Emotion

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Implicit Affective Evaluation of Visual Symmetry

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Symmetry and beauty are strongly linked, but is the positive response to visual symmetry automatic? We used the Implicit Association Test (IAT) to measure the valence of visual regularities in the absence of overt judgments. In our first experiment, participants classified dot patterns as random or having an axis of reflection, and words as positive or negative. When the same button was used to report reflection and positive words, responses were faster than when the same button was used to report reflection and negative words. We take this association to indicate an implicit preference for reflectional patterns. In subsequent experiments, a reflected pattern was preferred to a rotation or translation, and a rotational pattern was preferred to random patterns. In some cases these results were not in agreement with verbally reported preferences, but implicit preferences were always predicted by the speed at which patterns could be identified. We conclude that the IAT can unearth an automatic affective response produced by perceptual fluency.

Keywords: valence, symmetry, beauty, Implicit Association Test, fluency

Many authors have argued for a strong link between symmetry and beauty. For instance, in 1952, the physicist and mathematician Hermann Weyl wrote, “Beauty is bound up with symmetry” (p. 3), and Ramachandran and Hirstein (1999) listed symmetry as one of the key principles of the aesthetic experience. Indeed, symmetry has been featured in artworks spanning most cultures and eras (Arnheim, 1974; Washburn & Crowe, 1988). Preference for symmetry is present already in infants (Humphrey & Humphrey, 1989), and the visual system has been shown to process symmetry efficiently (e.g., Barlow & Reeves, 1979; for reviews see Tyler, 1995, and Wagemans, 1995).

Gestalt psychologists studied symmetry in relation to “goodness” (Wertheimer, 1923). Koffka (1935) linked goodness to the economy of perceptual processing, and Leeuwenberg (1971) later developed this concept in terms of information load (see also, van der Helm & Leeuwenberg, 1996). Later, Palmer (1991) confirmed that items located along the main axes of symmetry are rated high in “goodness.” More recently, Jacobsen and Höfel (2002) manipulated simple black and white geometrical patterns, and found that symmetry was the best predictor of subjective beauty. The importance of the fact that symmetry is processed efficiently compared with random patterns has more recently resurfaced in relation to the concept of “fluency” (Winkielman, Schwarz, Fazendeiro, & Reber, 2003). The *fluency hypothesis* states that people are sensitive to the efficiency of their own perceptual or cognitive processes, and high fluency elicits positive affect and subjective beauty (Reber, Wurtz, & Zimmermann, 2004).

Aesthetic judgments are notoriously difficult to study, and some psychologists even doubt that it is possible to do so in a meaningful way (Kubovy, 2000). One issue is that many factors need to be considered, including past experience and level of arousal (e.g., Berlyne, 1970). There is also a problem with the use of explicit rating scales, because some impressions may *not* occur spontaneously in the absence of any overt demand to report them (Höfel & Jacobsen, 2007). In other words, it is possible that a visual pattern would *only* have positive or negative valence when the observer has the *explicit intention* of evaluating its aesthetic appeal (Mastandrea, Bartoli, & Carrus, 2010). The focus of our study is on affective responses rather than the more elaborate concept of aesthetic experience. In particular, we were interested in responses that emerged quickly and spontaneously, and therefore we measured affective responses to regular and irregular visual patterns using a methodology that avoided explicit judgments.

We used the Implicit Association Test (IAT) to test the association between novel visual patterns and words with known positive or negative valence. Let us take as illustration an influential IAT study by Greenwald, McGhee, and Shwartz (1998). Participants saw words appear on a screen, and they pressed *Button 1* if the word had positive valence (e.g., “love”), and *Button 2* if the word had negative valence (e.g., “hate”). On interleaved trials, participants pressed *Button 1* for the image of a flower, and *Button 2* for the image of an insect. Response times were faster in these compatible blocks, compared with incompatible blocks, when the mapping was reversed (Button 1 for *insect or positive word*: Button 2 for *flower or negative* word). The response time differ-

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ence between these compatible and incompatible blocks was taken as a measure of *implicit preference* for flowers over insects.

In the above example, implicit preferences were consistent with overt evaluations, but this is not always the case. In subsequent experiments, Greenwald et al. (1998) used the IAT to measure an implicit preference for white over black faces in participants who *do not* report racial preferences. However, Nosek, Greenwald, and Banaji (2007) suggested that the IAT is not a lie detector that can discover secret racism; rather, different cognitive systems evaluate the same stimuli differently. Some of these systems create implicit preferences; others are employed when making verbal judgments. In this work we use the IAT to measure the valence of novel dot patterns in the absence of verbal reports.

We chose the IAT over other measures of implicit preference, such as affective priming, because in priming procedures stimuli are viewed passively. However, symmetry processing is modulated by attention. For instance, symmetry does not reliably pop out in visual search tasks (Wagemans, 1995; Olivers & van der Helm, 1998). The advantage of the IAT is that it requires participants to process and classify the target stimuli, without overtly requiring them to consider or report their preferences.

