

Implicit association of symmetry with positive valence, high arousal and simplicity

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Abstract. Symmetrical visual patterns are preferred to random patterns. Studies using the Implicit Association Test (IAT) have shown that symmetry is associated with positive valence words (e.g. love), and random with negative valence words (e.g. hate). Valence is an important aspect of emotion, but equally interesting is the relationship between the symmetry–random dimension and the dimensions of arousal and complexity. Possible links have long been discussed but empirical evidence is limited. Using a series of four IAT experiments, we report that participants implicitly associate symmetrical patterns with words high in arousal, and random patterns with low arousal. We also found that symmetrical patterns were associated with simple mathematic expressions, while random patterns were associated with complex expressions. No link was found for another aspect of mathematical complexity (smaller or larger numbers). This pattern of results shows that aesthetic responses to symmetry involve both positive valence and high arousal and that these emotional responses arise from the perceptual simplicity of symmetry, in line with the fluency account of aesthetics.

Keywords: perception of symmetry, IAT, valence, visual aesthetics.

1 Introduction

A preference for symmetry is well documented both in humans (Cardenas & Harris, 2006; Eisenman, 1967; Eysenk, 1941; Frith & Nias, 1974; Jacobsen & Höfel, 2002) and in many other species, from honeybees to chicks (Clara, Regolin, & Vallortigara, 2007; Wignall, Heiling, Cheng, & Herberstein, 2006). Symmetry has also been mentioned as a possible fundamental principle of aesthetics (Ramachandran & Hirstein, 1999) and a potential aesthetic primitive (Latto, 1995).

Most empirical work has involved explicit evaluation of symmetry (e.g. Eisenman, 1967; Frith & Nias, 1974; Jacobsen & Höfel, 2002); however, recent work has started to employ implicit measures. Makin, Pecchinenda, and Bertamini (2012a) used the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998; Nosek, Greenwald, & Banaji, 2007) to explore implicit preference for symmetry. Other authors have used the IAT for buildings (Mastandrea, Bartoli, & Carrus, 2011) or for paintings (Pavlović & Marković, 2012). This technique is designed to detect the strength of a person's automatic association between two categories. Let us consider the study in Makin et al. (2012a). On some trials, participants saw either symmetrical or random patterns, and pressed one button for symmetry and another button for random. On interleaved trials, they saw either positive or negative words, and pressed one button for positive and another for negative. In the compatible blocks, one button was used to report symmetrical patterns and positive words, and the other button was used to report random patterns and negative words. In the incompatible blocks, the response mapping was reversed. Reaction times in the compatible blocks were shorter than the incompatible blocks. This was interpreted as an implicit preference for symmetrical over random patterns. In this case, implicit preferences were in agreement with explicit preferences measured on the same subjects. Interestingly, implicit preferences diverged from explicit preference in some experiments. For example, the IAT revealed an implicit preference for reflectional symmetry over rotational symmetry, while people explicitly rated the rotational patterns as more beautiful than reflection. Implicit preference, on the other hand, was consistent with the speed of visual processing, with consistent preferences for the more rapidly

detected patterns. It is clear that the IAT is a useful tool in experimental aesthetics (Gattol, Sääksjärvi, & Carbon, 2011; Makin, Pecchinenda, & Bertamini, 2012b; Mastandrea et al., 2011). For instance, Pavlović and Marković (2012) found that positive paintings were paired with positive words and hedonically negative ones with negative words.

