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# Grouping by closure influences subjective regularity and implicit preference

Alexis Makin
Department of Experimental Psychology, Eleanor Rathbone Building, University of Liverpool, Liverpool, L69 7ZA, UK;
e-mail: alexis.makin@liverpool.ac.uk

Anna Pecchinenda
Department of Psychology, La Sapienza Università di Roma, Via Dei Marsi, 78, 00185 Rome, Italy;
e-mail: anna.pecchinenda@uniroma1.it

Marco Bertamini
Department of Experimental Psychology, Eleanor Rathbone Building, University of Liverpool, Liverpool, L69 7ZA, UK;
e-mail: marco.bertamini@liverpool.ac.uk

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**Abstract.** A reflection between a pair of contours is more rapidly detected than a translation, but this effect is stronger when the contours are closed to form a single object compared to when they are closed to form 2 objects with a gap between them. That is, grouping changes the relative salience of different regularities. We tested whether this manipulation would also change preference for reflection or translation. We measured preference for these patterns using the Implicit Association Test (IAT). On some trials, participants saw words that were either positive or negative and had to classify them as quickly as possible. On interleaved trials, they saw reflection or translation patterns and again had to classify them. Participants were faster when 1 button was used for reflection and positive words and another button was used for translation and negative words, compared to when the reverse response mapping was used (translation and positive vs. reflection and negative). This reaction time difference indicates an implicit preference for reflection over translation. However, the size of the implicit preference was significantly reduced in the Two-objects condition. We concluded that factors that affect perceptual sensitivity also systematically affect implicit preference formation.

**Keywords:** Symmetry, IAT, Fluency, Reflection, Translation, Aesthetics.

## 1 Introduction

The environment is full of symmetrical objects at all scales, and the visual systems of many animals are tuned to process symmetry efficiently, possibly because it is a valid cue for figure-ground segmentation or because it indicates the presence of other animals (for reviews, see Treder, 2010; Tyler, 1995; Wagemans, 1995). Symmetrical patterns are produced by transformations that preserve the metric structure of the pattern. In the plane, these transformations are reflection, translation, rotation and glide reflection (Palmer, 1991; Wagemans, 1995). Although these patterns are equally regular, some are more salient for the human visual system. Over 100 years ago, Ernst Mach noticed that bilateral reflectional symmetry is most easily detected, particularly when the axis of reflection is vertical (Mach, 1886/1959). The perceptual advantage for vertical reflection has subsequently been confirmed by many psychophysical studies, most measuring reaction times (Palmer & Hemenway, 1978; Royer, 1981; Wenderoth, 1994).

Several papers have shown that relative perceptual advantage for reflection compared to translation can be altered by the context in which the contours are presented (Baylis & Driver, 1995; Bertamini, Friedenberg, & Kubovy, 1997; Corballis & Roldan, 1974). When the reflected contours are part of the same object, detection is quicker than when the reflected contours are part of separate objects (Figure 1a and c). This within-object advantage does not hold for translation, and some studies have reported that translation is more rapidly detected when the translated contours form part of two separate objects (Figure 1b and d). This pattern of results is usually formalized as an interaction between regularity type (reflection, translation) and number of objects (one, two), and the cause of this interaction has been explored in several recent papers (Bertamini, 2010; Bertamini, Friedenberg, & Argyle, 2002; Friedenberg & Bertamini, 2000; Koning & Wagemans, 2009; Treder & van der Helm, 2007).

