University of Liverpool
School of Psychology

How processing of visual symmetry relates to preference for regular patterns, and the role of attention on preference formation

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by
Giulia Rampone

Supervisor:
Marco Bertamini

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They walked on rather aimlessly.
He hoped she wouldn't notice he was touched,
because he wouldn't have known
how to explain why.

Patrick White

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Abstract

The process of preference formation is influenced by many factors. These include intrinsic stimulus attributes as well as contextual factors, which are not directly related with the stimulus itself. In this PhD thesis I present seven studies that give significant new insights about how human preference is affected by intrinsic stimulus properties, as well as contextual factors. The common denominator is the use of abstract shapes forming regular patterns (reflectional symmetry). The presence of symmetry within the stimuli predicts preference, and there is behavioural evidence of an association between symmetry and positive valence. The first study shows the neural basis of this association (Part 1, Chapter 2). The thesis proceeds with four studies (Part 2, Chapters 3 – 6) exploring the role of (exogenous) attention on preference evaluation of abstract shapes that already contain intrinsic valence (symmetry/random). Previous research has demonstrated that attention plays a major role on preference formation. These studies showed that exogenous orienting of attention led to more positive evaluation of stimuli at cued locations, although this effect was sensitive to endogenous control. In the last part (Part 3), Chapter 7 explored preference devaluation of abstract symmetry with increasing visual eccentricity, as a potential consequence of reduced perceived regularity at farther locations. Random shapes, which do not lend themselves to coherent interpretation at fovea, were similarly evaluated at all eccentricities. Chapter 8 did not focus on preference. With a novel design, it explored how symmetry detection speed in the periphery was affected by the way attention was deployed in visual space. Overall these findings confirm the role of symmetry in aesthetic appreciation of abstract shapes. Importantly, they highlight a role of attention orienting and gazing in preference modulation. Defining what factors determine preference is key to understanding human behaviour and decisions. This thesis provides a significant contribution towards this goal.

1 Introduction and Overview

Humans often enjoy visual experience. Whether in an art museum or driving down the road, incoming information from the senses is routinely evaluated. People's behaviour inevitably depends on the valence attributed to objects: Do we like this object or dislike it? People orientate towards positively valenced objects and away from those with negative valence.

Can preference for visual stimuli be predicted? If yes, what are the determining factors? These are the key questions addressed in this thesis. Research has for years looked for the 'aesthetic primitives' within images: the essential visual attributes of the world that are positively evaluated. One such aesthetic primitive might be symmetry, which is positively rated by most people. The aim of Part 1 was to characterize the neural basis of this link.

Visual preference does not merely depend on intrinsic stimulus attributes. Contextual factors, which are not directly associated with the stimulus itself, can be important. Part 2 focuses on the role of attention on preference for abstract symmetric and random shapes. Part 3 examines preference for symmetry as a function of visual eccentricity. Chapter 1 begins with a brief review of the literature exploring implicit determinants of preference. This is a short introduction, as each chapter contains a fuller introduction linked to the specific experimental hypothesis. The literature review is followed by a Chapters' Overview, which summarises hypothesis, findings and conclusions addressed in each chapter.

What factors determine valance?

Psychologists have studies the perception, production, and response to a visual object as well as interactions with objects that evoke affective responses. Here I list some of the factors determining whether stimuli are evaluated positively or negatively.

Intrinsic property of the stimulus

One hypothesis is that there is a lawful relationship between stimulus properties and preference (see Spehar, Wong, van de Klundert et al., 2015). Some researchers believe that there are aesthetic universals, and thus some stimuli are liked by everyone (Aitken, 1974; Berlyne, 1971; Martindale, Moore, & Borkum, 1990). One example is visual symmetry, especially bilateral symmetry (henceforth 'symmetry' in this thesis). When people explicitly evaluate abstract patterns, symmetry is the best predictor of preference (Jacobsen & Höfel, 2003). Under certain conditions, there is an automatic association of symmetry with positive valenced words, and random configurations with negative words (Bertamini, Makin, & Pecchinenda, 2013; Bertamini, Makin, & Rampone, 2013; Makin, Pecchinenda, & Bertamini, 2012; Pecchinenda, Bertamini, Makin, & Ruta, 2014). However, mere presentation of symmetrical patterns has not been found to spontaneously produce a physiologically detectable emotional reaction. For example, Makin, Wilton, Pecchinenda, & Bertamini, (2012) recorded Electromyography (EMG) activity in response to abstract symmetry only when symmetry was categorized as *target* (task instruction: "report whether a reflection pattern has been seen: yes/no").

The association between symmetry and beauty is longstanding (e.g. (Enquist & Arak, 1994). Symmetry has been classified as one of the key principles of the aesthetic experience (Jacobsen & Höfel, 2003; Ramachandran & Hirstein, 1999). Indeed, the physicist and mathematician Herman Weyl claimed that "Beauty is bound up with symmetry", thanks to the "concordance of several parts by which they integrate into a whole" (Weyl, 1952, p.3).

One possibility is that people like symmetry because it is a reliable cue of attractiveness and fitness (e.g. Thornhill & Gangestad, 1999). If animals avoid parasites and accidents, they develop a symmetrical body plan. Animals could be attracted to this when seeking mates, evaluating food, or the strength of rivals (Grammer, Fink, Møller, & Thornhill, 2003). Preference for symmetry could be a generalization of this sensitivity to health and fitness.

There are alternatives to this evolutionary explanation. Basic properties of the stimuli, such as shape, size and brightness can alter the speed and efficiency of visual processing. Things that are fluently processed by the visual system are often positively evaluated, and those that are difficult and dis-fluently processed are negatively evaluated (Reber, Schwarz, & Winkielman, 2004b). Symmetry could be liked purely because it is fluently processed (Treder, 2010). This resembles the Gestalt psychologists' concept of "goodness" (or *Prägnanz*, Wertheimer, 1938), with goodness being the combination of *maximum* perceptual efficiency with *minimum* invested energy in perceptual processing (Koffka, 1935).

In other words, harmonious arrangements of the individual visual elements that form the object can make the holistic properties of the object immediately obvious (Redies, 2007). This kind of perceptual efficiency could be hedonically positive, and the symmetrical pattern positively evaluated. It could be that the resulting positive valence is an integral component of object perception, similarly to other properties like colour, shape or size (Lebrecht, Bar, Barrett, & Tarr, 2012) and an "emergent property in the brain of the beholder" (Zaidel, 2015).

Contextual factors.

Visual preference does not uniquely rely on the intrinsic properties of a stimulus. A neutral object may acquire different affective valence as a function of the context under which it is encountered.

In addition to intrinsic characteristics, the aforementioned *perceptual fluency* depends on other perceptual manipulations, which have been shown to influence affective responses. One of the most famous is *mere exposure* (e.g. (Zajonc, 1968), according to which frequency of exposure produces more positive evaluations. Other perceptual factors are subliminal priming, high figure-ground contrast, and longer stimulus exposure duration, and they have all been demonstrated to increase positive affective ratings (Alter &

Oppenheimer, 2009; Oppenheimer, 2008; Reber, Winkielman, & Schwarz, 1998).

As well as perceptual fluency, there is also sensory-motor fluency. Some objects are easily acted upon, and sensory-motor transformation is fluent. Others objects are awkward, and action planning and execution is difficult. It could be that people sensitive to the fluency of their own sensory motor transformations, and again, they could like objects which allow fluent action, and dislike those which are not fluently acted upon (Cannon, Hayes, & Tipper, 2009; Hayes, Paul, Beuger, & Tipper, 2008). Both perceptual and motor fluency depends on experience, so the fluency effect on preference formation can vary among individuals (Constable, Bayliss, Tipper, & Kritikos, 2013).

Preference is also intimately related to anticipation and expectation. The brain constantly makes predictions about future inputs. Sometimes these predictions are confirmed, but not always. When (top-down) predictions enter in conflict with up-coming (bottom-up) information, a "prediction error" signal is computed (see Van de Cruys & Wagemans, 2011). Cases in which predictions are confirmed could be rewarding (O'Doherty, 2004; Schoenbaum, Takahashi, Liu, & McDannald, 2011) and lead to higher preference (Ogawa & Watanabe, 2011). Alternatively, emotional responses may arise from discrepancies between expected and actual situations (Mandler, 2003; Van de Cruys & Wagemans, 2011), which may be converted into either positive or negative experiences depending on the situation (Mandler, 2003).

Preference is linked to inhibition of our own actions (Doallo et al., 2012; Fenske, Raymond, Kessler, Westoby, & Tipper, 2005; Kiss, Raymond, Westoby, Nobre, & Eimer, 2008). This has been tested with Go/No-Go tasks. Participants were presented with series of (Go) stimuli and were instructed to perform an action (i.e. pressing the button) until a No-Go signal commanded them to withhold a response. This inhibition signal is likely to occur when preparatory processes, leading to the motor action, are already underway. This inhibition causes devaluation of the stimulus.

Neuroimaging evidence had shown correlation between inhibition-depended devaluation and activity in the Orbitofrontal Cortex (Doallo et al., 2012), an area that controls inappropriate responses and other reward/punishment related states (Elliott & Dolan, 1999; Elliott, Friston, & Dolan, 2000; Horn, Dolan, Elliott, Deakin, & Woodruff, 2003; Nobre, Coull, Frith, & Mesulam, 1999; Schoenbaum et al., 2011)

A recent study used a variation of the Go/No-go task that was functionally opposite to the stop-signal task (Schonberg et al., 2014). It showed that preference for an item could be modulated by the presentation of an infrequent auditory cue to which subjects had to make a simple motor response (cue-motor approach). Stimuli associated with the Go signal were preferred to the No-Go stimuli. fMRI data revealed that enhanced preference was reflected on amplified activity in Ventromedial Prefrontal Cortex, which is involved in computation of goal-values during decision-making processes (Chib, Rangel, Shimojo, & O'Doherty, 2009; Hare, Malmaud, & Rangel, 2011; Hare, O'Doherty, Camerer, Schultz, & Rangel, 2008; Lim, O'Doherty, & Rangel, 2011; McNamee, Rangel, & O'Doherty, 2013; Tom, Fox, Poldrack, & Trepel, 2007).

Same anatomical areas might be associated with the monitoring of conflict that is triggered by the competition between tendencies to execute or inhibit a specific response (see also Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003; Yeung, Botvinick, & Cohen, 2004). It is interesting that behavioural evidence for response control correlate with the magnitude of neural activation. This provides clear evidence that the brain can compute context-modulated value signals, which remain accessible until the evaluative or choice period.

Top-down attentional selection of a target embedded in distractors has been demonstrated to change the affective value of targets and distractors, with distractors evaluated more negatively than targets. This has been named the 'distractor devaluation effect' (see the pioneer study of Raymond, Fenske, & Tavassoli, 2003). Distractor devaluation is the result of the attentional inhibition applied over the distractors. Alternatively, the way in which a stimulus is categorized could be sufficient to influence the value attributed to that object. Dittrich & Klauer (2012) showed that distractor devaluation could be reversed into target devaluation if instructions labelled the target as the to-be-rejected stimulus. Other studies have proposed that selective attention over one of two alternatives enhances positive evaluation for the attended option (Huang & Hsieh, 2013; Yagi, Ikoma, & Kikuchi, 2009).

This pattern of results suggests that endogenous attentional processes exert an influence on affective responses.

Affective values are not only modulated by intentional selection (i.e. the observer knows what he/she is looking for). The experimental manipulation of attention orienting, without performer's conscious intentions, has also been demonstrated to influence preference formation for the attended stimulus (Armel, Beaumel, & Rangel, 2008; Hare et al., 2011; Lim et al., 2011; Shimojo, Simion, Shimojo, & Scheier, 2003). An important role is attributed to task-irrelevant bottom-up variables that capture attention and influence preference in favour of the attended item (see Orquin & Mueller Loose, 2013). In particular these studies stress the concept that modulating the shift of attention is not enough. The involvement of oculomotor responses is fundamental for the formation of preference, because it is through the deployment of gaze that people select preferred information in the visual space.

Finally, object valence also depends on other people's gaze direction. Objects looked at are preferred over those looked away from (see the pioneer study from (Bayliss, Paul, Cannon, & Tipper, 2006), and this has nothing to do with attention itself but it is related to the social connotation of processing other people's gaze. However, the tendency of interpreting the other's gaze shifts as indicators of preference may be intimately linked with observations showing a causative role of gaze orienting in the construction of preference (e.g. Krajbich et al., 2010; Shimojo, Simion, Shimojo, & Scheier, 2003).

There is an extensive literature on the causative factors of preference formation, and this section provided a brief overview. In this thesis I seek to investigate three main issues: 1. Finding a neural correlate of the implicit link between symmetry and positive valence. 2. Testing whether and how (exogenous) attention influences evaluation of abstract patterns 3. Looking at how the appreciation of symmetry changes across the visual field. In the next session I indicate how these issues are addressed in the respective chapters.

Chapters' overview

Part 1

The thesis begins with an electrophysiological study exploring the congruency between symmetry and valence (**Chapter 2**). As already mentioned in this chapter, reflection symmetry is often judged as beautiful. Previous reaction-time based studies have shown that reflection symmetry facilitates processing of positive words, whilst random patterns facilitate negative words (Bertamini, Makin, & Pecchinenda, 2013). The present study explored the neural correlates of affective responses to symmetry. Several electroencephalography (EEG) studies have documented a consistent and sustained response to visual symmetry, over the lateral occipital cortex (LOC), on later components of the visual event related potential (ERP) (see Bertamini & Makin, 2014 for a review). This response is referred to as *Sustained Posterior Negativity* (SPN) and it represents a difference wave between symmetry and random, with the amplitude in symmetrical conditions being more negative than amplitude in random conditions.

In **Experiment 1(2)**[1] SPN was recorded from a cluster of posterior electrodes while participants viewed reflection or random patterns with either a positive or negative word superimposed. In the **Discriminate Regularity task**, participants categorized the patterns (reflection or random). In the **Discriminate Word task**, they categorized the words as positive or negative. In **Experiment 2(2)**, participants classified words and patterns on each trial. A difference between ERP waves from congruent (reflection with positive word, random with negative word) and incongruent trials (reflection with negative, random with positive) was observed in the Discriminate Word task of Experiment 1(2). This congruency effect began around 200ms, and persisted up to 1000ms post stimulus. From these results, I speculated that classifying words valence put participants into an evaluative mind-set that overgeneralized to the evaluation of the background patterns. Alternative interpretations are also discussed in Chapter 2.

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[1] The value in brackets reports the number of the chapter (e.g. Experiment 1(2) is Experiment 1, Chapter 2.

Part 2

Throughout our lives we are bombarded by relevant and irrelevant visual information. As a consequence, human brains selectively attend to, and process, this incoming information. This ability is adaptive because it allows selection of the most relevant information at a given point in time (e.g., Posner, Snyder, & Davidson, 1980).What we selectively attend to is a result of a dynamic interplay between two main competing factors: the observer's current needs or goals driving the allocation of attention, and the ability of task-irrelevant information to capture attention regardless of the observer's goals.

The abrupt onset of a peripheral cue is one of the most effective stimulations known to drive attentional allocation, independently of the individual's current goals (Jonides & Long, 1981; Jonides & Yantis, 1988; Yantis, 1993). This part investigates whether and how exogenous peripheral cues modulates preference evaluation of abstract patterns, which already possess an affective value (symmetry and random).

