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ORIGINAL PAPER

An exploration of how creativity, functionality, and aesthetics are related in design

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Abstract

Creativity is considered to have a significant impact on the design process and its outcomes, while aesthetics and functionality are considered key characteristics of products. A relationship between creativity, aesthetics and functionality is, therefore, often assumed, however, researchers view the relations between creativity, functionality and aesthetics differently. In this paper, the authors present first evidence that novelty, usefulness and surprise are the core elements of design creativity. The aim of this research is the exploration of the relations between functionality, aesthetics, novelty, usefulness, surprise, and overall creativity, by means of an experimental case study involving design experts evaluating forty-five design samples. Statistical analysis has been conducted to investigate and understand these relations. The results obtained indicate that aesthetics has a significant positive relationship with creativity but that functionality does not have a statistically significant relationship with creativity in general. Further analysis confirms that design creativity is strongly and positively related to novelty and surprise, but not significantly related to usefulness. In addition, high correlation coefficient values have revealed that creativity, novelty and surprise are perceived as the same dimension as are functionality and usefulness. This paper may be of interest to researchers, practitioners, and educators in the broader realm of design, including industrial design, creativity in design, engineering design, design innovation, product design and new product development. It provides new insights into how creativity is perceived within the field and offers a new point of view on creativity and its dimensions for the community to meditate and to debate.

Keywords Aesthetics · Creativity · Functionality · Novelty · Surprise · Usefulness

1 Introduction

Creativity is considered an essential element of human intelligence (Cross 2011). The human capacity for creativity has evolved over thousands of years driven by biological and social factors (Pringle 2013). The outputs of creativity, emerging from combinations of essential mental capabilities, are the results from long periods of work with several mini-breakthroughs (Childs 2018). These outputs, in forms of ideas, objects and actions, are conceived to be novel, useful, and of good quality (Carruthers 2011). In this study, the authors focus on creative products and the outcomes of creative processes or actions.

Creativity plays a significant role in the early phases of design (also known as the fuzzy front end) and benefits business performance in the long run (Sarkar and Chakrabarti 2011; Han et al. 2018a). It has been widely considered a fundamental part of the ideation phase of the design process, as innovative and successful designs often originate from creative concepts (Thompson and Lordan 1999; Chiu and Shu 2012; Toh and Miller 2015; Crilly and Moroşanu Firth 2019). Creative conceptual design is therefore considered central to innovative product development (Shai et al. 2009) and while creativity is a crucial measure of design effectiveness, customers may not explicitly indicate creativity as a requirement while seeking creative designs (Chiu and Shu, 2012).

Functionality and aesthetics are considered the core characteristics and success factors of products (Rahman et al. 2010; Cropley and Kaufman 2019). *Functionality* refers to the opportunities for action(s) which are afforded by a product, which enables consumer engagements (Ziamou

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and Ratneshwar 2003), and is considered the performance of a product in this paper (Cropley and Kaufman 2019). Design researchers generally agree that aesthetics refers to two concepts: the senses, particularly vision, represented by a product; and the specific cognitive reaction or response to a product (Crilly et al. 2004; Sonderegger and Sauer 2010). In this paper, *aesthetics* refers to the objective design features presented by a product in general, such as form and colour. In other words, it involves the visual and ergonomic appeal of a product to a user (Cropley and Kaufman 2019).

Several studies have investigated how *aesthetics* and *functionality* are related to *creativity*. Christensen and Ball (2016) claim that aesthetics, functionality and originality are the core dimensions of design creativity, but Sarkar and Chakrabarti (2011) conclude that novelty and usefulness are the core creativity components. Cropley and Cropley (2011) indicate that creativity involves aesthetic properties but also includes novelty and effectiveness. However, Christensen et al. (2015) indicate that aesthetics and creativity are distinct factors in product evaluation, but they both positively affect consumer willingness-to-pay. Acar et al. (2017) suggests aesthetics have little influence in creative product evaluation. Furthermore, in a study conducted by Kreitler and Casakin (2009), aesthetics and functionality are found to have no significant correlations with creativity. Bao et al. (2018) also show that aesthetics and functionality are not significantly correlated to creativity, but that the two dimensions themselves are highly correlated.

Innovation and creativity are often simultaneously explored by the engineering design community. Studies include those conducted by Chakrabarti (2013), Yannou (2013), and Crilly and Moroşanu Firth (2019). Innovation is defined as the development and intentional implementation of new and useful ideas (Bledow et al. 2009; Shalley et al. 2015), while innovative product design is significant in ensuring product success (Moon et al. 2015). Creativity, which signals the generation of ideas, is considered a prerequisite for innovation in design (Sarkar and Chakrabarti 2011; Shalley et al. 2015; Crilly and Moroşanu Firth 2019). Successful innovation depends on the generation of creative ideas, but merely generating creative ideas is insufficient for innovation (Starkey et al. 2016). However, a creative product is often considered the starting point for product innovation (Cropley et al. 2011). Aesthetics and functionality have been identified as the core dimensions of product design (Homburg et al. 2015), and the main aspects used by designers for product innovation (Shiu 2017). Goode et al. (2013) indicate that a product's visual appearance (aesthetics) is the first thing noticed by consumers in an innovation. Moon et al. (2015) claim that improving the functionality of a product leads to innovative product design. This shows that *creativity*, *aesthetics* and *functionality* all relate to innovation in some way.

Aesthetics, *functionality*, and *creativity* relate to one another to some extent in product design, but it appears there exist various different views on this relationship. Furthermore, few studies have investigated how the core dimensions of *creativity*, such as *novelty* and *usefulness*, relate to *aesthetics* and *functionality*, which could provide further insights. This study is an extension and new exploration of prior research conducted by Han et al. (2019a). It involves a more comprehensive literature review, a new case study with more types of samples, a larger sample size and more expert evaluators aiming to yield more general findings. The authors of this paper aim to explore how *aesthetics*, *functionality*, *creativity* and the core components of *creativity* relate to one another in the product design context, to gain new insights into their relationships. A case study is conducted by means of expert evaluation, and followed by statistical analysis. The results obtained provide new insights into design creativity and its interpretation, allowing to reconsider its definition and assessment. Design researchers, educators, and practitioners alike may benefit from this, both in their endeavours to develop new and innovative products that succeed in the market, and in the context of a scholarly debate.

In the following section, relevant work on *aesthetics* and *functionality* is reviewed. In Sects. 3 and 4, commonly used definitions and assessments of *design creativity* are investigated, respectively. A case study exploring the relations between *aesthetics*, *functionality* and *design creativity*, including its core dimensions, is provided Sect. 5, and followed by discussion in Sect. 6. The paper ends with a presentation of the key findings and conclusions drawn from this work.

2 Aesthetics and functionality in the design context

In real design, aesthetics play a major role (Reich 1993). The term *aesthetics* commonly refers to product aesthetics, which relates to 'what the product presents to the senses (especially vision)', and aesthetic experience, which relates to 'the perception of how pleasing (or otherwise) the process of regarding an object is' (Crilly et al. 2004). A perception of aesthetics is one of the first responses from consumers to a product, which is closely associated with visual information (Ulrich 2011). It, therefore, has a significant impact on the perception of a product as a whole (Mata et al. 2018). Aesthetics are particularly vital for a product that only slightly differs in functionality and price from its competitors (Moon et al. 2015; Lugo et al. 2016; Mata et al. 2018). It is often used to provide customers with an additional value proposition, in a competitive market of products possessing similar functionality (Perez Mata et al. 2017). Thus, aesthetics are

considered a key factor in customers' buying decision and satisfaction (Orsborn et al. 2009). Furthermore, it facilitates the acceptance of new technology and its success in society (Haug 2016; Eggink and Snippert 2017). For example, the success of technological products produced by Apple and Dyson are considered to be a result of their aesthetic appeal to customers. To clarify the discussion to this point, in this paper, *aesthetics* refers to product aesthetics in general and not aesthetic experience.

