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CREATIVITY TOOL SELECTION FOR DESIGN ENGINEERS IN IDEA GENERATION.

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Abstract

The aim of this study is to investigate the utility of a framework of selecting suitable creativity tools for designers according to personality attributes and design application. Five intuitive feeling (NF) design engineers who share similar if not identical personality type, were observed while using lateral thinking, which is suggested as one of the suitable creativity tools based on this framework, to produce ideas for a design task. The aim of this study is to understand the creative process that designers go through when using lateral thinking, and the perceived utility of this creativity tool in ideation by this personality group. The analysis of the ideation process revealed creative thinking is an intuitive and associative process where intuition and imagination are frequently employed by the intuitive feeling designers to construct the problem, trigger ideas or illustrate ideas. The subjects' positive evaluations towards the use of lateral thinking in ideation supported its utility, but factors such as ease of use and previous experience in using creativity tools should be taken into account when applying the framework.

Keywords: Creativity, lateral thinking, idea generation, intuition, personality

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1 INTRODUCTION

Many theories and approaches have been proposed to understand the nature of creativity since the promotion of scientific research on creativity in 1950s. How to enhance an individual's creativity remains central to creativity research, and this is also highlighted in the call by engineering industry for creativity along with other skills and abilities in engineering graduates. Creativity represents a complicated and multifaceted concept with many components, such as knowledge (Weisberg, 1999), cognition (Ward and Kolomyts, 2010), personality (Feist, 1999), intelligence (Kim et al., 2010), and motivation (Collins and Amabile, 1999), playing a role in determining how creative an individual will become. Creative potential exists in each and every person although to a varying amount (Simon, 1985), but with intervention it can be transformed into actual creative performance. It is believed that by using a personality informed approach to creativity with deliberate interventions, mainly in the form of creativity training and instructions, each individual can explore their creative potential more effectively and ultimately enhance their creativity. The most common practice in creativity training is the application of creativity tools. There are hundreds of creativity tools available and each has its own features, operational mechanisms, and pros and cons. Being flexible with different creativity tools would be of great benefit in order to stimulate creativity effectively.

2 THE SELECTION OF SUITABLE CREATIVITY TOOLS

We proposed a framework of selecting suitable creativity tools for designers to handle a design task that takes four variables into account: design problem, designers, design environment and creativity tool (Figure 1). For creativity to occur, environmental conditions that support creative thinking should exist. Certain personality characteristics and abilities must be possessed, or at least can be nurtured by the designer in order to use creativity tools effectively. A complicated creativity tool can prove to be challenging for novices who have not received any training and practice. In addition, the creativity tool must be appropriate for the design task at hand. A systematic engineering problem solving tool such as TRIZ, for example, does not appear to be the best candidate for generating ideas in strategic planning.

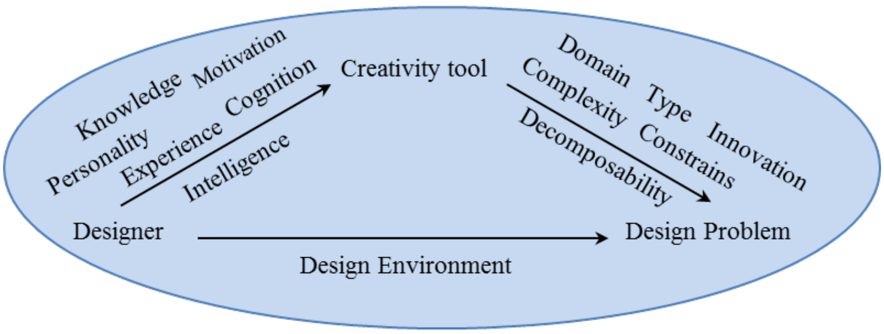

Figure 1. Variables in the selection of creativity tools (Yan et al., 2014a)

The effectiveness of creativity tools in facilitating idea generation is dependent upon many factors, such as the application domain, the complexity and difficulty of using this tool, the skills or training required of users, and potential risks when misused. Thus it is unwise to claim that one creativity tool would apply to all domains and all problems for all people (Runco, 2007). Creativity tools can be generally divided into two categories: intuitive/unstructured tools and logical/structured tools (Shah et al., 2000). Intuitive tools work by stimulating the unconscious thought processes of the human mind to increase the idea flow while systematic tools provide a defined direction for the concept generation. A typical example is TRIZ which applies a systematic approach to analyse functional requirements and generate solutions based on engineering principles and/or catalogued solutions from past experience. Creativity tools often integrate many operational mechanisms that aim to intrinsically promote idea flow or help remove mental blocks that inhibit creativity. These operational mechanisms include analogies (e.g. synectics), elements association (e.g. morphological analysis), imagery (e.g. mind mapping), suspended judgement (e.g. brainstorming), and transformation (e.g. SCAMPER).