In **Chapter 3**, a variation of the classic exogenous orienting paradigm (Posner, 1980) was employed. An uninformative peripheral cue was briefly presented (100ms) at either left or right of a fixation cross. This cue was followed by a novel abstract pattern after a short interval of 50ms. Participants performed a discrimination task reporting whether the pattern was symmetry or random as fast and accurately as they could. Participants saw a novel pattern on each trial and had to evaluate it immediately after offset. Evaluation consisted on selecting a value from 9 (like very much) to 1 (not like at all) on a vertical rating scale.

In **Experiment 1(3)**, one group of participants gazed and looked at the patterns as soon as these appeared on the screen **(overt condition)**. Valid cues reduced the time for oculomotor and manual responses to be initiated. More importantly, evaluation of patterns at validly cued locations was more positive, irrespective of their degree of regularity. Importantly, symmetry was still preferred over random, but evaluation within the same category was affected by an external factor (i.e. attentional modulation). This demonstrated that the value of objects with intrinsic valence could change as a function of attention orienting.

In the same experiment, I tested a condition in which participants performed the task maintaining eyes at fixation throughout the whole experiment (**Experiment 1(3)**, **covert condition**). In this condition participants covertly attended the patterns that they had to evaluate. When attention is captured at a given location, the oculomotor system is prompted to respond to that location. Gazing at an object, leads to its foveation for deeper processing. Shimojo et al. (2003) suggested that the first instantiation of preference formation emerges from implicit, reflexive overt orienting mechanisms.

It is well known that covertly attending and efficiently processing information in the periphery is possible (e.g. Posner, Cohen, Choate, Maylor, & Hockey, 1984). The so-called 'covert' deployment of attention produces biases in behavioural performance and neural processing in absence of 'overt' orienting (i.e. head or eye movements, Moore, Armstrong, & Fallah, 2003). However, I wanted to examine whether applying endogenous control on oculomotor response to the target pattern would interfere with the cueing effect on preference (although cuing was still expected to affect the speed of the discrimination task in covert attention). Pattern discrimination was faster at valid locations, as expected. However, preference ratings were only driven by pattern regularity and unaffected by attention modulation. Although not significantly, ratings in covert condition were also more negative overall than in the 'overt'-condition.

This result showed that attention and gaze shifts favoured the *valid – invalid* difference on preference, whilst endogenous control over oculomotor responses cancelled this effect. I speculated that this *valid – invalid* preference effect might depend on one of two factors, or a combination of the two. On one hand, valid cueing might enhance evaluation as the synergic action of two subsequent onsets increased the reflex of gazing towards the source of this stimulation. On the other hand, invalid cueing might lead to devaluation due to effortful inhibitory control for disengaging attention from cued location and shifting gaze to the opposite location.

Experiment 2(3) added a baseline condition in which pattern's location was not pre-cued. A similar trend (valid > no-cue > invalid) both on performance and evaluation was observed. This suggested that the *valid – invalid* effect emerged from a combination between enhanced responses and preference at the validly cued location, and costs associated with disengaging and reorienting attention in invalid conditions.

The results described in Chapter 3 evidenced that exogenous capture of attention could create a first instantiation of preference. When cuing failed in indicating the correct location of the target, the shift of attention that had been activated required an effortful process of inhibition and reprogramming of a new oculomotor response. The interplay of these processes might have played an important role in favouring a *valid – invalid effect* on preference. I also observed that constant level of inhibition applied on oculomotor response towards the to-be-evaluated pattern was responsible for cancelling any effect on evaluation. Therefore shifting attention is necessary but not sufficient for preference modulation. Gazing is necessary.

At the end of Chapter 3, I reported preliminary results from an experiment in which I tested *valid – invalid* cueing effect with longer cue-to-target intervals (or *interstimulus* intervals) (**Experiment 3a(3), 3b(3)**). The magnitude of the *valid – invalid* effect on SRTs and MRTs was expected to decrease or disappear with increasing ISI, and this should reflect on preference. For consistency with the aforementioned experiments only one ISI was employed in each sub-experiment. In **Experiment 3a(3)** ISI was 475ms and I expected to find no effect in any of the variables. In **Experiment 3b(3)** ISI was 900ms and an inhibitory mechanism (Inhibition of return, IOR; see Klein, 2000) might be activated, preventing attention from returning to previously cued locations. If IOR affected performance, faster responses would be recorded on invalid locations than valid locations. In case of IOR, it would have been interesting to see how this influenced preference. Results did not show any difference between valid and invalid conditions either on performance or preference, with any of the intervals employed. This experiment showed that cueing alone was not sufficient to influence preference evaluation on valid/invalid trials. It also suggested that the instantiation of preference manifests when attentional engagement is at its peak (short ISI). The fact that no IOR was obtained, however, highlighted some important methodological caveats that should be addressed in future experiments. These are discussed in more details in Chapter 3.

The second study (**Chapter 4)** employed a variation of the spatial cueing procedure. The onset of the peripheral uninformative cue preceded the appearance of a target, which was a simple circle. Participants in this study performed a detection task, reporting the location of the target (left/right). The abstract pattern (identical to Chapter 3) appeared immediately after response. Participants observed the pattern without making any explicit regularity-classification. At pattern offset, they rated their liking on a 9-points scale. In **Experiment 1(4)** patterns were presented at the same location as the target (either valid or invalid). In **Experiment 2**(4) the patterns appeared always at fixation. Target detection was facilitated by valid cueing in both experiments. Patterns evaluation was more positive for patterns in valid trials than patterns in invalid trials, but only when patterns appeared at the same location as the target (Experiment 1(4)).

The first important result from this study was that exogenous cuing was found to affect preference even when the to-be-evaluated patterns were irrelevant for the cuing task.

This study also tested two hypotheses. First, *valid – invalid effect* on preference might be associated with increased subjective experience of perceptual fluency on valid cue-to-target contingencies (see Reber, Wurtz, Zimmermann, 2001; Constable et al. 2013). This hypothesis was rejected: if valid cue-to-target contingencies increased experience of fluency, cue validity should bias evaluation also in Experiment 2(4). Moreover, these results suggested that preference was modulated at the moment in which attention was directed towards (or away) the cued location and dwelled at that location where the pattern was due to appear. In Experiment 2(4), gazing back to fixation on every trial was sufficient to cancel the *valid – invalid effect* on preference.

Experiment 3a(4), 3b(4) replicated the design of the two previous experiments respectively. This time participants maintained eyes at fixation throughout the whole experiment. Despite a significant cueing effect on RTs, preference was not influenced by cueing. This experiment replicated the results of Experiment 1, 'covert' condition in Chapter 3.

The study described in Chapter 4 confirmed that the exogenous manipulation of attention could influence explicit preference evaluation, and this could extend to non-target stimuli presented at the valid/invalid location. It also confirmed that shifting attention is not enough but gazing towards the location of interest favours the formation of preference. Finally it showed that endogenous control plays an important role over exogenous control, as it can cancel the exogenous effects.

Chapter 5 employed another variation of the cuing paradigm. In **Experiment 1(5)** the cue indicated the valid location of the incoming pattern on 80% of the trials (predictive cues). In **Experiment 2(5)** the proportion of valid:invalid was reversed (20% valid 80% invalid) (counter-predictive cues). The cues preceded the appearance of either abstract symmetric or random patterns, and we asked participants to rate their liking for the patterns. This study explored the effect of learned predictability and violation of expected contingency on preference evaluation. In the first case the predictable condition was valid condition: endogenous expectation and exogenous cueing synergistically cooperated. As expected response reactions and preference were enhanced for stimuli appearing at validly cued (and predicted) locations. In the second case endogenous and exogenous dimensions had opposite directions. The valid – invalid difference was cancelled in this experiment. Hence, as already suggested by previous experiments, endogenous control can overwhelm exogenous influence.

Overall these results show that exogenous cuing captures attention, and triggers a gazing response, influencing the way in which stimuli at valid/invalid locations are evaluated. However, some endogenous control can operate against this process. In the case of Experiment 1(5), Chapter 5, predictive cues created the appropriate attentional set that was prepared to respond positively to the cue and immediately activate the orienting system. I believe that this applies to predictive cues (Chapter 5), and, to some extend, also to uninformative cues (Chapter 3 and Chapter 4) (see Santangelo & Spence, 2008). In other words, it is possible that similar mechanisms (e.g. preparation to valid cue-to-target contingency) is involved in the modulation of preference observed with uninformative and predictive cues. In the second case (Experiment 2(5)), the initial attentional set can be prepared to counteract the exogenous influence, and this action cancels the *valid – invalid effect*.

The studies conducted so far have only observed that endogenous (inhibitory) control cancels the exogenous effects. It would be interesting to obtain a condition in which endogenous control uses the exogenous information to enhance attention orienting at the invalid location. Observing how this inhibitory process influences preference evaluation would add to the current set of results. This is what future studies should address, in order to understand whether and how endogenous and exogenous attention interact in creating a first instantiation of preference.

In **Chapter 6** I reported the results from a further analysis on eye-movement data from previous experiments (Experiment 1(3) and 2(3), Chapter 3; Experiment 1(5), Chapter 5). I observed that the time eyes dwelled over patterns significantly varied as a function of validity. In valid trials gaze-dwelling times were significantly longer than in invalid trials. This difference was likely to originate from the fact that pattern display duration was fixed (1500ms). Depending on the time required to a saccade to be initiated, duration of patterns' exposure to foveal processing could vary considerably. In a new study I tested the possible impact of pattern exposure duration on preference modulation. With a gaze-contingent technique, dwell duration over the pattern was controlled. A pattern display time of 1500ms was triggered in the moment in which eyes reached the pattern. Gaze thus could dwell over valid and invalid location for the exact same amount of time. Results showed a significant *valid – invalid effect* on preference even if gaze dwelled over patterns for the same amount of time.

In this study I ruled out a role of exposure duration on the preference effect elicited by peripheral cues.

Part 2

The second part of the thesis is divided in two chapters.

Chapter 7 explores visual eccentricity as a factor affecting preference. In previous chapters I discussed the importance of gazing. Gazing is important as it relates to foveation for deeper perceptual processing. The act of foveating an object is a crucial aspect for the construction of an aesthetic response to that object. Emotion-laden stimuli attract attention (see Yiend, 2010), which implies that the affective value of an object can be processed in the periphery. However, all the information related to the object can be extracted only through foveal processing. For example, a person in a shoe shop would be able to discriminate a beautiful shoe form an ugly one, located in the peripheral field. However, one would need to carefully look at each item to be able to express an opinion about it and make the right choice. It is thus conceivable to think that the evaluation of a stimulus would be more positive at fovea than in periphery. Moreover, the amount of information accessible to perception depends on the distance from the fovea. The same stimulus may be differently appreciated when processed at different locations. This study investigated whether preference evaluation of an item is inversely proportional to increasing eccentricity.

This study focused on how eccentricity affects preference for abstract bilateral symmetry and random patterns. As previously mentioned people show strong preference for symmetry over non-symmetrical configurations in abstract patterns. Among the different theories, preference for symmetry is believed to originate from the ease of its processing (Piotr Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Thanks to the specular correspondence of shape, size and position of elements along the axis of reflection, detection of symmetry is fast and efficient. This saliency of symmetry, however, is confined to central vision, and is known to decrease a few degrees of visual angle outside of the fovea (~1°, Sally & Gurnsey, 2001). Probably processing symmetry in the periphery destroys the regularity of elements along the axis in the retinal image, and this delays symmetry discrimination. At fovea symmetry is rich in perceptual information, which is immediately accessible to the visual system. This information becomes less accessible as distance from the fovea increases, and greater effort is required to undertake eccentricity correction. If preference for symmetry derives from its perceptual fluency, and fluency gradually decreases with eccentricity, preference should be affected by eccentricity in a similar fashion. On the contrary, random patterns are perceptually meaningless at fovea, as there is no spatial correspondence between elements. The lack of an optimal representational balance of visual components is likely to be the reason why random configuration is disliked in abstract shapes. Perceptual information associated with random patterns does not differ substantially at different locations on the retina. It is thus conceivable to hypothesize that retinal eccentricity would not predict modulation of aesthetic preference for random patterns.

In the study, dot patterns (4-fold reflection symmetry and random) were presented for 200ms within a large region. Participants were instructed to select a fixation location arbitrarily on each trial. Eccentricity values were calculated a posteriori by comparing ocular coordinates at pattern onset and coordinates for the centre of the pattern. **Experiment 1(7)** consisted of two Tasks. **In Task 1**, participants detected pattern regularity as fast as possible. In **Task 2** participants did not actively discriminate symmetry and evaluated their liking for the pattern on a 9-points Likert-scale. Results from Task 1 revealed that eccentricity did not affect symmetry detection. The absence of effect on manual reaction times, however, might be attributed to methodological aspects and not to uniform sensitivity at all eccentricities. In Task 2, preference for symmetry was sensitive to its location, and evaluation was gradually more negative as eccentricity increased. In line with our expectation, eccentricity did not predict more negative evaluation of random patterns. **Experiment 2(7)** was designed to further confirm that eccentricity was specifically a good predictor of symmetry devaluation, but not random. Participants were presented with one type of regularity, symmetry or random patterns. The task did not include processing of pattern regularity. Participants discriminated the proportion of black/white dots within the pattern. Then they evaluated their liking for the pattern. Even when only one type of regularity was presented and regularity was task-irrelevant, preference for symmetry decreased with increasing eccentricity, whereas eccentricity did not affect the evaluation of random patterns. Symmetry appreciation was thus sensitive to retinal eccentricity. Although symmetry devaluation could not be accounted for by our results on manual reaction times, there was evidence that this effect depended on reduced accessibility of perceptual information along the vertical axis.

By exploring how different locations in the periphery affects preference for regular patterns, this study extends knowledge about how visual preference of objects is vulnerable to factors that are not directly related to the object itself. This study corroborates the claim that attending to an object is necessary but not sufficient. Gazing towards an object, with the intention of fully processing the object at fovea, are fundamental requirements for a first instantiation of preference.

The study described in **Chapter 8** followed up the first study (Experiment 1(7)), but did not focus on preference. It explored whether the absence of eccentricity effect on symmetry discrimination was caused by methodological factors. In particular this study focused on the role played by the presence/absence of the fixation mark.

As previously mentioned symmetry in extra-foveal vision can be efficiently discriminated from random configuration. However, detectability of symmetry considerably drops with axis eccentricity (Barrett, Whitaker, McGraw, & Herbert, 1999; Gurnsey, Herbert, & Kenemy, 1998; Jukka Saarinen, 1988; Sally & Gurnsey, 2001), and it can be equated to foveal performance only by scaling up stimulus size proportionally with eccentricity (Tyler & Hardage, 1996). In our study, patterns' size was maintained unvaried across eccentricities. Therefore, the discrimination of symmetry from random patterns should be affected by distance from the fovea. Experiment 1(7) required participants to change fixation in every trial by choosing any location within the central circle, which was not identified by a fixation mark. The fixation mark is commonly used in almost every paradigm in experimental psychology. The principal function played by this stimulus is to engage attention on a specific point prior to target appearance, to minimize noise due to spreading of attention in the periphery. The absence of a physical fixation point in our experiments is likely to have facilitated the deployment of attention to the periphery (see Mackeben & Nakayama, 1993). This was combined with the fact that the incoming pattern location was totally unpredictable for the participant, and the probability of getting a pattern at fovea was very low.