Functionality reflects the consumers' perceptions of the ability of a product for fulfilling its purpose (Homburg et al. 2015). Srinivasan et al. (2012) suggest that functionality is more important than aesthetics as a product design element for consumers, and has a stronger impact on consumer satisfaction. It arises from product features and delivers specific benefits through usage (Srinivasan et al. 2012). Functional attributes are described as the actions required by a design problem, or the actions provided by the problem's solutions (Chakrabarti and Bligh 2001). As explained in Sect. 1, in this paper *functionality* refers to the performance of a product. The usefulness of a product refers to what it can do according to its functionality and how well users can explore the functionality offered (Rabiser et al. 2012). Usefulness can be recognized easily in functional products, but is more challenging to see in non-functional products (such as movies and arts) (Moldovan et al. 2011). As a consequence, *functionality* and *usefulness* are considered independent dimensions in this paper.

A product's functionality fulfils customer needs by problem solving and prevention, while aesthetics produce experiential pleasures by viewing, interaction, consumption, and sense of ownership (Rahman et al. 2010). Aesthetics and functionality are often used as assessment aspects in benchmarking activities for investigating competitors' products (Toh and Miller 2013). Sylcott et al. (2013) indicate that aesthetics are weighted less heavily than functionality in evaluating a design, while Haug (2016) argues that aesthetics are more important than functionality for noticing and appreciating a product. Hagtvedt and Patrick (2014) suggest a balance between aesthetics and functionality is needed in product design. Reich (1993) points out that functionality and aesthetic appeal may have conflicts. Alipour et al. (2017) indicate that function is a constructive goal for designers, whereas aesthetics is a detrimental goal. In addition, many researchers have argued that functionality is not assessable without usage or consumption, but Hoegg and Alba (2011) and Radford and Bloch (2011) hold the view that consumers often assess functionalities of products from just seeing them (Homburg et al. 2015). This usually occurs while consumers are purchasing new products, especially when doing so online. For example, a product with a highly machined appearance provides a strong cue indicating the technical robustness of the product (Radford and Bloch 2011). This indicates that *aesthetics* and *functionality* are correlated in design, which is in line with the findings of Bao et al. (2018).

3 Definitions of design creativity

Creativity is considered a crucial element in new product design and development. It is an integral part of design, contributing to problem-solving and innovative product development, occurring between the problem and solution space (Demirkan and Afacan 2012; Hsiao and MacDonald 2013). It is also claimed that creativity is a prerequisite for the generation of ideas for breakthrough products (Taura and Nagai 2017).

In addition to the design context, *creativity* is also a significant topic in psychology and cognitive science. Researchers from these areas have provided many definitions of *creativity* at various levels of scope and complexity. For example, 'the act of making new relationships from old ideas' (Koestler 1964); 'the process by which something so judged (to be creative) is produced' (Amabile 1983); 'the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)' (Sternberg and Lubart 1998); 'the production of novel, useful products' (Mumford 2003); 'a response to the continual innovation and resourcefulness that have become necessary for economic survival' (Craft 2003); 'the ability to come up with ideas or artefacts that are new, surprising, and valuable' (Boden 2004); 'creativity requires both originality and effectiveness' (Runco and Jaeger 2012); 'one that is novel and produced intentionally' (Weisberg 2015); and 'discovery of new possibility and bringing it into being' (Martin and Wilson 2017). The examples demonstrate the fierce and long-term debate surrounding the definition of *creativity*, but also consistently present *novelty* and *usefulness* as core elements of *creativity*.

To explore and understand how design researchers describe and define *creativity*, specifically in the context of design research, the authors reviewed more than twenty-five relevant articles published over the course of the past fifteen years in top-tier design research journals, including *Research in Engineering Design*, *Design Studies*, *Journal of Engineering Design*, *Journal of Mechanical Design*, and *International Journal of Design Creativity and Innovation*. An overview of the results is depicted in Table 1.

Similar to researchers from psychology and cognitive science, design researchers have used various definitions of *creativity*. Demirkan and Afacan (2012), who conduct research in design creativity, claim that the nature of creativity is so complex that no single definition could encompass and identify this concept. Rodgers and Jones (2017) show that it is challenging for design students and tutors to define and conceptualise creativity. As indicated

Table 1 Definitions of creativity in the design context

Definitions of creativity	Authors	Source
'The relative efficiency of design value generation.'	Redelinghuys and Bahill (2006)	*Journal of Engineering Design*
'Creativity produces work that has the quality of being both original and useful.' and 'Designs that are fresh and new to the domain.'	Jeffries (2007)	*Design Studies*
'The ability to generate new ideas or new association between existing ideas.'	Kazerounian and Foley (2007)	*Journal of Mechanical Design*
'A person's ability to produce a novel and appropriate product.'	Kim et al. (2007)	*Design Studies*
'Ideas or concepts that are both novel and useful.'	Robertson et al. (2007)	*Journal of Mechanical Design*
'The generation of ideas that are novel and appropriate.'	Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010)	*Design Studies*
'Creativity occurs through a process by which an agent uses its ability to generate ideas, solutions or products that are novel and valuable.'	Sarkar and Chakrabarti (2011)	*Design Studies*
'Creativity occurs through a process by which an agent uses its ability to generate ideas, solutions and products that are novel and useful.'	Chulvi et al. (2012)	*Journal of Engineering Design*
'The conceptual judgement of the design instructors.'	Demirkan and Afacan (2012)	*Design Studies*
'The act of creating something new, a new insight, a new theory or a novel design.'	Eckert et al. (2012)	*Journal of Engineering Design*
'Idea, concept or product that is considered creative by the design team and/or in the organization.' and 'A novel way of satisfying all constraints.'	Onarheim (2012)	*Journal of Engineering Design*
'A process to evaluate a problem in an unexpected or unusual fashion to generate ideas that are novel. Also, creativity (noun) refers to novelty and originality.'	Oman et al. (2013)	*Research in Engineering Design*
'The ability to produce something that is both novel and useful.'	Sosa and Marle (2013)	*Journal of Mechanical Design*
'Creativity is often characterized by referring to the novelty (e.g., solutions have less frequent features) and utility (i.e. solutions satisfy precise needs) of the solutions.'	Doboli and Umbarkar (2014)	*Design Studies*
'The creative idea be both novel (to an individual, a group or the world) and appropriate. It is sometimes additionally required that the idea be non-obvious, surprising or efficient.'	Crilly (2015)	*Design Studies*
'Novelty, value, and surprise.'	Grace et al. (2015)	*International Journal of Design Creativity and Innovation*
'A measure of value or novelty which is expressed (or made tangible or visible) in a design.'	Lee et al. (2015)	*International Journal of Design Creativity and Innovation*
'The process of developing new and original ideas that are somehow appropriate for a specific function, or occasion, thus bringing value to prospective users or adopters.'	Valgeirsdottir et al. (2015)	*International Journal of Design Creativity and Innovation*
'The action events that are novel in the context of a collaborative environment.'	D'Souza and Dastmalchi (2016)	*Design Studies*
'Three characteristics: novelty, usefulness and surprising.'	Mahdizadeh Hakak et al. (2016)	*International Journal of Design Creativity and Innovation*
'Original, appropriate, and unexpected.'	Snider et al. (2016)	*Research in Engineering Design*
'Newness (or difference) and task appropriateness (or usefulness).'	Tan (2016)	*International Journal of Design Creativity and Innovation*
'Useful, novel and surprising.'	Kelly and Gero (2017)	*International Journal of Design Creativity and Innovation*
'An inspirational force that generates new ideas or produces novel combinations of existing ideas, leading to further solutions or deeper understanding.'	Keshwani et al. (2017)	*Journal of Engineering Design*

Table 1 (continued)

Definitions of creativity	Authors	Source
'Production of novel, useful products, or ideas that are both original and feasible.'	Toh and Miller (2019)	*Journal of Mechanical Design*
'How feasible and unique the ideas are.'	Zheng and Miller (2019)	*Journal of Mechanical Design*
'The development of new, useful and surprising things.'	Crilly and Moroşanu Firth (2019)	*Design Studies*

in Table 1, *novelty* and *usefulness* are considered to be the two key elements of defining *creativity* in design. This is in line with the common definition of design creativity provided by Sarkar and Chakrabarti (2008).

