasoning, Magnani, 2009, pp.9-10), or based on some specific situation to ask for general principles and to look for generalization (inductive reasoning, Aliseda, 2006, p. 33), or even randomly ask a question from educated guesses (abductive reasoning, Peirce, 1997, p. 242) to keep the design activities in progress. Sometimes, when designers are in the processes of addressing functional problems in space, spatial reasoning would also be applied. Spatial reasoning relates to how people reason about the spatial relations among objects (Byrne & Johnson-Laird, 1989). These reasoning cognitions set up assumptions, and generate solutions to sustain the processes of design.

An experienced designer would use rules of inference relating to the three-dimensional aspect of objects in space to arrange functional compositions, predict and evaluate results for design solution generation. The resulting phenomenon on applying reasoning in design would be that a unique inference would lead to the generation of a consequential unique product regardless of what type of reasoning was applied.

7. Design is to use strategies for generating a design

While designers are thinking on form generation, they spend effort on developing strategic procedures and/or methodologies to strategically create the form. For instance, the elevation grammar used by Frank Lloyd Wright in his Prairie Houses design is a good example (Chan, 1992). In digital architecture, methodological or algorithmic approaches are also commonly applied for form generation. For example, for generating a high-rise building tower in Grasshopper, designers would use similar functional components for: (1) flexibly setting up the number of floors, (2) determining each floor height and orientation of lift to create the tower

body, and (3) using twist and angle functions to generate twisted shapes (if the designers choose to). These are the standardized sequences of form generation bound by the modelling nature or functions available in Grasshopper. Other generally or commonly used design methods include metaphor, analogy, and iconic representation. Utilization of any well-planned strategy would lead to the phenomenon of creating an outstanding form.

8. Design has the human nature of repeating or making repetition

Repetition is a cognitive strategy subconsciously or consciously used to repeat the same action or thinking. It happens in language, music, learning and design. For example, in language, repeated words in rhetoric would emphasize the to-be-expressed linguistic message to achieve the purposes of persuasion (Boisvert, 2011). In music, repeating a fixed rhyme, beat, or melody would generate a pleasant and impressive piece of music (Yeston, 1976). In learning, a repeated exercise (or called drill or rehearsal) on a particular task would improve learning effects (Atkinson & Shiffrin, 1968). Therefore, we learn how to ride a bicycle by repeatedly practicing. In design, repeated function in design and structure would make a coherent and economic building (Goodridge, 1998, Mithen, 2005).

The resulting phenomenon of repetition created in design products is rhythm. In fact, rhythm does generate some regularity, simplicity, balance, and hierarchical order of composition in the design products that could be well perceived and easily comprehended by beholders (Chan, 2012). Alvar Aalto's church design (see Figure 1) demonstrates such beautiful phenomena shown by the four repetitions of the same curved beam on ceiling. If there are skylights on top of the beam, then the shadows and lights casting onto the walls and floor would create another additional layer of rhythm, which can be seen in his Riola Church in Riola di Vergato, Italy designed in 1966.

Figure 1. Rhythm in Alvar Aalto's Heilig-Geist-Church design in Wolfsburg, German, 1958-1962. (Christian Ganshirt/Wikimedia Commons)

WHAT ARE THE PHENOMENA CAUSED BY DESIGN COGNITION?

From reviewing these eight essential cognitive operations and drawn from study data collected from conducting psychological studies (Chan, 2000, 2001) and case studies (Chan, 2015); two aspects of design patterns should be carefully discussed. These two special aspects of style and creativity are resulting phenomena coming from executing these design cognitions. In fact, style and

creativity do signify good quality of design and, thus, have been used as labels to represent certain special characters of designing.

1. Style

Style is the designer's special ways of doing things, which create certain characters in products. These characters are signified by features in products. Thus, style is recognized by the features occurring in a product and across products. It is the repetition of the same features displayed in products that manifests a style (Chan, 1994). Here, the term *feature* is defined as either the physical appearance of an element shown in a design product, or its functional feature of the product. The reasons of generating repeated features should be the design intention applied across products on the use of similar design knowledge schema, similar generated algorithm, similar reasoning, or even similar goal sequences that generate certain similar physical appearance or functional components (Chan, 1992, 1993, 2001). The recycling of these cognitions does create similar features and the reasons for continually using these design intentions might be caused by the designers' mindset. Yet, the driving force of style is the cognitive factor of repetition by repeating some cognitive factors yielding the same features in products, which automatically manifests the appearing and existence of a style.

