THE EMOTIVE QUALITIES OF PATTERNS: INSIGHTS FOR DESIGN

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Abstract

The role of pattern use in the visual arts has not been fully analysed in terms of its emotive and semantic values. Patterns have played a dominant role in art, architecture and design for thousands of years but their nuanced relationship with human observers has not been systematically analysed – the emotive and semantic qualities of their forms are yet to become fully clear. This paper presents work in experimental aesthetics, analysing the emotive and semantic qualities of commonly used patters. Focus groups were used as a means of analysing a set of sixteen distinct patterns where each group considered each pattern and assigned each one emotive and semantic values. The patterns were sourced from a wide variety of cultures and varied hugely in terms of their underlying geometry; angular forms, curved forms and symbolic content. Our results reveal that many patterns have complex emotive connotations and can sometimes convey strong value judgements that we suggest are derived from the qualities of their form and foundational structure. The possible reasons for these phenomena and the implications for design practice and design research and subsequently discussed.

Keywords: Emotional design, Design theory, User centred design, Aesthetics, Patterns

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1 INTRODUCTION

Work in experimental aesthetics and visual perception has spanned the last century, but the analysis of design, artistic artefacts and form generally with respect to human emotion is still emerging (Desmet and Hekkert 2014). In the realm of design theory, a great deal of work has been produced recently regarding the emotive qualities of objects and interactions, including the important studies by Patrick Jordan (2002) and Don Norman (2004). While this work has proved seminal, we seek to expand understanding of form by exploring a specific area of artistic expression; *patterns*. Patterns have been used as a feature in art, design and architecture for thousands of years and are an important part of the story of aesthetics having come to feature on a wide variety of objects in a huge multiplicity of styles. From the classical Greek and Egyptian styles that were typically simple and geometric to the Art Nouveau movement which developed a highly organic, complex and non-linear aesthetic (Howard, 1996), patterns have been features of them all.

This research uses qualitative methods to address the emotive and semantic qualities of patterns. So far, detailed analysis of patterns has only examined their underlying structure and how this relates to geometry as well as historical and cultural changes (Hann, 2012, 2013). Recent work in experimental aesthetics has suggested that human beings have a very strong and possibly innate preference for particular kinds of forms and associate particular emotive experiences with abstract geometry (Bertamini et al., 2016). For instance, the structural formations of patterns could convey deep semantic meaning to observers extending beyond simply "form preference". This has implications for the emerging research in design, emotions and semantics telling us that we have highly complex relationships with the artefacts that populate our lives, where products can affect us at an almost immediate instinctive level. Desmet and others (2008) and Krippendorff (2005) have demonstrated for example that semantic meaning can develop over a period of time, derived from the emotive interactions we have had with a particular object. Creative expression through form, and interpretation of form, what has been called the "aesthetic encounter", is clearly a highly complex and nuanced phenomenon, the understanding of which must consider a large body of social and cultural factors (Csikszentmihalyi and Emery Robinson, 1990).

This work initially addresses what a pattern is and how one is defined and created using sets of rules. Secondly we consider literature regarding form perception, allowing us to examine form both as a process of instinctual emotive analysis and as a process of meaning making. This forms the foundation of our qualitative study that details human responses (emotive and semantic) to a set of sixteen culturally prominent patterns. Lastly we offer an interpretive analysis of the results - we discuss the reasons for the noted trends and offer possible modes of application for wider design practice including meaning driven interaction design and computational form development.

2 BACKGROUND - WHAT IS A PATTERN?

Patterns, as conventionally conceived, consist of several important elements, limited but not restricted to; *repeatability, symmetry, infinite coverage of a plane, deconstruction into simple shapes or rules, colour and symbolism*. It is the repeatable nature of the forms or motifs that allow them to cover a theoretically infinite plane without gaps or the rearranging of elements – this is technically known as a "tiling" pattern. Repeating forms that may have gaps but still cover a plane is known as an "all-over" pattern.

The creation of patterns follows simple structural rules using shapes and symmetry that allow repetition to emerge. Ching and Juroszek (1998) defined shape as a “characteristic outline or surface configuration of a form” that can only exist in reference to other shapes; shapes and symmetry are the key constituents in a pattern. Structural elements are used to define and develop shapes within the context of a pattern. Work analysing these structural elements has been extensively undertaken by Michael Hann (2012, 2013). Hann shows that points and lines are the basis of structure and are the sources from which all geometry is created – points determine position and are dimensionless entities. Line can be considered as a moving point or the path between two points, a change from one state to another. The concept that line can convey some kind of energy or relates to natural forces or states of change has been explored in some depth by Ingold (2015), Barratt (1989) and earlier by D’Arcy Thompson who conjectured that the form of living creatures could be conceived as a "diagram of forces" (Thompson, 1917). These are important insights to consider when assessing the visual elements of patterns.