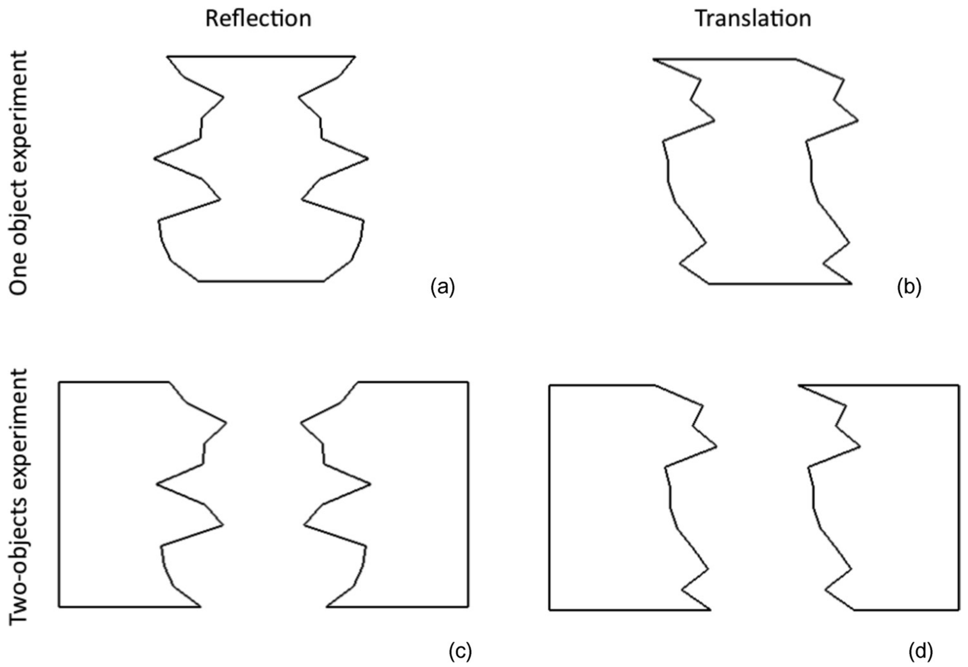


**Figure 1.** Examples of reflection and translation in the One- and Two-objects experiments. (a) Reflection One-object. (b) Translation One-object. (c) Reflection Two-objects. (d) Translation Two-objects.

Symmetry holds a particular fascination because it is so closely related to subjective beauty. Artists and architects have celebrated symmetry for thousands of years (Ramachandran & Hirstein, 1999), and symmetry has consistently been shown to be the best predictor of preference for abstract, geometrical patterns (Eisenman, 1967; Eysenk, 1941; Jacobsen & Hofel, 2002). The current study tests a single hypothesis: Factors that affect the salience of visual regularities should also affect preference for these patterns. Specifically, preference for reflection over translation should be altered by whether the contours are part of the same object.

This prediction is based on the idea that sensitivity should be linked to preference. Many authors have discussed this idea, and in particular it is central to the *fluency account* of aesthetics (Reber, Wurtz, & Zimmermann, 2004). This fluency theory maintains that objects that are processed fluently (i.e., quickly detected and unambiguous) are preferred to those that are processed less fluently (i.e., difficult to detect or ambiguous). There is some empirical support for the fluency hypothesis (Cannon, Hayes, & Tipper, 2010; Topolinski, 2010; Winkielman & Cacioppo, 2001; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). However, one advantage of the current work is the comparison between stimuli that are equally regular in mathematical terms but are processed differently by the visual system.

Previous work on preference has typically involved explicit ratings. However, this approach has various problems. Participants may respond according to assumed desires of the experimenter or make cold judgements based on some available visual variable, in the absence of any emotional response to the stimuli. We avoided these issues by measuring preferences using an Implicit Association Test (IAT, Greenwald, McGhee, & Schwartz, 1998; Nosek, Greenwald, & Banaji, 2007). The IAT involves participants classifying items by pressing one of two buttons. On some trials participants saw patterns like those in Figure 1 and had to classify them as reflection or translation. On interleaved trials, participants saw words and had to classify them as positive or negative. In the *compatible* blocks of trials, the same button was used to report a reflection pattern or a positive word, and another button was used to report a translation pattern or a negative word. In *incompatible* blocks, the response mapping was reversed (button 1 for translation or positive, button 2 for reflection or negative, see Table 1). The crucial metric is the mean response time in the compatible blocks compared to mean response time in the incompatible blocks. Faster response times in the compatible blocks than the incompatible blocks indicates that the association between reflection patterns and positive words and the association between translation patterns and negative words are stronger than the opposite pair of associations (reflection and negative, translation and positive). The experiment is *not* based on the assumption that

**Table 1.** The order of blocks and response mappings in the IAT experiment. For half the participants, incompatible blocks were presented first, and training blocks were rearranged accordingly. Participants ran through the procedure twice, once with One-object stimuli and once with Two-object stimuli

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

reflection patterns are positive and translation patterns are negative in *absolute terms* (some observers may perceive translation as positive in a different context). Instead, our IAT is a tool for measuring *relative* implicit preference.