2. Creativity

Creativity has been seen as the ability to create meaningful ideas, forms, sounds, methods, performances and interpretations; and all these creations ought to be new. From the point of identifying the driving forces of creativity, it has been defined operationally as "the particular actions of consciously operating knowledge through some reasoning to generate a design idea that has a certain functional, aesthetic and marketable value; and that resulting production is new, novel, beautiful, and accepted by the public (Chan, 2015). When a design product is generated by a designer that has never been generated before, then the design is a creative one and the designer is also creative.

Factors that trigger creativity are the execution of the following cognitive operations, as listed in the previous section: changing the design goal that changes the problem structure (item 1), making special associations to come up with a novel form (item 2), asking special questions to lead to a novel form creation (item 3), utilizing a special schema from memory that causes a special association (item 4), finding a special representation to make up a new form (item 5), applying special reasoning (item 6), and developing a totally new strategy to create a new form (item 7). As long as the exercises of these cognitive factors do lead to the creation of a novel form that is functional, marketable and has not been created before, then creativity is used to label such a design quality and ability.

WHAT ARE THE CORRELATIONS BETWEEN STYLE AND CREATIVITY?

Style and creativity do correlate to each other, which could be understood from seeing them as entities. In style, common features, created by a designer and appearing in his/her design products, are used to label the designer's individual style. A series of psychological experiment data (Chan, 1994) has proven that the number of four features appearing in a product is the threshold of defining a style. When the number of features in products is three, then it is the threshold of recognizing the style through perception. This is because when the number of features drops down to 3, interference among features affects visual perception (Chan, 1994). Thus, more features will manifest its style stronger than fewer features. Metaphorically speaking, a larger number of features will glue the style stronger than a smaller number that appears in products (Chan, 2000).

In creativity, features shown in products are also used to demonstrate a designer's creativity. If a feature is created by a designer that is new, novel and has not been created before, then this creative feature signifies the creativity of this designer. More of such features created by the same designer do demonstrate a higher level of creativity in comparison to other designers (Chan, 2015).

However, style and creativity are both the by-products of cognitive activities shown in design products, and they do have correlations. The correlation is affected by the cognitive operation. For instance, a novel project is created by unusual cognitive activities. Without the activities, creation would not be done, and consequently no style be generated. On the other hand and seen from the product side, the features used to define an individual style must be the original creation by the same designer and four of them repeated at least in three products. Thus, a stylistic designer is also a creative creator, but a creative designer might not be a stylistic one if the design products do not have four features repeated at least three times. Furthermore, the same style should be maintained for some period of time and followed by new creation to avoid negative impact from visual fatigue. If a stylistic designer has the style created for a long time without new changes of the style, then he or she is not a creative designer.

COULD THESE COGNITIVE PHENOMENA BE IMPROVED BY CHANGING COGNITION?

As explained, style and creativity are the phenomena generated by the cognitive procedures applied by designers in designs. The change of cognitive pattern would change the resulting phenomena, which would improve either individual style or creativity. Concepts are explained in the followings.

Can style be improved?

Style can be improved by expanding the degree of style through increasing the number of common features in products to make it strong (Chan, 2000). The way of increasing the number of common features in design is to create more new features periodically and repeat these features more times in more products. The concept of having more features appear in products to improve a style could be seen in the examples given in Figure 2. Figure 2 shows the designs of Prairie Houses style by Frank Lloyd Wright, Modern Architecture style by Richard Meier, and Sea Ranch vernacular style by Charles Moore. Numbers of common features created by the architects at that time of creation representing their style are ranged from 11-8, 6-5, and 5-4 respectively; details of their names are itemized in other publications (Chan, 2000, 2015). As explained, the degree of style is in proportion to the number of features, thus Prairie Houses style has the strongest style among them, whereas Modern Architecture style is more appealing than the Sea Ranch vernacular style.

Figure 2. Buildings designed by FLW, Richard Meier and Charles Moore.
2.1- Arthur Heurtley House, 1902. (Steven Kevil/Wikimedia Commons)
2.2- High Museum of Art in Atlanta. (Chris Yunker/Wikimedia Commons)
2.3- Sea Ranch House II taken from Littlejohn (1984), in Moore Tour section.

- A product that has a cute image would definitely attract more consumers or users. It is the same in style and could be enhanced by the creation of a fashionable and avant-garde appearance. Features having modern favour and vernacular character that match with on-going cultural trends would be more visually appealing than out-of-date features. Of course, a new feature that

has not been seen before and locates on the visual focus centre would also be an attractive style. For example, by comparing the Prairie Houses style by Wright or his followers, the New York 5 of Modern Architecture style, the vernacular style by Charles Moore in Figure 2, versus the Deconstructionism style by Peter Eisenman, and the Parametric Modelling trend generated by Zaha Hadid in Figure 3; different viewers and designers would have different preferences on selecting their appreciated styles. Young viewers might select more modern appearances of the style than the conventional styles selected by other age groups.