As Hann (2012) elucidates, patterns utilise the power of symmetry to create a state of non-randomness and apparent order. With respect to all-over patterns, four symmetry operations are key*; A) Transition B) Rotation C) Reflection D) Glide reflection* – illustrated in Figure 1 below. It is from these simple rules that the complexity seen in patterns emerges. Variations in design elements, motifs and degrees of repetition and rotation culminate in the overall aesthetic effect of a pattern design. Hann notes that pattern motifs can achieve a maximum of a six-degree rotational symmetry based on one of the five Bravais lattice frameworks. Additional visual factors such as proportion, order vs disorder and simplicity vs complexity, also play a role in the overall visual experience.

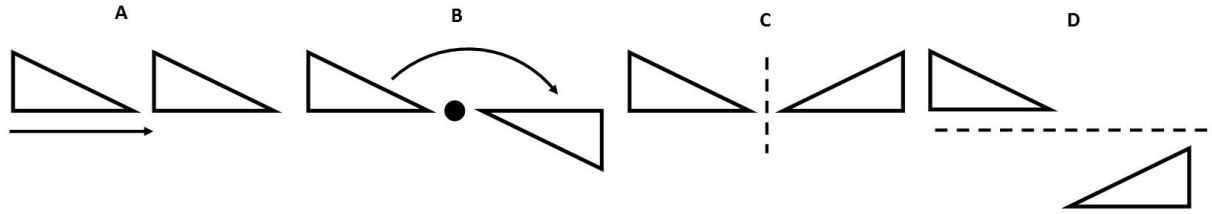


Figure 1. Symmetry operations – (A) Transition, (B) Rotation, (C) Reflection, (D) Glide reflection, adapted from Hann (2012)

With the development of art generally, the nature of pattern has changed constantly. The Greeks and later the Romans cemented what are now called the Classical aesthetic style which has remained influential especially in the Western tradition up to the present day giving symmetry and order a prominent role (Boardman, 2001). More recent history has seen significant expansion in pattern usage. During the period now known as the Industrial Revolution, the capacity for mass producing products accelerated hugely. Particularly in textiles, metal work and ceramics – the industrialisation of these product types grew concurrently with a new market demand and more designs began to materialise as the consumer base gradually widened. Key figures such as Josiah Wedgewood and William Morris developed patterns that became hugely popular and aesthetically influential through their respective work with ceramics and textiles during the 18th and 19th centuries (Forty, 1986). This set the scene for the present day where patterns are a principal feature of the fashion industry with different permutations being introduced every season appropriated from a range of cultures including India, China and Africa – subtle reinventions of known patterns to continuously whet the appetite of consumers.

3 PERSPECTIVES OF FORM

The way we perceive form has been the subject of several important studies in experimental psychology and aesthetics over the last century and is relevant for our analysis of pattern. Patterns are geometrically multifarious varying in complexity and structure. To understand them more deeply, we must first analyse their geometric foundations – the shapes that make them up. It is here that we must consider work on visual perception, where many of the studies have abstraction to approach the analysis of geometry.

3.1 Emotion in curves and angularity

Much research has shown a more positive connection emotionally and semantically to curved objects. At the cognitive level, it has been suggested that emotions serve as an "adaptive function" that can be affected by interactions with form – this event has been conceptualised as an *appraisal* (Arnold, 1960). Early studies in human visual perception showed that there was some link to curved objects and positive emotive interpretation. An early study by Poffenberger and Barrows (1924) showed that an angular or jagged line in the form of a wave was associated with words such as "serious" and "hard" and that curved lines by contrast were associated with the words "gentle" or "playful". The emotion could be altered by changing the angle of the line's inflection – a point also intimated by the design theorist Rowena Reed Kostellow (Hannah, 2002). A later set of studies by Collier (1996) found similar results looking at a range of simple stimuli. Additionally, a more recent set of experiments testing observer responses to curves and angularity in a range of contexts showed that observers are drawn more towards curvature but do not necessarily dislike angularity (Bertamini et al., 2016). In another study, ordinary people were shown to be able to "embody emotion" within shape implying a link between the visual and the tactile

construction of form (Melcer and Isbister, 2016). Additionally, the empirical evidence regarding the curvature preference has been recently summarised by Gómez-Puerto and others (2015).
In a design context, emotion can be a powerful tool (see Norman (2004) for a detailed analysis). Based on the antecedent work on visual perception, Mothersill and Bove Jr (2015) have developed a model of form and emotion that demonstrates how subtle changes in the characteristics of simple shapes can transform the emotive interpretation. In design practice, the principle of expressly using form as an emotive manipulator through sensory properties has been explored extensively in the field of Kansei Engineering where an understanding of pattern may prove a useful tool (Lévy, 2013).