In previous work we reported implicit preference for reflection over translation using the IAT (Makin, Pecchinenda, & Bertamini, in press), but in this study, we focus on the role of grouping. Participants completed two IAT experiments, one where reflection and translation were properties of a single object (Figure 1a and b) and one where the same type of contours formed two separate objects (Figure 1c and d). Note that the closure of the contours was not task-relevant, as is typical for the study of effect of closure on perception of symmetry. We predicted that preference for reflection would be attenuated in the Two-objects version of the experiment, in line with the perceptual differences.

Although we have cited some problems with overt aesthetic judgements, we nevertheless compared the IAT results to explicit preference scores obtained from another sample of participants. Explicit ratings were obtained for reflection and translation patterns in one and two-object conditions. This is informative because implicit and explicit preferences are not always matched: Indeed, Makin et al. (in press) documented cases were IAT and explicit ratings were in agreement, but also cases where opposite implicit and explicit preference patterns were found.

## 2 Methods

### 2.1 Participants

Forty participants from the University of Liverpool took part in the IAT experiment (age, 18–41, mean age, 23, 9 male, 2 left-handed). All had normal or corrected-to-normal vision. Some participants were rewarded with course credit, and all were naive 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). Another 40 participants filled in the explicit ratings questionnaire (age, 18–47, mean age, 30, 15 male, 5 left-handed).

### 2.2 Apparatus

Participants sat in a darkened room approximately 57 cm from a 120-Hz CRT Sony Trinitron monitor. A program written in C++ and OpenGL controlled the experiment. Participants entered responses using the left (‘z’) and right (‘/’) keys of the keyboard. Stimuli were generated using a random walk algorithm dictating the inwards and outwards turns of a vertical line. There were 10 changes in direction (see Figure 1). The height contours and the objects were approximately to 5° angle of visual angle. The reference horizontal distance between the contours was 3.18° angle. From this reference, the vertices of the convexities and concavities of each contour were displaced by a value between −0.91° angle and 0.91° angle. The appearance of two objects was created with a rectangular closed contour, and the total width of the Two-objects stimulus was 9.1° angle.

Words were selected from the ANEW database (Bradley & Lang, 1999) and were identical to those used by Makin et al. (in press). 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, DEATH). The words differed significantly in term of valence but were matched for frequency and arousal (see Makin et al., in press, for additional statistical details).

### 2.3 Procedure

The procedure was typical of IAT experiments (Nosek et al., 2007). A single IAT session comprised 10 blocks of 20 trials (Table 1). These blocks were not always presented in the same order. For half the participants, the order was as follows: In the first block, participants saw reflection or translation patterns, and they pressed the left button for reflection, and the right button for translation. In the second block, 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 translation) 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 translation patterns or negative words. Next, two more training blocks were presented that included only reflection or translation patterns. Here, the response mapping was reversed, participants learned to use the left button to report translation patterns, and the right key to report reflection. There were then another three blocks of *incompatible* experimental trials (left button for translation or positive, right button for reflection or negative). For the other 20 participants, the incompatible block was presented first and the training blocks were rearranged accordingly. Participants completed two IAT experiments. In the *One-object experiment*, stimuli were composed of a single central item. In the *Two-objects experiment*, stimuli were composed of two objects with either a reflected or translated abutting contour (Figure 1). The order in which the experiments were completed was counterbalanced with other factors.