The current work addresses an old question in empirical aesthetics using the IAT. It has long been thought that there is a law-like relationship between the perceived simplicity/complexity of a stimulus, the level of arousal it elicits, and its valence. Daniel Berlyne hypothesised that people like an intermediate level of arousal (Berlyne, 1974). He suggested that complexity is related to arousal, so a simple stimulus produces little arousal, and a complex stimulus produces high arousal. Therefore, he suggested that complexity should be related to preference with an inverted U-shaped function, so that people prefer patterns with a mid-level of complexity, and he found some empirical support for this (Berlyne, 1970). In fact, early pioneers of empirical aesthetics, such as Birkhoff (1933) and Eysenk (1941), had already described the importance of an optimal balance between simplicity and complexity. For Birkhoff, this idea was best captured by the ratio of balance over complexity, whereas for Eysenk the two combined multiplicatively (Boselie & Leeuwenberg, 1985). It is well established from work on emotion that arousal and valence can be dissociated. Arousal, unlike valence, is not positive or negative, and can be associated with either positive or negative states, and with either approach or avoidance behaviour. According to Apter (1976), there is no optimal arousal level, because optimal arousal changes over time even for a given individual.

More recently, work on fractals continues to explore preference for mid-range stimuli (e.g. Spehar, Clifford, Newell, & Taylor, 2003), while the theoretical work on perceptual fluency (e.g. Reber, 2012) and prediction error (Van de Cruys & Wagemans, 2011) argues that a preferred artwork or pattern is fluently processed and understood, but cannot be too simple and obvious. However, measuring ease of processing is not easy, and recent evidence suggests that observers like complex visual displays such as consumer products via a process of elaboration (Carbon & Leder, 2005), and artworks via a process of “aesthetic Aha!” (Muth & Carbon, *in press*).

Berlyne’s proposed role for arousal has been somewhat neglected in recent years (Berlyne, 1970; Locher & Nodine, 1989). One problem is that the definition of arousal is vague, perhaps referring to the activation of the sympathetic nervous system, or perhaps to cortical arousal. Berlyne argued that arousal increases with complexity. Random patterns are, in a formal sense, more complex than symmetrical patterns (Pizlo, 2008; Tyler, 1995; Wagemans, 1995), so they should theoretically be more arousing. Nevertheless, the opposite hypothesis, that symmetry is more arousing, is also tenable. Bilateral symmetry is associated with objectness (Bertamini, 2010) and it has also biological relevance, indicating health or reproductive fitness in others (Møller, 1992; Swaddle & Cuthill, 1994). Moreover, before the abundance of manufactured objects, symmetry may have been a visual cue indicating that another animal had you in its line of sight: a situation which requires preparation for action (Tyler, 1996). In light of these considerations, we adopted the hypothesis that symmetrical patterns are more closely associated with arousal than random patterns.

In our first experiment, we gave participants four different IATs, following the multidimensional IAT paradigm proposed by Gattol et al. (2011). Each IAT measured a different set of implicit associations (Table 1). The first IAT was a replication of the study by Makin et al. (2012a) and designed to measure associations between symmetry and positive words, and between random and negative words. A novel, second IAT explores arousal. On compatible blocks, participants pressed the same key to report symmetry and high arousal words (e.g. explosion), and the other key for random patterns and

Table 1. The four IATs in our multidimensional design. The target dimension was always symmetry but this was a reflection in Experiment 1 and a rotation in Experiment 2. Examples of the images are shown in Figures 1 and 3. The table lists the other dimension used in the IAT.

Experiment	Dimension (with examples)		
1	Valence	<i>Rainbow</i>	<i>Evil</i>
2	Arousal	<i>Excitement</i>	<i>Chair</i>
3	Complexity	$2 + 3$	$134/372*34$
4	Numerosity	24	69

low arousal words (e.g. pillow). On incompatible blocks, the response mapping was reversed, so people pressed one key for symmetry and low arousal, and the other for random and high arousal. Faster mean reaction time in the compatible blocks would suggest that the symmetrical patterns are perceived as more arousing than the random patterns. In the third IAT, we explored links between regularity and complexity dimensions. Participants again classified patterns as symmetrical or random, but also classified mathematic expressions as simple (e.g. $2 + 3$) or complex (e.g. $134/372*34$). In the compatible blocks, the one button was used for simple expressions and symmetrical patterns, and the other button for complex expressions and random patterns. In the incompatible blocks, this was reversed. Faster reaction time (RT) in the compatible blocks would suggest that symmetry is seen as simple, and random as complex. Finally, the fourth IAT explored a different conception of complexity, which can be described as numerosity. If the presence of symmetry means that stimuli are simpler, then symmetry may be associated with small numbers, and random with large numbers. There is some evidence in the literature that stimuli forming a good gestalt are perceived as less numerous (Frith & Frith, 1972), so this was predicted.