3.2 Meaning and symbolism

Emotion is one important factor in the visual experience of form, another is the meaning that is derived from the form. Important insights regarding the interpretation of meaning in abstract shapes come from the school of Gestalt psychology. The Gestalt school put forward a holistic approach to form interpretation where the visual elements are considered all at once where "the whole is other than the sum of its parts" – visual elements with potentially symbolic cultural importance may only be intelligible when seen in the context of the whole (see Pinna and Reeves (2009) for further insights). This is critical to consider when analysing patterns that are comprised of multiple visual elements. Recent work in Gestalt theory has shown that small deviations in familiar geometric shapes induce what is called a "sense of happening" in observers – meaning is ascribed to a very abstract form (Pinna, 2010). This so called "sense of happening" should be considered when assessing the geometric properties of patterns as its presence may significantly alter emotive interpretations of a form or sets of forms.

4 ASSESSING EMOTION AND MEANING IN PATTERNS

We took a qualitative and interpretivist approach to address how patterns relate to discrete emotive experiences or semantic values. Considering the prior work in form perception detailed earlier, we hypothesised that particular patterns would have strong emotive and semantic connotations for the human observers. More specifically, it was proposed that angular pattern structures are more likely to inspire negative emotions and the curved pattern structures are more likely to inspire emotions of a positive nature. Findings like this would corroborate with the range of studies detailed above, the key point of difference is how the relationships between the geometric features may alter emotive responses. Semantic analyses of pattern are currently very limited which this work also hopes to address with these findings.

4.1 Workshop approach

With close reference to David Wade's (1982) pattern source book and other online sources, sixteen patterns were chosen based on their form, structure and cultural prominence including Spanish, Celtic, African and Middle Eastern patterns (Figure 2). They were also selected on the basis of the symmetry rules discussed by Hann (2012) meaning there was an adequate range of pattern complexity amongst the sixteen. The patterns were broadly categorised into three groups – angular, curved and mixed depending on the dominant features of each. Overall, six patterns were categorised as structurally angular, six as curved and three as mixed which the authors considered a good range of diversity for considering their respective emotive and semantic differences.
The workshop exercise included 12 student participants from design and engineering backgrounds. The students were then split into focus groups of either two or three members. This focus group approach meant that the effects of personality type could be mitigated as disagreements in interpretation could be discussed and consensus reached. Each group was required to observe a pattern for a total of two minutes and assign a maximum of three emotive and three descriptive (semantic) values to each using a provided worksheet. The worksheet contained 36 emotive terms ranging from highly positive to highly negative ("anger" compared to "joy" for instance) which would be used to describe the patterns. These terms were selected with reference to the models of emotion found in work by Plutchik (1980) primarily, and also by Shaver and others (1987). Not only did this research provide a large array of emotive terminology, the models also propose the levels of intensity that each emotion is subjectively experienced, relative to the others - an important factor to consider. A list of descriptive (semantic) terminology was also included but participants were not required to use this, it was only used as a source of inspiration.

The patterns were displayed one by one in a randomised order and were all presented as monochrome – while colour can be an important element of patterns, we were only interested in reviewing the raw form qualities. The sixteen patterns used for the experiment are shown in Figure 2 with a caption detailing their assigned category. The order in which they are presented below is the same randomised order used for the workshop.