Each trial began with a fixation cross, which was present for 1,000 ms. The word or pattern then appeared and remained on the screen until participants pressed the button. Cue words were presented on the left and right sides of the screen to indicate the response mapping. For example, when a pattern appeared in the first training block, the cues “reflection” and “translation” were presented, whereas when a word appeared in the second training block, the cues “positive” and “negative” were presented. In the compatible blocks, the cue word on the left read “reflection or positive” and the cue word on the right read “translation or negative”. Conversely, in the incompatible blocks, the cue words read “translation or positive” and “reflection or negative”. Incorrect responses were signalled with the message “WRONG”. Participants were instructed to make accurate responses as quickly as possible.

Explicit preference ratings for the same pattern types were obtained from a group of 40 new participants. Patterns were rated on a Likert scale [$-3$ (very ugly) to $+3$ (very beautiful), with zero as neutral]. Participants rated 10 examples of each of the four pattern types (Reflection, Translation $\times$ One-object Two-objects). These were generated in the same way as the images used in the IAT.

### 2.4 Analysis

Trials were excluded from all analysis if participants pressed the wrong button, or if reaction time was $>10$ s (standard in the IAT literature, Nosek et al., 2007). Approximately 5% of the trials were excluded in total. Preference for reflection over translation was defined as faster mean response times in the compatible than incompatible blocks. However, following the conventions of the IAT literature, we normalized this reaction time difference by dividing it by the *SD* of response times in all experimental blocks to give a *D* score (Nosek et al., 2007). Positive *D* scores indicate an association between reflection and positive words and between translation and negative words. We take this as a measure of implicit preference for reflection over translation. *D* scores were compared to zero using one-sample t tests (significant effects indicating a preference for reflection over translation), and in the One- and Two-objects experiments using paired sample t tests (significant effects indicating greater reflection preference in either the One- or Two-object experiments).

## 3 Results

Each participant completed two IAT experiments designed to measure preference for reflection over translation. In the One-object experiment, the contours that were either reflected or translated were connected to form a single object, while in the Two-objects experiment, the same contours were connected to form two objects (Figure 1). We predicted that preference for reflection would be reduced in the Two-objects experiment.

Results are shown in Figure 2a. It can be seen that in both the One- and Two-objects experiments, $D$ was greater than zero, indicating an implicit preference for reflection, $t\,(39) > 3.668$, $p < .002$. As predicted, this implicit preference for reflection was significantly greater in the One-object experiment than in the Two-objects experiment, $t\,(39) = 2.622$, $p = .012$.

It was likely that the order in which participants completed the experiments (One-object first, Two-objects first) would have a nontrivial effect on implicit preference. The results for these two groups of participants are shown separately in Figure 2b, and this pattern was explored further with planned t tests. The group of participants who completed the One-object experiment first showed a large difference between the One and Two-objects experiments, $t\,(19) = 2.905$, $p = .009$, while there was little difference for the group who completed the Two-objects experiment first, $t\,(19) < 1$, N.S[1,2].

In some of the training blocks, participants discriminated between reflection and translation patterns, without the presentation of words in interleaved trials (Table 1). Previous work suggests that the detection speed advantage for reflectional symmetry should be larger in the One-object experiment than in the Two-objects experiment. To facilitate comparison with preference, we computed detection speed difference between the reflection and translation trials and divided this score by *SD* in all trials. Positive scores indicate that people were quicker to respond to reflection than translation. Overall, the advantage for reflection was larger in the One-object experiment than in the Two-objects experiment, although the anticipated effect was not significant, $t\,(39) = 1.548$, $p = .130$, Figure 2c. However, when the results were broken down by Experiment Order, we found a significant effect in the group who completed the One-object experiment first, $t\,(19) = 2.388$, $p = .028$, not for the group who completed the Two-objects experiment first, $t\,(19) < 1$ N.S, Figure 2d. This parallels the implicit preference data from the same participants.