Before describing the details of our studies, we need to clarify the meaning of the term symmetry. There are different types of symmetry, generated by different rigid, isometric transformations (reflection, translation, and rotation), even if we restrict ourselves to the plane. The reason we all immediately think of reflectional symmetry when symmetry is mentioned is not an accident, as this type is the most salient for the human visual system, especially when the axis is vertical. This interesting aspect of human perception was discussed in Mach (1886/1959) and confirmed by empirical evidence showing a detection advantage for reflectional symmetry (Barlow & Reeves, 1979; Bertamini, Friedenberg, & Kubovy, 1997; Bruce & Morgan, 1975; Royer, 1981). In our studies we compared different rigid transformations and therefore we use the term regularity rather than symmetry. Moreover, because we can generate an infinite number of regular or irregular dot patterns, we never presented the same pattern twice and therefore avoided any effect of familiarity.

It should be noted that symmetry is not the same as the more abstract concept of *balance*, which has also been considered extensively by scholars interested in aesthetics. Artists may find balance intuitively, by offsetting figural elements with equal subjective visual weight. For example, a prominent face may be balanced by a distant horizon on the other side of the composition (Arnheim, 1974). Balance can also be quantified and used as a predictor of preference ratings (e.g., Wilson & Chatterjee, 2005); however, it is not the topic of our study.

It is also important to note that the use of visual symmetries allowed us to compare patterns that are equal in terms of mathematical regularity and information content (as measured, e.g., by redundancy, cf. Leeuwenberg, 1971), but differ in terms of *perceived regularity*. For example, the regularity in a reflectional pattern is more apparent than the regularity in a translation or rotation pattern, despite the fact that these patterns share the presence of a rigid transformation (e.g., Bertamini, Friedenberg, & Argyle, 2002).

We report a series of six IAT experiments that investigated the automatic association of visual patterns with positive or negative words, and the link between implicit preference and perceptual fluency. Participants were all from the School of Psychology community, usually enrolled in the undergraduate program, and received course credit as an incentive for their participation. The majority of our 188 participants were female (72.34%), because more females enroll in this course. Participant age range was 18 to 46, with a mean age of 22.05. The skewed age range was the result of a few older students and other participants recruited opportunistically. These experiments revealed cases where implicit preferences were in agreement with explicit evaluations of the same stimuli, and cases where implicit and explicit preferences were misaligned. However, positive valence words were always associated with patterns that were processed more fluently (as measured by the response time for pattern classification).

Experiment 1: Reflection Versus Random

In this experiment we presented a pattern of dots reflected around the vertical axis and a pattern of random dots (see Figure 1), interleaved with words with positive or negative valence. We hypothesized that there would be an association between reflection and positively valenced words. This should manifest as faster response times when reflection and positive words were reported with the same button (in the compatible blocks), than when reflection and negative words were reported with the same button (in the incompatible blocks). This implicit preference would be consistent with the explicit preference for reflectional symmetry found in previous studies that have used a variety of different stimuli (e.g., Cárdenas & Harris, 2006; Eisenman, 1967; Jacobsen & Höfel, 2002).

Method

Participants

Twelve participants (aged 18 to 44, mean age = 21.75, three males, one left-handed) took part in the study in exchange for course credit. They had normal vision and were naive with respect to the experimental hypothesis.

Apparatus

Participants sat in a darkened room in front of a Cathode Ray Tube (CRT) monitor. Stimulus presentation was controlled by a program written in C++ and OpenGL. The computer was an Apple Macintosh, running OSX, with a Sony Trinitron monitor. Participants entered responses using the left ("z") and right ("/") keys of the keyboard. Stimuli comprised of 48 black dots on a white background. The regular stimuli had a reflection around the vertical axis. The random stimuli were not constrained except that there were an equal number of dots in each side of the vertical axis (see Figure 1). Therefore, the categorical distinction (reflection or random) was specified by the relationship between the two halves, and it was impossible to distinguish between conditions from just one side. New patterns were generated in each new trial.

Words were selected from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999). There were 10 positive words (heaven, loyal, freedom, honor, lucky, kiss, rainbow, pleasure, paradise, friend), and 10 negative words (cancer, disaster, poison, hatred, accident, torture, filth, sickness, evil,