Surprise is commonly defined as the violation of expectations, it is often interchangeable with the term *unexpectedness* or *unexpected* (Becattini et al. 2017). It is considered to be a game-changer in creative product design, triggering attention and curiosity (Becattini et al. 2020). Aiming to design products that (positively) surprise the customer could significantly increase individually perceived creativity (Gotzsch 2017). Although many researchers use novelty and usefulness to describe design creativity, others argue that it is necessary to augment these two criteria by adding surprise to measure the unexpectedness of a design (Gero et al. 2019). A number of researchers have claimed surprise to be a nuance or an element of novelty, while many others indicate that surprise might be an independent dimension of creativity (Becattini et al. 2017). For example, Chiu and Shu (2012) consider surprise as a degree of novelty; Zheng and Miller (2020) describe surprise as an indicator of novelty; and Koronis et al. (2019) define novelty as the 'surprisingness' and originality of a concept. However, Boden (2004) considers surprise as the essence of creativity, along with newness and value. Nguyen and Shanks (2009) indicate surprise, novelty and value are the core characteristics of creativity. Simonton (2012) claim that a creative idea is novel, useful and surprising. Moreover, Maher et al. (2013) indicate that surprise stems from violating expectations, but novelty does not necessarily imply a violation of expectations in a space of expected designs. Grace et al. (2015) describe surprise as the notion of evoking astonishment and unexpectedness that is not included in novelty. Acar et al. (2017) even argue that surprise should be the second factor of creativity, which is more important than usefulness, besides novelty. As shown in Table 1, *surprise* or *surprising* (alternatively *unexpectedness* or *unexpected*) have been used increasingly as the third element to describe *creativity* in design research in recent years. In this study, *surprise* is considered a separate dimension that does not relate to *novelty*. Therefore, we suggest that *novelty*, *usefulness* and *surprise* may be the three key elements for defining *design creativity* based on the research conducted.

As depicted in Table 1, not one of the many *creativity* definitions reviewed directly include the term *aesthetics*. Only Valgeirsdottir et al. (2015) have employed *'functionality'* in describing *creativity*, where *creativity* is described as 'the process of developing new and original ideas that are somehow appropriate for a specific function, or occasion, thus bringing value to prospective users or adopters.' However, a few researchers have involved *aesthetics* and *functionality* in describing *design creativity*. For example, Cropley and Cropley (2005) propose a four-dimensional model to define creativity for engineering products, which involves relevance and effectiveness, novelty, elegance (aesthetics), and generalizability; and Acuna and Sosa (2011) suggest the two basic elements for defining creativity are novelty and functionality. To provide more insights from another perspective, criteria used for creativity assessments are investigated in the next section. To be more specific, whether *functionality* and *aesthetics* are included in assessing *creativity* in design is explored.

4 Assessments of design creativity

Creativity assessment plays a vital role in selecting creative ideas for products, as well as identifying better designers and inventors (Sarkar and Chakrabarti 2011). It also ensures an understanding of creativity and its measures (Jagtap 2019). Human judgement-based criteria for creativity assessment are amongst those most often used in existing literature. This section reviews several popular criteria-based creativity assessment methods used in design research.

Creative Product Semantic Scale (CPSS) is a design creativity measurement approach for individual products proposed by O'Quin and Besemer (1989). It involves three conceptual dimensions which are resolution, novelty, and elaboration and synthesis. Resolution refers to valuable, useful and logical. Novelty includes original, germinal and surprising. Elaboration and synthesis represent complex, understandable, well-crafted, organic, and elegant. Chulvi et al. (2012) presents the use of an adapted questionnaire-based CPSS, which mainly focuses on novelty and utility (resolution), for the particular needs of the research. In the same line, García-García et al. (2017) employ novelty and style for their adapted CPSS questionnaire.

Novelty, quality, quantity and variety, proposed by Shah et al. (2003), are often used for evaluating the effectiveness of an idea generation method. Novelty refers to the newness of an idea to an individual or the history. Quality indicates the feasibility of an idea. Quantity represents the total number of ideas generated by an individual or a group. Variety shows the number of categories of the ideas generated. Novelty and quality are associated with the assessment of the degree of creativity of an idea generated. Similarly, Plucker and Makel (2010) employ originality, flexibility, fluency and elaborations, and Lopez et al. (2011) use novelty, feasibility, quantity and variety for creativity assessments.

Horn and Salvendy (2009) employ novelty, affect and importance to measure product design creativity. Novelty is defined as the newness and uniqueness of a product. Affect is described as the product's ability to attract, delight and stimulate the product's evaluator or user. Importance refers to the suitability and criticality of the product. The three dimensions of product design creativity have shown a connection with consumer satisfaction.

Novelty and usefulness are used in a creativity assessment method, proposed by Sarkar and Chakrabarti (2011), for evaluating a product or an idea. In this method, novelty refers to something new and original, which is assessed by employing the Function-Behaviour-Structure (FBS) model and the SAPPhIRE model (Chakrabarti et al. 2005). Function plays an important role in this novelty assessment, as it is the core element used to differentiate novel products from others. Usefulness refers to social value, which is measured by utilizing Eq. (1). The overall creativity of a product can then be calculated by Eq. (2). It has been suggested that this assessment method may better reflect designers' collective and intuitive notion of design creativity.

$$\begin{aligned}\text{Usefulness (U)} = &\text{Level of importance (L)} \times \text{Rate of popularity of use (R)} \\ &\times \text{Frequency of usage (F)} \times \text{Duration of use or Duration of benefit per usage (D)}\end{aligned} \tag{1}$$

$$\text{Creativity (C)} = \text{Novelty (N)} \times \text{Usefulness (U)} \tag{2}$$

Novelty, usefulness and cohesiveness are used by Chiu and Shu (2012) to measure design creativity of individual concepts. Novelty involves originality, newness and surprise; usefulness includes value and appropriateness; and cohesiveness involves wholeness, elaboration, detail, clarity and style.

Demirkan and Afacan (2012) propose three factors, composed of 31 items, for evaluating creativity of artefacts, particularly in the context of design education. Factor 1 is the novelty and affective characteristics of the artefact. It is associated with the shape of design, involving items such as novel, unusual, different, new, and shape. Factor 2 is the elaboration characteristics of the artefacts, which is related to harmony of design elements as well as geometric and figure-ground relations. It involves items such as geometric, harmony, balanced, and integrated. Factor 3 involves items such as order, number, repetition, unity and rhythm, which is known as design principles.

Novelty, usefulness, aesthetics, and complexity are the four criteria used by Lee et al. (2015) for measuring design creativity. Novelty and usefulness refer to the creativity measurement dimensions often used in the design domain. Aesthetics indicates the degree of how aesthetically appealing a design is. Complexity refers to the level of difficulty presented by a product, which is specifically related to the complex forms generated in parametric design.

Originality, functionality and aesthetics are proposed by Christensen and Ball (2016) for creativity assessment. Originality assessment is tied closely to the birth of ideas, while functionality assessment focuses on the life of ideas. Assessments of aesthetics rest on affective and cognitive aspects relating to object perceptions.

Novelty and quality are used by Srinivasan et al. (2018) for evaluating creative design concepts. In their approach, novelty refers to the exploration of new solution spaces, while quality measures the fulfilment of the requirement.

Starkey et al. (2019) employ usefulness and uniqueness for evaluating design creativity. Uniqueness is based on perceptions of surprise and originality, while usefulness is founded on perceptions of utility, logic, value and understandable of the idea.

A summary of the design creativity assessment criteria discussed is shown in Table 2. Several sets of human judgement-based criteria have been proposed to assess design creativity, of which *novelty* and *usefulness* are often used. This is in line with definitions of *creativity* in the design context illustrated in Sec. 3 *Novelty* generally refers to originality and newness. Many researchers have included quality as another element in evaluating design creativity. Girotra et al. (2010) have proposed four variables to govern the quality of ideas generated. These involve the average quality, the number, the variance in the quality, and the capability to discern the quality of ideas produced. A product, which is considered useful, delivers quality, value, and feasibility by fulfilling requirements. *Usefulness* therefore refers to quality, feasibility, and value. He and Luo (2017) have theoretically reasoned and empirically found that the novelty profile of an inventive design can influence its potential usefulness value in a non-intuitive manner through

Table 2 Criteria for design creativity assessment

Criteria	Authors
Novelty, resolution, elaboration and synthesis	O'Quin and Besemer (1989)
Novelty, quality, quantity, variety	Shah et al. (2003)
Novelty, affect, importance	Horn and Salvendy (2009)
Originality, flexibility, fluency, elaborations	Plucker and Makel (2010)
Novelty, feasibility, quantity, variety	Lopez et al. (2011)
Novelty, usefulness	Sarkar and Chakrabarti (2011)
Novelty, usefulness, cohesiveness	Chiu and Shu (2012)
Novelty, utility	Chulvi et al. (2012)
Novelty and affective characteristics, elaboration characteristics, design principles	Demirkan and Afacan (2012)
Novelty, usefulness, complexity, aesthetics	Lee et al. (2015)
Originality, functionality, aesthetics	Christensen and Ball (2016)
Novelty, style	García-García et al. (2017)
Novelty, quality	Srinivasan et al. (2018)
Usefulness and uniqueness	Starkey et al. (2019)

investigating 3.9 million patents. However, in this paper, *novelty* and *usefulness* are considered independent variables, which echoes the view presented in most of design creativity studies.