Explicit ratings were obtained for the same four pattern types (Reflection, Translation) × (One-object, Two-objects) from another group of 40 participants. In both One- and Two-object conditions, reflection was preferred to translation, $t\,(39) > 6.485$, $p < .001$. However, reflection preference was

[1]The IAT analysis was ultimately based on the mean response times in the compatible and incompatible blocks, where the means included response times to the words and images. It is informative, although unconventional, to break down the results further: We analysed response times to the words and images separately. The response times to the images were analysed as a function of three within-subjects factors [Response mapping, (compatible, incompatible) × Regularity (reflection, translation) × Object number (One-object, Two-objects)], and a between-subjects factor [Experiment order (One-object first, Two-objects first)] with mixed ANOVA. There was a main effect of Response mapping, $F\,(1, 38) = 21.246$, $p < .001$, because participants were quicker to respond to images in the compatible blocks, and a main effect of Object number, because people were quicker to classify the One-object patterns, $F\,(1, 38) = 25.342$, $p < 0.001$). There was no main effect of Regularity, $F\,(1, 38) < 1$, N.S, and no Regularity × Object number interaction, $F\,(1, 38) < 1$, N.S. There was a significant interaction between Object Number and Experiment order, $F\,(1, 38) = 32.781$, $p < .001$), reflecting the fact that slowed RT in the Two-object experiment was only apparent in participants who did the Two-object experiment first. There was also a significant interaction between Response mapping, Object number and Experiment order, $F\,(1, 38) = 8.672$, $p = .005$. This interaction is actually another manifestation of the pattern in Figure 1b, although it was obtained from responses to the images only. The pattern can be described as follows: the group of participants who did the One-object experiment first had reduced compatibility advantage in the Two-object experiment, while the group who did the Two-object experiment first had comparable compatibility advantage in the One- and Two-objects experiments. The response times to words were analysed in the same way, with the factor Valence (positive, negative) in place of Regularity. There was a main effect of Response mapping, because participants were faster in the compatible blocks, $F\,(1, 38) = 14.802$, $p < .001$. There was no effect of Object number, $F\,(1, 38) < 1$, N.S, or Valence, $F\,(1, 38) < 1$, N.S. The significant interactions were between Object number and Experiment order, Response mapping and Object number and a three-way interaction between Response mapping, Object number and Experiment order, $F\,(1, 38) > 4.985$, $p < .033$). Again the three-way interaction is another manifestation of the results in Figure 1b, although it reflects response times to words only.

[2]We analysed error rates as a function of the within-subjects factors Response mapping (compatible, incompatible) and Object number (One object, Two-objects) and the between-subjects factor Experiment order (One-object first, Two-objects first) with mixed methods ANOVA. As expected, participants made fewer errors in the compatible blocks than in the incompatible blocks [4% vs. 6%, $F\,(1, 38) = 7.60$, $p = .009$]. There were no other effects or interactions, $F\,(1, 38) < 2.227$, $p > .143$.