In **Experiment 1(8)**, two procedures were compared to test symmetry detection across eccentricity: in the first task observers selected where to look (similarly to Experiment 1(7)) and in the second task they were provided with a fixation mark. Like in the previous study the display consisted of a large grey central circle in which an abstract dot pattern (bilateral symmetry or random) was presented for 200ms at a randomly selected location. In **Task-NoF (No Fixation)** participants arbitrarily choose any point within the circle. There was no physical stimulus to fixate, so participants maintained fixation on an empty space. In **Task-FC (Fixation Cross)** was identical, but a fixation cross was presented at different locations within the circle. Manual reaction time and accuracy were recorded. Eccentricity was found to not affect manual responses in Task-NoF, although a decrement in accuracy was observed. Both accuracy and speed of manual reaction decreased with increasing eccentricity in Task-FC. **Experiment 2(8)** showed eccentricity effect on manual reaction times by using a central fixation mark, despite a reduced range of eccentricity values. This study confirmed that the fixation cross plays an important role in the deployment of attention in the visual field. In the General Discussion of Chapter 8, I speculate that sensitivity to symmetry probably declined with increasing eccentricity in a similar fashion in all tasks, as eccentricity always predicted impaired accuracy. Manual response speed instead may be under the influence of participant's pre-attentional status, which in turn is biased by a number of factors (i.e. presence/absence of the fixation cross).

This finding has implications not only for the study of symmetry perception, but also for traditional paradigms used to study attention. First, it highlights that manual reaction times may not be a reliable index of perceptual or attentional facilitation. Instead, RTs are deceptively complex and may be biased by the pre-attentional state of the participant. Second, it suggests that effects observed with paradigms providing fixation marks might not generalise to the case of freely chosen fixations. Finally, this study provides insights about the way in which attentional phenomena are studied in the lab and advocates for combining highly controlled experimental designs with ecologically valid measures.

In summary the present PhD thesis describes evidence for different mechanisms of preference modulation for regular abstract patterns. I employed symmetric patterns, which are consistently evaluated as beautiful, and compared them to random patterns, which are normally disliked. With the EEG technique, I observed that the association between visual symmetry and positive valence was visible at the neurophysiological level (Part 1). Symmetry evaluation was found to decrease with increasing retinal eccentricity, suggesting that the appeal of symmetry is related to the amount of perceptual information accessible to visual processing (Part 3). Part 2 showed that the evaluation of pattern regularity is not simply category-based (symmetry evaluated positively and random evaluated negatively). Preference evaluation within each category can be modulated through experimental manipulation of attention. Although these studies employed abstract shapes, they provided important insights on the role of attention, in particular attention capture, gaze orienting and foveation, in the formation of preference for visual stimuli.

Part 1

EEG measure of the link between symmetry and positive valence

2 Electrophysiological analysis of the affective congruence between pattern regularity and word valence

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2.1 Abstract

Reflection symmetry is an important property of human designs and biological organisms, and it is often judged to be beautiful. Previous reaction-time based studies have shown a congruency effect, where reflection symmetry facilitates processing of positive words, and random patterns facilitate negative words. But what is the neural basis of affective responses to symmetry? In Experiment 1 we recorded ERPs from posterior electrode clusters while participants viewed reflection or random patterns with either a positive or negative word superimposed. In the Discriminate Regularity task, participants categorized the patterns (reflection or random). In the Discriminate Word task, they categorized the words as positive or negative. In Experiment 2, participants classified words and patterns on each trial. We found a difference between ERP waves from congruent (reflection with positive word, random with negative word) and incongruent trials (reflection with negative, random with positive). This congruency effect began around 200ms, and persisted up to 1000ms post stimulus, and was only present in the Discriminate Word task. We suggest that when evaluating words, participants automatically evaluate the background pattern as well, and this alters early visual processing.

2.2 Introduction

Symmetry is linked to beauty, and is associated with positive valence. In this study we explore the visual processing of symmetry using a paradigm in which symmetric patterns are presented together with positive or negative words. It has been suggested that reward mechanisms exist along all stages of visual processing and that these networks produce aesthetic experiences. Therefore, we predicted that event related potentials should respond to congruency between visual regularity and word valence.

Perception of symmetry

The artificial environment created by humans is full of symmetrical designs. Symmetry appears in visual art and architecture (Carlson, 2002), but also in literature and music (Ball, 2008), where it overlaps with terms like "harmony", "proportion" and "balance". Moreover, symmetry is everywhere in the biological world. The origin of life rises from a fascinating strategy of the eukaryotic genome: the mitotic spindle. Thanks to its mirror symmetrical configuration, cells replicate in two identical copies. Moreover, a rigid genetic coding tuned to symmetry controls the distribution of cells bilaterally along the main axis during the embryogenesis of most species. If development is unimpeded, most animals become anatomically symmetrical, and thus symmetry is also an indicator of mate quality (Møller, 1992; Møller & Thornhill, 1998; Swaddle & Cuthill, 1994). A preference for symmetry is well documented in several animal species, such as finches (John P. Swaddle & Cuthill, 1994), honeybees, chicks (Clara, Regolin, & Vallortigara, 2007; Wignall, Heiling, Cheng, & Herberstein, 2006) and gazelles (Møller, Cuervo, Soler, & Zamora-Muoz, 1996). Humans also perceive symmetrical faces and bodies as more attractive (Bertamini, Byrne, & Bennett, 2013; Cárdenas & Harris, 2006; Rhodes, Proffitt, Grady, & Sumich, 1998).

The visual system perceives symmetry efficiently (Barlow & Reeves, 1979; Palmer & Hemenway, 1978; Treder, 2010; Tyler, 1995; Wagemans, 1995; Bruce & Morgan, 1975) possibly because the strict correspondence of position, shape and measure along a central axis fosters the economy of processing (Koffka, 1935). Gestalt psychologists assigned a high level of "goodness" to symmetrical patterns (Wertheimer, 1938; Koffka, 1935) and Palmer (1991) confirmed that symmetrical structures are rated high in "goodness". Preference for symmetry can also be explained by the fluency hypothesis (Winkielman, Schwarz, Fazendeiro, & Reber, 2003), which states that people are sensitive to the ease of their own perceptual or cognitive operations, and that fluent processing is experienced as hedonically positive (Reber, Schwarz, et al., 2004; Reber, Wurtz, & Zimmermann, 2004).

There have been several neuroimaging studies looking at symmetry (see Treder, 2010). Functional MRI studies have discovered symmetry-related activations in the Lateral Occipital Cortex (Yuka Sasaki, Vanduffel, Knutsen, Tyler, & Tootell, 2005; Tyler et al., 2005) and other extrastriate regions like V3a, V4, V7 (Yuka Sasaki et al., 2005). Of particular interest for our work, Jacobsen & Höfel (2003) reported a symmetry related ERP component at occipital sites, called the Sustained Posterior Negativity (SPN). After the visual evoked potential, amplitude was more negative for symmetrical than random patterns, at least up to 1100ms post stimulus onset. The authors suggested that the SPN results from accurate and sustained visual analysis of the pattern before deciding whether it was symmetrical. However, the SPN can also be recorded when participants do not attend to regularity (Höfel & Jacobsen, 2007) and when either random or reflection patterns are targets (Makin et al., 2012). The LORETA source localization technique identified the SPN neural generator in the lateral extrastriate visual cortex (Makin et al., 2012), providing evidence that the brain regions identified in fMRI studies generate this ERP.

Makin, Rampone, Pecchinenda, & Bertamini, (2013) further demonstrated that the SPN is sensitive to different visual regularities: reflection, rotation and translation. However, reflection symmetry seems to be the preferred stimulus for visual regularity detectors, producing the largest SPN. This is in agreement with psychophysical studies, which have repeatedly shown reflection symmetry to be the most salient regularity (Bertamini, Friedenberg, & Kubovy, 1997; Friedenberg & Bertamini, 2000; Makin, Pecchinenda, & Bertamini, 2012).

Other studies have focused on the emotional reaction to symmetry. For example, Bertamini, Makin, & Pecchinenda (2013) used an affective priming procedure where symmetrical or random patterns were briefly presented, and then a word appeared. Participants had to classify the word as positive (e.g. Love) or negative (e.g. Hate) as quickly as possible. It was predicted that people would have been quicker to respond in the congruent conditions, where a positive word followed a symmetrical pattern or a negative word followed a random pattern than, in the incongruent conditions (symmetry then negative or random then positive). The expected reaction time advantage for congruent conditions was found, but only when participants had to attend to the prime as well as the word. Nevertheless, these results confirmed a link between the symmetry-random and positive–negative dimensions. It might be possible this happened at the level of conceptual categories, and the results do not have to be explained by an immediate affective response to the stimuli (but see Pecchinenda, Bertamini, Makin, & Ruta, 2014), for behavioural evidence for automatic affective responses).

The current work re-examined the congruence effects found in affective priming studies by using EEG techniques. The experiment was a modified version of the affective picture-word interference task (Glaser & Düngelhoff, 1984; Houwer & Hermans, 1994; Stroop, 1935) in which two stimuli – a target and a distractor – are presented superimposed. There are four possible relations between pictures and words: both target and distractor have positive or negative valence (congruent conditions); target is positive and distractor is negative or target is negative and distractor is positive (incongruent conditions). It is possible that presenting words and patterns superimposed would induce participants to process regularity and valence dimensions simultaneously.

We hypothesized that the brain is sensitive to the difference between congruent trials (reflection with positive word; random with negative word) and incongruent trials (reflection with negative word; random with positive word). We recorded Event Related Potential (ERP) waveforms produced by congruent and incongruent conditions.

The congruency effect was explored on several ERP components and time-windows, where previous research has demonstrated ERP responses to regularity or valence independently. We mainly focused on the Sustained Posterior Negativity, which is known to be sensitive to symmetry and sustained for the whole exposure time of the stimulus. If congruence sensitive potentials overlapped considerably with the SPN, it would suggest that visual networks that are sensitive to symmetry are also sensitive to valence.

We also focused on ERP components usually modulated by emotional variables. The Early Posterior Negativity (EPN) is the first ERP response to the emotional content of visual stimuli. It peaks around 200–300ms after stimulus onset with lateroccipital scalp distribution (see Citron, 2012; Hajcak, MacNamara, & Olvet, 2010). The EPN responds preferentially to high emotional valence and arousal, and is larger for stimuli with either positive or negative valence than stimuli with neutral valence (Junghöfer, Bradley, Elbert, & Lang, 2001; Schacht & Sommer, 2009a, 2009b; Harald T Schupp et al., 2004; Harald T Schupp, Junghöfer, Weike, & Hamm, 2003; Scott, O'Donnell, Leuthold, & Sereno, 2009). This emotional response is thought to be automatic and effortless (Kissler, Herbert, Winkler, & Junghofer, 2009) and could reflect spontaneous attention capture by emotionally salient stimuli (Schacht & Sommer, 2009a, 2009b; Schupp et al., 2007). ERPs associated with early emotion discrimination and symmetry recognition share similar topography, and the SPN begins around the same time as the EPN. If the congruent/incongruent difference emerges at this early time point, it would suggest the evaluation of the patterns happens immediately after the initial visual analysis is complete.

We also analysed the Late Posterior Positivity (LPP), or Late Positive Complex (LPC). LPP belongs to a group of positive components associated with explicit evaluation of a stimulus (Citron, 2012). Contrarily to EPN, LPP has been found only when the emotional content of the stimuli was task-relevant or when semantic processing was required (Fischler & Bradley, 2006). It peaks between 500 and 800ms over centro-posterior regions (Citron, 2012; Hajcak et al., 2010) and its amplitude is consistently larger for emotional stimuli than neutral (Hinojosa, Méndez-Bértolo, & Pozo, 2010; Kanske & Kotz, 2007; Schacht & Sommer, 2009a). This component seems to be more sensitive to differences in valence than EPN, with greater positivity bias in some cases (Herbert, Junghofer, & Kissler, 2008; Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Kissler et al., 2009) but greater negative bias in others (Kanske & Kotz, 2007; Schacht & Sommer, 2009b). Because LPP is associated to voluntary evaluation of emotion, a congruency effect observed on LPP, would indicate the link between symmetry/random and positive/negative dimensions happens at a later conceptual level.

Additionally, possible alterations of Visual Evoked Potentials (VEP) were also contemplated. After all, the N1 component is sensitive to regularities (Makin et al., 2012b) with greater amplitude for reflection and rotation patterns than random or translation patterns (Makin et al., 2013). N1 amplitude modulations have also been observed in response to arousing and valenced words (Kissler et al., 2009; Scott et al., 2009). In light of previous literature showing N1 sensitivity to both pattern regularity and word valence, we investigated whether N1 amplitudes would differ between congruent and incongruent trials.

This study consisted of two experiments. Experiment 1 was divided in two tasks. Half of the subject classified the valence of the words in the first task, and classified the regularity of the pattern in the second task. The other half of subjects performed the same tasks but with opposite order. In Experiment 2, all participants attended to word valence and pattern regularity simultaneously. After each trial, they classified either regularity or word valence, but they did not know in advance which response was required (for this reason, they were forced to pay attention to both patterns and words). We considered this to be an important factor, since previous studies suggest that symmetry and words must be attended to produce a congruency effect (Bertamini et al., 2013).

2.3 Experiment 1

In Experiment 1, stimuli consisted of black and white abstract patterns with a two-fold reflectional symmetry or random organization. These patterns were generated in the same way as those presented in Bertamini, Makin, & Rampone, (2013). All patterns had a word with either positive or negative valence superimposed on them (**Fig. 1**).

Experiment 1 consisted of two tasks. In one task participants attended to the regularity dimension, and pressed one button for reflection and the other for random (we will name it the Discriminate Regularity task). In the other task participants classified word valence. They pressed one button for positive and another button for negative (Discriminate Word task). Half of subjects performed the Discriminate Regularity task first and Discriminate Word task second, while the order was switched for the other participants.

We focused our analysis on ERPs described in previous literature. First, We were interested in whether the amplitude of Sustained Posterior Negativity (SPN), which is sensitive to symmetry, would differ on congruent and incongruent trials. Second, we explored possible modulations of ERP usually involved in the processing of valence, such as EPN and LPP, In addition, we also investigated whether congruent and incongruent conditions would alter visual evoked potentials, like P1 and N1.

2.3.1 Methods

2.3.1.1 Participants

Forty participants were involved in this study (aged 18 to 40, 9 males, 3 left handed). Participants had normal or corrected to normal vision. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

2.3.1.2 Apparatus

EEG was recorded using a BioSemi Active-Two amplifier in an electrically shielded, and darkened room. EEG was sampled continuously at 512 Hz from 64 AgCl scalp electrodes arranged according to the international 10–20 systems. Two additional electrodes, called Common Mode Sense (CMS) and Driven Right Leg (DRL) were used as reference and ground. Biopolar VEOG and HEOG electrodes were positioned above and below the right eye, and on the outer canthi of both eyes, respectively. The EOG data was obtained from 4 external channels of the same BioSemi amplifier.