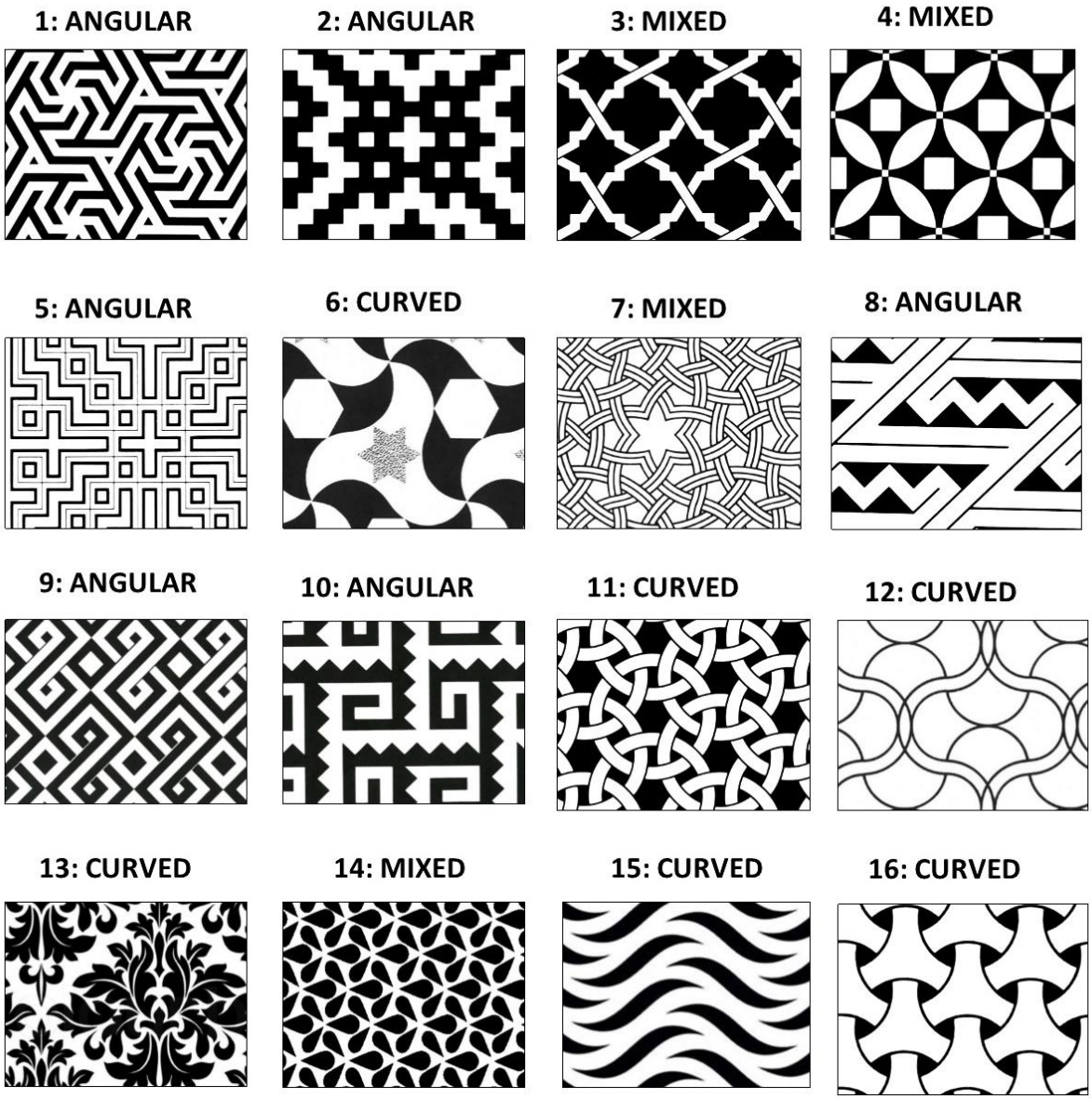
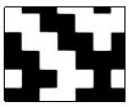
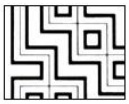
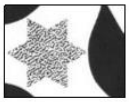
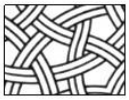
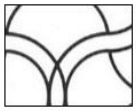


Figure 2. Patterns utilised during workshop experiment, adapted from Wade (1982) and open source material

5 RESULTS

Following the workshop, an analysis was undertaken where the results were checked for trends. While it was rare for all of the groups to produce identical emotive and descriptive values for a specific pattern due to the interpretivist nature of the exercise, we did however observe notable similarities in terms of broad emotion type and experiential intensity, "joy" and "excitement" for example. While these are recognised as different emotions, they can both be categorised as positive and of a generally high intensity. The results from the workshop are summarised in Table 1. For most the patterns the emotive and sematic values were quite clear and many of the groups converged in their separate interpretations, some results were less conclusive.