In a previous study (see Yan et al., 2014a), we initially applied this framework to four designers with diverse design background and personality types. It was suggested that they use creativity tools that suit them best on an engineering problem. The positive outcomes and feedback from the users increased our confidence in the utility of this framework and encouraged us to look further into it. Therefore an in-depth study was arranged where possibly a more focused personality group that represents the most common personality types in design engineering will use the same suitable creativity tool to deal with the same design task. This qualitative study will focus on understanding the creative process that designers go through when using one of the suitable creativity tools suggested by the framework, as well as designers' subjective evaluations towards the application of this creativity tool on the design task. The former will reveal how the creativity tool triggers the subjects' creative thinking, and the latter will investigate whether and how all the subjects within the personality group find this creativity tool useful. These findings will provide evidence on the efficacy of this framework. Any new insights emerging from this study will not only increase our understanding of the creativity tool itself, but also of the framework of selecting creativity tools based on personality attributes and design application; they will also lay the foundation for future quantitative studies where the findings can be expanded and generalized in a large sample.

3 THE PERSONALITY APPROACH TO CREATIVITY

Although creativity in an individual is reliant upon multiple components, evidences suggest that personality has trumped intelligence as a predictor of lifetime creative achievement (Feist and Barron, 2003). Personality can be considered as something unique to a person and is relatively consistent and stable over time and situation (Yan, 2012). Using a personality approach has many benefits, for instance, personality traits are reflected in behaviours and therefore an understanding of one's personality traits can predict an individual's future behaviour.

3.1 The personality assessment- Myers-Briggs Type Indicator (MBTI)

As an important branch of personality theory, personality type enjoys widespread popularity and continues to receive attention in the research community and commerce. Personality type theories assume that people can be allocated in one of a limited number of types and aim to classify people into distinct categories. One of the most widespread and accepted personality type theories is the Myers-Briggs Type Indicator (MBTI). The MBTI instrument identifies four cognitive functions: Sensing (S), Intuition (N), Feeling (F) and Thinking (T), together with two attitudes that individuals orient towards the outer world, namely Extraversion (E) or Introversion (I), and it consists of three dichotomies that Jung identified (Jung, 1971). Myers and Briggs added a fourth dimension of Judging (J) and Perceiving (P), which describes an individual’s approach to life. The dynamic interplay of the four scales generates a total of 16 personality types. A brief description of the four dichotomies is given in Table 1.

Table 1. Myers-Briggs model of personality

Attitudes	**Extraversion (E)**	**Introversion (I)**
	Outer world	Extraverted Intuition
Information Gathering	**Sensing (S)**	**Intuition (N)**
	Five senses; Here and Now	Six sense; Future possibilities
Decision Making	**Thinking (T)**	**Feeling (F)**
	Logic and objective; Cause-effect	Value based; Person-centred
Approach to life	**Judging (J)**	**Perceiving (P)**
	Planned and organized; Have things settled	Flexible and spontaneous; Keep options open

3.2 Design Engineers

The subjects in this study are recently graduated Innovation Design Engineering (IDE) masters students from the Royal College of Art and Imperial College London. IDE postgraduates are from diverse design and engineering backgrounds as well as other disciplines where the applicants have demonstrated an aptitude for design. An initial investigation of the personality type and preferences of IDE students enrolled in 2010/2011 and 2011/2012 by using the Keirsey Temperament Sorter (KTS) instrument as an alternative to MBTI revealed that design engineers differ from mechanical engineers and the UK general population in a considerable way (see Yan et al., 2013). These findings are further supported by follow-up studies, which extended the investigation to a larger population including IDE students from 2010 to 2014. The most prominent personality type among IDE sample is INFP, followed by ENFP, both of which are far less common compared with the UK general population (OPP, 2011), which hinted the possibility that design engineering has attracted NFPs in particular, or resulted in their selection. In terms of the personality preferences, creative design engineering students exhibit remarkable preferences for intuition (N) and feeling (F) (Yan et al., 2013). Previous studies suggested that intuition is significantly associated with creativity (e.g. Guilford, 1966; Shen et al., 2008). Although the feeling type is the minority in engineering (McCaulley, 1990), most design engineers are feelers (Gautam and Singh, 2010).