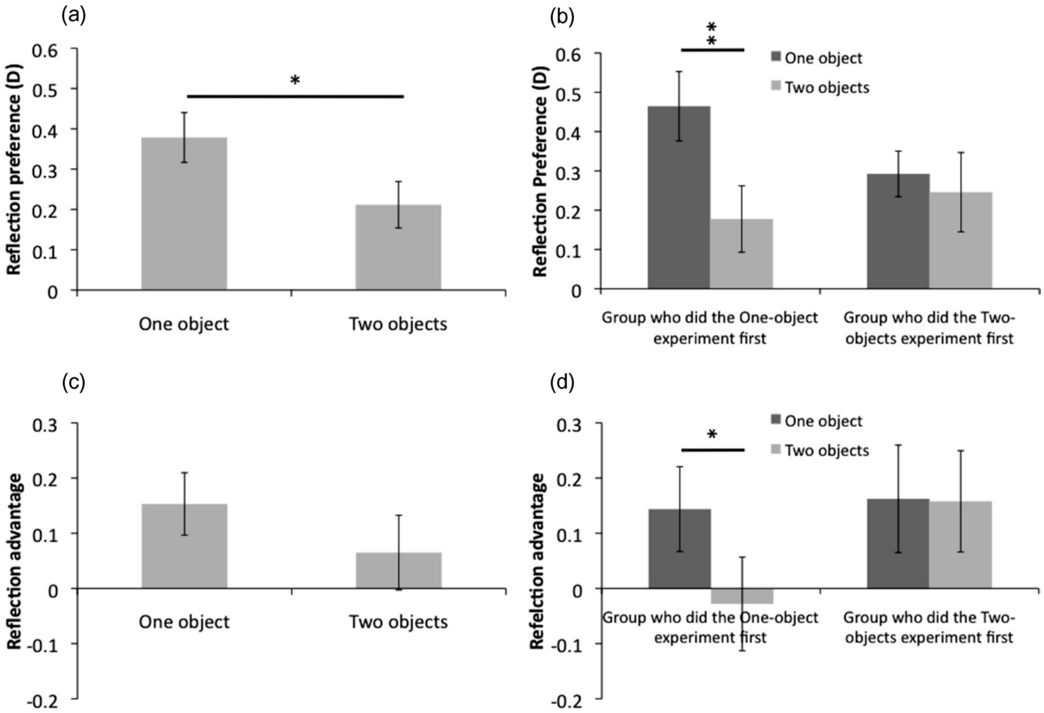


**Figure 2.** (a) Implicit preference for reflection over translation in One- and Two-objects experiments. Positive *D* scores indicate magnitude of preference for reflection. (b) The preference scores in (a), shown for the group of people that did the One-object experiment first, and the group who did the Two-objects experiment first. Note that in all conditions, *D* was greater than zero, indicating ubiquitous preference for reflection over translation, however the size of this preference is modulated by number of objects and experiment order. (c) Normalized reaction time differences from the training blocks of the One- and Two-objects experiments. Positive values indicate faster reaction to reflection patterns than translation patterns. (d) The data from (c) are shown for the groups who completed the One- or Two-objects experiments first. All error bars = ±1 *SEM*.

stronger for the One-object than for the Two-objects stimuli, $t$ (39) = 3.112, $p$ = .003. This explicit preference data are similar to the of implicit preferences measure by the IAT.

## 4 Discussion

We used the IAT to investigate implicit preference for reflection over translation. In all conditions, participants were quicker to respond when the same button was used for reflection patterns and positive words than when the response mapping was reversed. We interpret this as a measure of implicit preference for reflection (Nosek et al., 2007). This preference for reflection over translation replicates one of the IAT experiments reported by Makin et al. (in press). The novel finding in the current work was that grouping modulated the magnitude of the implicit preference: more specifically, reflection preference was significantly greater when the contours were closed to form a single object than when they were part of two spatially separated objects. Some previous studies have found that reflection is more fluently processed than translation within a single object, but that this difference is attenuated or sometimes reversed in two-object conditions (Baylis & Driver, 1995; Bertamini, 2010; Bertamini et al., 2002; Bertamini et al., 1997; Koning & Wagemans, 2009; Treder & van der Helm, 2007). The fact that the same visual factors affect preference scores highlights the close relationship between perceptual salience and preference.

This result is consistent with the fluency hypothesis, which states that the fluency of perceptual or cognitive processing is an important mediator of aesthetic responses (Reber et al., 2004). While a link between perceptual fluency and preference has been reported in the literature, most work has used explicit ratings, and it is difficult to know whether these results generalize to preferences formed spontaneously, that is, in the absence of any requirement to make a decision about the relative merits of the stimuli (Hofel & Jacobsen, 2007). The IAT therefore has certain advantages over other protocols more commonly used in empirical aesthetics (Mastandrea, Bartoli, & Carrus, 2011).

There was one important caveat to our IAT results: The effect of number of objects on implicit preference was greater for the group of participants who completed the One-object experiment first. Moreover, detection speed during training blocks was subject to similar order effects. Although we did not predict these order effects, the fact that prior experience had a common effect on both detection speed and implicit preference indicates a close relationship between these variables (see Watson & Kramer, 1999, for further analysis of past history effects in object-based attention).

Some readers would have noticed that the effects on detection speed were measured in training blocks, while effects on preference were measured in blocks of compatible and incompatible response mappings (Table 1). Moreover, when the response times to the images in these blocks were analysed in isolation, there was no detection speed differences between reflection and translation, and no interaction between regularity type and number of objects, that is, the results usually reported in the literature (see footnote 1). This seems to imply (problematically) that the fluency differences that putatively give rise to relative preferences do not manifest in the crucial blocks. However, response times in these blocks provide a poor measure of detection speed because the same keys are used to report word valence on interleaved trials. Therefore, we are not surprised that detection speed differences between reflection and translation are not apparent here.