Table 1. Ascribed emotive values and semantic association of 16 patterns

Pattern	Ascribed emotive values	Semantic associations
1 	• Strong trend towards ***negative emotions*** • Medium to high intensity • Key values: "anger" "aggression" "nervousness" "uncertainty"	• Strong associations with angularity and complexity
2 	• Moderate trend towards ***negative emotions*** • Medium intensity • Key values: "indifference" "distraction" "nostalgia"	• Strong associations with simplicity, confusion and instability
3 	• Strong trend towards ***negative emotions*** • High intensity • Key values: "anger" "contempt" "amazement"	• Strong associations with tradition and sophistication • Additional associations included strength and power
4 	• Moderate trend towards ***positive and neutral emotions*** • Medium intensity • Key values: "affection" "joy" "distraction"	• Associated with tradition and decoration • Additional associations included simplicity and playfulness
5 	• Moderate trend towards ***negative emotions*** • Medium intensity • Key values: "uncertainty" "apprehension" "intrigue"	• Associated with confusion and irrationality
6 	• Strong trend towards ***positive emotions*** • High intensity • Key values: "joy" "excitement" "love" "affection"	• Associated with fun, fluidity and instability
7 	• Weak trend towards ***positive emotions*** • Low intensity • Key values: "vigilance" "trust" "serenity"	• Strong associations with power, heaviness and symbolism
8 	• Strong trend towards ***negative emotions*** • Medium intensity • Key values: "nervousness" "uncertainty" "apprehension"	• Strong associations with angularity and spikes • Additional associations included insecurity and instability
9 	• Strong trend towards ***negative emotions*** • High intensity • Key values: "rage" "grief" "disturbance" "uncertainty"	• Associated with evil, power, heaviness and solidness
10 	• Strong trend towards ***negative emotions*** • High intensity • Key values: "fear" "nervousness" "distraction"	• Strong associations with wackiness, instability and confusion • Additional associations included wild animals
11 	• Strong trend towards ***positive emotions*** • Medium intensity • Key values: "trust" "acceptance" "optimism" "serenity"	• Strong associations with tradition and symbolism • Additional associations included security and strength
12 	• Moderate trend towards ***positive emotions*** • Medium intensity • Key values: "serenity" "love" "joy" "affection"	• Strong associations with fluidity, lightness and curvature • Additional associations included surprise and mysteriousness

13 	• Strong trend towards ***negative emotions*** • High intensity • Key values: “disgust”	• Strong associations with decoration and tradition • Additional associations included wealth and sophistication
14 	• Strong trend towards ***negative emotions*** • Medium to high intensity • Key values: “uncertainty” “sadness” “anger”	• Association with curiousness
15 	• Strong trend towards ***positive emotions*** • Medium to high intensity • Key values: “serenity” “ecstasy” “love” “joy”	• Strong association with waves, fluidity and lightness
16 	• Strong trend towards ***positive emotions*** • Medium to high intensity • Key values: “trust” “excitement” “interest” “anticipation”	• Association with strength, power and solidness • Additional associations included organic

6 DISCUSSION - WHAT PATTERNS MEAN TO US

6.1 Angularity

This study has brought some new insights with respect to how humans interpret the form and structure of patterns. What is of immediate interest is how the different patterns can elicit different intensities of emotive feedback. The work on emotion by Robert Plutchik (1980) allowed us to consider the general level of intensity of the emotions elicited by the patterns by relating them to his models. It should also be considered that linguistically there is some overlap between emotive descriptors and semantic descriptors - "confusion" can be a feeling or something could *appear confusing* for example; a distinction it is important to note.

Considering that every single angularly dominant pattern used for the study was associated with negative emotions, we must look to the emotive intensity and the semantic links for deeper insights. Pattern 1 for example is highly angular utilising six-fold rotational symmetry that appears to intricately connect. This was associated semantically with "complexity" and emotively with "anger" and "contempt". If we compare this result with the result for pattern 9, the emotive qualities noted as "rage" and "grief" are similar. Pattern 9 is aesthetically similar to pattern 1 – both are moving across the plane at non-right angles and in addition, both have spiral-like formations. Pattern 9 did, however, have much clearer semantic values, associated strongly with "power", "heaviness" and even "evil".

Other similarities included patterns 8 and 10. Both had negative emotive association which were the same or semantically similar but of varying intensities – "nervousness" and "apprehension" noted for pattern 8 and "fear" and "nervousness" noted for pattern 10. Interestingly, if we consider the structure and form of the pattern we see the same structural element, a jagged form. Poffenberger and Barrows (1924) noted a similar result in their early work where a jagged line was associated with the words "hard", "serious" and "powerful". In a general sense, all the patterns with a form that was structurally angular were related to negative emotions and were frequently aligned semantically with concepts of "power", "strength" and on several instances with "confusion" and "instability". The reason for this apparent conflict in interpretation is not clear but we speculate the affects described by Gestalt holism may be an influencing factor, possibly the "sense of happening" mentioned in section 3.2.