The NFs, also known as the Idealists from the Keirsey Temperament Theory (Keirsey, 1998), consist of the majority of IDE students (43.2%) (Yan et al., 2013), which is in huge contrast with that of the UK general population (14%) (OPP, 2011). NFs are characterised as insightful and helpful, they communicate and inspire others and 'are good at envisioning the future and meeting people's needs'. It is our intent to select the suitable creativity tools for intuitive feeling design engineers and understand how the implementation of this creativity tool can stimulate their creative thinking in ideation and enhance the production of ideas.

4 DESIGN EXPERIMENT

The goal of this design experiment is to investigate the usefulness of a specific creativity tool for the NFs personality group, which is suggested by applying the framework of selecting creativity tools according to personality attributes and design application. It is of special interest to understand the creative processes that designers go through that lead to the production of new ideas when using a suggested creativity tool, which could shed light on why and how this creativity tool is useful and thereby suitable for this personality group. However, it is not our focus in this study to evaluate the outcomes of the design process. In this design experiment five design engineering graduates were asked to generate some new ideas for a design task by using the same creativity tool. This experiment employs a think-aloud protocol in order to capture the creative process (Wallas, 1926), especially the incubation and illumination phases.

4.1 The subjects

Five IDE graduates from the NFs group, especially the NFPs, were invited to participate in this design experiment. Prior to the design experiment, all the subjects have taken the Keirsey Temperament Sorter®-II (KTS®-II) survey as a substitute for MBTI. Empirical studies have shown high correlation between KTS and MBTI in measuring personality types (Kelly and Jugovic, 2001; Quinn et al., 1992), and KTS can be used as an alternative to MBTI (Cheng et al., 2010). The survey was followed by an individual feedback session to ensure that the indicated personality type describes the individual concerned. The subjects share identical personality type or similar preferences that only differ in one initial. They have 0-4 years (M=2.6) of professional design related experience. Their personality profile is summarized in Table 2.

Table 2. Design Engineers' personality profile

	Gender	Background	Design Experience	Personality type	Dominant Function	Auxiliary Function
DE1	Female	BFA Fine art, MSc+MA IDE	4 years	ENFP	Extraverted Intuition	Introverted Feeling
DE2	Male	MA Architecture, MSc+MA IDE	3 years	ENFP	Extraverted Intuition	Introverted Feeling
DE3	Female	BA Industrial Design, MSc+MA IDE	1.5 years	INFP	Introverted Feeling	Extraverted Intuition
DE4	Male	BA Mechanical Engineering, MSc+MA IDE	2 years	INFP	Introverted Feeling	Extraverted Intuition
DE5	Female	BA Industrial Design, MSc+MA IDE	0	ENFJ	Extraverted Feeling	Introverted Intuition

4.2 The design task

The design task is a part of a real-life engineering problem concerning occasional chain spill from hoists and gantries at the Royal Albert Hall (RAH) (see Figure 2). It is reported that the lengths of slack chain from electric chain hoists that are used to support production equipment can occasionally spill from collection bags posing possible risks to people below. The RAH had previously consulted industrial crane specialists for potential solutions but this did not result in any new suggestions other than considering using rigid collection bags as in industrial situations, which can be impractical and have other deleterious implications. The subjects are asked to propose new ideas towards this problem.