If the four IATs yield the predicted results, it would show that symmetric patterns are associated with simple mathematical expressions, small numbers, high arousal, and positive valence. This pattern of results would equally show that random patterns are associated with complex mathematical expressions, large numbers, low arousal, and negative valence.

2 Experiment 1

2.1 Methods

2.1.1 Participants

Thirty-two participants from the University of Liverpool took part in the experiment (age 18–27 years, mean age 19 years, six male, two left handed). All had normal or corrected-to-normal vision. Some participants were rewarded with course credit, and all were naïve with regard to the experimental hypothesis. The experiment had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

2.1.2 Apparatus and stimuli

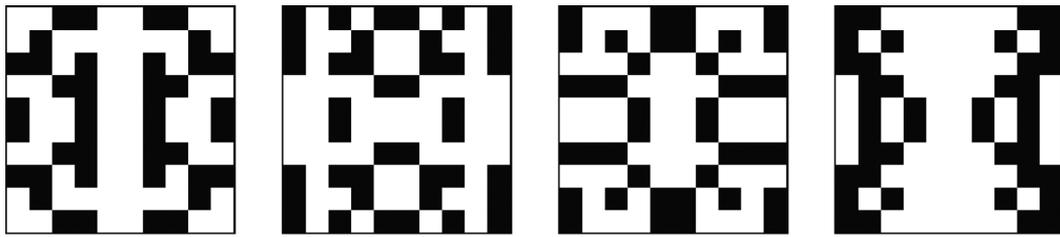
Participants sat in a darkened room approximately 57 cm from a 60-Hz CRT monitor. A program written in Python and using Psychopy (Peirce, 2007) controlled the experiment. Participants entered responses using two keys of the keyboard. The patterns were generated from a black and white checkerboard (10×10) and new patterns were created in each trial so that there was never a repetition of the same pattern. Examples are shown in Figure 1. The square was approximately 10° of visual angle.

Words were selected from the ANEW database (Bradley & Lang, 1999). In the case of valence, the words were identical to those used by Makin et al. (2012a): 10 positive words (HEAVEN, LOYAL, FREEDOM, HONOUR, LUCKY, KISS, RAINBOW, PLEASURE, PARADISE, and FRIEND) and 10 negative words (CANCER, DISASTER, POISON, HATRED, ACCIDENT, TORTURE, FILTH, SICKNESS, EVIL, and DEATH). These words were matched for mean frequency and arousal.

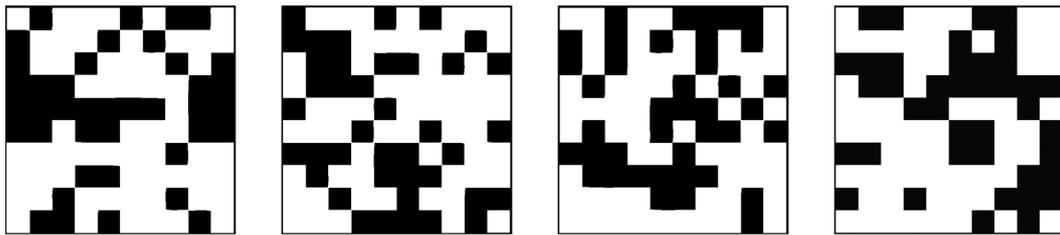
For arousal, the words were high (MIRACLE, EXCITEMENT, WIN, TERRIFIED, KILLER, ENRAGED, THRILL, DEATH, ORGASM, RAGE) or low (PILLOW, DREARY, NONCHALANT, PENCIL, SECURE, CHAIR, BUTTER, BIRD, INDIFFERENT, SQUARE). These words were matched for mean frequency and valence.