2.3.1.3 Stimuli

Stimuli were generated using the Psychopy software (Peirce, 2007) and presented on a CRT monitor with resolution 1280 by 1024 pixel at 60 Hz. The stimuli consisted of patterns generated from a black and white checkerboard (10X10). New patterns were created in each trial so that there was never a repetition of the same pattern. The square was approximately 10° of visual angle. Words were selected from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999), which provides standardized valence, frequency and arousal scores for each word. There were 72 negative words (M= 1.90) and 72 positive words (M= 8.17), with the valence difference highly significant (p< .001). These words were matched for mean frequency and arousal (p= .26). A complete list of the words is provided in supporting material for Bertamini et al. (2013). There were four possible combinations of stimuli, as shown in **Fig. 1**: random with negative words (random-negative), random with positive words (random-positive), reflection with negative words (reflection-negative) and reflection with positive words (reflection-positive).

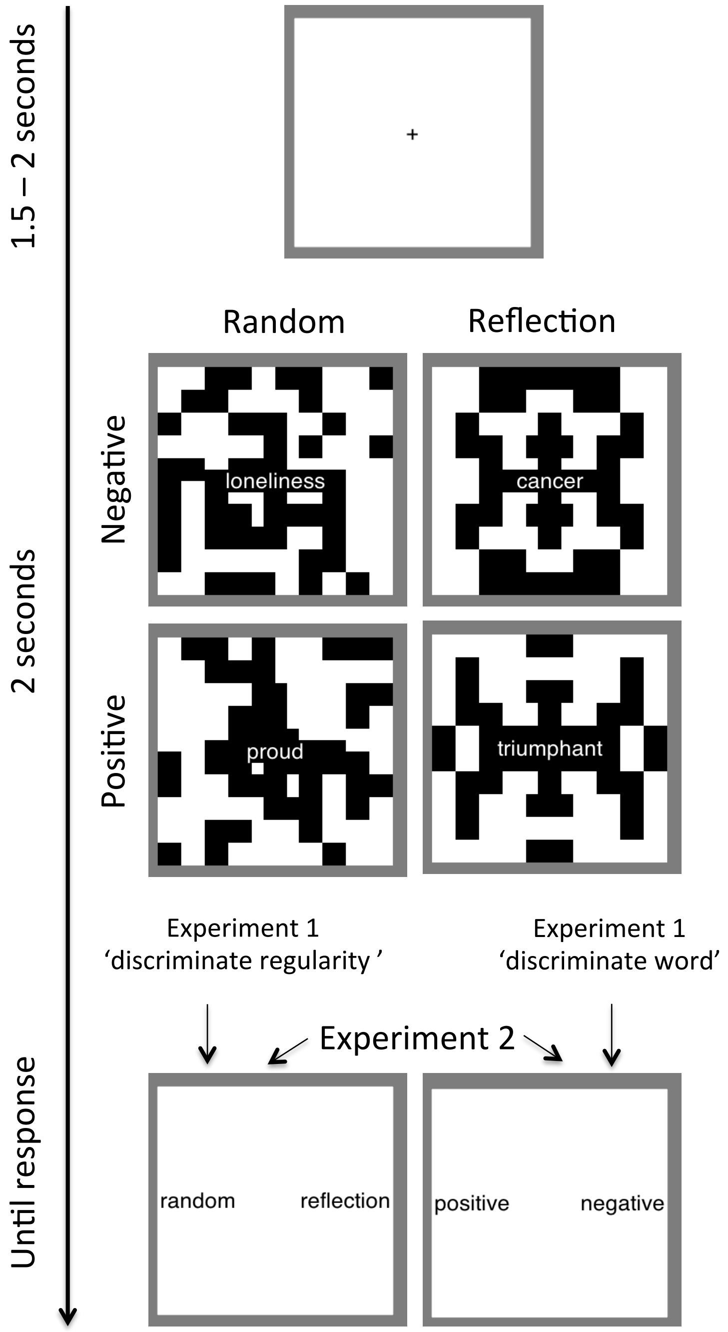

Figure. 1. Trial structure of the Experiments In both Experiments trials began with a fixation screen of variable duration from 1.5 to 2 s. Stimuli were presented at fixation for 2 s. They consisted of abstract novel patterns, reflection or random, superimposed on a word with positive or negative valence. Therefore there were four possible combinations: random-negative and reflection-positive were the congruent conditions; random-positive and reflection-negative were the incongruent conditions. In the Discriminate Word task of Experiment 1, the response-screen asked participants to report the valence of the word as positive or negative. In Discriminate Regularity task of Experiment 1, the response screen asked them to report the patterns as random or reflection. In Experiment 2, one of the two response-screens might appear after stimulus presentation, and participants could not predict which judgment would be required when viewing the stimuli. The position of words on the response screen indicated whether to press the left or right button to enter a particular response. Positioning was reversed in half the trials.

2.3.1.4 *Procedure*

Participants sat 140 cm from the monitor with no head constraint or chin rest. After the electrodes were attached, participants were told to fixate on a central cross during the baseline period and when the patterns were on the screen.

Participants used the 'A' and 'L' buttons of a computer keyboard to enter their responses. Each trial started with a variable inter trial interval (ITI, 1.5 to 2 s) in which a fixation cross was presented. After this, a black and white pattern with a valence word written on the top was presented and remained on the screen for 2 s. The trial structure is shown in **Fig. 1**.

In the Discriminate Regularity task, at the end of each trial the response screen asked to report the regularity of the pattern ("Reflection...Random" or "Random...Reflection"). In Discriminate Word task, participants saw a similar response screen and were required to report the valence of the word ("Positive...Negative" or "Negative...Positive"). The left or right position of the words on the response screen varied between trials, and the position indicated which key to press. For example, if the word Reflection was on the left of the response screen, and the pattern was a reflection, then the correct key was the left key. The configuration of the response screen was counterbalanced across other factors and not predictable for the participants. Participants, therefore, did not know which hand to respond with until the response screen appeared. This procedure was the same used in (Makin et al., 2012) to prevent the development of lateralized motor preparation potentials during the stimulus presentation (Murray, Schrater, & Kersten, 2004).

Each task consisted of 144 trials and was divided into four blocks of 36 trials each. Participants were allowed to take a break to rest between blocks. The tasks followed one after the other with a longer break between them. A practice session, of 20 trials, preceded each task and reproduced the design of the experiment to ensure participants understood the instructions.

2.3.1.5 *EEG analysis*

We used the EEGLAB toolbox in Matlab to analyse the EEG trace offline. Raw data from 64 scalp electrodes were re-referenced to a scalp average, and low pass filtered at 25 Hz. Data was resampled at 128 Hz to reduce file size, and segmented into -0.2 to +2 s epochs, with a -0.2 to 0 s baseline. After this, Independent Components Analysis (Jung et al., 2000) was used to remove artefacts produced by blinks and eye movements. Data was reformed as 64 components, and an average of 7.85 components were removed from each participant (min=4, max=13). After ICA, trials with amplitude greater than ±100μV at any electrode were excluded.

The average proportion of excluded trials did not differ significantly between any of the conditions analysed in both tasks (ranging between 11% and 13% of excluded trials).

Participants were instructed to fixate throughout the trials, and the ICA procedure was employed to eliminate eye movement artefacts. However, this is not enough to remove the cortical consequences of eye movements from the ERP signal. We thus analysed the activation of horizontal and vertical eye movements channel in all conditions. EOG raw data were epoched (-0.2 to 1 s) but were not subjected to any other treatment. Mean EOG activity for the conditions did not differ in any of the two tasks ($p > .1$). This analysis was necessary to ensure eye artefacts did not distort the results.

In line with previous research on symmetry-related ERPs (Makin et al., 2013; Makin et al., 2012) and emotion words ERPs (Scott et al., 2009) we measured amplitudes of specific ERP deflections in the following time intervals: P1 from 100 to 130ms, N1 from 170 to 200ms, Sustained Posterior Negativity from 250 to 1000ms (Makin et al., 2012). EPN component was analysed at the time window 200–300ms (Kissler, Herbert, Peyk, & Junghofer, 2007; Scott et al., 2009). Grand-average ERPs were computed across four posterior electrodes on the right hemi- sphere (P6 P8 P10 PO8) and homologous electrodes on the left hemisphere (Scott et al., 2009). LPP was analysed from a cluster of four centro-parietal electrodes (Pz P1 P2 POz) accordingly to the main studies on this complex (see Citron, 2012).

2.3.2 Results

Each participant saw 72 random patterns with negative words (random-negative), 72 random patterns with positive words (random-positive), 72 reflection patterns with negative words (reflection-negative) and 72 reflection patterns with positive words (reflection-positive). In the Discriminate Word task they attended to the words written on top of the patterns and reported the valence, as positive or negative. In the Discriminate Regularity task they attended to the patterns and reported the degree of regularity as reflection or random. Participants gave the correct response on most trials both in the Discriminate Word task (Mean correct= 98%, SD= 1.01%) and the Discriminate Regularity task (Mean correct= 97%, SD= .95%)

Note that participants responded after the trial, and responses were not speeded. We measured the proportion of correct responses but did not record reaction times. Speeded button presses during stimulus presentation were used in behavioural affective priming studies (e.g. Bertamini, Makin, & Pecchinenda, 2013) but this procedure would have produced motor ERPs, which would have interfered with the effects of interest.

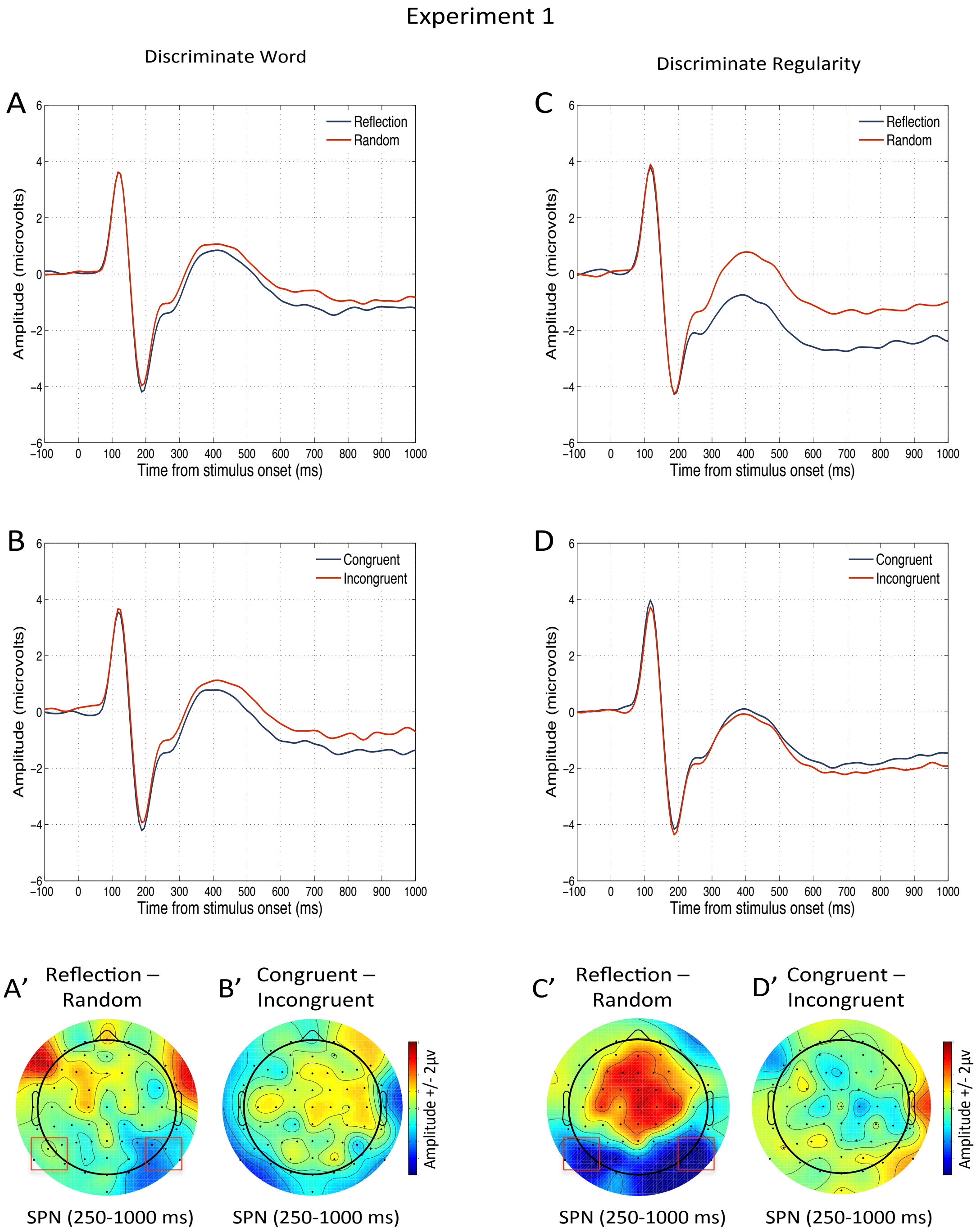

Figure 2 Grand Average ERPs [N= 40] from Experiment 1 the Discriminate Word task and the Discriminate Regularity task are plotted. Panels **A** and **C** show reflection random conditions. (**B**) and (**D**) show congruent and incongruent conditions. (**A′**)–(**D′**) Topographic difference maps at the time window corresponding to the SPN component (250–1000ms). Each map represents a head, and each black dot represents an electrode. The data show the difference between the two conditions. Red squares indicate the electrodes selected for analysis.

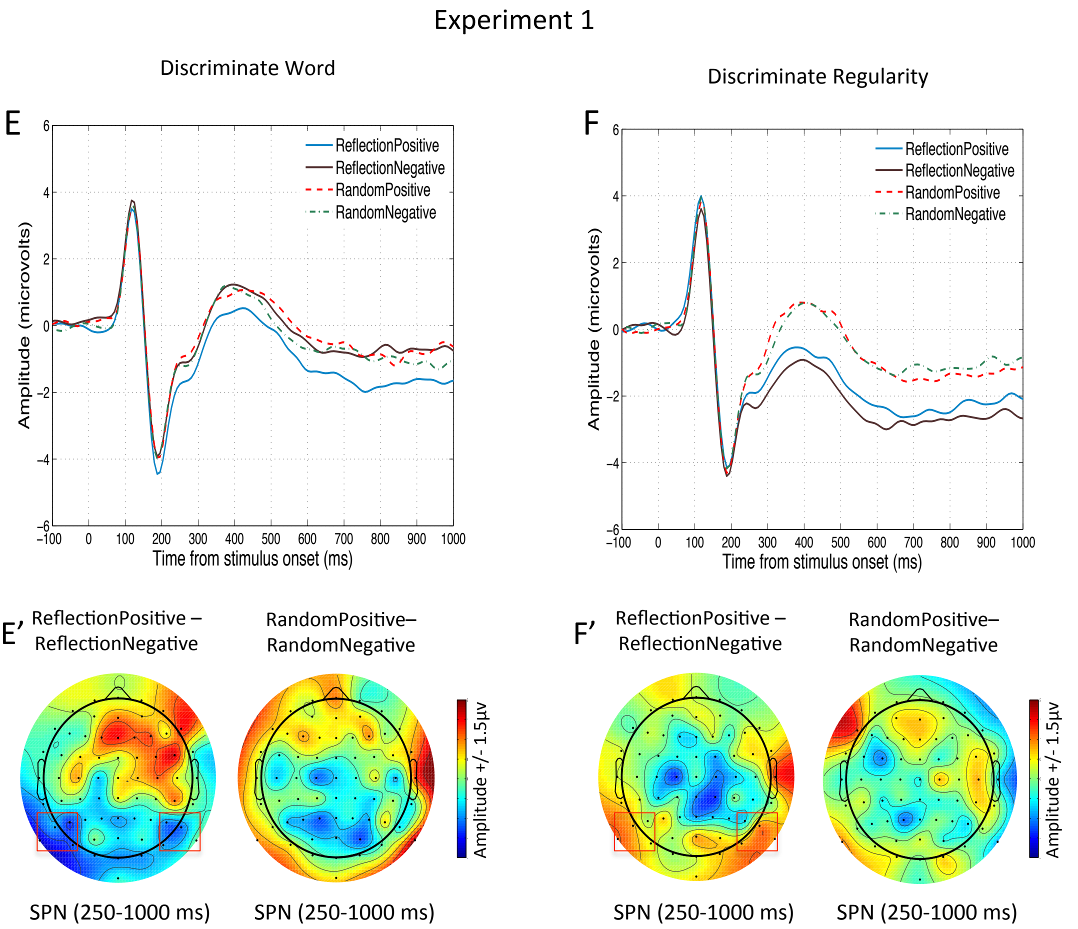

Figure 3. Grand Average ERPs [N= 40] of the sub-conditions of the congruent and incongruent trial from Experiment 1 the Discriminate Word task and the Discriminate Regularity task. (**A**) and (**B**) show reflection-positive, reflection-negative, random-positive and random-negative waveforms. (**A′**) and (**B′**) Topographic difference maps at the 250–1000ms time window for the two sub conditions. Red squares indicate the selected electrodes.