Functionality and *aesthetics* are used more frequently in *design creativity* assessment than in defining *creativity*. For instance, Christensen and Ball (2016) have included both functionality and aesthetics as the core assessment dimensions. 'Function' has been considered a significant element in assessing novelty in the approach proposed by Sarkar and Chakrabarti (2011). The CPSS approach proposed by O'Quin and Besemer (1989) involves aspects of aesthetics, such as elegance. The criteria used by Lee et al. (2015) and García-García et al. (2017) includes aesthetics and style, respectively. The set of factors considered by Demirkan and Afacan (2012) also involves items associated with aesthetics, such as appeal and delight, but these factors are used to assess paintings rather than products or processes. However, *surprise* is used less frequently for assessing rather than describing *creativity* in a direct manner. Some researchers, such as O'Quin and Besemer (1989), Chiu and Shu (2012), and Starkey et al. (2019) have included *surprise* in *novelty*. This is in contrary to the findings in Sec.3 of which *novelty* and *surprise* are considered independent variables.

Throughout Sects. 3, 4, the authors investigated how *creativity* is defined and assessed in the context of design. Although *novelty* and *usefulness* are the core dimensions used in both assessing and defining *creativity*, *surprise* has been used more often as the third dimension of *creativity* in recent years. Therefore, it can be deduced that *novelty*, *usefulness*, and *surprise* are the three core elements of *design creativity*. *Functionality* and *aesthetics* are also employed in both defining and assessing *design creativity*, but less frequently. However, some researchers, such as Kreitler and Casakin (2009) and Bao et al. (2018) have indicated that *aesthetics* and *functionality* have no significant relations with *creativity*. Furthermore, few studies have explored how *aesthetics* and *functionality* are related to the core dimensions of *creativity*, such as *novelty* and *usefulness*. A case study addressing these points is provided in the following section.

5 Case study

A case study has been designed to explore the relationships, in the product design context, between *aesthetics*, *functionality*, and *creativity* and its core dimensions. This section first describes the methodology used to conduct the case study, and then presents the results with associated analyses and interpretations.

5.1 Methodology of the case study

Three types of products were selected to be observation samples: vases, chairs and lamps, which represent different degrees of functional and aesthetic attributes. In this study, vases are considered highly aesthetic products, which are essentially decorative objects that have clear design constraints (Reed 2013). They are often associated with aesthetics and aesthetic measures in design research. For example, vases are used by Perez Mata et al. (2017) to study the relationships between aesthetic features, perceptions, ownership, and consumer background. Conversely, chairs are ideal tangible products representing both functional and aesthetic values in design (Cropley and Kaufman 2019). They are often employed in design research, such as by Hung and Chen (2012) and Cropley and Kaufman

(2019). Finally, lamps are regarded as products with high functionality, which involves broad technological-focused problem-solving processes. Gupta et al. (2017) indicate that lighting (lamp) industries have shifted their focus from aesthetics to functionality. Lamps are becoming more and more so-called 'smart' products, alternatively functional products, that involve functions such as intelligent control, speaker, wireless charger, and flexible structure.

Chairs and lamps are frequently used in design creativity research, of which chairs are used more extensively. For example, Besemer (1998) has employed three chairs to demonstrate the empirical use of Creative Product Semantic Scale, Yu and Nickerson (2011) have used chairs to investigate crowd creativity, Christensen et al. (2015) have used lamps to investigate how creativity and beauty affect consumer willingness-to-pay for a product, and Horn and Salvendy (2009) have employed both chairs and lamps to measure consumers' perceptions of product creativity. In comparison, vases are used less frequently in design creativity studies, as they may have a relatively simple functionality in general.

In this case study, *novelty*, *usefulness*, *surprise*, *aesthetics* and *functionality* are the five factors to be investigated, of which *novelty*, *usefulness* and *surprise* are the three key elements of *design creativity*. The five factors are employed to measure the relationships among *design creativity*, *aesthetics* and *functionality*, using *novelty*, *usefulness* and *surprise* to represent *design creativity*. In addition, overall *creativity* is considered the sixth factor, which is employed to explore its relationship with *novelty*, *usefulness* and *surprise*, as well as its direct relationship with *aesthetics* and *functionality*. According to the preceding, the definitions of the six factors used in this study are presented in Table 3, where the definitions of *aesthetics* and *functionality* are in line with the descriptions in the study conducted by Cropley and Kaufman (2019).

The vase, chair and lamp design samples used in this case study were chosen from the winners of international design competitions, such as the iF and Red Dot design awards. For each type of product, fifteen specific samples were selected:

Table 3 Definitions of the six factors

Factors	Definitions
Aesthetics	The ergonomic and visual appeals of a product
Functionality	The performance of a product
Novelty	Originality and newness
Usefulness	Value and feasibility
Surprise	Astonishment and unexpectedness
Creativity	The outcome of 'the process by which something so judged (to be creative) is produced' (Amabile 1983)

fifteen vases, fifteen chairs, and fifteen lamps. Random purposive sampling was used to select the samples. The use of design competition winners in design research has shown positive results in several recent studies. For example, Wang (2016) has proposed a set of winning formulas for metaphor design; Yilmaz et al. (2016) have developed 77 evidence-based design heuristics for supporting early conceptual design; Hölttä-Otto et al. (2018) have explored the success rates of innovative products launched by new ventures and established firms; and Han et al. (2019b) have identified three approaches for producing combinational creative ideas, by employing and analysing design competition-winning products in their studies. Furthermore, aesthetics and functionality are the core evaluation and judging criteria of these design competitions or awards. Wang and Chan (2010) have indicated that these design competitions are often creativity-oriented. It is therefore proven to be reliable to use products selected from the winners of the design competitions as samples.

Expert evaluation (please refer to Sec. 5.2 for details) is used in this case study as the method to investigate the relationships among *aesthetics*, *functionality*, and *creativity* (*novelty*, *usefulness*, and *surprise*). Employing experts for evaluation in design creativity research has become a dominant approach, for example, the studies conducted by Sarkar and Chakrabarti (2011), Han et al. (2018b), and Cropley and Kaufman (2019). As a consequence, it is suitable and reliable to employ experts for evaluating the design samples. Details of the design samples, including names, descriptions and images, are provided to the expert for evaluation, as shown in Fig. 1. According to the information provided, the experts are asked to evaluate the design samples using the six factors discussed in this paper: *aesthetics*, *functionality*, *novelty*, *usefulness*, *surprise* and overall *creativity*. Instructions of the interpretations of the six factors are provided to the experts prior to starting the evaluation. However, the experts are not informed of the source of the samples used in the case study to avoid biased evaluations. The evaluation involves a 7-point Likert rating scale, ranging from 1 ('poor') through 4 ('moderate') and up to 7 ('excellent'). The experts rated the six factors using the 7-point rating scale respectively for each design sample in the evaluation.