Makin et al. (in press) discussed various issues with the IAT methodology, but there is one issue that requires further consideration: Would participants like the fluently processed patterns if this did not entail good performance in a speeded task? Put another way, people may like perceptual ease itself, or they may like the fact it allows them to perform the task well. The IAT cannot discriminate these possibilities. Nevertheless, good performance cannot explain the *explicit* preference ratings we obtained from a new group of 40 participants, which were similar to the implicit preferences measured by IAT. We therefore favour the theory that perceptual fluency produces a positive attitude to the patterns, which can be measured with implicit or explicit techniques (best used together to obtain converging evidence).

It is worth considering the perceptual literature in more detail here. The One-object advantage for reflection could be due to a more general process whereby spatial attention is drawn to single objects, while some other perceptual influence may counteract this ubiquitous effect during translation detection. One possibility is that translation is discovered through a lock and key matching process, akin to mental object rotation, where translated contours are mentally shifted until they overlap (Baylis & Driver, 1995; Bertamini et al., 1997)? Some participants report consciously using the lock and key strategy, although in a study that looked at this the awareness of this strategy was not linked to better performance (Bertamini et al., 2002). However, there are problems with the lock and key hypothesis. Koning and Wagemans (2009) presented two-object regularities and reported that translation patterns are still more quickly detected than reflection, even when the task-relevant contours in question were on the *outside* face of the patterns, and the internal, facing contours were not translational, making lock and key matching difficult. Following their *structural coding* account, these authors argued that the one- and two-object displays are suited to different regularities because reflection typically signals the presence of one object and translation signals presence of two objects in real-life environments. Consideration of the example stimuli in Figure 1 reveals another factor: For reflection, whenever there is a convexity on one side, there is a convexity on the other. Contour polarity is positively correlated for the reflection patterns, and the visual system uses this cue. For translation, there is a negative correlation between the contours (convexity on one side is matched with concavity on the other), making them the opposite of reflection. This feature may make the translation regularity more difficult to detect. However, the disadvantage is attenuated when the translation spans two objects (Bertamini et al., 2002). The relative strength of these factors and their interactions remain unresolved (Bertamini, 2010), but what is crucial for the current study is that whatever accounts for detection speed differences also accounts for implicit preferences.

## 5 Conclusion

This study tested a single hypothesis, based on the idea that the visual system's sensitivity to regularity is directly linked to human preference formation. A specific implementation of this idea is provided by the fluency account of aesthetics. Any variable that influences detection speed should also influence implicit preference. We measured implicit preferences for reflection and translation using the IAT. It is known that reflection is more quickly detected than translation, but that this effect is reduced when the contours are closed to form two separate objects. We found exactly the same interaction between type of regularity and number of objects on implicit preference. A separate study found the same pattern of preferences using an overt ratings procedure, that is, an explicit judgement. This provides evidence that the IAT is sensitive to changes in preference produced by relative perceptual saliency and not just preferences produced by good performance.

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**Alexis Makin** (1983) studied undergraduate Psychology and Neuroscience at the University of Manchester (2003–2006). He completed a PhD thesis on eye movement control and memory for velocity in 2010. He now works at the University of Liverpool studying aesthetics and visual symmetry perception, in collaboration with Marco Bertamini and Anna Pecchinenda.

**Anna Pecchinenda** studied psychology at Sapienza University of Rome, Italy. She then worked at Universitè Laval in Québec, Canada, and in 2000 she moved to the University of Hull, UK. Since 2010 she has been at Sapienza, University of Rome. Her research interests are broad across affect and cognition.

**Marco Bertamini** studied psychology at the University of Padova, Italy, and then at the University of Virginia, USA. He moved to Liverpool in 1999, where he established the Visual Perception Lab. His interests are broad across visual perception and cognition. For more information visit http://www.liv.ac.uk/VP.



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