Event related potentials

We were interested in testing the congruency effect in posterior ERPs, which have previously been linked to symmetry and valence processing. The analysis was conducted on the time-windows: 100–130ms (P1), 170–200ms (N1), 200–300ms (EPN) and 250–1000ms (SPN) 500–800ms (LPP). For each time window, we initially performed repeated measure ANOVAs with two within-factors [Task (Discriminate Word, Discriminate Regularity) Congruency (Congruent, Incongruent)]. We followed this by analysing sub conditions of the congruent and incongruent trials [Task (Discriminate Word, Discriminate Regularity) Pattern regularity (reflection, random) Word valence (positive, negative)] where appropriate.

Grand-averages ERPs were collapsed across all 40 participants separately for the Discriminate Word (**Fig. 2A** and **B** and **Fig. 3A**) and the Discriminate Regularity tasks (**Fig. 2C, D** and **Fig. 3B**). Topographic maps in **Fig. 2A′** and **2C′** show the difference between reflection and random conditions at the SPN time window (250– 1000ms), while topographic maps in **Fig. 2B′** and **2D′** show the difference between congruent and incongruent trials. **Fig.3A**, **3B** and **3A′**, **3B′** show ERP waveforms and topographic maps of sub conditions separately for the two tasks. The most important effect was the difference between reflection-positive and reflection-negative waves in the discriminate word task. This congruency effect was recorded at posterior electrodes from 200 to 1000ms. This effect was absent in the discriminate regularity task.

Visual evoked potentials

The P1 component was different between the two tasks (F(1,39)= 4.637, p= .04), with a smaller peak in the Discriminate Word task than the Discriminate Regularity. Congruent and Incongruent conditions showed similar P1 in both tasks (F (1,39)= .695, p= .201). In line with previous findings (Makin et al., 2013, 2012a,b), P1 was identical between reflection and random trials (F(1,39)= .003, p= .923) and in both tasks (F(1,39)= .006, p= .940). P1 was also similar for positive and negative words (F(1,39)= .01, p= .923) and in both tasks (Task Word valence: F(1,39)= .068, p= .795).

N1 showed a marginal effect of Task (F(1,39)= 3.069, p= .08), with Discriminate Word eliciting a smaller peak than Discriminate Regularity. Importantly, there was a Task Congruency interaction (F(1,39)= 5.890, p= .02), because in the Discriminate Word task, N1 was marginally larger in the congruent trials than incongruent trials (t(39)= -1.886, p= .06), as shown in **Fig. 2B**.

We explored this marginal effect further by analysing sub- conditions separately (**Fig. 3**A). The N1 component showed a three- way interaction between Task, Pattern regularity and Word valence (F(1,39)= 6.134, p= .02). Reflection-positive stimuli elicited a greater N1 than reflection-negative stimuli in the Discriminate Word task (t(39)= 2.393, p= .022), while there was no difference between random-positive and random-negative (t(39)= .723, p=

.5). Hence, the congruent interaction between positive words and reflection patterns elicited a unique negative response after 200ms from stimulus onset. **Fig. 2**A shows a more negative wave for reflection patterns than for random patterns (**Fig. 2**A), although this trend was not significant (F(1,39)= 3.094, p= .086). There were no other effects or interactions.

Early posterior negativity and sustained posterior negativity

ERPs at the EPN and SPN latency were explored by analysing the electrodes over the extrastriate visual area in the time windows 200–300ms and 250–1000ms from stimulus onset, respectively. There was a significant main effect of regularity in both components (EPN: F(1,39)= 27.464, p< .001; SPN: F(1,39)= 25.353, p< .001). Reflection patterns produced negative amplitude compared to random patterns. In the SPN time window, there was also a significant Task X Pattern regularity interaction (EPN: F(1,39)= 3.239, p= .08; SPN: F(1,39)= 20.186, p< .001). In the Discriminate Regularity task the difference between reflection and random was highly significant (t(39)= - 8.284, p < .001); while it was weaker in the Discriminate Word task (t(39)= - 3.220, p< .01) (see **Fig. 2**A–C). Word valence did not produce any main effect (F(1,39)= 1.064, p = .31), however, there was a significant Task X Valence interaction (F(1,39)= 5.228, p< .03) because positive words elicited more negative deflection than negative words only in task Discriminate Word (t(39)= -2.437, p= .02).

We were interested on the effect of pattern-words interaction on the SPN component. There was no main effect of Congruency (EPN: F(1,39)= .98, p= .33; SPN: F(1,39)= 2.182, p= .15), but the interaction between Task and Congruency was significant (EPN: F(1,39)= 6.735, p= .013; SPN: F(1,39)= 5.176, p= .03). Paired sample t-test revealed a significant congruency effect in the Discriminate Word task (EPN: t(39)= -2.638, p= .01; SPN: t(39)= -2.798, p= .008), with congruent trials eliciting more negative amplitude than incongruent trials. There was no such effect in the Discriminate Regularity task (EPN: t(39)= 1.177, p= .25; SPN: t(39)= .598, p= .553).

We explored differences between the four sub-conditions. There was a significant three-way interaction of Task, Pattern regularity and Word valence (EPN: F(1,39)= 4.473, p= .041; SPN: F(1,39)= 7.113, p= .01). In the

Discriminate Word task the difference between reflection-positive and reflection-negative stimuli was significant (EPN: t(39)= -2.058, p= .04; SPN: t(39)= -3.681, p= .001). Conversely, the amplitudes of random-positive and random-negative conditions were almost identical (EPN: t(39)= 1.210, p= .23; SPN: t(39)= .713, p= .5). Therefore the congruency effect observed in the Discriminate Word task seems to be exclusively related to the association between reflection patterns and positive words (see **Fig. 3**A).

The analysis of LPP revealed a main effect of Word valence (F(1,39)= 4.889, p= .033) with negative words eliciting a more positive ERP than positive words. There were no other significant main effects or interactions. Finally we also tested whether the above effects might be modulated by task order (Discriminate Word first, Discriminate Regularity first). However, task order had no significant effect on ERPs. In summary the most important effect was the difference between congruent and incongruent waves at posterior electrodes from 250ms onwards. This congruence effect was only present in the discriminate word task, and no such effect was found in the discriminate regularity task.

2.3.3 Discussion of Experiment 1

Experiment 1 investigated affective congruence between patterns and words with ERP techniques. Words with positive or negative valence, but equal level of arousal, were superimposed on black and white patterns containing reflectional symmetry or a random configuration. Importantly, participants performed two separate tasks. In one task they judged the valence of the word and ignored the pattern below. In the other task, they classified the regularity of the pattern and ignored the word. The most important ERP result from Experiment 1 was a difference between congruent and incongruent waves in the Discriminate Word task. This persisted from around 200ms to the end of the epoch. The topography and latency of this difference wave was similar to the symmetry-related SPN. This effect was extended to the N1 component, although the effect was not robust at this latency. Note that we analysed the Early Posterior Negativity (EPN) separately from the SPN and found that these components over- lapped in all conditions. For this reason, we considered these components together. The congruence effect in the Discriminate Word task was not limited only to the EPN latency; it persisted throughout the SPN interval.

The characteristics of other ERPs help explain why we only recorded a congruency effect in the Discriminate Word task. In the Discriminate Regularity task, there was a large SPN, with lower amplitude in the reflection than the random trials. The SPN was reduced, but still present, in the Discriminate Word task. This result suggests that regularity can be processed even if not attended, and other studies have also recorded the SPN under passive viewing conditions (Höfel & Jacobsen, 2007; Makin et al., 2013). Given this evidence that both patterns and words were processed in the Discriminate Word task, it is not surprising that we only found a congruency effect here. Conversely, in the Discriminate Regularity task, resources were focused on pattern regularity, and valence of words cannot be processed as a secondary task.

Note that the term congruent indicates the average of reflection–positive and random-negative conditions and incongruent is the average of reflection-negative and random-positive conditions. However, most of the congruency effect is attributable to the difference between reflection-positive and reflection negative waves, with little difference between random-positive and random-negative waves. Moreover, the reflection positive wave was different from the other three waves. We will return to this aspect in the General discussion.

The analysis of LPP revealed that overall negative words elicited a more positive ERP than positive words. The fact that there was no interaction with task suggested that words valence was not totally ignored in the Discriminate Regularity Task, but the contribution of attention would be important for emotional words to influence the processing of patterns (Bayer, Sommer, & Schacht, 2010; Hinojosa et al., 2010).

In summary, Experiment 1 suggested that reflection could be detected without effort (although the same processes are pronounced when regularity is attended and classified). This pre-attentive symmetry processing interacts with overt, explicit word-valence discrimination, resulting in a difference between congruent and incongruent trials. In Experiment 2 we investigated this issue further by forcing participants to attend to both word valence and pattern regularity on every trial.

2.4 Experiment 2

The design of Experiment 2 was identical to Experiment 1, but participants had to report either the regularity of the pattern or the valence of the word at the end of the trial, and they did not know which dimension would be probed in advance, while the stimuli were on the screen. Therefore, they were forced to attend to both shapes and words simultaneously. Experiment 2 essentially combined the two tasks (the Discriminate Word task and the Discriminate Regularity task) described above in Experiment 1 in one single experiment.

2.4.1 Method

Twenty-four participants[2] (aged 18 to 35, 5 male, 2 left handed) took part. None of these people participated in the Experiment 1. The stimuli were generated in the same way of the Experiment 1, whereas the procedure differed slightly. The response screen, presented immediately after the stimuli, might require either to report regularity or valence.

The type of response screen was counterbalanced across other factors, and, importantly, was not predictable for the participants. Participants therefore were forced to attend both to the pattern and the word.

A linear-detrend procedure was used to remove high amplitude drift from 4 participants. An average of 9.05 components were removed from each participant (min= 4, max= 13). The average proportion of excluded trials did not differ significantly either between trials with random and reflection patterns (13% vs 13%, p= 0.7) or between trials with negative and positive words (12% vs 13%, p= 0.7). However, the interaction between regularity and word valence was significant (p= .03). Slightly more trials excluded in the random-positive condition were more than in the random-negative condition (14% vs 12%, p= .02), while there was no significant difference between

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[2] Note that the number of participants in Experiment 2 (twenty-four) differs from the number of participants in Experiment 1 (forty). Because we did not observe a congruency effect in Experiment 2, one might argue this was due to a lack of power. However we analyzed the data from 24 participants on Experiment 1 and observed a similar pattern of results

reflection-positive and reflection-negative conditions (13% vs 12%, p= .4). EOG analysis was also conducted and did not reveal any significant main effect or interaction (p> .1), suggesting eye movement artefacts were equally spread across all experimental conditions.

ERP analysis was identical to the Experiment 1. We took in consideration the time windows: 100–130ms (P1), 170–200ms (N1) and 250–1000ms (SPN). Mean amplitudes were computed across the same electrodes of the Experiment 1, and conditions analysed were the same as shown in **Fig. 4A–C** and **4A′–C′**. LPP was also analysed in the time window 500–800ms at the same electrodes of Experiment 1.

2.4.2 Results

The experiment consisted of one whole task of 288 trials. Twenty-four participants saw 72 reflection patterns with a positive word, 72 reflection patterns with a negative word, 72 random patterns with a positive word and 72 random negative patterns with a negative word. After each stimulus they might be required to report either the type of regularity of the pattern or the valence of the word. Importantly, participants could not predict what type of response screen they would have been prompted to. This procedure forced them to attend both to patterns and words simultaneously. Participants gave the correct response on most trials (Mean correct= 93%, SD= 2.13%).

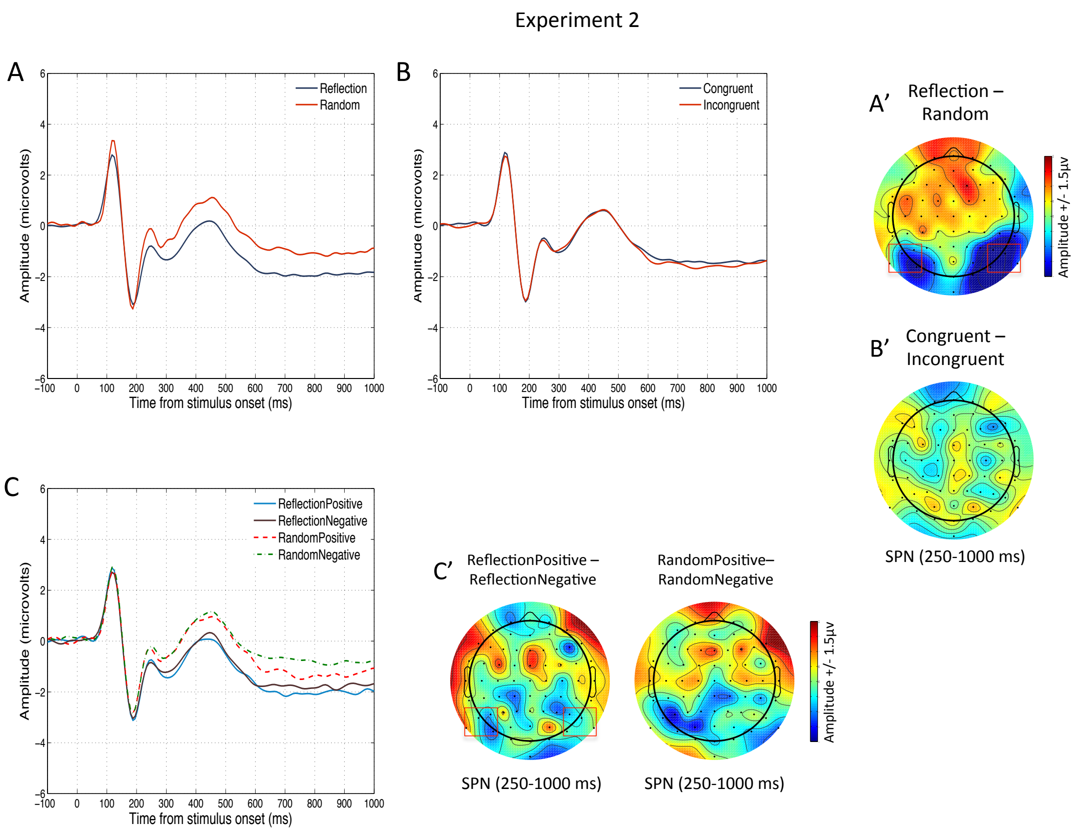

Figure 4 Grand Average ERPs [N1⁄424] from Experiment 2 at the selected electrodes (indicated by the red squares). (**A**) Reflection and random (B) congruent and incongruent (**C**) reflection-positive, reflection-negative, random-positive and random-negative. (**A’**)–(**C’**) Topographic difference maps at the 250–1000 ms time window between the conditions.