To create stimuli that differed in complexity, two types of mathematical formulas were generated. In simple formulas, there were two numbers between 1 and 5, added or subtracted together (e.g. $4 + 3$). In complex formulas, there were three numbers, each between 1 and 999, and any of the four arithmetic operations (e.g. $56*147/71$). We assume that the first type will be perceived as simple and easy, and the second type as complex.

In another version of the experiment, complexity was manipulated differently, while still using numbers. We refer to this dimension as numerosity. A single number was displayed and the task was to decide whether the number belonged to the set of small numbers (defined as below 50) or the set of large numbers (defined as above 50). Small numbers were chosen between 10 and 49 and high numbers between 51 and 99. Therefore, all numbers were always two digits in length to control for visual size.



Examples of patterns with reflectional symmetry



Examples of random patterns

Figure 1. Four examples of reflection and random patterns. In the experiment, new patterns were generated for each trial through a random number generator, and the likelihood of repetition was minimal. Participants classified the images by pressing one of two keys.

2.1.3 Procedure

The procedure was typical of IAT experiments (Nosek et al., 2007) and in particular it was similar to the multidimensional IAT introduced by Gattol et al. (2011). We describe the procedure for the valence IAT in detail as example, as the others were based on the same template. In the first block, participants saw reflection or random patterns, and they pressed the left button for reflection, and the right button for random. In the second block, the positive and negative words were presented, and participants responded with left button for positive and right button for negative. After that there were two blocks of experimental trials. In the compatible blocks, the left button was used to report reflection or positive words, while the right button was used to report random patterns or negative words. Next, two more training blocks were presented that included only reflection or random patterns, but the response mapping was reversed. Participants had to use the left button to report random patterns, and the right key to report reflection patterns. There were then two blocks of incompatible trials (left button for random or positive, right button for reflection or negative). In all blocks, cue words were present on the screen to indicate the response mapping. The order of the blocks was reversed for half of the participants, thus presenting incompatible blocks before compatible blocks.

Incorrect responses were signalled with the message “WRONG” on the screen and participants had to correct their response for the experiment to move on. Participants were instructed to make accurate responses as quickly as possible.

The same procedure and the same number of trials were used in IAT that tested arousal, complexity and numerosity. A Latin square was used to decide the order in which participants took part in the four IAT sessions (valence, arousal, numerosity, and complexity). The four orders were ACNV, CNVA, NVAC and VACN.

2.1.4 Analysis

Trials from the compatible and incompatible blocks were excluded if participants pressed the incorrect key, and if reaction time was greater than 10 seconds. Approximately, 7% of the trials were excluded. Implicit association was measured as the difference in response times between the compatible and the incompatible blocks. Moreover, following the conventions of the IAT literature (Nosek et al., 2007), we divided this difference in reaction time by the standard deviation (SD) of response times in the experimental blocks, separately for each participant. This measure, called *D* score, is obtained for each participant and IAT, and is positive when there is an association in the predicted direction. We performed an overall mixed ANOVA with one within-subjects factor (dimension [valence, arousal,

complexity, and numerosity]) and two between-subjects factors (order [ACNV, CNVA, NVAC, and VACN]) and (sex of participant [male, female]). This ANOVA tested the difference between the dimensions and whether presentation order had an effect. Separately, we evaluated the values of D against zero for each dimensions to test whether the association was significant. The α level was adjusted for multiple comparisons to 0.0125 (0.05/number of independent comparisons). In the ANOVA, there was no violation of sphericity according to Mauchly's test.

2.2 Results

Each participant completed the four IAT sessions designed to measure implicit associations of reflection and random patterns and one other dimension (valence, arousal, complexity, and numerosity). The overall pattern of results is shown in [Figure 2](#).