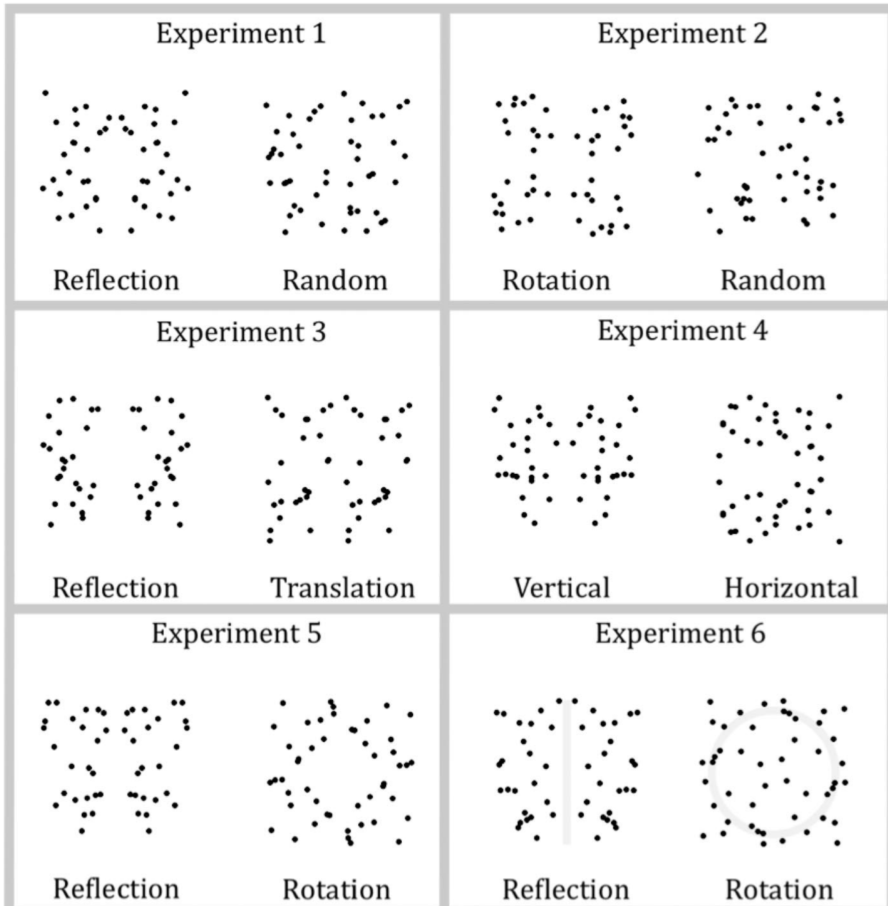

Figure 1. Examples of stimuli used in all experiments. New patterns were generated for each trial. The pattern on the left side of each panel was predicted to be associated with positive words, and therefore implicitly preferred.

death). The valence of the positive words was greater than the valence of the negative words (7.94 vs. 2.04, $p < .001$, scale = 1 to 9), where the most positive available word was *triumphant* and the most negative was *rape*). However, the sets were balanced for arousal (5.95 vs. 5.72, $p = .508$, scale 1 to 9) and frequency (47.4 vs. 50.4, $p = .890$, scale = 1 to 1599), and were typical of previous IAT experiments (e.g., Greenwald et al., 1998).

Procedure

The design was based on the recommendations of Nosek et al. (2007). The experiment was split into 10 blocks of 20 trials. For half the participants, the procedure was as shown in Table 1: In the first block (training) participants saw reflectional or random patterns, and they pressed the left button for reflection, and the right button for random. In the second block (training) the positive and negative words were presented, and participants responded with left button for positive and right button for negative. Next there were three blocks of experimental trials. In these *compatible* blocks, patterns (reflection or random) and words (positive or negative) were presented in alternate trials. 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 dot patterns. Here, the response mapping was reversed, participants learned to use the left button to report random patterns, and the right key to report reflection. There were then another three blocks of *incompatible* experimental trials (left button for positive words or random patterns, right button for negative words or reflection patterns). While reversed response mapping is known to impair performance in itself, the additional training blocks and feedback on each trial should minimize this order effect (Nosek et al., 2007). For the other six participants, the incompatible block was presented first, and the compatible block second. Training blocks were rearranged accordingly. In all trials the stimuli remained on the screen until response.

Above each stimulus, cue words were presented on the left and right sides of the screen according to the response mapping of that trial. For example, when a pattern appeared, the cues “symmetry” and “random” were presented, whereas when a word appeared, the cues “positive” and “negative” were presented. If participants pressed the wrong button, the message “Wrong” appeared. They were instructed to make accurate

Table 1
A Sequence of Events Used in Experiment 1. Each Block Comprised 20 Trials. For Half of the Participants, the Incompatible Blocks Were Shown First, and the Training Blocks Were Rearranged Accordingly

Block	Block type	Left button	Right button
1	Training	Reflection pattern	Random pattern
2	Training	Positive word	Negative word
3	Compatible	Reflection pattern or positive word	Random or negative word
4	Compatible	Reflection pattern or positive word	Random or negative word
5	Compatible	Reflection pattern or positive word	Random or negative word
6	Training	Random pattern	Reflection pattern
7	Training	Random pattern	Reflection pattern
8	Incompatible	Random pattern or positive word	Reflection pattern or negative word
9	Incompatible	Random pattern or positive word	Reflection pattern or negative word
10	Incompatible	Random pattern or positive word	Reflection pattern or negative word

responses as quickly as possible. Written instructions were presented on-screen before each block.

At the end of the experiment, participants completed a questionnaire designed to measure their explicit aesthetic preference of the same stimuli. They saw 10 reflection and 10 random patterns, and rated them on a 7-point Likert scale (–3, *very ugly*, to 3, *very beautiful*). We did not explicitly label the midpoint of the scale.

Analysis

The mean reaction time (RT) from the compatible and incompatible trials was obtained for each participant. Trials where participants had pressed the wrong button, or where response time was greater than 10 s were excluded. We then computed the *D score* for each participant.[1] This is the difference between mean RT in the compatible and incompatible trials, divided by the standard deviation in these trials. A positive *D score* indicates that participants responded quicker in the compatible trials. Explicit preferences were computed by subtracting each participant's mean rating of reflectional patterns from their mean rating of random patterns. One-sample t tests were used to confirm the presence of implicit or explicit preferences (test value = 0). The effect size d is reported alongside p values. This is not to be confused with the *D scores* obtained from each participant's IAT data.

Results

Eleven of the 12 participants showed an implicit preference for reflection over random patterns, $t(11) = 3.601$, $p = .004$, $d = 1.04$, Figure 2A. After completing the IAT, all 12 participants rated reflection patterns as more beautiful than random patterns in the explicit judgment task, $t(11) = 12.824$, $p < .001$, $d = 3.70$, Figure 2B.