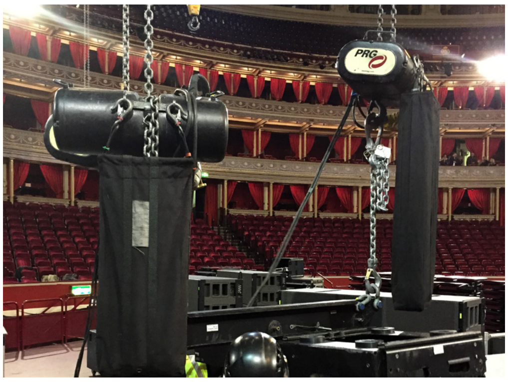

Figure 2. A hoist system during load in at RAH illustrating the chain retention bags

4.3 The selection of creativity tools for design engineers

All the design engineers in this experiment are NFs whose trait characteristic is to rely heavily on intuition and feeling, which implies that they trust hunches and instincts, and value human concerns and harmony. Thus intuitive creativity tools that exploit the unconscious thought processes of human mind will be more favourable for intuitive individuals than a structured one that relies on a defined direction to search for solutions systematically. Likewise, creativity tools that take advantage of human emotions and imagination will be more preferable for a feeling person than those require objective analysis and impersonal judgment.

In terms of the design problem, it appears to be a long-standing problem that requires improvements or modifications to the existing system. Previous consultancy with industrial specialists has highlighted the need for new perspectives towards the problem. Therefore the intent of suggested creativity tools should focus on helping overcome mental blocks and thereby enlarge the solution search space. It should also help get rid of stereotypical thinking and encourage thinking outside the box in order to broaden perspectives and seek alternatives.

The environment variable of this framework will exert limited influences as the design experiment is taken in a quiet office inside the Mechanical Engineering Department at Imperial and the subjects will use the creativity tool to handle design task individually. Therefore the environmental factors, such as time constraints and group influences, will have limited effects on ideation, so it is regarded as negligible and will not be isolated for discussion in this study.

After a thorough consideration of these variables, as one of the most suitable creativity tools, lateral thinking was recommended for NFs design engineers to generate ideas for the chain spill problem. Originally proposed by Edward De Bono (1970), lateral thinking is concerned with breaking out of a particular mind-set and generating new ideas by using one's imagination. By escaping from natural, obvious and cliché patterns of thought and throwing away preconceptions, the limitations of established patterns can be overcome and information will be put together in new ways to inspire ideas. There are many lateral thinking techniques, including the reversal method, brainstorming, analogies, random stimulation, and the 'PO' provocation (De Bono, 1970). The analogies technique is selected in this study because analogical thinking is a human cognitive capability that almost everyone possesses and uses, albeit with varying proficiency. This hints that design engineers are less likely to encounter any insurmountable obstacles when using it providing with adequate instructions and facilitations.

The analogies technique is principally concerned with 'generating some movement', getting going and starting a train of thought. Its main usefulness lies in that by employing analogies predominantly as a provocative means, a new way of looking at the situation will be enforced and the reconstruction of the problem by rearranging information via analogy will be stimulated, rather than waiting patiently for the advent of chance circumstances that provide information that will trigger an insight. By using this tool, the problem under consideration is related to an analogy, as the analogy is developed along its own lines of development, which can be expressed directly in terms of the actual objects involved or the processes involved, the problem is carried along with the analogy all the time. In the end the development of the analogy is transferred back to the original problem (requiring a 'force-fit') to see what happens to the problem. Such force-fit transferences can generate new perspectives towards the original problem and help reconstruct it, and can also yield new insights.

4.4 Procedures

The subjects received an identical design brief and were asked to produce conceptual ideas for solving this problem by using lateral thinking. This study follows a think-aloud protocol. Each subject was observed working on the same design task individually for 1 hour in an isolated office, including 10 minutes design brief, 40 minutes ideation and 10 minutes post-observation interview. A prior survey revealed the use of lateral thinking among subjects is rather limited, except for DE2 who is familiar with this tool and uses analogies frequently, all other four designers only use analogies occasionally and indirectly if not unconsciously. In the beginning, the subjects were briefed about the analogies technique and four types of analogies including direct analogy, personal analogy, symbolic analogy, and fantasy analogy (Gordon, 1961); a simple and non-related example was offered to demonstrate how to use this technique. Then the subjects received the design task and started ideation. All the ideas were captured or sketched on A4 paper. The last 10 minutes was used for a post-observation interview, which included five items using a five point Likert scale to evaluate the participants' responses to the easiness, frequency of use, usefulness, and level of satisfaction when using this tool, as well as another five open-ended questions to identify the types of analogy used and the main reasons behind, as well as encountered obstacles, pros and cons, and personal reflections regarding the ideation process. The whole process was audio recorded and the audio recordings were transcribed afterwards on a line-by-line basis. The ideation processes were analysed to understand how lateral thinking can effectively stimulate designers' creative thinking and encourage idea flows.