There was a significant effect of dimension ($F(3, 75) = 18.44, p < 0.001$) but no effect of order or sex, and no interactions. Next we analysed each dimension separately, to assess whether D scores were significantly greater than zero. In the case of valence, the D score was greater than zero ($t(31) = 10.34, p < 0.001$, see also confidence intervals on [Figure 2](#)). This suggests that symmetry is associated with positive words and random with negative words, as found previously (Makin et al., 2012a). In the case of arousal, the D score was also greater than zero ($t(31) = 6.46, p < 0.001$). This finding is novel and suggests an association between the symmetric patterns and words that were higher on arousal, and between random and low arousal words. There was also a significant effect of complexity. The D score was greater than zero ($t(31) = 2.94, p = 0.006$), showing that symmetrical patterns are associated with simple expressions, and random with complex expressions. However, there was no effect in the numerosity IAT ($t(31) = 0.34, n.s.$). Together, the last two findings suggest an association between symmetry and complexity but only when complexity is operationalised as task difficulty.

3 Experiment 2

Experiment 1 showed that participants associated reflectional symmetry with positive words, high arousal words and simple mathematical expressions. Conversely, they associated random patterns with negative words, low arousal words and complex expressions. Experiment 2 compared rotational symmetry with random patterns using the same multidimensional procedure. This is an important comparison. If the results generalise across symmetry types, it would be more reasonable to discuss them in terms of properties of the visual system rather than in terms of the biological significance of symmetry.

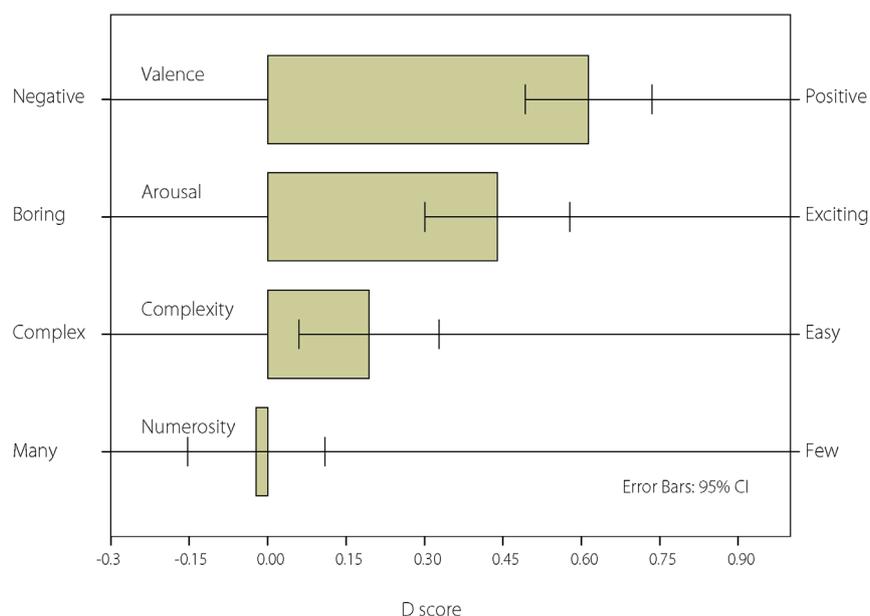
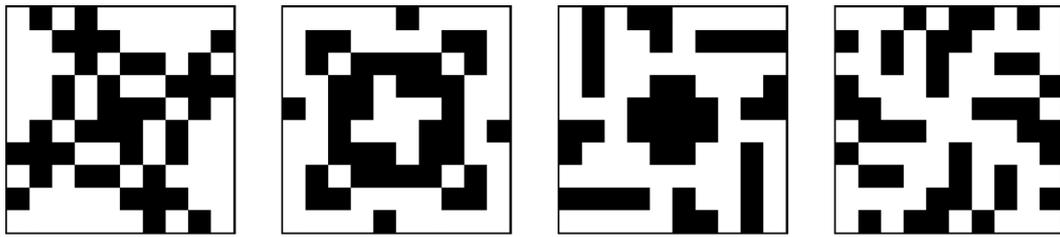
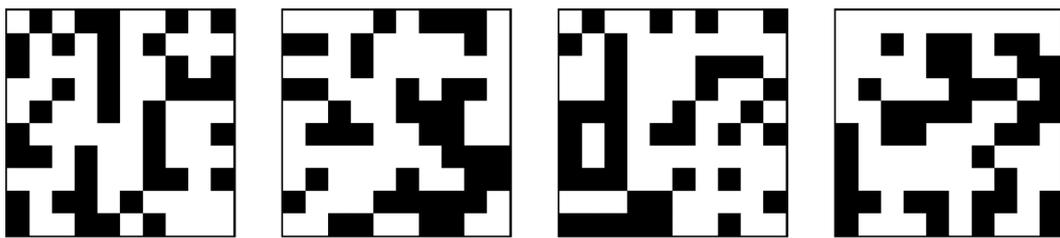