Further examples of vases used are provided in Fig. 2, demonstrating a glimpse of the samples selected for this case study. In Fig. 2, Two Way Watering Pot (d) is a decorative vase that can be used as a watering pot offering two kinds of watering approaches for plant leaves and roots, respectively; Segment (e) involves two portions that can be attached to form a complete vase, as well as used separately as two vases; and Rosenthal Squall (f) is a vase reminisces about a whirlwind. Besides, FONTAINE, as shown in Fig. 1a, is a combination of a two-tier plate and a filigree vase. It shows that the samples selected have differentiations in both

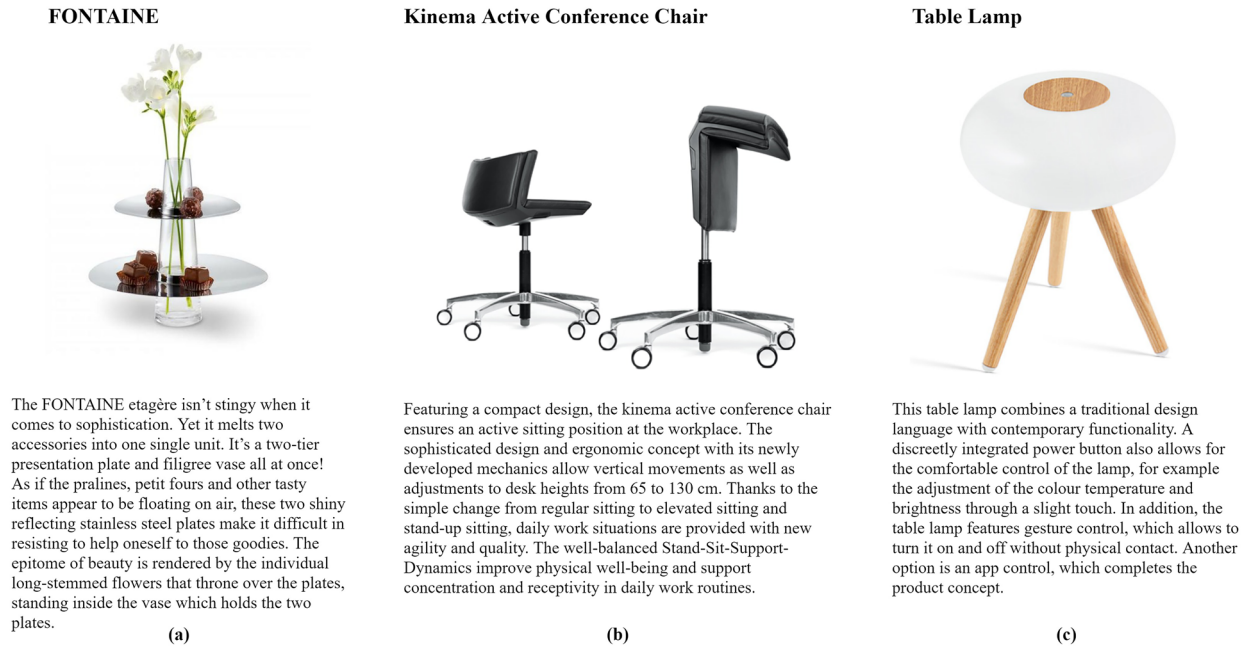

Fig. 1 Representative examples of designs employed in the case study: (**a**) vase, (**b**) chair, (**c**) lamp

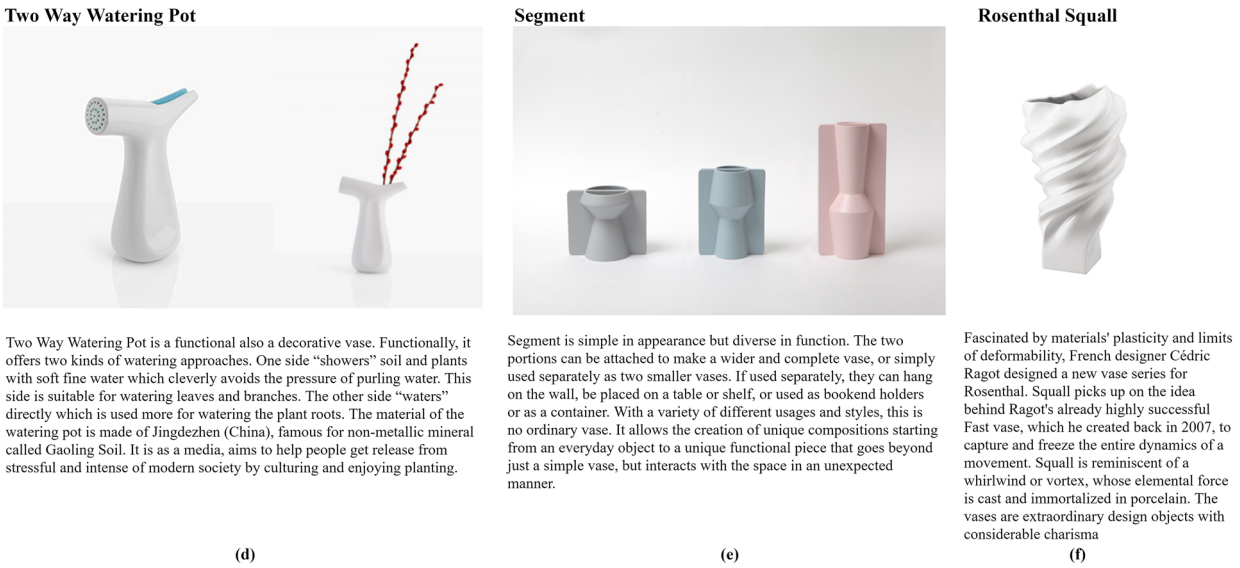

Fig. 2 Further examples of vases employed in the case study

aesthetics and *functionality*, even in products with simple functional attributes.

5.2 Case study results

Twenty design experts volunteered to participate in the evaluation, mainly for intrinsic motivations, such as personal interest, enjoyment, or inherent value of and learning from the activity. Nineteen provided valid results, which include ten males and nine females. Their mean age is 32.58 years [Standard Deviation (SD) = 7.69] and their mean years of design experience is 10.26 (SD = 6.88). They signed up with standard ethical protocols concerning the use of data. Although at a first glance the number of experts involved may appear to be low, Lai et al. (2006) indicate that there is no common agreement as to the minimum number of experts required for such evaluations. Furthermore, Achiche et al. (2013) indicate that the number of experts needed in

an evaluation is far less compared with employing general people. Many design studies involving expert evaluations have employed a low number of experts, for example, less than six experts have participated in the studies conducted by Doré et al. (2007), Charyton and Merrill (2009), and Achiche et al. (2013), respectively. Therefore, the nineteen experts employed in this case study can be considered a sufficient number.

The forty-five design samples (fifteen vases, fifteen chairs, and fifteen lamps) were provided to the experts for evaluation using the evaluation approach discussed in the previous section. The samples were evaluated individually by each of experts, based on their experience and knowledge, measuring the following six factors: *functionality*, *aesthetics*, *novelty*, *usefulness*, *surprise* and overall *creativity*.

A Cronbach's alpha test was conducted to indicate the internal consistency of the rating scores for the conducted case study. As shown in Table 4, the Cronbach's alpha of the ratings of the vase, chair and lamp examples are 0.964, 0.968 and 0.966 respectively, which suggests excellent internal consistency. The overall Cronbach's alpha is 0.986, which also indicates excellent overall internal consistency. The results of the Cronbach's alpha test therefore suggest that the expert evaluation conducted possesses good reliability. The mean values of the six factors of each sample for vases, chairs, and lamps, rated by the design experts, are calculated for further analysis, as shown in Tables 5, 6, 7, respectively. For instance, vase sample 1 has a mean *creativity* value of 4.63 with a standard deviation (SD) of 1.35, as shown in Table 5. Its mean *functionality*, *aesthetics*, *novelty*, *usefulness* and *surprise* values are 3.53 (SD = 1.39), 4.79 (SD = 1.20), 4.95 (SD = 1.39), 3.79 (SD = 1.15), and 4.32 (SD = 1.22), respectively.