Event related potentials

Congruent and Incongruent conditions did not differ in amplitude in the EPN or SPN time-windows (EPN: t(23)= 0.245, p= .8; SPN: t(23)= 0.637, p= .5). There was a main effect of regularity: the amplitude of the reflection wave was significantly more negative than the random wave (EPN: F(1,23)= 14.230, p < .001; SPN: F(1,23)= 28.562; p< .001). There were no other effects or interactions (Fs< 1.0 and ps> .1). Also VEPs were not modulated by any factors in this experiment (Fs< 1.0 and ps> .1). We did not find any effect or interaction at the LPP level except for marginally higher amplitude for negative over positive words (F(1,23)= 3.38, p= .08).

2.1.1. Experiment 2 discussion

In Experiment 2 we only observed difference between reflection and random patterns. This SPN replicates Experiment 1 and previous work (e.g. Jacobsen and Hofel, 2003; Makin et al., 2013). However, we did not find a difference between congruent and incongruent trials, despite the fact that people had to attend to both regularity and word valence within the same trial. This differs from the significant congruency effect recorded in the Discriminate Word task in Experiment 1. One possibility is that participants did not attend to the words and patterns simultaneously in Experiment 2, but rather classified and remembered one dimension, then the other.

2.5 General discussion

In this study we employed an ERP variation of the word-pattern interference task to investigate emotional responses to symmetry. Behavioural studies, employing a similar paradigm, reported a congruency effect between positive/negative words and reflection/random patterns (Bertamini, et al. 2013; Makin, et al., 2012a). In two experiments we investigated equivalent congruence effects on ERPs. We were interested to see whether the congruency between valence and pattern regularity affected the Sustained posterior Negativity, a symmetry specific ERP component (Makin et al., 2012b, 2013). Stimuli consisted in novel abstract patterns with random or reflection configuration. Words with positive or negative valence were superimposed on the patterns. In Experiment 1, participants performed two blocked tasks: One required a classification of words valence (positive or negative). The other task was to report the regularity of patterns (reflection or random). The crucial aspect of Experiment 1 was that both tasks could be performed ignoring the task-irrelevant factor. Conversely, in Experiment 2 both factors were task-relevant in all trials, and participants attended to words valence and patterns regularity simultaneously.

Our most important finding was a congruency effect in the Discriminate Word task on Experiment 1. From around 200 to 1000ms, amplitude was lower in congruent trials than incongruent trials. This overlapped with the Sustained Posterior Negativity (SPN), both in terms of latency and topography. It is instructive that no congruency related ERPs were recorded in the Discriminate Regularity task of Experiment 1, or in

Experiment 2, where participants attended to both word valence and pattern regularity on every trial. We also note that the congruency effect in the Discriminate Word Task of Experiment 1 was largely driven by the unique reflection-positive waveform.

How can we explain these results? It seems that the relationship between word valence and pattern regularity only affects ERP amplitude when participants are deliberately classifying the words as positive or negative and regularity was processed pre-attentively. It could be that participants were put into an evaluative mindset by the word valence classification task, and this overgeneralized, so people spontaneously evaluated the valence of the background patterns as well, and thus noticed relationships between the valence of patterns and words.

The situation was apparently different in the Discriminate Regularity task, in which there were no such congruency effects. Here regularity could have dominated early visual processing, so people did not read the central words at all, or at least did not process word valence. It seems that attention was focused on pattern regularity, and this competed with the processing of word valence. Although emotional words are known to elicit task-independent emotional effects (Kissler, Assadollahi, & Herbert, 2006; Schacht & Sommer, 2009a), some degree of post-perceptual linguistic processing is required for this (Bayer et al., 2010; Hinojosa et al., 2010). It seems that such a process did not occur in the Discriminated regularity task of Experiment 1.

What about the fact that the reflection-positive trials produced a unique wave in the Discriminate Word task? One explanation refers to the target status of patterns and words. Reflection patterns may be classified as targets in a 2AFC reflection/random discrimination task (Makin et al., 2012b), while the random patterns are non-targets (Rothermund & Wentura, 2004). Likewise, positive words are detected more quickly than negative words (Hinojosa et al., 2010; Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009; Kuchinke et al., 2005; Kuchinke, Võ, Hofmann, & Jacobs, 2007; Unkelbach, Fiedler, Bayer, Stegmüller, & Danner, 2008) so positive words might also be targets. This means that in trials where a reflection pattern is combined with positive words, two target stimuli are presented simultaneously. This perhaps explains why the reflection-positive word waveform differs from the others ERPs in the Discriminate Word task.

We also note that the unique reflection-positive wave resembles normal SPN for reflection symmetry, whereas the reflection-negative is similar to random waves. In other words, the symmetry-related SPN was present when positive words were presented on top of the patterns, but not when negative words were presented. It is possible that processing positive words required less sustained attention than negative words; so visual resources were freed to discriminate between regularity of the background patterns, and the familiar SPN component was observed. We could state this in a different way: negative words may activate extra-striate networks, and this blocks the processing of symmetry.

Negative words may block symmetry perception at other levels of the visual hierarchy as well. This is plausible if we consider that processing negative valence and symmetry might involve greater activation of the right hemisphere, for example. It is broadly accepted that the preferential neural substrate of emotions is the right hemisphere (Right Hemisphere Hypothesis: Borod, Haywood, & Koff, 1997). However, there is consistent evidence that the right hemisphere responds especially to negative emotion (the Valence Hypothesis: Davidson, 1995). Curiously, Makin et al. (2012b) reported a right lateralized posterior alpha desynchronization during reflection/random discrimination, which indicates right hemisphere preference for processing symmetry. The fact that both negative words and reflection background involve right hemispheric activation, suggests these two dimensions share common neural substrates.

In addition to modulations of the SPN and EPN in Experiment 1, we also found that LPP amplitude was greater for negative words, replicating other results (Franken, Gootjes, & van Strien, 2009; Gootjes, Coppens, Zwaan, Franken, & Van Strien, 2011; Hofmann et al., 2009; Cacioppo & Berntson, 1994; Kanske & Kotz, 2007; Schacht & Sommer, 2009b; H T Schupp et al., 2000). The networks that generated the LPP might interact with those which process symmetry, although the LPP was produced in conditions where there was no congruence effect, so the nature of these links is unclear.

The findings of this study can be contrasted with previous ERP studies on symmetry evaluation. Hofel and Jacobsen (2007) found that ERPs that distinguished between subjectively beautiful and ugly patterns were absent when there were no explicit instructions to evaluate the patterns aesthetically. Similarly, fMRI studies revealed a “beauty-induced” signal boost only when participants had to classify the symmetric/random stimuli as beautiful or not (Jacobsen, Schubotz, Höfel, & Cramon, 2006). These authors concluded that aesthetic evaluation of abstract patterns is an intentional rather than a spontaneous process. However, in the current study, we found some evidence for automatic evaluation of patterns, at least when people were engaged in a concurrent word evaluation task.

We can also contrast the ERP results with previous behavioural studies, which employed similar stimuli and paradigms. In their affective priming study, Bertamini et al. (2013) presented a pattern for 250ms, immediately followed by a word. When prime patterns were attended and classified, a congruency effect was found: words classification was faster on congruent trials when positive words were preceded by reflection or negative words were proceeded by random, compared to incongruent trials (reflection then negative or random then positive). In Bertamini et al. (2013) stimuli were not spatially and temporally over- lapping as there were in the experiments reported here. However, it is possible that after the 250ms of presentation, sustained responses to symmetry remained, so when words were presented, the visual system might be still tuned to symmetry/random, but it was not directly processing regularity any more, hence the interaction with word valence.

Similarly, in experiments on symmetry and valence that used the implicit association test (Bertamini et al., 2013), patterns and words were alternated in a relatively fast sequence. Participants attended and processed both patterns and words, but never simultaneously. It can be seen that the results of Bertamini et al. (2013) are consistent with results of Experiments 1, in that there is a congruency effect in the absence of simultaneous classification of patterns and words.

2.6 Conclusions

Several behavioural studies have reported an automatic positive response to symmetry, and speculated that neural mechanisms involved in symmetry detection might be connected with those that produce positive affect. The current work supports this theory and shows that the brain is sensitive to the congruence between regularity and word valence dimensions. We recorded a difference between posterior ERP waves on congruent (reflection-positive word or random negative word) and incongruent (reflection negative or random positive) trials. As far as we know, our study is the first that investigates this kind of regularity–valence interaction with EEG. Our results show that this congruency effect exists and occurs relatively early, around 200 ms after stimulus onset. However, this effect was not equivalent in all conditions. When observers evaluated word valence we found a congruency effect, but there was no such effect when they judged pattern regularity. We suggest that this is due to the fact that word valence is easier and faster to evaluate, allowing time and resources to process the valence of the pattern.

Part 2

Exogenous cuing of attention and preference formation for abstract patterns

3 The role of exogenous attention on visual preference formation for abstract patterns

* This study has been submitted for publication as: Rampone, G., Makin, A.J. & Bertamini, M. The role of exogenous attention on visual preference formation for abstract patterns. (submitted to *Acta Psychologica*, currently under revision)

3.1 Abstract

Attention plays a key role in how people process and evaluate stimuli. In this study we used salient events (exogenous cues) in the periphery to drive attention towards target locations. An uninformative peripheral cue was followed by a novel abstract pattern after an interval (inter-stimulus interval, ISI) of 50ms. Participants performed both a discrimination task and then a preference evaluation of the pattern. In Experiment 1, one group of participants made an overt saccade to the target, and we found that a valid exogenous cue reduced response latency (RTs) and increased preference for patterns at the cued location. Another group of participants maintained fixation and moved spatial attention covertly. Cueing affected discrimination performance but not preference. These results support a link between (overt) exogenous attention and preference. Experiment 2 added a no-cue condition. We observed a similar trend (valid > no-cue > invalid) both on performance and evaluation. This confirms a close relationship between attention and preference, but only when oculomotor responses are coupled with attentional orienting. These results highlight an important role of gaze orienting as the link between visual exogenous attention and preference formation.

3.2 Introduction

In many everyday situations people make preference choices and evaluations, from choosing a t-shirt in the wardrobe, contemplating a painting in the museum or being attracted by the shining sign of a restaurant. Exogenous attention, as well as endogenous orienting, plays a critical role.

There is a large literature on the relationship between emotion and attention, with growing interest on the role of attention in modulating affective responses. Several studies have shown that task-irrelevant emotional stimuli are powerful in triggering reflexive shifts of attention (e.g. Finucane, 2011; see also review from Yiend, 2010) – suggesting a connection between the emotional and orienting systems. In this study we tested the opposite relationship: does stimulus-driven shift of attention have an impact on affective responses? We employed an exogenous cuing paradigm (Posner, 1980), which is a well-established technique for the control of attention orienting. Participants evaluated their preference for a non-familiar abstract shape, presented either at the same (valid) or opposite (invalid) location as a cue. Before discussing the specific design of the study, we briefly review what is known about the effect of attention on affective processes.

The affective consequences of visual attention

People's behaviour is guided by the affective value that the brain assigns to objects during (visual) processing. Importantly, there is recent growing consensus that attention influences preference. Attention can be deployed to objects either endogenously (i.e. according to individual's goal) or exogenously (i.e. in response to exogenous stimulation) (Carrasco, 2011; Chica, Bartolomeo, & Lupiáñez, 2013). A pioneering study by Raymond, Fenske, & Tavassoli (2003), showed that attentional selection affects emotional evaluation through the inhibition of the distracting information (see Tipper, 1985). This inhibition is re-instantiated if the distractor is presented again and misattributed to the stimulus in form of affective devaluation. This *distractor devaluation* has been found with a number of different stimuli (see Fenske & Raymond, 2006; Goolsby et al., 2009; Griffiths

& Mitchell, 2008; Martiny-Huenger, Gollwitzer, & Oettingen, 2014; Veling, Holland, & van Knippenberg, 2007), although other studies have shown that attentional selection positively enhanced targets evaluation (Huang & Hsieh, 2013; Yagi et al., 2009). Endogenous attention selection processes have thus been demonstrated to entail evaluative consequences. These, however, may be likely to depend on mental coding of the selection process prior to stimulus exposure: positive codes are assigned to the to-be-selected stimuli, while negative codes are assigned to the to-be-ignored stimuli (Dittrich & Klauer, 2012).

Effects of attention on preference formation have also been shown through the exogenous manipulation of attentional orienting (Armel, Beaumel, & Rangel, 2008; Hare et al., 2011; Lim et al., 2011; Schonberg et al., 2014; Shimojo et al., 2003). Incidental bottom-up variables, either salient stimulus features (i.e. brightness, colour, shape size) (Milosavljevic, Navalpakkam, Koch, & Rangel, 2012; Navalpakkam, Kumar, Li, & Sivakumar, 2012) or stimulus non-related features (Schonberg et al., 2014), have been shown to capture attention and influence preference in favour of the attended item.

Down-stream attentional modulation of preference is out of the conscious intention of the observer and, consequentially, is not biased by prior categorization of attended and non-attended items. The exogenous attention approach thus presents some advantages for the investigation of the emotional consequences of attention.

The studies mentioned so far have used procedures in which two items were compared, and one was attended more than the other. Considering that the brain is constantly presented with a multitude of stimuli every time, and operates by first assigning a value to all of the options under consideration and then comparing them (Rangel, Camerer, & Montague, 2008; Wallis, 2007), it seems logical to investigate attention-depended preference effects with forced choice paradigms. The limit of this approach, however, is that it measures a relative value between the most attended and the least attended stimulus (Lim et al., 2011). Consequentially, it does not clarify whether attention directly alters the value attributed to the different stimuli or preference for the attended stimulus indirectly originates from the exclusion of the unattended stimulus from the consideration set (Orquin & Mueller Loose, 2013).

Current research

In order to investigate whether down-stream attention orienting has direct effect on preference evaluation, we employed a version of the exogenous orienting paradigm (Posner, 1980). Observers saw an uninformative cue on the left or the right of fixation. The target appeared at the same location as the cue (valid location) on 50% of trials, or at the opposite location (invalid location) on 50% of trials. The target was an abstract pattern (symmetrical or random). Participants performed a symmetry discrimination task, giving their response as fast and accurately as possible. After a fixed amount of time, the pattern disappeared and participants made a preference evaluation using a Likert scale (like very much – not at all). This paradigm was different from those used in previous studies. First, bottom-up attention did not depend on target characteristics. Attention orienting was manipulated in a separate step, prior to target appearance. Second, only one stimulus appeared on each trial. Therefore all stimuli were targets. Third, affective evaluation was not based on the comparison between two or more stimuli. Participants evaluated each stimulus independently. We are aware that this type of task does not reproduce real world situations. On the other hand, with this approach we expected to obtain a more direct measure of the emotional consequences of exogenous attentional manipulation.