5 RESULTS

The five design engineers generated 70 ideas in total (M=14). The number of ideas generated varied from 7 to 26 per designer. They looked at analogies from different domains, mainly in mechanical engineering but also involving materials, physics, electronics, robotics, electromagnetism, chemistry, zoology, and even theology. All the subjects had a seemingly similar ideation process.

5.1 The purpose of using lateral thinking

When using the analogies technique, subjects were immersed in analogical thinking and elements association processes to conceive fresh ideas or views towards the problem. Three main purposes that these cognitive processes served were identified by interpreting the transcripts: problem construction, idea trigger, and idea illustration. This showed that analogies have been used most for triggering ideas (74.3%), secondly for the illustrating ideas (18.6%), with least for problem identification (7.1%). The counting of analogy use is based on the number of different analogical sources being retrieved rather than how many times these sources have been repeatedly used for the same purpose during the whole process.

5.1.1 Problem construction

When embarking on the design task, subjects tended to clarify the problem by recalling familiar facts to increase their understanding of the nature of the problem. For example, DE2 recalled an experiment conducted by the MIT about a walking chain that can walk on its own (see Table 3).

5.1.2 Idea trigger

Analogies are most frequently used to trigger ideas. The connection to engineering domain searching for similar experiences was made almost instantly and straightforwardly for most of the design engineers; this is anticipated given their engineering background as relevant knowledge is already available in their long-term memory and was stimulated in the first place; it could also be due to the easiness of accessing domain analogies. Design engineers have explored different components, systems, mechanisms, and processes in mechanical engineering and transferred back to the hoist system. For instance, almost all of them proposed to use a pulley drum to collect the chain instead or use chain made of lightweight materials (e.g. Table 3).

5.1.3 Idea illustration

It was also observed that the subjects referred to an analogous source to illustrate an abstract concept or to make the idea easier to understand. For example, DE2 related to the PlayStation to concretize his concept of a movement capture mechanism (Table 3); DE3 referred to an acrobat when she tried to describe the action of chain rotating and rolling up.

Table 3. Purposes of using lateral thinking technique- Analogies

Excerpt of Transcript: Walking Chain (Problem identification)
"The first thing I have been thinking is like why we have these problems, what would be the changes? Er, I don't know, there was an experiment in MIT where they put a looped chain on a motor pulley, they started to rotate the chain, and turned on the motor to full speed, and they knocked that chain out, all the chain made the crazy reaction, you know, the chain just walked itself and started to roll, like the chain is flying, it's quite crazy how they became. If they (RAH) can find out how this happens… "
Excerpt of Transcript: Pulley and giant fork (Idea Trigger)
"…or it can spin onto a pulley so it's like also collected in a different way, so it's not in the bag but it will be attached at one point somewhere and then turn around and being collected like … you could use a giant fork, like you roll your pasta, so you just roll chain on the fork… "
Excerpt of Transcript: movement capture (Idea illustration)
"…Maybe there is a net that even if the, er, I remembered the machine from the PlayStation, well, they have the PlayStation thing, that, when you see there is a movement, you can activate some kind of triggers, so maybe I can use that too, for example, put a safety net when the chain is coming … "

5.2 The creative process when using lateral thinking

For most of the subjects, the creative process seemed to proceed very implicitly because it was not easy to clearly identify the occurrence of insights from the transcripts. The incubation phase appeared to be taking place unconsciously until an appropriate source was retrieved abruptly, at least very limited cues can be derived from the transcripts to anticipate the occurrence of an idea. Then the subjects expanded this analogy, related to the problem and transferred the features back to it as they consolidated such connections. Such 'force-fit' led to an idea coming into being; one example is the idea of a self-knitting system (Table 4).