Figure 2. The D score is a measure of the strength of the association between two categories. Four separate D scores were collected on the association between reflectional symmetry and random patterns with valence, arousal, complexity, and numerosity. Positive D scores indicate that reflection was associated with positive words, high arousal words, simple expressions, and small numbers. The first three predictions were confirmed, with D scores significantly greater than zero.



Examples of patterns with rotational symmetry



Examples of random patterns

Figure 3. Four examples of rotation and random patterns. As with Experiment 1, the patterns were generated for each trial and there was therefore no repetition.

Rotational symmetry is a different type of regularity, which is detected less quickly in perceptual discrimination tasks (e.g. Royer, 1981). Examples of rotational symmetry are shown in [Figure 3](#).

3.1 Methods

3.1.1 Participants

Thirty-two participants from the University of Liverpool took part in the experiment (age 18–29 years, mean age 20 years, five male, four left handed). All had normal or corrected-to-normal vision. Some participants were rewarded with course credit, and all were naïve with regard to the experimental hypothesis. The experiment had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki.

3.1.2 Apparatus and procedure

Everything in the procedure and design of the experiment was the same as in Experiment 1. The only difference was the nature of the regular patterns. These are illustrated in [Figure 3](#).

3.2 Results

The analysis was the same as in Experiment 1, and the overall pattern of results is shown in [Figure 4](#). In the ANOVA, there was no violation of sphericity according to Mauchly's test. There was a significant effect of dimension ($F(3, 75) = 8.84, p < 0.001$) but no effect of order or sex, and no interactions.

Next we compared D scores from each IAT against zero. For valence, the D score was greater than zero ($t(31) = 8.31, p < 0.001$) replicating Experiment 2 of Makin et al. (2012a). In the case of arousal, the D score was greater than zero ($t(31) = 7.42, p < 0.001$). There was also a significant effect of complexity. The D score was greater than zero ($t(31) = 3.74, p = 0.001$). However, this was not true in the case of numerosity ($t(31) = 0.10, n.s.$).

In short, all results with rotational symmetry resemble those of Experiment 1. To confirm this statistically, we combined the data in a new ANOVA with experiment as a between-subjects factor. There was a significant effect of dimension ($F(1, 186) = 39.25, p < 0.001$) which, crucially, did not interact with experiment ($F(3, 186) = 2.03, n.s.$). This demonstrates that the pattern of results was similar in Experiment 1, with reflectional symmetry, and Experiment 2, with rotational symmetry.

We also explored whether the D scores in the different IATs were correlated with each other: for example, would people who perceived symmetry as higher valence perceive it as simpler or more