These results of Experiment 1 were followed-up by four manipulation checks. First, we tested whether the cue words "symmetry" and "random" (presented above the patterns, see Methods) were responsible for the results. We reran Experiment 1 on six more participants (aged 20 to 31, mean age = 26.17, one male, 0 left-handed) but used the category "vertical" instead of "symmetry." The cue words were "vertical" and "random." There was again an implicit preference for reflectional symmetry, $t(5) = 6.416$, $p = .001$, $d = 2.62$. This confirmed the implicit preference for reflection was not entirely dependent on the use of the word "symmetry" as a cue.

Second, we repeated Experiment 1, but halved the number of dots in the random condition, so the reflection and random patterns were now matched in terms of nonredundant dots (cf. Leeuwenberg, 1971). Six participants (aged 19 to 24, mean age = 20, two males, 0 left-handed) still showed an implicit preference for reflection, $t(5) = 4.124$, $p = .009$, $d = 1.68$. This confirms that implicit preference for reflection was not attributable to a difference in redundancy.

Third, because the explicit judgments could have been affected by the preceding IAT, we presented the questionnaires to 12 more participants (aged 19 to 24, mean age = 20.92, two males, 0 left-handed) who had not taken part in the IAT. Again, there was a significant preference for reflection over random dot patterns, $t(11) = 5.42$, $p < .001$, $d = 1.56$. This confirmed that the explicit preference was not produced by an experimental order effect.

Fourth and finally, we asked whether the implicit preference for reflection was dependent upon participants processing and categorizing pattern regularity. We used the Extrinsic Affective Simon Task (EAST, De Houwer, 2003) to investigate this. Our version of the EAST was ostensibly an IAT designed to measure preference for blue over green dot patterns. However, half the patterns had reflectional symmetry, and half were random. Although the dots were now colored, the same algorithm used in Experiment 1 controlled their spatial arrangement. We tested the hypothesis that participants would be quicker to press the "positive" button (i.e., the button also used to report positive words) whenever a reflection pattern was presented, and quicker to press the negative button (i.e., the button used to report negative words) whenever the random pattern was presented. Participants were never required to judge regularity, only dot color or word valence. Twenty-four participants were involved (aged 18 to 43, mean age = 22.63, 10 males, two left-handed). Exclusion criteria were the same as Experiment 1, and there were now 40 trials in each block. We analyzed RT as a function of regularity (reflection or random) and

[1] Previous IAT studies differ in their treatment of error trials and use of *D scores*. However, for the six IAT experiments, we also analyzed mean RT or included RT for error trials and these alternative analyses did not alter the pattern of results.

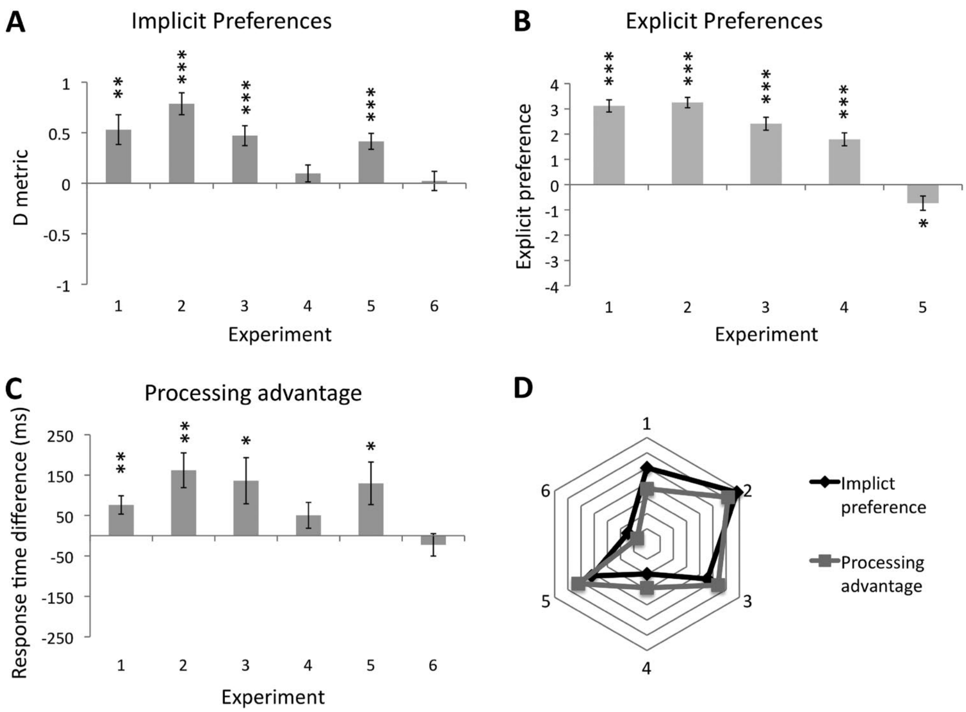

Figure 2. (A). Implicit preferences in the six experiments. Positive *D scores* refer to an implicit preference in the predicted direction. (B). Explicit preferences. A positive difference score refers to an explicit preference in the predicted direction. (C). Response time difference between the preferred and nonpreferred patterns. A processing advantage (positive values) indicates faster responses to the preferred stimuli. (D). Radar-plot showing the relationship between data from A and C (normalized to eliminate difference in y-axis scale). Each point on the hexagon represents one experiment. Eccentricity indicates larger values. Stars indicate the significance of one-sample *t* tests. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. Error bars represent ± 1 Standard Error of the Mean (S.E.M).

response key (positive or negative) with a 2-factor repeated-measures analysis of variance. There were no main effects or interactions, $F(1, 23) < 1.004$, $p > .326$, $\eta < 0.043$). This contrasts with the robust implicit preference for reflection in Experiment 1, where participants attended to the presence or absence of regularity.