This study tested the effect of attention on abstract patterns instead of real objects. We chose unfamiliar patterns to avoid artefact associated with individual preferences for specific items (Lebrecht et al., 2012). It is also interesting to compare evaluation of positive and negative items (Albrecht & Carbon, 2014; Armel et al., 2008). Patterns in our study had either a symmetric or random configuration. It has been consistently reported that most people prefer symmetrical stimuli (Bertamini, Makin, & Pecchinenda, 2013; Bertamini, Makin, & Rampone, 2013; Pecchinenda, Bertamini, Makin, & Ruta, 2014; Enquist & Arak, 1994). This regularity effect allowed us to test the effect of attention on stimuli that are universally disliked (random) and stimuli that are universally liked (symmetry). A further advantage of using random and symmetrical patterns was to disguise the research question. We used a post-experiment questionnaire in which participants reported their views about the research aim. This confirmed that participants were unaware of possible cuing influences on their preference ratings.

Peripheral cues were employed in order to trigger a reflexive and reliable shift of attention towards the location of stimulation. The visual system is particularly sensitive to onsets, brightness changes and rapid motion (Franconeri, Hollingworth, & Simons, 2005; Serences & Yantis, 2006; S Yantis & Jonides, 1990), which signal the presence of a new object in the visual field that requires perceptual analysis (Enns, Austen, Lollo, Rauschenberger, & Yantis, 2001; Hillstrom & Yantis, 1994; S Yantis & Hillstrom, 1994)

A cuing paradigm to study preference modulation has been demonstrated with eyes gaze cues (Bayliss et al., 2006). Central face stimuli could look at one of two locations before the appearance of a neutral object. Participants evaluated objects presented at the gazed location more positively than objects presented at the opposite location. This effect, however, is likely to be a consequence of humans' sensitivity to others' gaze direction and not a consequence of attention orienting per se (Bayliss, Frischen, Fenske, & Tipper, 2007; Capozzi, Bayliss, Elena, & Becchio, 2014; Ulloa, Marchetti, Taffou, & George, 2014). In fact, central arrow cues (Bayliss et al., 2006) or pointing hands (Ulloa et al., 2014) did not affect preference evaluation, despite a significant attention effect. Gaze cues, however, are more effective in triggering reflexive orienting than central symbols (Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004; Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006). For this reason they might share more similarities with exogenous abrupt onsets in driving attention.

Gaze shifts are intimately connected with attentional responses to cues. When attention is captured towards a location, an eye movement is automatically prepared towards that location (Kowler, Anderson, Dosher, & Blaser, 1995; Sheliga, Riggio, & Rizzolatti, 1994). In the metaphorical view of attention as a spotlight beam, eyes represent the light that illuminates the attended area. However, the environment carries too much information for the human visual system to process at once. Some locations or objects must be selectively prioritized at the expense of others. A fundamental problem for the visual system is to decide which locations or objects deserve priority. The brain has evolved the capacity of shifting attention to different locations in the space without gazing, and processing extrafoveal information efficiently (e.g. (Mangun et al., 2001; Moore et al., 2003; Michael I Posner et al., 1980). Covert attention is an important strategy for processing information that is either not relevant enough to deserve foveation or is too rapid for a saccade to reach it.

In evaluative and decisional processes, attention and eye movements are, instead, tightly coupled. Gazing at an object is important because it leads to foveation for deeper sensory processing and gathering information about its characteristics. Shimojo, Simion, Shimojo, & Scheier (2003) proposed a model suggesting that the process of preference formation emerges from gazing. In a Two Alternative forced choice task, they presented pairs of faces to the two sides of the screen, and experimentally manipulated the amount of attention (time of foveal inspection) allocated to one of the two alternatives. Only one face was present on the screen at any time, and the two stimuli alternated between the left and the right side of the screen, so that observers had to shift their gaze and foveate one face at a time. They also performed two control experiments in which exposure, without orienting, was manipulated. In the first one, the same presentation sequence was used, but participants were instructed to fixate in the center of the screen throughout the trial. In the second control faces were presented in an alternating manner in the middle of the screen. A preference bias effect for the most attended alternative was observed only when gaze shifts were involved. In the other cases the visual stimuli were retinotopically and temporally identical, but there was no gaze shift. No preference effect was recoded. The study suggested that attending one alternative is necessary but not sufficient for an attentional bias on preference. Gaze allocation is likely to play an implicit causative role in the instantiation of preference (Armel et al., 2008; Krajbich et al., 2010; Schotter, Berry, McKenzie, & Rayner, 2010; Shimojo et al., 2003; Simion & Shimojo, 2006, 2007). This may be consistent with the fact that people interpret others' gaze as reflecting their preference (Ulloa, 2014).

In Experiment 1 we tested the hypothesis that an exogenous cue would improve performance and preference for patterns at cued *(valid)* location. This task required discrimination and preference evaluation of complex patterns, which was likely to elicit the impulse of gazing. One group of participants were instructed to perform a saccade towards the pattern (*overt* condition). However, we also expected a cueing effect on pattern discrimination even without overt orienting. How important is executing a saccade towards the cued location in the modulation of preference? The other half of participants was instructed not to move their eyes throughout the whole task (*covert* condition). If shifting attention is necessary but not sufficient to bias preference choices in the absence of gaze orienting (Shimojo et al., 2003), it is possible that the cuing effect on preference would be cancelled in *covert* conditions.

Experiment 2 tested whether *valid* exogenous cuing increased liking, or whether *invalid* exogenous cuing decreased liking. We replicated Experiment 1 by adding a *no-cue* condition. This provided a baseline against which we could test preference for validly and invalidly cued patterns.

In both experiments we analysed the cuing effect on saccadic reaction times (SRTs), accuracy and manual reaction times (MRTs), as indicators of the effective attentional modulation. To maximise attention at *valid* locations the interval between the offset of the cue and the onset of the pattern (inter-stimulus interval, ISI) was short (50ms) (Chica, Martín-Arévalo, Botta, & Lupiáñez, 2014).

3.3 Experiment 1

Experiment 1 investigated whether orienting attention to a stimulus presented at a pre-cued location changed the affective evaluation of that stimulus. The stimuli used were of two types: random and symmetrical. These patterns were generated in the same way as those presented in Bertamini, Makin, & Rampone (2013) and Rampone, Makin, & Bertamini (2014) (see **Fig. 1**A). Exposure duration of the patterns was fixed at 1.5s, independently of response speed. Moreover, the same pattern was never presented twice. Therefore other factors known to affect preference, namely stimulus duration, repeated exposure and familiarity, were controlled

(Reber, Winkielman, & Schwarz, 1998; Zajonc, 1968). The Inter- stimulus interval (ISI) was 50ms. We expected facilitation on perceptual performance at *valid* (pre-cued) locations, and also expected that this boost of attention would result in enhanced preference ratings for the stimulus presented at that location. Half of the participants performed a saccade towards the pattern before giving their response (*overt* condition: shift of attention + eye movement to target location). The other half of participants maintained fixation throughout the trial (*covert* condition: shift of attention to peripheral target + central fixation).

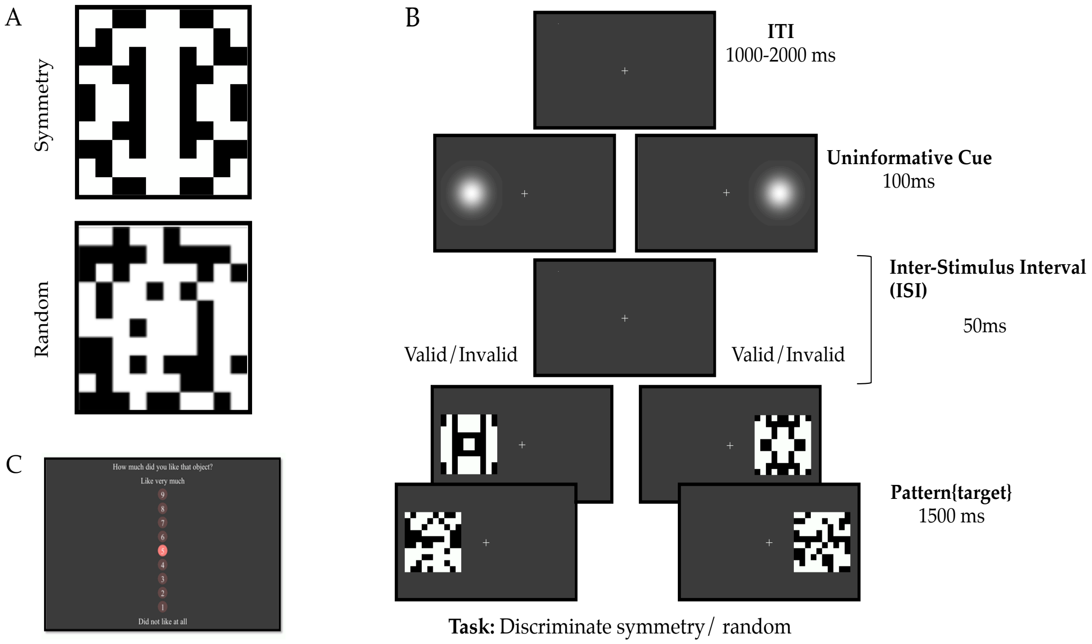

Figure 1. (**A**) Types of stimuli used. (**B**) Sequence of events for each experimental trial. After a variable inter-trial interval (ITI) the cue flashed either on the left or on the right. Note the cue was not-predictive (in 50% of trials it indicated target location. In the other 50% of trials it indicated opposite location). The inter-stimulus interval (ISI) was 50ms. The target stimuli remained on the screen for 1500ms. During this time participant discriminated the degree of regularity of the pattern (random, symmetry) and reported it as fast and accurately as possible. Note that half participants kept fixation until patterns appeared, then they performed a saccade towards the pattern before giving their response. The other participants never moved the eyes from fixation. (**C**) Example of the 9-point rating scale (9- like very much; 1- did not like at all). This was presented after pattern offset and remained on the screen until participants confirmed their selection.

3.3.1 Method

3.3.1.1 Participants

Sixty naïve participants took part in the experiment (15 males, 7 left handed, age 17-34; mean =22). The participants were recruited from the School of Psychology's undergraduate participant panel, gave informed consent, and received course credit for participation. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

3.3.1.2 Apparatus and Stimuli

Participants sat 57cm in front of a 16-in LCD monitor with resolution 1280X1024 pixels at 75Hz refreshing rate. A chinrest aligned to the centre of the screen constrained head position. The left eye movements were sampled at 120Hz using an ASL Eye-Track D6 (Applied Science Laboratories, Bedford, MA) infrared eye-monitoring camera mounted below the screen. Stimuli were generated using the Psychopy software (Peirce, 2007) and controlled by a PC running Windows XP – 32bit.

Stimuli were presented on a dark-grey background (RGB -0.7, -0.7, -0.7 decrement from grey). The fixation mark consisted of a white cross (2^o of visual angle) in the centre of the screen. The fixation cross was presented continuously, with the exception of the evaluation task. Exogenous cues consisted of a local brightness increase (modulated by a Gaussian envelope) with size 400 pixels (~ 12.8^o). Target stimuli consisted of abstract patterns generated from a black and white checkerboard (10 X 10) and measured 320 pixels (~ 10.3^o). The patterns could have either random or two-folded bilateral symmetric configuration (see **Fig. 1A**). Pattern and cue were presented either at the left or the right of fixation, at an eccentricity of 300 pixels (~ 9.6^o). The same pattern was never repeated within the same experimental session. Preference ratings were recorded with a 9-point rating scale presented at the center of the screen (see **Fig. 1C**). Numbers were columned from 9 to 1, headed by the words “Like very much” at the top and the words “Did not like it at all” at the bottom. Nine corresponded to the most positive rating and 1 the most negative. Participants used a gamepad with direction-arrows to give their responses.

3.3.1.3 Procedure

The sequence of events in a trial is shown in **Fig 1B**. Each trial started with a variable inter trial interval (ITI) from a minimum of 1000ms to a maximum of 2000ms. The exogenous cue immediately followed and flashed for 100ms either on the left or on the right of the fixation cross. After an Inter-stimulus interval (ISI) of 50ms, the target-pattern was presented at the same location indicated by the cue (Valid location) 50% of trials, and at the opposite location of the cue (Invalid location) on the remaining 50% of trials. Participants were required to keep fixation until the pattern appeared. Thirty participants performed a saccade towards the pattern as soon as it appeared on the screen (*overt condition*). The other participants maintained eyes at fixation through the whole trial (*covert condition*). Participants were instructed to respond as fast and accurate as possible to pattern regularity. Reponses were given by using the bottom-shoulder buttons of a gamepad. Half of the participants pressed the left button for 'symmetry' and the right button for 'random'; the other half did the opposite. Patterns remained on the screen for 1500ms. In this experiment we ensured all patterns were seen for the same amount of time before being evaluated. The rating scale immediately followed the patterns. Participants moved on the rating scale with the directional up/down buttons of the gamepad, and pressed another button to confirm their choice. After 500ms, the fixation screen was presented and a new trial started. The experiment consisted of 128 trials. There was a break every 32 trials, in which participants could rest and disengage the eyes from the screen.

A practice session of 32 trials preceded the experiment, to ensure participants familiarized with the stimuli. They did not evaluate the patterns during practice, and they were told about this task only before starting the proper experiment. Moreover, in the practice session patterns remained on the screen for 1000ms. If participants did not manage to respond before that time, patterns were replaced by the message "too late" at the centre of the screen for 500ms.

3.3.1.4 Design

A whole experiment consisted of 128 trials, 64 of which were *valid* and 64 *invalid*. Each condition contained 32 symmetric pattern and 32 random patterns. Cue and pattern position was balanced, so that both appeared on the left and right side of the screen the same number of times.

No participant ever saw the same pattern twice. However, all participants saw the same patterns and pattern location was balanced across conditions and participants. In other words, *pattern A* was presented both on *valid* and *invalid* conditions, and both on the left and the right side of the screen. In this way we ensured differences in evaluation between *valid* and *invalid* conditions involved the same patterns.

3.3.1.5 Data Analysis

A 2X2X2 mixed ANOVA was performed. Attention shift (overt vs. covert) was a between-subjects factor, whereas Validity (invalid trials vs. valid trials) and Pattern regularity (random vs. symmetry) were within-subject factors. Mean accuracy and manual reaction times (MRTs) from each subject were computed and analysed to assess exogenous cuing effects on performance. Likewise, preference ratings were analysed to investigate exogenous cuing effect on preference formation.

A 2X2 repeated measures ANOVA (with Validity and Pattern Regularity as within-subject factors) was also performed on Saccadic latency (SRTs) for participants who overtly shifted attention to the patterns.

Finally, an analysis was conducted to check the possibility of a relationship between location of the pattern and key used to classify the pattern as symmetrical or random. Simon spatial compatibility effects may arise when subjects are required to make a rapid left/right motor response to a stimulus dimension other than position, and the stimulus appears either at left or right location (e.g. Simon & Acosta, 1982). Responses are usually faster when stimulus position and position of pressed key correspond. This congruency might also affect preference ratings, as motor fluency is known to influence affect and liking (e.g. Rolf Reber, Wurtz, & Zimmermann, 2004). We tested this possibility with a 2X2X2 ANOVA, in which pattern position (left, right) and pressed key position (left, right) were within-subject factors and attention shift (overt, covert) was between-subject factor. The analysis was performed on manual reaction times and preference ratings.