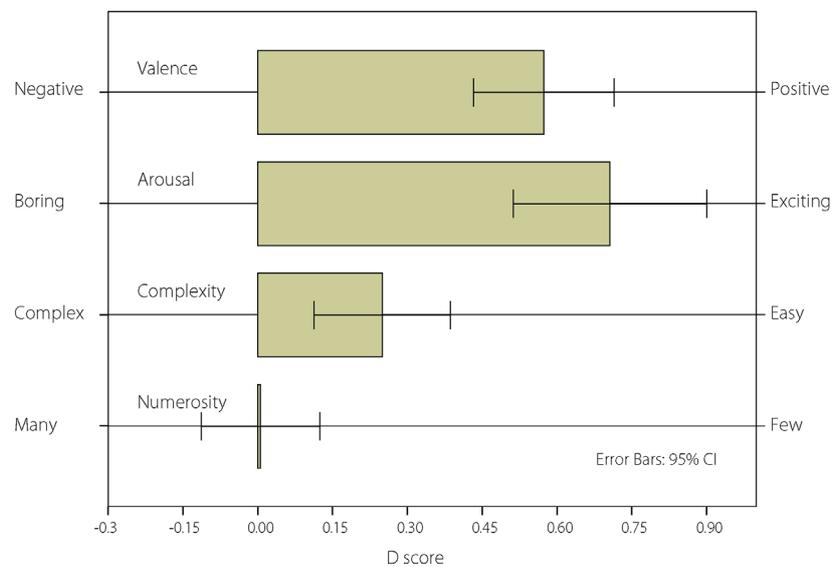


Figure 4. Results of Experiment 2. Conventions are the same as in [Figure 3](#).

arousing? We did not find any statistical evidence for this in either experiment ($0.08 < r < 0.17$ for Experiment 1 and $-0.14 < r < 0.18$ for Experiment 2).

4 Discussion

We explored an old issue in empirical aesthetics using a new technique—the multidimensional IAT (Gattol et al., 2011). It has been suggested that the relative balance between simplicity and complexity influences preferences (Birkhoff, 1933; Eysenk, 1941) and that complexity may produce arousal, with a mid-level of complexity producing optimal levels (Berlyne, 1970, 1974). In Experiment 1, we explored the relation between reflectional symmetry and valence, arousal, complexity and numerosity. Each of the four IATs, completed by the same subjects, measured a different pattern of implicit associations. Results of the valence IAT replicated the findings by Makin et al. (2012a), demonstrating that reflectional symmetry was associated with positive words, and random patterns were associated with negative words. The IAT on arousal showed that participants associated reflection with high arousal words and random with low arousal words. The IATs on complexity showed that they associated reflection with simpler mathematical expressions, and random with complex expressions. There was no effect in the IAT on numerosity. Experiment 2 used the same design as Experiment 1, but with rotational symmetry rather than reflectional symmetry. The pattern of results was very similar across Experiments 1 and 2.

With the exception of the numerosity IAT, these results conformed to predictions. Let us consider what they mean for our understanding of aesthetics. First, it is theoretically significant that reflectional symmetry was associated with high arousal as well as positive valence. This is the opposite of what would be predicted if the complexity of visual stimuli and arousal were positively related, in which case random patterns would be more arousing. Meanwhile, the results of Experiment 2 appear to rule out any explanations in terms of biological relevance or reproductive fitness, because rotational symmetry produced the same pattern of results as reflectional symmetry.

These findings are consistent with the fluency hypothesis of aesthetics (e.g. Reber, 2012). According to this hypothesis, the brain is sensitive to the ease and efficiency in which perceptual or cognitive operations are completed, and high fluency is experienced as hedonically positive, at least under certain attributional conditions (Reber, Wurtz, & Zimmermann, 2004). Symmetry is a good gestalt, and the visual system can extract both reflectional and rotational symmetry efficiently (probably in extrastriate visual areas: Makin, Wilton, Pecchinenda, & Bertamini, 2012; Sasaki, Vanduffel, Knutsen, Tyler, & Tootell, 2005). Regular patterns would thus have higher perceptual fluency than random patterns. The results of the multidimensional IAT suggest that the response to high fluency patterns has two dimensions, namely valence and arousal.