In subsequent experiments, we found that the IAT can detect more subtle implicit preferences for less salient regularities.

Experiment 2: Rotation Versus Random

Experiment 2 investigated implicit preference for rotation over random patterns (see Figure 1). The regular patterns mapped onto themselves with a 90° rotation, while the random patterns were the same as Experiment 1. Another set of 12 participants (aged 18 to 45, mean age = 23.33, six males, 0 left-handed) were involved. All participants showed an implicit preference for rotation over random dot patterns, $t(11) = 7.284$, $p < .001$, $d = 2.10$, Figure 2A, and all explicitly preferred rotation as well, $t(11) = 15.821$, $p < .001$, $d = 4.57$, Figure 2B. The results of Experiment 2 replicate those of Experiment 1, extending the findings to rotation.

Experiment 3: Reflection Versus Translation

In Experiment 3, we used the IAT to measure preferences for one type of regularity over another type of regularity, namely vertical reflection over a translational transformation, where all the dots on one side were repeated on the other side (see Figure 1). We predicted a preference for vertical reflection because efficient or fluent perceptual processing is a predictor of subjective beauty (Reber et al., 2004), and reflection is more rapidly detected than translation (Bruce & Morgan, 1975; Wagemans, 1995). However, unlike the random patterns, the translation is similar to reflection because one half of the pattern matches the other half after a rigid transformation (i.e., it is redundant). In this sense, both patterns are equally regular and the concept of economy would predict no difference.

The stimuli were similar to Experiment 1, except that a translation was used in place of random patterns. Twenty-four participants were involved (aged 18 to 45, mean age = 21.21, eight males, two left-handed). The two alternative regularities were shown to participants before testing, and none of them had difficulty seeing the nature of each transformation within the dot patterns.

There was a strong implicit preference for reflection over translation, with 19 of the 24 participants giving positive *D scores*, $t(23) = 4.773$, $p < .001$, $d = 0.97$, Figure 2A. The explicit preference for reflection over translation was present in all 24 participants, $t(23) = 9.366$, $p < .001$, $d = 1.91$, Figure 2B.

The results of Experiment 3 show implicit and explicit preference for reflections over translations. This could be because reflection is always associated with beauty, or because it is processed more fluently. Leaving this issue to one side for the moment, the results of Experiment 3 show that the IAT can detect preferences for specific regularities, and not just for patterns relative to noise. It also shows that degree of redundancy (as measured by how many positions have to be encoded to store the whole pattern) does not predict either implicit or explicit preferences (as this was the same for reflection and translation patterns).

Experiment 4: Vertical Versus Horizontal

Experiment 4 asked whether participants preferred vertical axes of reflection to horizontal axes of reflection (see Figure 1). The rationale for predicting this was similar to that of Experiment 3: Vertical symmetry is more salient than horizontal symmetry (Mach, 1886/1959; Palmer & Hemenway, 1978). However, 32 participants (aged 18 to 45, mean age = 20.75, six males, three left-handed) showed no overall preference for vertical axes, $t(31) = 1.164$, $p = .253$, $d = 0.21$, Figure 2A. This was in contrast with their explicit judgments, where 29 of the 32 participants favored vertical patterns, $t(31) = 7.021$, $p < .001$, $d = 1.24$, Figure 2B. This discrepancy suggests that different systems can mediate implicit and explicit preferences. The results parallel findings from the social psychology literature, where IAT effects and verbal reports are sometimes misaligned (e.g., Greenwald et al., 1998).

Experiment 5: Reflection Versus Rotation

In Experiment 5, we used the IAT to measure implicit preference for a vertical reflection over a rotation (see Figure 1). Again, we predicted that reflection would be preferred, because of its processing advantage. The prediction was confirmed. Eighteen of the 24 participants (aged 18 to 28, mean age = 19.50, two males, one left-handed) implicitly preferred reflection to rotation, $t(23) = 5.251$, $p < .001$, $d = 1.07$, Figure 2A. This was the opposite of the pattern for explicit preferences, where 19 of the 24 participants preferred the rotational patterns, $t(23) = -2.565$, $p = .017$, $d = -0.52$, Figure 2B. It is possible that implicit preferences are governed by perceptual fluency, while explicit preferences are guided by additional factors as well. For instance, implicit preferences may reflect an automatic affective response, whereas explicit preference could be more closely linked to "aesthetics" in the classic sense of the word, and therefore more dependent on culture, past experience, and expectations.

The Role of Perceptual Fluency in Implicit Preference Formation

It has been suggested that perceptual fluency is an important mediator of preference formation (Reber et al., 2004). In this section, we focus more closely on the role of fluency in producing the implicit preferences measured by the IAT.