Figure 3. Buildings designed by Peter Eisenman and Zaha Hadid. 3.1- The Wexner Center for the Arts, 1989. (labia/Wikimedia Commons)
3.2- Heydar Aliyev Cultural Center in Baku, Azerbaijan, 2007-2012 (Interfase/Wikimedia Commons)

Could creativity be improved?

- Creativity could definitely be improved by triggering cognition to make a change, or even change the pattern of cognitive procedures. One notion is to make various associations to various resources or to make unrelated associations or links in design, which is the method of divergent thinking (Guilford, 1950, 1967; Torrance, 1962, 1966; Runco, 1991). Cognitive psychologists suggest that knowledge is learned from making association. When chunks of knowledge are learned and developed, they will be stored in memory by the same format of association, and retrieved later by the same links of association as well. Thus, it is suggested to make different connections between concepts to lead to different approaches for generating creative thinking. While working on a design, it is also suggested to do more reading on different fields of accounting, business, engineering, information technology, or medicine. It is because more exposure to various areas will increase the possibilities of instantly linking different information at hand for unusual design considerations. Of course, results from unusual links would definitely generate creative forms.

- Another notion of improving creativity is to provide an encouraging environment that allows divergent thinking. For instance, in design studio teaching, unusual design concepts created by students should be allowed and accepted to encourage out-of-box thinking. Results of out-of-box thinking might create a novel design product, which provides a potential opportunity for inspiring more creativity.

- Lastly, creativity could also be triggered by finding different representations. This notion can be found in cognitive psychology that the correct representation used could help solve a well-defined problem (Korf, 1980, Kaplan & Simon, 1990). In solving design problems, the representation used shall not only be right, but be unique. As a matter of facts, designers in their design processes are always searching for representation to represent the design solution. A unique representation would generate a creative work. For instance, the simple façade of the Azuma House designed by Tadao Ando is an unusual representation for the façade and entrance design, which is a solid wall with just a door opening without door panel or windows (see Figure 4). Thus, it was a new design concept at that time and was regarded as a creative design.

CONCLUSIONS

Thinking is human intelligence. Cognition is the factors that manage thinking. Design cognition is the thinking on generating some beautiful, functional, and marketable artifacts. Style and creativity are the cognitive phenomena caused by the executions of design cognition, recognized as entities and identified by the common features appearing in design products.

Figure 4. The façade of the Azuma House by Tadao Ando. (Wikimedia Commons)

The first appearance of a newly generated feature, if it is novel, beautiful, usable, valuable, and recognized by the public, would be the index of creativity possessed by the designer. More of such new creative features generated by an individual or a group signifies a higher level of creativity of the individual or group. When the number of features grows, then a set of features is formed. If the members of the set are repeatedly applied in many products by the same designer or the same group of designers, then a common feature set is shaped and an individual, historical, regional, or group style is manifested as well. More of the number of features in the common feature set does signify a stronger style of the person, period, region, or group.

If creative features in the common set appearing in design products are not compelling enough to be recognized by viewers, a creative designer would not be seen as a stylistic designer. Likewise, a stylistic designer might not be a creative designer, if the common set of features stays for a long time without new creations. Architecture design and fashion design are two good examples in this regard.

As a summary, features that exist in products must be changed from time to time. Any change of feature would change creativity and style. However, the quantity (the number of features) change of style and creativity is not that significant as their changes on quality (the content of features). A cute product style is a generation by a creative designer driven by creative cognitive patterns that would be popularly loved by users and viewers. After the quantity of features reaches the threshold of three, its signified style is recognized, then the quality of these features is more important than their quantity.

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REFERENCES

Aliseda, A. (2006). Abductive reasoning: logical investigations into discovery and explanation. Vol 330. Springer, The Netherlands.

Anderson, J. R. (1980). Cognitive psychology and its implications. W. H. Freeman, San Francisco.

Anderson, J. R., Bower, G. H. (1973). Human associative memory. V. H. Winston & Sons, New York.

Atkinson, R. C., Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In Spence KW, Spence JT (Eds) The psychology of learning and motivation. Vol 2, Academic, New York, 89-195.

Boisvert, D. R. (2011). Charles Leslie Stevenson. In: Zalta EN (Eds) The Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/sum2011/entries/stevenson/ Accessed 14 August 2021.

Bower, G. H. (1970). Organizational factors in memory, Cognitive Psychology, 1 (1),18-46.