Table 4 Results of the Cronbach's alpha test

	Vases	Chairs	Lamps	Overall
Cronbach's alpha	0.964	0.968	0.966	0.986

Likert scales are often considered ordinal data, and therefore Spearman correlation tests are employed to explore the directions of relations and the strengths existing among the six factors (*functionality*, *aesthetics*, *novelty*, *usefulness*, *surprise* and *creativity*). The tests are conducted employing the mean factor scores of the vase, chair, and lamp samples, respectively, as described in the preceding section. The results of the Spearman correlation tests for vases, chairs and lamps are shown in Tables 8, 9, 10 respectively. In the tables, a positive Spearman correlation coefficient (r_s) indicates a positive monotonic correlation where the dependent parameter tends to increase while the independent parameter increases. A negative Spearman correlation coefficient (r_s) suggests a negative monotonic correlation where the dependent parameter tends to decrease when the independent parameter increases. A zero Spearman correlation coefficient (r_s) indicates a non-monotonic correlation, where there are no tendencies for the dependant parameter to increase or decrease while the independent parameter increases. A higher magnitude of the Spearman correlation coefficient (r_s) suggests a stronger correlation between the dependant and independent parameters, and vice versa. There is a statistically significant correlation between two parameters while the p value $*p < 0.05$, and a statistically highly significant when $**p < 0.01$. The interpretation of the Spearman correlation coefficients (r_s) is based on the guidance provided by Dancey and Reidy (2014), of which

Table 5 Results of the expert evaluation: vases – mean value (standard deviation)

Samples	Factors					
	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
1	3.53 (1.39)	4.79 (1.20)	4.95 (1.39)	3.79 (1.15)	4.32 (1.22)	4.63 (1.35)
2	4.58 (1.27)	4.42 (1.39)	4.89 (1.02)	4.53 (1.39)	4.42 (1.27)	5.05 (1.00)
3	4.68 (1.49)	5.16 (1.27)	4.84 (1.46)	4.68 (1.26)	4.63 (1.56)	5.21 (1.32)
4	4.89 (1.41)	3.68 (1.62)	4.63 (1.49)	4.53 (1.53)	4.37 (1.56)	4.74 (1.45)
5	3.47 (1.04)	4.95 (1.67)	4.37 (1.72)	3.63 (1.13)	4.00 (1.56)	4.47 (1.76)
6	3.89 (0.97)	5.11 (1.45)	4.95 (1.28)	4.00 (1.12)	5.00 (1.17)	4.95 (1.32)
7	3.79 (1.00)	4.79 (1.54)	4.63 (1.31)	4.00 (1.03)	4.26 (1.29)	4.37 (1.35)
8	3.89 (1.02)	5.37 (1.22)	5.32 (1.30)	4.37 (1.35)	5.32 (1.38)	5.37 (1.18)
9	3.84 (1.18)	5.68 (1.26)	5.42 (1.53)	3.84 (1.27)	5.58 (1.31)	5.47 (1.31)
10	4.37 (1.13)	4.05 (1.57)	4.74 (1.21)	4.42 (1.18)	4.26 (1.21)	4.16 (1.18)
11	4.16 (1.69)	4.63 (1.22)	5.32 (1.26)	4.16 (1.69)	4.68 (1.49)	5.32 (1.17)
12	3.89 (1.25)	5.79 (1.20)	4.63 (1.13)	4.42 (1.31)	4.00 (1.38)	4.47 (1.19)
13	3.89 (1.21)	4.63 (1.38)	5.47 (1.27)	4.00 (1.12)	5.47 (1.60)	5.00 (1.45)
14	3.79 (0.95)	4.79 (1.24)	4.95 (1.36)	3.68 (1.22)	4.68 (1.13)	5.05 (1.32)
15	3.74 (1.12)	3.26 (1.52)	3.68 (1.66)	3.95 (0.89)	3.47 (1.60)	3.42 (1.60)

Table 6 Results of the expert evaluation: chairs – mean value (standard deviation)

Samples	Factors					
	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
1	4.95 (1.23)	5.53 (1.14)	5.00 (1.03)	4.84 (1.04)	4.84 (1.09)	5.26 (1.07)
2	5.00 (1.26)	4.05 (1.10)	3.16 (1.35)	5.26 (1.12)	2.95 (1.67)	3.32 (1.26)
3	4.74 (1.16)	4.00 (1.30)	4.05 (1.28)	4.74 (1.16)	3.32 (1.13)	3.89 (1.48)
4	5.05 (1.64)	3.26 (1.33)	5.16 (1.46)	4.95 (1.61)	5.00 (1.52)	4.95 (1.54)
5	4.74 (0.91)	4.42 (1.43)	3.89 (1.33)	4.58 (1.18)	3.79 (1.36)	4.21 (1.32)
6	4.16 (1.53)	4.95 (1.57)	5.26 (1.74)	4.11 (1.68)	4.79 (1.40)	5.32 (1.42)
7	4.95 (1.23)	4.00 (1.08)	4.89 (1.25)	5.11 (1.21)	4.79 (0.95)	4.84 (1.23)
8	5.32 (1.49)	2.84 (1.35)	2.95 (1.39)	4.95 (1.57)	2.37 (1.09)	2.95 (1.19)
9	4.42 (1.04)	5.37 (1.38)	5.42 (1.50)	4.00 (1.26)	5.42 (1.39)	5.47 (1.53)
10	4.63 (1.38)	4.05 (1.36)	4.42 (1.43)	4.21 (1.58)	4.47 (1.79)	4.58 (1.50)
11	4.58 (0.94)	4.32 (1.30)	3.53 (1.46)	4.37 (1.13)	3.32 (1.52)	3.68 (1.56)
12	4.58 (1.23)	4.95 (1.50)	4.68 (1.49)	4.53 (1.39)	4.32 (1.08)	4.89 (1.29)
13	4.58 (1.14)	4.47 (1.27)	5.00 (0.92)	4.47 (1.23)	4.53 (0.88)	4.63 (1.13)
14	4.89 (1.33)	4.53 (1.14)	5.11 (1.25)	5.00 (1.21)	4.63 (1.35)	5.32 (1.22)
15	4.53 (1.27)	4.63 (1.42)	4.26 (1.07)	4.47 (1.23)	3.68 (1.03)	4.05 (1.32)

Table 7 Results of the expert evaluation: lamps – mean value (standard deviation)

Samples	Factors					
	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
1	4.11 (1.41)	3.74 (1.33)	3.79 (1.79)	4.47 (1.35)	3.79 (1.51)	3.68 (1.13)
2	5.16 (0.99)	4.47 (1.31)	3.79 (1.54)	5.00 (1.08)	3.37 (1.63)	4.05 (1.19)
3	4.53 (1.31)	4.32 (0.98)	3.89 (1.17)	4.37 (1.35)	3.68 (1.26)	4.05 (1.00)
4	4.74 (1.45)	3.47 (1.39)	5.00 (1.41)	4.47 (1.43)	4.84 (1.23)	4.68 (1.30)
5	4.47 (1.27)	4.79 (1.36)	5.42 (1.53)	4.00 (1.30)	5.11 (1.59)	5.42 (1.43)
6	5.05 (1.43)	4.05 (1.32)	3.42 (1.35)	5.21 (1.15)	3.32 (1.30)	3.63 (1.22)
7	4.79 (1.00)	4.68 (1.62)	5.05 (1.57)	4.42 (1.09)	5.00 (1.52)	5.05 (1.39)
8	4.05 (1.10)	5.42 (1.27)	4.53 (1.39)	4.21 (0.95)	4.32 (1.59)	4.42 (1.57)
9	5.26 (1.25)	4.16 (1.35)	5.16 (1.39)	5.26 (1.02)	4.79 (1.32)	5.47 (1.14)
10	5.11 (1.02)	4.53 (1.19)	3.58 (1.43)	5.11 (1.12)	3.32 (1.38)	3.58 (1.09)
11	4.53 (1.09)	4.05 (1.36)	3.47 (1.35)	4.53 (0.94)	3.16 (1.35)	3.95 (1.28)
12	4.26 (1.16)	5.00 (1.45)	4.89 (1.41)	4.11 (1.29)	4.68 (1.45)	4.89 (1.41)
13	4.32 (1.13)	5.16 (1.18)	5.26 (1.29)	4.42 (1.43)	4.79 (1.40)	4.95 (1.36)
14	4.53 (1.31)	4.37 (1.42)	3.95 (1.28)	4.32 (1.30)	3.84 (1.56)	4.11 (1.45)
15	4.11 (1.12)	5.32 (1.22)	4.42 (1.46)	4.32 (1.08)	4.16 (1.31)	4.58 (1.57)