First, we note that response time in the training blocks, where participants classified the dot patterns (Blocks, 1, 6, and 7; see Table 1), were in agreement with the implicit preferences (Figure 2C). For example, in Experiment 1, participants were quicker to respond to reflection than random patterns, $t(11) = 3.336$, $p = .007$, $d = 0.96$. In Experiment 2, responses were faster to rotation than random patterns, $t(11) = 3.761$, $p = .003$, $d = 1.09$. In Experiment 3, responses were faster to reflection than translation, $t(23) = 2.380$, $p = .026$, $d = 0.49$. In Experiment 5 responses were faster to reflection than rotation, $t(23) = 2.464$, $p = .022$, $d = 0.50$. In all these experiments, implicit preferences mirrored the processing advantages reported above.

Moreover, in Experiment 4, where participants showed *no* implicit preference for vertical or horizontal reflections, there was *no* difference in response time during the training blocks, $t(31) = 1.577$, $p = .125$, $d = 0.28$. This is again consistent with the idea that perceptual fluency guides implicit preference formation (Figure 2C).

To test this account more rigorously, we conducted an additional experiment. Experiment 6 was similar to Experiment 5 except that a low-contrast vertical gray bar was placed behind the dots in the reflection patterns, and a gray circle was placed behind the dots in the rotation patterns (see Figure 1). This additional background made the reflection/rotation classification trivial, thus eliminating fluency differences. A new sample of 24 participants were involved (aged 18 to 37, mean age = 23.75, eight males, one left-handed). As expected, the inclusion of background patterns eliminated the difference in response time during the training blocks, $t(23) = -0.805$, $p = .429$, $d = -0.16$, Figure 2C, and also the implicit preference for reflection, $t(23) = 0.242$, $p = .812$, $d = 0.05$, Figure 2A. Experiment 6 suggests that preference for reflection over rotation results from the relatively efficient processing of reflection. It also confirms that the results of Experiment 5 were not produced by the categories per se, or the choice of cue words, because these were identical in Experiments 5 and 6.

The close relationship between implicit preference and processing advantage can be seen in Figure 2D. Here, the 6 mean values from Panels A and C were normalized (in order to eliminate differences in the scale of the y-axis), and then overlaid on a radar-plot. The impression that the contours were very similar was confirmed statistically: With just 6 data points, there was a significant correlation between normalized processing advantage and the normalized preference scores, $r = .867$, $p = .025$, $r^2 = 0.75$. This analysis further indicates that relative perceptual fluency differences result in an implicit preference for the more fluently processed pattern.

Next we looked at the processing advantage versus implicit preference relationship within each experiment. Each participant's processing advantage was calculated as above, and their implicit preference was computed as the response time difference between compatible and incompatible blocks. The correlation was only significant in experiments where reflectional symmetry was contrasted with another type of regularity (see Table 2). Power was not equal in all experiments, so this result should not be overinterpreted. To overcome this, we repeated the analysis after aggregating the scores for the 128 participants in the six main IAT experiments. For this analysis, the experiment mean was subtracted from each participant's score to remove variance attributable to task differences. After standardization, there was still a positive correlation between processing advantage and implicit preference, $r = .316$, $p < .001$, $r^2 = 0.10$, implying that participants whose classification-speed differences were more pronounced during training had a larger implicit preference for the more rapidly detected pattern. This analysis was post hoc, and more data are needed for a fuller analysis of individual differences.

Previous studies have also cited perceptual fluency in consideration of IAT results. For example, Chang and Mitchell (2009)

Table 2
The Relationship Between Processing Advantage and Implicit Preference in Each Main IAT Experiment. Significant or Borderline Significant Effects are in Italics

Experiment label	Stimuli	r	p	N
Experiment 1	Reflection vs. Random	−0.008	0.980	12
Experiment 2	Rotation vs. Random	−0.082	0.799	12
Experiment 3	Reflection vs. Translation	0.476	0.019	24
Experiment 4	Vertical vs. Horizontal	0.181	0.320	32
Experiment 5	Reflection vs. Rotation	0.404	0.050	24
Experiment 6	Reflection vs. Rotation (background)	0.481	0.017	24

found that people implicitly associated fluently processed items that are otherwise unrelated. Our results could thus arise from association of the fluent categories (e.g., reflection and positive words). However, we found no evidence that positive words were classified more rapidly in our six IAT experiments, analysis of Block 2, $t(127) = 0.963$, $p = .337$, $d = 0.07$, so this explanation is less plausible. Instead, certain patterns could acquire positive valence by virtue of their perceptual fluency, and *only then* become associated with positive words.

One could argue that the above finding rests on a null result, which is itself in need of explanation, because previous work has shown that positive information is processed more fluently than negative information (e.g., Unkelbach, Fiedler, Bayer, Stegmuller, & Danner, 2008). We therefore conducted two further control experiments. First, we repeated Experiment 1 but used neutral and nonwords in place of positive and negative words on six new participants (aged 21 to 35, mean age = 26.33, two males, 0 left-handed). Because neutral words are more fluent than nonwords, they should be associated with reflectional symmetry according to the account of Chang and Mitchell (2009). All six participants showed the predicted effect, $t(5) = 9.360$, $p < .001$, $d = 3.82$. However, as there is a strong semantic link between a random set of letters and a random set of dots, we tested this issue further by deliberately making the negative words much more fluent than the positive words in another control experiment with six participants (aged 21 to 46, mean age = 27.33, two males, 0 left-handed). The positive words were long and low frequency (ecstasy, valentine, terrific, promotion, treasure, excellence, affection, sweetheart, paradise, triumph). The negative words were short and high frequency (hell, mad, war, bomb, sad, dead, hate, pain, alone, fear). Positive and negative words were matched for arousal (6.20 vs. 6.18, $p = .97$). The differences between negative and positive words were significant (valence, 8.35 vs. 2.18, $p < .001$; frequency, 10.2 vs. 129.5, $p = .02$). According to the Chang and Mitchell (2009) account, symmetrical dot patterns should be associated with the more fluent *negative* words. In contrast, we found that symmetry was still associated with the positive words, $t(5) = 3.813$, $p = .012$, $d = 1.56$. This suggests that the IAT effects reported here do reflect the positive valence of symmetry, not simply the association between fluently processed patterns and words.[2]