Dimensional accounts of emotion support the distinction between valence and arousal (Mauss & Robinson, 2009). For example, happiness can be described as a state with positive valence and medium arousal, anger can be described as a state of negative valence and high arousal. Meanwhile, neuroimaging studies have distinguished neural responses to valence and arousal words from the same database we used, with valence judgements recruiting the orbitofrontal cortex, and arousal processed in the amygdala (Lewis, Critchley, Rotshtein, & Dolan, 2007). Perhaps perceptual fluency produces responses in both regions.

The implicit association of regularity with simple mathematical operations is interesting. Although Makin et al. (2012a) inferred the perceptual fluency of regular and random patterns from discrimination speed differences in the training blocks, the complexity IAT suggests that participants also categorise the symmetrical patterns as simpler. It could be that this perceived fluency (insomuch as simplicity and fluency are overlapping constructs) explains the results of the valence and arousal IATs, as mentioned above. However, the design of the experiment may have influenced the outcome because participants performed four IATs one after the other. Although this was counterbalanced and there were no interactions involving experiment order, we decided to conduct a control study. Participants ($N = 12$) were asked to perform an IAT with the same procedure and design as of Experiment 1 but on only one dimension: complexity. They were naïve with regard to the experimental purpose and had not performed other IATs. We computed the D score and found that it was significantly greater than zero ($t(11) = 2.408; p < 0.05$). This replication confirmed that participants associate symmetry with simple and random with complex expressions.

A note of caution is necessary when considering the results of our IATs. First, there is no indication that the reflection and rotation patterns shown in our experiments actually produced emotional responses. More precisely, these patterns were implicitly associated with emotional words, and these associations could be due to learned semantic knowledge, or the memory traces of emotional responses experienced outside the laboratory. Nevertheless, the results tell us something about the way patterns are implicitly evaluated and demonstrate that perceived simplicity is consistent with high arousal and positive valence. Future studies will test whether the patterns are so evaluated because of their relative simplicity or because of some other factor. Our correlation analysis did not support a direct relation—for example, there was no evidence that participants who perceived symmetry as simpler had stronger implicit preferences. However, the study was not designed to measure this correlation, and there may be independent sources of noise in the different IATs.

The interpretation of IAT effects has been debated. For example, Rothermund and Wentura (2004) discussed the possibility that IAT effects are enhanced by salience asymmetries. On each trial, participants make a two-alternative forced choice (2AFC) discrimination, and if the alternative items differ in salience (for any reason), then they might process the task as mere target detection, and code the more salient stimulus as target present and the other as target absent. Reaction times would decrease when both target-present responses are made with the same key and target-absent responses with the other. It is likely that symmetry would be perceived as more salient than random, and would thus be coded as target. However, as Makin et al. (2012a) point out, this account would lead to symmetry being associated with negative words which is more salient according to Rothermund and Wentura, and this is the opposite of what was found. However, the salience asymmetry account could still explain the effects in the arousal and complexity IATs, although the salience of the stimuli would need to be independently measured in order to pursue these arguments further (see Makin et al., 2012, for physiological measurement of hedonic responses to symmetry and target detection).

In summary, these results are consistent with previous IAT experiments, which have shown a link between fluency and implicit preference. Makin et al. (2012a) found that patterns that were more quickly detected were invariably those that were preferred. Meanwhile, Makin et al. (2012b) found that visual manipulations of object grouping that altered the relative fluency of reflectional and translational symmetry also changed implicit preference for these regularities. This work goes beyond previous studies, in showing that the participants implicitly judge the regular patterns to be simpler, and by showing that implicit preference has both valence and arousal dimensions.

5 Conclusion

This study used the multidimensional IAT procedure to clarify some outstanding questions in empirical aesthetics. We found that reflectional and rotational symmetries were associated with simple expressions, while random patterns were associated with complex expressions. Perhaps regular pat-

terns were perceived as more fluent than random patterns, and, because of this, the regular patterns were implicitly associated with emotional words. Unlike previous IAT studies, we found that this emotional response had two dimensions, valence and arousal. Regular patterns were associated with both high valence and high arousal, and also with the ease of processing a mathematical expression.

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