6.2 Curvature

In contrast to the patterns with an angular structure, the patterns based on curves were consistently related with positive emotive, corroborating with the results from Bertamini and others (2016) among other studies. If we first consider the results for patterns 6, 12 and 15 – all three dominated by large curves – we see similar emotive responses. All were interpreted as relating to feelings of "joy", "love", "affection", "serenity" and even "ecstasy" and all semantically associated with "fluidity". Aesthetically, patterns 6 and 12 are structurally similar in form, largely constructed from large interlocking curves similar to sinusoidal waves. It is perhaps the pattern's aesthetic similarity to waves that means both were

related to the element of water or fluids. This could also explain the emotive associations – the energy of free-flowing water could relate to the excitement and happiness that feelings of love and affection bring. As Kostellow Reed had noted, the character of abstract shapes is affected by the direction and inflections meaning that wave forms with frequent undulations could easily convey positivity (Hannah, 2002). Pattern 15 is rather directly related to wave forms and from an aesthetic stand point appears like the abstract representation of a river or flowing water. It was unsurprising in this instance that this pattern was related to fluid and waves. Interestingly, pattern 12 was considered "mysterious" and pattern 14 "curious", though it is unclear why this is the case.

Patterns 7 and 11 which also contained structurally congruent features were interpreted in similar ways. Pattern 7 was considered to contain both angular and curved forms but features large ring-like forms directly comparable to the forms within pattern 11. Notably, both patterns were associated with the concept of "trust" and "serenity". We propose this is perhaps due to the aesthetic of the pattern being strongly symbolic of these concepts in some way – the structure of interlocking rings could imply a sense of "togetherness" and, by extension, possibly relating to the concept of friendship. Pattern 11 notably contains a Vesica Piscis (two discs intersecting) which was used commonly throughout Byzantine and Renaissance art as a symbol of Christ (Lawlor, 1989). This deep cultural meaning may be influencing the observers at some level. Semantically, the forms were also considered similarly; many groups felt the forms had a symbolic nature and in addition felt the forms connoted the related concepts of "strength", "power" and "security". Also of note are the results for pattern 16 which were emotively and semantically parallels of patterns 7 and 11, pattern 16 is very noticeably different in form. The reason for the similar responses is conceivably due to the interlocking structure of the forms. An interlocking structure in some configuration seems to suggest to observers the concept of "togetherness" and by extension the emotion of "trust". The semantic responses of strength and power seem to suggest that people relate these concepts with the emotive quality of trust.

6.3 Key findings

Given the limited scale of this study, we cannot claim to have made categorical discoveries regarding the nature of pattern interpretation. We can however offer two key qualitative insights based on the results that can be used as a foundation of further exploration of pattern.

1. *The more complex nature of pattern form and the structural relationships of the form influence the emotive feedback. This is a logical extension of Gestalt holism where the contextual nature of form alters how it is visually interpreted - its aesthetic meaning is changed. Our results largely corroborated with the previous studies analysing curvature and angularity but differed in terms of emotive intensity between the patterns and presented radically different semantic values*
2. *Patterns that included curved interlocking features were notable for the strong feedback they received. This study suggests that curved interlocking features are emotively associated with "trust" and semantically associated with "power", "security" and "solidness". We speculate this may be due to a certain structural view of emotive visualisation - the forms look structurally secure in context and by extension relate to the concept of trust. By contrast, the angular patterns that may appear structurally disjointed were emotively associated with "nervousness" semantically with "confusion" and "instability"*

6.4 Applications for design

Considering the insights that were collected during the study, we can now discuss the possible applications of this work in design practice. Patterns have been applied in a design context for thousands of years but we offer a more systematic framework for their use in the context of design emotion or emotive products. The applications in the two-dimensional world - use on fabrics or wallpaper is patently obvious; we would like to offer novel applications in the three-dimensional world of physical product interaction.

Hypothetically, three-dimensional pattern based structures could be generated by translation procedures from sets of two-dimensional pattern designs - this can also be viewed as a form of precisely designed surface texturing. Potentially, these could be applied on a wide variety of products for bespoke emotive responses. In a simple product context, there is scope for utilising such a method to create more emotionally and semantically interesting products. Desmet and others (2005) for instance have shown how simple design features can initiate a so called "WOW" response in users of hand-held products making the product seem more interesting and desirable. These principles could be used for the emotive

texturing of laptop of phone casings for example. Given recent developments in additive manufacturing, the mass customisation of products in this way in not farfetched (Gao et al., 2015), despite limitations in material capability. CNC machining is another promising area with respect to the possible texturing of notably metal surfaces with the process gradually becoming more economical. CNC machining offers the shaping of materials that additive processes cannot recreate with extensive research continuing into the processes' geometric accuracy and limitations (Lasemi et al., 2010).