Brown, T. (2009). The making of a design thinker, Metropolis, 60-62. https://metropolismag.com/viewpoints/the-making-of-a-design-thinker/

Byrne, R. M. J., Johnson-Laird, P. N., (1989). Spatial reasoning, Journal of Memory and Language, 28(5), 564-575. https://doi.org/10.1016/0749-596X(89)90013-2

Chan, C. S. (1990). Cognitive processes in architectural design problem solving, Design Studies, 11(2), 60-80. https://doi.org/10.1016/0142-694X(90)90021-4

Chan, C. S. (1992). Exploring individual style through Wright's design, Journal of Architectural and Planning Research, 9(3), 207-238.

Chan, C. S. (1993). How an individual style is generated, Environment and Planning B: Planning and Design, 20(4), 391-423. https://doi.org/10.1068/b200391

Chan, C. S. (1994). Operational definition of style, Environment and Planning B: Planning and Design, 21(2), 223-246. https://doi.org/10.1068/b210223

Chan, C. S. (1997). Mental image and internal representation, Journal of Architectural and Planning Research, 14(1), 52-77.

Chan, C. S. (2000). Can style be measured? Design Studies, 21(3), 277-291. https://doi.org/10.1016/S0142-694X(99)00011-3

Chan C. S. (2001). An examination of the forces that generate a style, Design Studies, 22(4), 319-346. https://doi.org/10.1016/S0142-694X(00)00045-4

Chan, C. S. (2011). Design representation and perception in virtual environments. In: Wang XY Tsai J (Ed) Collaborative Design Virtual Environments (pp. 29-40). Springer, Amsterdam.

Chan, C. S. (2012). Phenomenology of rhythm in design, Journal of Frontiers of Architectural Research, 1(3), 253-258. https://doi.org/10.1016/j.foar.2012.06.003

Chan, C. S. (2015). Style and creativity in design. Springer International Publishing, Switzerland.

Cross, N., Cross, A. C. (1995). Observations of teamwork and social processes in design, Design Studies, 16, 143-170. https://doi.org/10.1016/0142-694X(94)00007-Z

Eastman, C. (2001). New directions in design cognition: Studies of representation and recall. In: Eastman C, McCracken M, Newsteller W (Ed) Design knowing and learning (pp. 147-198). Elsevier, Amsterdam.

Echenique, M. (1972). Models: a discussion. In: Martin, L March L (eds) Urban space and structures. Cambridge University Press, Cambridge, 164-174.

Goodridge, J. (1998). Rhythm and timing of movement in performance drama, dance and ceremony. Jessica Kingsley, London.

Guilford, J. P. (1950). Creativity. American Psychologist, 5, 444-454. http://dx.doi.org/10.1037/h0063487

Guilford, J. P. (1967). The nature of human intelligence. McGraw-Hill, New York.

Hatch, L. (1988). Problem solving approach. In: Kemp WH, Schwaller AE (Ed) Instructional strategies for technology education. Glencoe, Mission Hills.

Kaplan, C., & Simon, H. A. (1990). In search of insight, Cognitive Psychology, 22, 374-419. https://doi.org/10.1016/0010-0285(90)90008-R

Korf, R. E. (1980). Toward a model of representational changes. Artificial Intelligence, 14, 41-78. https://doi.org/10.1016/0004-3702(80)90033-8

Kosslyn, S. M. (1975). Information representation in visual images, Cognitive Psychology, 7, 341-370. https://doi.org/10.1016/0010-0285(75)90015-8

Littlejohn, D. (1984). Architect, the life and work of Charles W Moore. Holt, Rinehart and Winston, New York.

Magnani, L. (2009). Abductive cognition. The epistemological and eco-cognitive dimensions of hypothetical reasoning. Springer, Berlin/Heidelberg.

Mithen, S. (2005). The singing Neanderthals: The origins of music, language, mind and body. Weidenfeld & Nicolson, London.

Newell, A., Simon, H. A. (1972). Human problem solving. Prentice-Hall, Englewood Cliffs.

Peirce, C. S. (1997). Pragmatism as a principle and method of right thinking: The 1903 Harvard lectures on pragmatism. SUNY Press, Albany.

Penfield, W. (2015). Mystery of the mind: a critical study of consciousness and the human brain. Princeton University Press, Princeton, NJ.

Runco, M. A. (1991). Divergent thinking. Ablex Publishing, Westport, CT.

Schon, D. A. (1983). The reflective practitioner. Temple-Smith, London.

Torrance, E. P. (1962). Guiding creative talent. Prentice Hall, Englewood Cliffs.

Torrance, E. P. (1966). Torrance tests of creativity. Personnel Press, Princeton.

Wimmer, G. E., Shohamy, D. (2012). Preference by association: How memory mechanisms in the hippocampus bias decision, Science, 338 (6104) 270-273. https://doi.org/10.1126/science.1223252

Yeston, M. (1976). The stratification of musical rhythm. Yale University Press, New Heaven.

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