Table 8 Results of the Spearman correlation test—vases

Variables	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
Functionality	\					
Aesthetics	−0.182	\				
Novelty	0.132	0.270	\			
Usefulness	0.918**	−0.108	−0.089	\		
Surprise	0.261	0.305	0.920**	0.009	\	
Creativity	0.320	0.419	0.777**	0.131	0.857**	\

**$p < 0.01$, *$p < 0.05$

Table 9 Results of the Spearman correlation test—chairs

Variables	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
Functionality	\					
Aesthetics	−0.650**	\				
Novelty	−0.351	0.507	\			
Usefulness	0.874**	−0.493	−0.295	\		
Surprise	−0.182	0.435	0.936**	−0.197	\	
Creativity	−0.327	0.619*	0.955**	−0.251	0.921**	\

**$p < 0.01$, *$p < 0.05$

Table 10 Results of the Spearman correlation test—lamps

Variables	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
Functionality	\					
Aesthetics	−0.460	\				
Novelty	−0.175	0.420	\			
Usefulness	0.752**	−0.620*	−0.460	\		
Surprise	−0.178	0.321	0.958**	−0.465	\	
Creativity	−0.072	0.376	0.953**	−0.387	0.911**	\

**$p < 0.01$, *$p < 0.05$

$0 < |r_s| < 0.3$ indicates a weak correlation, $0.3 \leq |r_s| < 0.7$ suggests a moderate correlation, and $0.7 \leq |r_s| < 1$ refers to a strong correlation.

For the vase samples, the correlation coefficient between *functionality* and *aesthetics* is −0.182, which indicates a negative and weak correlation with no statistical significances, as shown in Table 8. In addition, there are no statistically significant correlations between *functionality* and *creativity* ($r_s = 0.320$), as well as *aesthetics* and *creativity* ($r_s = 0.419$). However, there is a statistically significant positive and strong correlation between *functionality* and *usefulness* ($r_s = 0.918$**). With regards to the relations among design *creativity* and its three core elements (*novelty*, *usefulness*, and *surprise*); *novelty* is strongly correlated to *surprise* ($r_s = 0.920$**) and *creativity* ($r_s = 0.777$**) with positive statistical high significance, while *surprise* is also strongly positively correlated to *creativity* ($r_s = 0.857$**) with statistical high significance.

For the evaluation of chair samples, there is shown to be a statistically highly significant negative and moderate correlation between *functionality* and *aesthetics* ($r_s = -0.650$**), while there is a statistically significant positive and moderate correlation between *aesthetics* and *creativity* ($r_s = 0.619$*), as shown in Table 9. *Functionality* is positively and strongly correlated to *usefulness* ($r_s = 0.874$**) with statistical high significance. For *creativity* and its core elements, there are statistically highly significant positive and strong correlations between *novelty* and *surprise* ($r_s = 0.936$**), between *novelty* and *creativity* ($r_s = 0.955$**), and between *surprise* and *creativity* ($r_s = 0.921$**), which is also in line with the vase samples.

With regards to the lamp samples, there are no statistically significant correlations among *functionality*, *aesthetics* and *creativity*, which is in line with the vase examples, as shown in Table 10. Similar to the vase and chair samples, *functionality* is positively and strongly correlated to *usefulness* ($r_s = 0.752$**), but *aesthetics* is negatively and moderately correlated to *usefulness* ($r_s = -0.620$*), with statistical significance. With regards to the vase and chair samples, there are also statistically highly significant strong and positive correlations between *novelty* and *surprise* ($r_s = 0.958$**), *novelty* and *creativity* ($r_s = 0.953$**), and *surprise* and *creativity* ($r_s = 0.911$**).

For all three types of products, no significant correlations were identified between *functionality* and *creativity*. Only the chair samples showed a moderate and positive relation between *aesthetics* and *creativity*, while the other two types of product have shown no significant correlations. Furthermore, only the chair samples evaluations indicated a moderate and negative relation between *aesthetics* and *functionality*.

In terms of the relations between *functionality*, *aesthetics*, and the core elements of *creativity*, it is evident that there is a strong and positive correlation between *functionality* and *usefulness* for all three types of products. However, *functionality* was found to have no significant correlations with *novelty* and *surprise*. Furthermore, no significant correlations have been shown between *aesthetics* and the three core elements of *creativity*, except the lamp samples which indicate a moderate and negative relation to *usefulness*.

For *creativity* and its three core elements, there are strong and positive relations between *novelty* and *creativity*, *surprise* and *creativity*, as well as *novelty* and *surprise*, across all three types of products. However, no significant correlations are shown between *usefulness* and *creativity*, *usefulness* and *surprise*, as well as *usefulness* and *novelty*.

6 Discussion

As shown in the preceding section, Spearman correlation tests were conducted to analyse the relations among the six factors: *functionality*, *aesthetics*, *novelty*, *usefulness*, *surprise*, and *creativity*, for samples of vases, chairs and lamps. Several similar correlation results are shown in all three types of products, especially the relations between *creativity* and its three core elements (*novelty*, *usefulness*, and *surprise*). Some correlations, however, are only depicted in particular types of products, which may be related to the products' functional and aesthetic attributes. Therefore, the forty-five samples, including the fifteen vases, fifteen chairs and fifteen lamps, are analysed as a whole to yield a more general result. The Spearman correlation test results for the overall product samples are provided in Table 11.

In consideration of all three types of products as a whole, there are no statistically significant correlations between *functionality* and *creativity*, while there is a positive, moderate statistically and highly significant correlation between *aesthetics* and *creativity* ($r_s = 0.528$**). Furthermore, *aesthetics* is negatively and moderately correlated to *functionality* ($r_s = -0.501$**) with a statistical high significance.

This indicates that *creativity* is positively and moderately related to *aesthetics*, but not significantly correlated to *functionality* in general, for the samples concerned. It shows a different result against the studies conducted by Kreitler and Casakin (2009) and Bao et al. (2018) who hold the view that *functionality* and *aesthetics* have no significant relations to *creativity*. Furthermore, these results also suggest that designs perceived to be less functionally appealing are more likely to be considered to have better aesthetics.

In terms of the relations between *functionality* and the three core elements of creativity, *functionality* is not statistically significantly correlated to *novelty* or *surprise*, but it is positively and strongly correlated to *usefulness* ($r_s = 0.888$**) with statistically high significance. According to Cropley and Kaufman (2019), a correlation coefficient of greater than 0.8 suggests redundancy in general. It therefore implies *functionality* and *usefulness* are measuring the same construct of a product. This shows that the two factors refer to the same dimension in assessing creative designs, which is in contrary to the findings in the review Sect. 2.

For *aesthetics* and the three core elements, *aesthetics* is positively and moderately correlated to *novelty* ($r_s = 0.463$**) and *surprise* ($r_s = 0.439$**), but negatively and moderately correlated to *usefulness* ($r_s = -0.449$**), with statistical high significance. This indicates that a design perceived to be more aesthetically appealing is likely to be perceived as more novel and surprising, but less useful. It also suggests that increasing the *usefulness* of a product will lead to a decrease in its *aesthetics*, which is in line with the preceding result that shows a negative correlation between *functionality* and *aesthetics*.

The analysis of how *functionality* and *aesthetics* relate to *design creativity* and its three core elements show that *aesthetics* is more important than *functionality* in creative product assessment, of which *aesthetics* is identified to have a positive relationship with *creativity*, *novelty* and *surprise*. The results also suggest that *functionality* and *usefulness* represent the same dimension, but has no significant relations with *creativity* and a negative relation with *aesthetics*. The relations between *creativity* and its three core elements (*novelty*, *usefulness*, and *surprise*) are therefore analysed to provide more insights.

As depicted in Table 11, *creativity* is found to have positive and strong relations with both *novelty* ($r_s = 0.925$**) and *surprise* ($r_s = 0.908$**). Furthermore, it is shown that *novelty* is positively and strongly correlated to *surprise* ($r_s = 0.945$**), which has implied that *novelty* and *surprise* are measuring the same construct of a product based on the perceptions of the design experts involved in the case study. This is in contrary to the findings of the review section that *novelty* and *surprise* are claimed as independent factors. Moreover, the result has indicated that *novelty*, *surprise*

Table 11 Results of the Spearman correlation test—overall

Variables	Functionality	Aesthetics	Novelty	Usefulness	Surprise	Creativity
Functionality	\					
Aesthetics	−0.501**	\				
Novelty	−0.251	0.463**	\			
Usefulness	0.888**	−0.449**	−0.336*	\		
Surprise	−0.212	0.439**	0.945**	−0.336*	\	
Creativity	−0.159	0.528**	0.925**	−0.253	0.908**	\

**$p < 0.01$, *$p < 0.05$

and *creativity* refer to the same dimension perceived by the design experts, for the case study concerned.