Furthermore, three-dimensional pattern form could be used as a mode of guidance for users. Recent research has shown that particular structural elements in products can convey types of uses, buttons convey "pressability" for example (You and Chen, 2007). This idea relates to the concept of "affordances" put forward by the psychologist J. J. Gibson (1979), advanced by Norman (1988) and then again expanded recently by Vardouli (2015) in an artefact-centric framework. The key point here is that designed components can convey meaning. Forms of surface texturing could hence convey types of meaning possibly related to aspects of product function or something more abstract such as emotion. While affordance theory deals with the visual aspects of interaction, physical interaction can also be considered. Recent research has noted the large diversity of emotive responses to interactions with products (Desmet, 2012) with other work showing how particular physical characteristics or feedback mechanisms can actually teach the user how to use a product (van der Linden et al., 2011). Additionally, there is some evidence to suggest that interaction with a product can convey a "product personality" (Desmet et al., 2008). But this research also showed that appearance was a stronger factor when determining this personality. These interaction characteristics could potentially be an interesting narrative to follow for design practitioners possibly using bespoke pattern designs to convey a coherent product personality.

Given recent developments in form generation methods, there is scope for developing and applying pattern form in a computational design framework. Recent work by Neri Oxman (2012) has applied complex material computation in an industrial design context, although Oxman's work has a more functionalist approach, a similar principle could be applied for creating emotive texturing based on pattern design principles. Overall, design through computation and computational making are becoming more prominent (Ozkar, 2015) and utilising emotive patterns and texturing could be a fruitful future endeavour for design practice and research.

7 CONCLUSION

Following a review of the history of pattern use and the theory behind their form, structure and creation, this study has presented a set of qualitative insights from a workshop experiment analysing responses to the aesthetic of patterns. We concluded that patterns dominated by curved forms were associated with more positive emotions whereas patterns dominated by angular forms were generally associated with more negative emotions. These results corroborate with findings from a wide range of other studies and were not necessarily surprising. The differences in form between the patterns caused subtle variations in how they were emotively interpreted and unpicking this could be the topic of a future study. Semantically, the pattern interpretations were hugely diverse and surprisingly did not necessarily relate to the emotive interpretations. One very clear result was the relationship between the emotion of "trust" and patterns containing curved interlocking features in contrast to angular and more disjointed patterns that were associated with "nervousness" and "confusion". We propose that in some sense this interlocking form motif is highly symbolic of trust as a concept and may be in some way culturally ingrained. Patterns are an important part of the story of the visual arts and have not been fully appreciated for their emotive and semantic complexities. There is scope for the design industry to use pattern as a means of producing more emotionally rich objects through advanced manufacturing technology and computational approaches to form generation and in turn provide new layers of meaning in the experience of using products.

REFERENCES

Arnold, M.B. (1960), *Emotion and Personality*, Volume 1, Columbia University Press

Barratt, K. (1989), "Logic and Design", In: *Art, Science & Mathematics*, Design Press.

Bertamini, M., Palumbo, L., Gheorghes, T.N. and Galatsidas, M. (2016), “Do observers like curvature or do they dislike angularity?”, *British Journal of Psychology*, Vol. 107 No. 1, pp. 154–178.

Boardman, J. (2001), *The Oxford History of Classical Art*, Oxford University Press.