Table 4. Excerpt: Idea of Self-knitting system

Excerpt of Transcript: Self-knitting system.
"…it's a very technical problem… I mean it's clear what it does, the problem is basically how it fits into the bag, and also like how it is attached… it has everything relate to knitting, because you also have like the strands of the wool that you kind of try to organize yourself, so you could knit the structure to fall down, or you can knit maybe the structure that is holding on to. Like the 3D weaving, you just weave the structure yourself… It could be like a device that knit things together and then dis-knit it again. It could be like a system of feeding the chain in a way that is kind of organized, but it has to be flexible in a way that it's like when they need strands, it will be able to get loose without being knotted, ideally I guess. So I have the strands… I need some guidance for theses strands…"

After clarifying the problem, an appropriate source emerged abruptly by referring the chain spill issue to the process of knitting wool - they both could get 'knotted'. Attention was temporarily directed away from the target problem and focused on expanding the analogy. To avoid creating knots, the strands of wool can be knitted to stay 'organized' and form a compliant structure, but it can also be unravelled if necessary. An attempt was made to transfer these features back and map them onto the original problem; loose chain must be somehow organized to enter the hoist motor, but once it exits the hoist and falls into the collection bag, it can be dismantled somehow and stay inside the bag so that the chain spilling issue would not occur. The subject also referred to the 3D weaver machine from an IDE project to elaborate this idea. Then the designer moved to conceive how to guide the chain falling. When stuck, they often entered into fantastic thinking to get inspirations. The phenomenon of jumping from idea to idea was often observed, with the association of elements of thoughts occurring very quickly and obscurely, leading to the arrival of a new idea less predictable. Metaphoric expressing was also indicated from the transcripts. When conceiving ideas or imagining the applied situation, the subjects often regarded the entities as something alive and personified the entities described. For example, *"...train the chain to be aware…"* or "*Why did they (the chain) have to come out?*" etc. In addition, wild imagination was also a key element of the fun experience of using lateral thinking. The subjects were observed to employ a lot of fantastic thinking, such as "*we can hire superman to collect the slack chain…*" or "*We can train a monkey to guard the chain falling while providing peanuts as a reward…*" Such expressions served more like an icebreaker or atmosphere activator rather than an incubator of actual ideas at the current stage, but it is possible that they actually inspire other ideas or transform into potential ideas when appropriate interventions are enforced afterwards.

5.3 Self-reported subjective evaluations

The five design engineers were interviewed after the ideation session. To analyze their responses to the first five items in the questionnaire, values from -2 to 2 were assigned to the five point Likert scale accordingly. For example, when assessing the easiness of using analogy, very easy, easy, neutral, difficult, and very difficult equals 2, 1, 0, -1, and -2 respectively. The results are shown in Table 5.

Table 5. Evaluation indicators of the use of lateral thinking analogies technique

	Easiness of use	Frequency of use	Usefulness in problem construction	Usefulness in idea generation	Level of satisfaction
M	0.6	0.8	0.8	1.4	1
SD	0.55	1.3	0.83	0.54	0.71

For the last five open-ended questions, it was found that the most commonly used analogy type is fantasy analogy, followed by direct and personal analogy; however, symbolic analogy has never been used in this study. Easiness and straightforwardness of the analogies, as well as subjects' familiarity with them are the main reasons why they chose certain analogies (see Table 6).

Table 6. The types of analogy used by design engineers and main reasons given

	Direct analogy(D)	Personal analogy(P)	Fantasy analogy(F)	Symbolic analogy(S)	Reasons
DE1			√		Most familiar with it
DE2	√		√		Easy to understand
DE3	√	√	√		Straightforwardness, easiness (D & P); ice breaker and get rid of tight thinking (F)
DE4	√		√		Most natural way to handle a new problem
DE5	√	√	√		Automatically use (P&D); F&S can be difficult to use for realistic problems

The most pronounced obstacle to use creativity tool reported by the subjects was the difficulty to combine elements that are not related to each other at all. They also argued that limited understanding of the problem was another obstacle to problem solving. On the other hand, one of the most obvious merits of this creativity tool was that using analogy can activate creative thinking and this was their typical response to a new problem, but it could also be a weakness because sometimes it is difficult to leave the known safe area of what is usual; one subject also expressed his concerns with using "tools".
In general, five NFs suggested the creativity tool was very interesting and useful to seek alternatives but caution must be taken in considering these results. To be specific, DE1 admitted that using lateral thinking was an interesting way to explore ideas but she believed professional knowledge in engineering was essential to generate appropriate ideas. This is understandable considering her background being fine art. DE2 who uses lateral thinking regularly believed that visual inputs would be beneficial for analogical thinking. Both DE3 and DE5 expressed their desire to use this tool within

a group to interact and stimulate each other with crazy ideas. DE4 was careful with tools because he believed his creative process cannot be simplified into categories of thinking, and his incentive to create is based on his free will to create however he wants, rather than using tools that seems to confine him to a specific way of thinking.