Discussion

This series of IATs demonstrate that preference for novel visual regularities can be measured *without* asking participants to report their judgments overtly. In Experiment 1, participants classified words as either positive or negative, and patterns as either reflection or random. The patterns were composed of 48 black dots on a white background, and differed only in terms of their regularity. When the same button was used to classify reflection patterns or positive words, response times were quicker than when the same button was used to classify reflection patterns or negative words. This classic IAT effect demonstrates an *implicit* preference for reflection over random dot patterns, and is thus consistent with *explicit* ratings made by both our own participants and those in earlier investigations (e.g., Cárdenas & Harris, 2006; Eisenman, 1967; Jacobsen & Höfel, 2002).

Before we consider the results of the other experiments, it is worth pointing out that the existing data on reflectional symmetry preference are nuanced. Krupinski and Locher (1988) found that symmetrical patterns were judged low in *artistic value*, possibly because complexity is a more important factor (Locher & Nodine, 1989). This result highlights an apparent contradiction in the literature; both symmetry and complexity are rated positively (e.g., Jacobsen & Höfel, 2002), even though the presence of symmetry actually *reduces* pattern complexity (in that fewer elements need to be encoded, Leeuwenberg, 1971). However, it is likely that the role of complexity further depends on its potential for arousal (Berlyne, 1970) and on the task parameters (Markovic & Gvozdenovic, 2001, found that simplicity is preferred in difficult and restricted conditions). Familiarity can also produce significant changes. For instance, Tinio and Leder (2009) have found that when observers were highly familiar with simple stimuli, they subsequently judged complex stimuli more beautiful, and vice versa. Despite all these important findings, bilateral symmetry remains a good predictor of explicit preference. We found that it is

[2] It is possible that there are sex differences in symmetry preference. For example, it has been shown that dances by symmetrical males are rated more attractive by females, while the reverse pattern is less pronounced (Brown et al., 2005). There was a disproportionate number of females in our experiments, so we cannot make strong conclusions about sex differences. Nevertheless, we investigated whether implicit preferences in male participants were outliers with regard to the averages reported in Figure 2A. Each participant's D score was standardized against the average from the relevant experiment. We found that the standardized score for the 33 male participants significantly greater than the group average, $t(32) = 2.113$, $p = .042$, $d = 0.37$, suggesting that males had slightly stronger implicit preferences than females. There was nothing unusual about implicit preferences in the subset of eight left-handed participants, $t(7) = 0.157$, $p = .879$, $d = 0.06$.

implicitly preferred as well. Importantly, our methodology minimized differences in complexity (number of dots was fixed) and in familiarity (patterns were never repeated).

In subsequent experiments, the same IAT procedure uncovered implicit preferences for rotation over random patterns (Experiment 2), and for vertical reflections over translations (Experiment 3) and rotations (Experiment 5). These results are robust, and we see the IAT as a useful tool for empirical studies of visual preference, and indirectly, for studies of aesthetic experience (although see Kubovy, 2000, who argues that the empirical approach to aesthetics is too reductive).

In our procedure there was no task requirement to evaluate the visual patterns but observers may have done so automatically. In general, automatic mental processes are efficient, unintentional, uncontrollable, and unconscious. However, these features do not inevitably co-occur, nor are they easy to define (for reviews on this issue, see Bargh & Ferguson, 2000; Moors & De Houwer, 2006). We thus talk about automatic evaluation in the broadest sense, while acknowledging that it may not satisfy stricter definitions of automaticity.

Although the nature of automatic processing is debated, our results do provide insight into *why* our participants had the implicit preferences they did. We found that people implicitly preferred patterns they could process rapidly: Reflection patterns were responded to more rapidly than random, rotation, or translation patterns, and reflection was implicitly preferred to these alternatives. In Experiment 6, when processing differences were eliminated, implicit preferences also disappeared. Finally, there was a positive correlation between the magnitude of participants' response time differences and the size of their implicit preferences. Considering these results, we conclude that the IAT reliably measures aesthetic preferences that arise from differences in perceptual fluency.

This is consistent with a recent view within the psychology of aesthetics. It has been suggested that people are sensitive to the efficiency or fluency of their own cognitive operations (Reber et al., 2004), and that people have a preference for fluently processed stimuli (Topolinski, 2010; Topolinski, Likowski, Weyers, & Strack, 2009). The fluency hypothesis draws some of its empirical support from the *mere exposure effect*, in which previously seen stimuli seem more attractive (Zajonc, 1968), and it can also account for the well-known effect of prototypicality on subjective beauty (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). The current work adds to previous studies by showing that the relative perceptual fluency of visual dot patterns engenders implicit preferences as well as explicit ones.