Ching, F.D.K. and Juroszek, S.P. (1998), *Design Drawing*, John Wiley & Sons.
Collier, G.L. (1996), "Affective synesthesia: Extracting emotion space from simple perceptual stimuli", *Motivation and Emotion*, Vol. 20 No. 1, pp. 1–32.
Csikszentmihalyi, M. and Emery Robinson, R. (1990), T*he Art of Seeing: An Interpretation of the Aesthetic Encounter*, Getty Publications
Desmet, P.M.A. (2012), "Faces of product pleasure: 25 positive emotions in human-product interactions", *International Journal of Design*, Vol. 6 No. 2, pp. 1–29.
Desmet, P.M.A. and Hekkert, P. (2014), *Special Issue Editorial : Design & Emotion*.
Desmet, P.M.A., Ortíz Nicolás, J.C. and Schoormans, J.P. (2008), "Product personality in physical interaction", *Design Studies*, Vol. 29 No. 5, pp. 458–477.
Desmet, P.M.A., Porcelijn, R. and van Dijk, M. (2005), "How to design wow. Introducing a layered-emotional approach", *Proceedings of the Conference Designing Pleasurable Products and Interfaces*, TU Eindhoven, Eindhoven, No. 2005, pp. 71–89.
Forty, A. (1986), *Objects of Desire: Design and Society since 1750*, Thames and Hudson
Gao, W., Zhang, Y., Ramanujan, D., Ramani, K., Chen, Y., Williams, C.B., Wang, C.C.L., et al. (2015), "The status, challenges, and future of additive manufacturing in engineering", *Computer-Aided Design*, Elsevier Ltd, Vol. 69, pp. 65–89.
Gibson, J.J. (1979), *The Ecological Approach to Visual Perception: Classic Edition*, Vol. 20, Psychology Press
Gómez-Puerto, G., Munar, E. and Nadal, M. (2015), "Preference for Curvature: A Historical and Conceptual Framework.", *Frontiers in Human Neuroscience*, Vol. 9 No. January, p. 712.
Hann, M. (2012), *Structure and Form in Design: Critical Ideas for Creative Practice*, Bloomsbury.
Hann, M.A. (2013), *Symbol, Pattern & Symmetry: The Cultural Significance of Structure*, Bloomsbury.
Hannah, G.G. (2002), *Elements of Design: Rowena Reed Kostellow and the Structure of Visual Relationships*.
Howard, J. (1996), *Art Nouveau: International and National Styles in Europe*, Manchester University
PressIngold, T. (2015), *The Life of Lines, Routledge*.
Jordan, P.W. (2002), *Designing Pleasurable Products: An Introduction to the New Human Factors*, CRC Press
Krippendorff, K. (2005), *The Semantic Turn: A New Foundation for Design*, CRC Press
Lasemi, A., Xue, D. and Gu, P. (2010), "Recent development in CNC machining of freeform surfaces: A state-of-the-art review", *CAD Computer Aided Design*, Elsevier Ltd, Vol. 42 No. 7, pp. 641–654.
Lawlor, R. (1989), *Sacred Geometry : Philosophy and Practice*, Thames and Hudson.
Lévy, P. (2013), "Beyond Kansei Engineering: The emancipation of Kansei design", *International Journal of Design*, Vol. 7 No. 2, pp. 83–94.
van der Linden, J., Schoonderwaldt, E., Bird, J. and Johnson, R. (2011), "MusicJacket—Combining Motion Capture and Vibrotactile Feedback to Teach Violin Bowing", *IEEE Transactions on Instrumentation and Measurement*, IEEE, Vol. 60 No. 1, pp. 104–113.
Melcer, E. and Isbister, K. (2016), "Motion, Emotion, and Form", *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*, No. May, pp. 1430–1437.
Mothersill, P. and Bove Jr., V.M. (2015), "The EmotiveModeler: An Emotive Form Design CAD Tool", *Extended Abstracts of the ACM CHI'15 Conference on Human Factors in Computing Systems*, Vol. 2, pp. 339–342.
Norman, D.A. (1988), *The Psychology of Everyday Things*, Basic Books
Norman, D.A. (2004), *Emotional Design: Why We Love (or Hate) Everyday Things*, Basic Books
Oxman, N. (2012), "Material Computation", *Manufacturing the Bespoke: Making and Prototyping Architecture*, pp. 256–265.
Ozkar, M. (2015), "Visualizing making: Shapes, materials, and actions", *Design Studies*, Vol. 41, pp. 1–22.
Pinna, B. (2010), "New Gestalt principles of perceptual organization: an extension from grouping to shape and meaning", *Gestalt Theory*, Vol. 23 No. 1, pp. 11–78.
Pinna, B. and Reeves, A. (2009), "From perception to art: how vision creates meanings.", *Spatial Vision*, Vol. 22 No. 3, pp. 225–272.
Plutchik, R. (1980), *Emotion, a Psychoevolutionary Synthesis*, Harper & Row.
Poffenberger, A.T. and Barrows, B.E. (1924), "The Feeling Value of Lines.", *Journal of Applied Psychology*, American Psychological Association, Vol. 8 No. 2, pp. 187–205.
Shaver, P., Schwartz, J., Kirson, D. and O'Connor, C. (1987), "Emotion knowledge: Further exploration of a prototype approach", *Journal of Personality and Social Psychology*, Vol. 52 No. 6, pp. 1061–1086.
Thompson, D.W. (1917), *On Growth and Form*, Cambridge University Press.
Vardouli, T. (2015), "Making use: Attitudes to human-artifact engagements", *Design Studies*, Elsevier Ltd, Vol. 41, pp. 137–161.
Wade, D. (1982), *Geometric Patterns and Borders*, Wildwood House Ltd.
You, H. and Chen, K. (2007), "Applications of affordance and semantics in product design", *Design Studies*, Vol. 28 No. 1, pp. 23–38.