6 DISCUSSION

The observations and interviews provided some interesting results regarding the usefulness of lateral thinking for intuitive feelers on an engineering problem. The primary purpose of triggering ideas by using analogies technique is expected; this is also shown in subjective evaluations where the subjects claimed this tool as more useful in generating ideas than constructing problem. The least use for problem construction is surprising. One explanation could be that design engineers are solution focused who spend more time on generating varying solutions with high level of creativity rather than following the problem-driven design strategy which focuses on problem analysis before generating solutions (see Yan et al., 2014b). The analogy use for idea illustration implies that designers can benefit more from this creativity tool within a group because referring to analogical sources that people are familiar with can provide a common basis for communication.

The extensive use of intuition and feeling functions by the five design engineers was observed. Creative thinking is an intuitive and associative process where the subjects often follow hunches and inspirations to 'sniff' around and conceive ideas along the way. There seems to be no logical way to predict and foresee the occurrence of new ideas. In addition, the subjects tended to empathize with the problem by consistently personifying the entities described, or even becoming part of the problem to feel and imagine the possible scenarios; this also echoes the comment that using personal analogy is their typical way to contemplate. These findings could be attributed to NFs' inherent tendencies to feel and envision, which provides theoretical support for the general claim that lateral thinking suits NFs by exploiting their primary and auxiliary cognitive functions. The subjective questionnaire provided more insights on the appropriateness and usefulness of lateral thinking for the NFs group.

The frequency of use of lateral thinking is diverse (the SD value is the largest among the five indicators), but overall it is not a common tool for the subjects, nor do they consider it easy to use, although they admitted this creativity tool was highly effective in generating ideas and were satisfied with the process and outcomes. This is a 'bitter-sweet' finding; for one thing lateral thinking is not easy to use and it is not usually the subject's first choice, but on the other hand, the application of it produced satisfying results and design engineers in the study were satisfied and positive with the use, which highlights that lateral thinking has promising potential in facilitating NFs' creative thinking although it may require active promotion, explicit instructions and practice. This has again stressed that factors such as easiness and experience of use should be taken into account when evaluating the appropriateness of specific creativity tools for a target personality group.

It was surprising to find that the most common analogy type used by design engineers is fantasy analogy, followed by direct analogy. This could be due to NFs being most comfortable with fantasy thinking by exploiting their 'wild' imagination. The frequent use of direct analogy is predictable given that it is plain and straightforward to pick up even as a novice. Designers also use personal analogy occasionally, this could be explained by that the subjects are inherent feelers who feel it natural to empathize with the problem and feel the way ahead in a complex problem area. No evidence of symbolic analogy use was found, which could result from the difficulty of mentally constructing the problem, especially when no visual cues were provided.

Regarding the general comments, all the subjects' offered positive evaluations towards the usefulness of lateral thinking, although a few issues raised our attention. For a practical engineering problem, remote association and analogical thinking could be difficult or even fertile, especially for a novice designer. In addition, lateral thinking might be more valuable and useful when being applied in a group where team interaction can stimulate creative ideas. DE4's concerns with creativity tools also underscore potential issues with designers who are reluctant to use tools. This also indicates the challenges we may encounter when promoting the use of creativity tools. As an INFP, his inclination to a flexible and spontaneous approach (P) and trusting intuition (N) explains his fear of being constrained in a rigid way of thinking. This has indirectly supported an assumption behind the framework that unstructured creativity tools may be more favourable for intuitive people.

7 CONCLUSIONS

In this study the framework of selecting suitable creativity tools was applied on the NFs personality group. The analysis of the ideation process as well as the responses from a post-design interview offered both theoretical and empirical support to the usefulness of lateral thinking for NFs and the framework itself, which encourages future comparative studies that objectively evaluate the appropriateness of a creativity tool for a given personality group using quantitative methods to verify the validity of this framework. In the meantime, different factors, such as easiness and previous experiences in using this creativity tool, must be considered when promoting creativity tools and the framework of creativity tool selection according to personality attributes and design application, especially to those who are reluctant to use or sceptical of creativity tools.

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