The result also shows that there are no significant correlations between *usefulness* and *creativity*, while there are negative correlations between *usefulness* and *novelty* ($r_s = -0.336$*) and *surprise* ($r_s = -0.336$*). This confirms the findings in the preceding that *functionality* and *usefulness* are perceived as the same factor which is not significantly related to *creativity*. Furthermore, $r_s = -0.336$* is a low correlation coefficient, which is close to the values of suggesting weak correlations ($0 < |r_s| < 0.3$). We could consider the correlation between *usefulness* and *novelty* is 'weak', as well as between *usefulness* and *surprise*.

The main findings of this study indicate that *design creativity* is only related to *aesthetics* with positive and moderate effects in general considering the vase, chair and lamp samples as a whole, but it is not significantly related to *functionality*. However, this may not be a generalised result that could be applied to all types of products, due to the specificity of the product types involved in the study. For example, the vase and lamp samples have shown no significant direct relations between *creativity* and *aesthetics*, while the chair samples have indicated a significant relation. Further explorations have shown that *creativity*, *novelty* and *surprise* are perceived as the same dimension by the experts involved in the case study, as well as *usefulness* and *functionality*, for all the results concerned. While the case study results might be specific to the types of products involved and the design experts who participated, general implications of the relationships are discussed below. This provides design researchers and practitioners with more insights into generating creative concepts and assessing creative products.

Comparing with *functionality*, *aesthetics* is shown to have a stronger relation with *design creativity* in general, especially for classical products that have rather stable functionalities, such as chairs. Thereby, it implies that a design with better aesthetic attributes are perceived more creative. The result is also reflected in terms of the relations between *functionality*, *aesthetics* and the core elements of *creativity*. *Aesthetics* is more likely to have a significant relation with *novelty* and *surprise*, while *functionality* and *usefulness* are perceived as the same factor. This suggest that, for a classical product (such as chairs), improving its aesthetic rather than functional attributes could increase its *creativity*, *novelty*, and *surprise* perceived.

Although many researchers have involved *novelty* and *usefulness* in defining and assessing *design creativity*, the findings above have indicated that *usefulness* is not significantly related to *creativity* for the case study concerned. Furthermore, some researchers also considered *surprise* as the third dimension of *design creativity*, which is independent from *novelty*. However, the case study conducted has shown that *novelty* and *surprise* refer to the same dimension. In addition, the results show that *creativity*, *novelty* and *surprise* are perceived as the same dimension by the design experts involved. It thereby indicates that, even though *creativity* involves *usefulness*, *novelty* and *surprise*, individuals perceive creative designs as the ones that are *novel* or *surprising*.

However, the results of the case study might be influenced by the limitations of using the images and text descriptions of the product samples rather than the physical objects in the case study. Although researchers, such as Hoegg and Alba (2011) and Radford and Bloch (2011), claim the *functionality* of a product is often assessed from just seeing it, it might still be challenging for individuals to perceive the full scope of the *functionality* of a product without hands-on experience. The results might also be determined by the three types of products, vases, chairs and lamps, selected. These types of products are classic and have rather stable and maturely defined functionality in general. In terms of radically new and path-breaking products with first-of-its-kind functions, *functionality* or *usefulness* may contribute more to design *creativity*, *novelty* and *surprise*.

In summary, the outcomes of this research lead to a new point of view for the community to reflect upon, allowing for a scholarly debate of *creativity* and its dimensions. As illustrated in the preceding, Kreitler and Casakin (2009) and Bao et al. (2018) claim that *creativity* is not related to *aesthetics* and *functionality*. However, the results of this research reveal that *design creativity* is related to *aesthetics*, which is supported by studies of other researchers, including (O'Quin and Besemer 1989; Cropley and Cropley 2005; Lee et al. 2015; Christensen and Ball 2016; García-García et al. 2017). Our results further suggest that there is no direct relationship between *creativity* and *functionality*, which is contrary to other studies, for example (Acuna and Sosa 2011; Sarkar and Chakrabarti 2011; Valgeirsdottir et al. 2015), that conclude *functionality* should be considered a significant dimension of *creativity*. Our research also shows that *novelty* and *surprise* are actually measuring the same construct, which is in agreement with work conducted by other researchers including O'Quin and Besemer (1989), Chiu and Shu (2012), Starkey et al. (2019), and Zheng and Miller (2020), whereas Boden (2004), Simonton (2012), Maher et al. (2013), Grace et al. (2015), and Acar et al. (2017) argue the opposite point, indicating that *novelty* and *surprise* are independent dimensions. Moreover, our research results indicate that *creativity* is not directly related to *usefulness*, while *creativity*, *novelty* and *surprise* are perceived as the same dimension. This is in opposition to most of the current studies in design, for example (Jeffries 2007; Kim et al. 2007; Robertson et al. 2007; Sarkar and Chakrabarti 2011; Chiu and Shu 2012; Chulvi et al. 2012; Sosa and Marle 2013; Crilly 2015; Grace et al. 2015; Mahdizadeh Hakak et al. 2016; Kelly and Gero 2017;

Crilly and Moroşanu Firth 2019; Starkey et al. 2019), and psychology and cognitive science, such as (Sternberg and Lubart 1998; Mumford 2003; Boden 2004; Runco and Jaeger 2012), which claim that *usefulness*, *novelty* and/or *surprise* are the core dimensions of *creativity*. Therefore, elusive and debatable positions regarding the relations between *creativity* and its dimensions remain, requiring further explorations.

7 Conclusions

The research presented throughout this paper revealed that *novelty*, *usefulness* and *surprise* are the three core elements of *design creativity*. *Functionality* and *aesthetics* are often considered the core of design, however, existing literature presents inconsistent and conflicting opinions on the relationships between *functionality*, *aesthetics* and *creativity*. To date few studies have considered such core creativity elements into the relationship explorations. A case study was conducted to address the issues and provide new insights. Through an experimental approach, the design experts involved evaluated the *creativity*, *novelty*, *surprise*, *usefulness*, *functionality* and *aesthetics* of forty-five design samples. The samples include three types of products for investigation, vases, chairs and lamps, representing typical products that focus on different functional and aesthetical attributes. Statistical correlation analysis was performed to explore the relationships.

Overall, the case study conducted revealed that *design creativity* is positively related (directly and indirectly through its core elements) to *aesthetics*, but not significantly related to *functionality* in general. This shows that the ergonomic and visual appeals (*aesthetics*) tend to be more important than the performance (*functionality*) of a product, while regarding the product's design creativity. However, it is shown that the relations might varies from product to product, according to the product's aesthetic and functional attributes. The study has also indicated *creativity* is not significantly related to *usefulness* which represents the same dimension as *functionality*. Furthermore, it is shown that the design experts, involved in the case study, perceive *creativity*, *novelty* and *surprise* as the same dimension. This is against the common understanding of *design creativity* which involves *usefulness* and *novelty* as the core elements, as well as the recent findings that consider *surprise* as the third element which is distinct from *novelty*. This might also affect how we normally assess creative products, which is mainly based on the product's novel and useful features.

The outcomes of the research conducted represent a contribution to the body of knowledge in research on design, creativity, innovation, engineering design, product design, and new product development. The results obtained provide evidence for how *design creativity* is perceived by design experts while considering *functionality* and *aesthetics*. In practice, it is suggested that designers could moderately increase the degree of *design creativity* of a product by improving its ergonomic and visual appeals, especially for classical products that have maturely defined functionality. This may be of importance to new product design and development, where *creativity* is considered a prerequisite for generating innovative products that ensures product success. Most importantly, the study allows for new meditations and debates on how *creativity* should be defined, assessed, and interpreted, as well as the role that *creativity* plays in design-related research areas and professional practice.

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