More generally, IAT effects could be influenced by the temporary emotional or cognitive conditions at the time of testing, or long-lasting attitudes acquired though life experience. In a recent demonstration of these factors, Dagupta, DeSteno, Williams, and Hunsinger (2009) found that preexperimental levels of negative emotion, along with prevailing cultural stereotypes, both affected the implicit evaluation of social out-groups. Likewise, in our experiments, current mood or exposure to artistic norms could contribute to the observed results. Such influences could act directly, or via their impact on relative perceptual fluency.

It is also possible that our experiments measured an *innate* affective response to particular regularities. Indeed, reflectional symmetry is a cue that some animals use in mate selection, possibly because it can act as a proxy for mate quality (Johnstone, 1994; Møller, 1992; Tyler, 1995; Brown, et al., 2005). Furthermore, facial attractiveness is related to facial symmetry, and facial attractiveness can be evaluated automatically (Olson & Marshuetz, 2005, although see Swaddle & Cuthill, 1995). This type of adaptive mechanism can explain the origin of the preference for reflectional symmetry in humans. However, it does not fully explain the correlation between processing advantage and preference. Nor can it explain why the preference for reflection over rotation disappeared when a background was included in Experiment 6, or why participants reliably preferred rotation to random dot patterns in Experiment 2. On the other hand, this pattern of results is entirely consistent with the predictions of the fluency hypothesis.

Along similar lines, one could also ask whether the implicit preference recorded here was the result of people's preexisting attitudes toward conceptual categories such "symmetry" and "random," or whether preference was the result of a positive affect elicited by the actual patterns they saw on the screen. The IAT was originally designed to measure category-level effects (Greenwald et al., 1998). Nevertheless, consideration of the above results suggests that the shape of the stimuli were involved in preference formation. On the one hand, changing the label for the regular pattern had little impact on the results. One the other hand, placing a background behind the stimuli eliminated implicit preferences, even though the categories and the cue labels were unchanged. It is thus likely that the implicit preferences index affective responses to the stimuli, rather than just a preexisting aesthetic preference for the category symmetry.

One other recent study has employed the IAT to measure aesthetic preferences. Mastandrea et al. (2010) found an implicit preference for figurative over abstract artworks, and for classical over contemporary architecture. Although this investigation resembles ours, our study is different in two key ways. First, the rich (and possibly familiar) artworks used by Mastandrea et al. (2010) could have evoked preexisting memories and opinions, whereas our dot patterns had no semantic content. Second, Mastandrea et al. (2010) used aesthetically connoted words (such as "beautiful" or "ugly"), whereas we used generic positive and negatively valenced words (such as "kiss" or "sickness"). This would suggest that our experiments tapped a simpler kind of affective response, which was less dependent on semantic associations.

As mentioned before, our results were also independent of familiarity, in the sense of changes due to previous exposure to a particular stimulus. This familiarity can in theory develop even within an experiment, but in our procedure all our dot patterns were novel and were never presented twice, even to the same observer. What was repeated was only the regularity within the patterns.

One aspect of the IAT methodology that is still debated is the role of the relative salience the two items presented in each trial. Rothermund and Wentura (2004) argued that some IAT results are attributable to these *salience asymmetries*. That is, the discrimination is facilitated when the more salient item of each stimulus pair is reported using the same button. Interestingly, this account would predict that the more salient patterns, such as reflection, would be associated with the negative words. However, we found the opposite to be the case in our experiments: That is, we usually found an association between the more salient patterns and positive words.

More recently, Chang and Mitchell (2009) argued that salience asymmetries can be produced by fluency, and responses are facilitated when the more fluent item from each category are reported using the same button. This alternative account of salience asymmetry is more specific than that discussed by Rothermund and Wentura (2004), and it does predict the current results, again without reference to valence. However, as one control experiment found that our original IAT effect remained even when the negative words were made more fluent than the positive words, we conclude that reflectional symmetry obtains positive valence by virtue of perceptual fluency, and is thereby associated with positive words.

Another interesting finding was that the implicit preferences were not always aligned with explicit judgments. In particular, the explicit rating scales revealed a strong preference for vertical over horizontal reflections, but there was no comparable implicit preference. More strikingly, there was an explicit preference for rotation over reflection, while the implicit preference pattern was the opposite. It could be that implicit preferences are based entirely on perceptual fluency, but explicit preferences are based on other factors, such as the balance between simplicity and novelty (Berlyne, 1970; Dodgson, 2009).

Numerous studies have measured explicit aesthetic judgments (some recent ones: Jacobsen & Höfel, 2002; Jacobsen, Schubotz, Höfel, & Cramon, 2006; Kawabata & Zeki, 2004; Lindgaard, Fernandes, Dudek, & Brown, 2006, as well as those mentioned above). However, our findings suggest that overt reports are only one aspect of the human aesthetic response. Other parallel systems may mediate preferences when we are not *trying* to form an opinion (cf. Höfel & Jacobsen, 2007).

In conclusion, the current work provides evidence that the IAT can detect the valence of novel, meaningless visual forms, and can be used as an implicit measure of preference. We suggest that these implicit preferences were produced by relative differences in perceptual fluency. Preferences measured by the IAT sometimes differed from overtly reported judgments. This does not mean they are unreliable or false. Rather, our results are in agreement with the view that the human brain can form preferences at many levels. Research on aesthetic preferences needs not focus only on overt judgments, or assume that they are the only predictor of real-life choices.

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