Data cleaning. In the analysis of the manual response, trials in which MRTs were below 150ms were considered as anticipation and excluded from the analysis (0.1% of trials). Trials in which no response was given during pattern presentation (1500ms) were considered as misses and discarded (2.4% of trials). Criteria for exclusion were also applied for oculomotor responses. Eye movement/saccade-Data were analysed with Matlab. Data loss due to movement artefacts or eye blinks was the 2.8% of trials. In overt conditions, trials in which eyes were not at fixation during the cue period were excluded. A time-window was defined starting at cue onset and extending to 100ms after cue offset (200ms, 24 samples). If the difference between the greatest X-value and the smallest X-value exceeded a threshold of 2° from fixation, trials were discarded. Anticipatory saccadic responses were 5.8% and were excluded from analysis. Moreover, trials in which there was no overt saccadic response to the pattern were excluded (1.5% of trials). Eyes position was calculated by averaging samples within a time window going from 100ms after pattern onset and 1000ms after pattern onset (108 samples). This value needed to be greater than 2° from average fixation to be considered as valid. In *covert* conditions eyes were required to not move from fixation throughout the whole trial. Trials in which eyes moved farther than 2° from fixation were excluded (5.9%).

In total, 6976 trials, which correspond to 90.8% of the original trials, were included in the analysis. Average proportion of trials included was similar for each condition (*random* 90.7%, *symmetry* 91.0%, *invalid* 90.9%, *valid* 91.3%).

3.3.2 Results

Cuing effect on performance

Occulomotor Responses: Saccadic Latency. Thirty participants performed a saccade to the pattern as soon as it appeared (*overt* condition). The main effect of Validity was significant ($F_{(1,29)} = 113.796$, $p < .001$, $\eta^2_p = .797$) (See **Fig. 3A).** The interaction between validity and pattern regularity was significant ($F_{(1,29)}$= 4.941, p = .034, η^2_p = .146), suggesting a greater *valid – invalid* difference for symmetry ($t_{(29)}$ = -11.409, p < .001, d= 4.2) than random ($t_{(29)}$ = -9.107, p < .001, d= 3.4). However, mean saccadic latency towards random and symmetric patterns was similar ($F_{(1,29)}$= .005, p = .943) as shown in **Fig. 2A**. All other main effects and interactions were not significant (p > .1).

Manual Responses: Error Rates. Main effect of Attention shift was significant ($F_{(2,58)}$= 8.676, p = .005, η^2_p = .130). Error rate in the *overt* condition was 5.9% (SE .9). Errors rate in the *covert* condition was 9.6% (SE .9). There was no other significant main effect or interaction.

Manual Responses: Reaction Times. Only trials with correct responses were considered in this analysis. The main effect of Validity was significant, as RTs were faster in *valid* conditions than *invalid* conditions ($F_{(1,58)}$ = 61.446, p < .001, η^2_p = .514) (**Fig. 3B**). Main effect of Attention shift (overt vs covert) was marginal ($F_{(2,58)}$= 3.587, p= .063, η^2_p = .058). This suggests a tendency for faster responses in *covert* conditions than *overt* conditions (difference = 49ms, SE 26ms).

The interaction Validity X Attention shift was also significant ($F_{(2,58)}$= 10.447, p = .002, η^2_p = .153), suggesting greater *valid – invalid* effect when attention was overtly oriented ($t_{(29)}$= -6.422, p < .001, d = 2.4) than covertly oriented ($t_{(29)}$= -4.454, p < .001, d= 1.6). Main effect of Regularity ($F_{(1,58)}$= 2.950, p = .091, η^2_p = .048) and three-way interaction Validity X Pattern Regularity X Attention shift ($F_{(2,58)}$= 3.371, p = .07, η^2_p = .055) were not significant (see **Fig. 2B**). There were no other main effects and interactions (p > .1).

Cuing effect on preference

Fig. 3C shows preference ratings for *invalid* and *valid* condition respectively. Only trials with correct responses were considered in this analysis. The main effect of Validity was significant ($F_{(1,58)}$ = 13.040, p = .001, η^2_p = .184), confirming more positive ratings for *valid* trials than *invalid* trials. There was a Validity X Attention shift interaction ($F_{(2,58)}$ = 4.163, p = .046, η^2_p = .067): the *valid – invalid* difference was significant when attention was directed overtly ($t_{(29)}$= 3.873, p = .001, d= 1.4), but not when participants covertly attended the patterns ($t_{(29)}$= 1.105, p = .278, d= 0.4). Plots in **Fig. 3D** show ratings-bias (*valid – invalid* difference) for each individual. In *overt* condition 21 out of 30 participants showed a positive bias, which means they tended to rate patterns on valid locations more positively. In *covert* condition 17 out of 30 participants showed either null or opposite effect. Descriptively, ratings in the covert conditions were generally more negative than in the overt condition (see **Fig. 3C**). However, this difference did not reach significance ($F_{(2,58)} = 2.687$, $p = .1$).

The main effect of Pattern Regularity was significant ($F_{(1,58)} = 98.831$, $p < .001$, $\eta^2_p = .630$): symmetry was rated more positively than random. Pattern Regularity interacted with Attention shift ($F_{(2,58)} = 7.535$, $p = .008$, $\eta^2_p = .115$) (**Fig. 2C)**. The size of *symmetry – random* difference was smaller in *overt* conditions ($t_{(29)} = 5.336$, $p < .001$, $d = 1.98$) than *covert* conditions ($t_{(29)} = 8.556$, $p < .001$, $d = 3.2$).

Simon spatial compatibility effect

The analysis on manual reaction time did not reveal any significant main effect. The interaction between pattern position and pressed-key position was also not significant ($F_{(1,58)} = .476$; $p = .493$; $\eta^2_p = .008$). Similarly, the correspondence between pattern position and position of key pressed did not affect preference evaluation (all ps > .1).

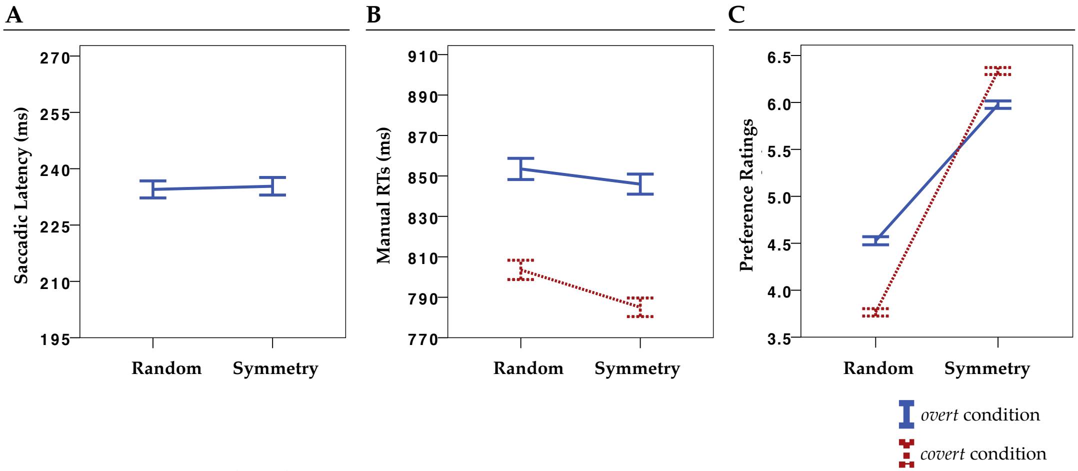

Figure 2. Line graphs show results for symmetry and random patterns in Experiment 1. Solid blue lines indicate overt condition and dashed green lines indicate covert conditions. (**A**) Mean saccadic latency (only for overt condition); (**B**) Mean manual RTs; (**C**) mean preference ratings. Error bars indicate ± 1 SE.

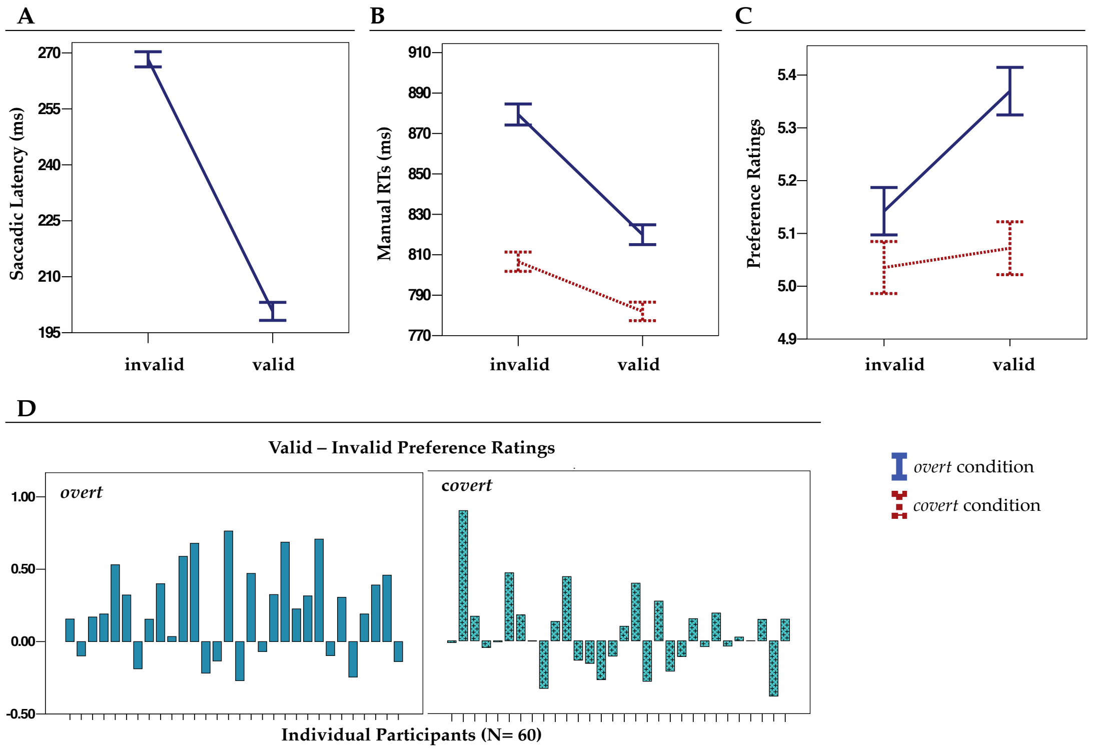

Figure 3. (**A** – **C**) Line graphs show results on invalid and valid trials from Experiment 1. Solid blue lines indicate overt condition and dashed green lines indicate covert conditions. (**A**) Mean saccadic latency (only for overt condition); (**B**) mean manual RTs; (**C**) mean preference ratings. Error bars indicate ± 1 SE. (**D**) Bar graphs for each experiment, illustrating the rating biases shown by individual participants (in the order in which they were recruited). Bars above zero indicate that a participant rated valid patterns more positively than invalid patterns.

3.3.3 Discussion of Experiment 1

In agreement with our expectations, exogenous cuing triggered a reflexive and immediate shift of attention towards one of the two locations. Orienting attention to the cued location resulted in faster pattern discrimination. More importantly, valid cueing enhanced preference, as patterns at cued locations were liked more than patterns at uncued locations.

The comparison of overt and covert shift of attention assessed whether oculomotor responses played a role. Results suggested that a *valid – invalid* effect was significant only when gaze orienting accompanied the shift of attention. The plot showing individual *valid – invalid* ratings evidences the absence of effect for people performing *covert* conditions (**Fig. 3C**).

It has been proposed that factors easing perceptual processing (indicated by faster RTs) affect liking (Reber et al., 1998; Reber, Wurtz, & Zimmermann, 2004). As exogenous cues facilitate perception at valid locations, one could argue that the *valid – invalid* effect observed on preference is associated with the cueing effect on manual reaction times. However, there was *a validity* effect on manual reaction times both in *overt* and *covert* conditions. As the brain efficiently reacted to exogenous cuing even without foveation, it is unlikely that preference modulation in *overt* conditions resulted from response facilitation in the discrimination task. Results from Experiment 1 therefore suggest that preference modulation was linked to attention orienting, but not necessarily to performance facilitation.

Why does valid cueing enhance preference only when a saccade to the pattern was performed? Integrating oculomotor responses to either cued or uncued patterns might play a critical role for the *valid – invalid* difference observed on preference. This is in line with the hypothesis that instantiations of preference emerges from gaze orienting mechanisms (Krajbich et al., 2010; Shimojo et al., 2003). A reversed possibility cannot be excluded. Orienting of attention to a location is accomplished through activation of a specific oculomotor program (Belopolsky & Theeuwes, 2009; Rizzolatti, Riggio, Dascola, & Umiltá, 1987). Oculomotor responses are highly sensitive to abrupt onsets (Ludwig, Ranson, & Gilchrist, 2008). *Valid – invalid* effect on preference might be nullified in *covert* conditions because of top-down inhibitory control exerted on saccadic response. Inhibitory control over the prepotent motivation of performing an action (i.e. gazing at the pattern) may have negative influence on evaluation (e.g. (Doallo et al., 2012; Fenske et al., 2005; Kiss et al., 2008; see also Filevich, Kühn, & Haggard, 2012). We assume top-down inhibition of the foveation reflex was applied both on valid and invalid trials during covert performance. Possibly this inhibitory control overwhelmed the cuing effect and levelled off the difference between the valid and invalid conditions. A third (less probable) alternative could be that the reduced *valid – invalid* effect results from moderate amount of neural activity with covert shift of attention compared to overt shift (Beauchamp, Petit, Ellmore, Ingeholm, & Haxby, 2001). Note that facilitation on manual reaction times was significantly smaller in covert conditions. It is possible that lower neural activity in covert was not sufficient to elicit a cueing effect on preference.

Finally, it was interesting that pattern regularity did not alter the cuing effect. As mentioned in the Introduction, a preference for symmetry over random was expected. Consistently with our prediction, participants used mainly the lower part (5 to 1) of the rating scale for random patterns and the upper part (5 to 9) for symmetry. In a recent study Albrecht & Carbon (2014) observed that improving the perceptual accessibility of stimuli amplified the valence of the stimuli: that is, positive stimuli were evaluated more positively and negative stimuli were evaluated more negatively. In a 2-AFC task, experimentally boosting attention to one item enhanced the probability of choosing appealing items and decreased the probability of choosing aversive items (Armel et al., 2008). On the contrary, we observed that modulations induced by exogenous cuing were similar for symmetry and random.

In summary, this first experiment showed that exogenous cueing captures attention, and enhances preference for patterns at valid locations. The experiment also suggested a causative role of overt gaze orienting in the *valid – invalid* preference effect. Experiment 2 was conceived in order to replicate the results and understand whether the *valid – invalid* effect results from positive evaluation of *valid* patterns or devaluation of *invalid* patterns.

3.4 Experiment 2

Experiment 2 was similar to Experiment 1. The only addition was a *no-cue* condition added to the *valid* and *invalid* conditions. In the *no-cue* condition patterns were not preceded by a cue. The aims of this experiment were two. First, we were interested in ensuring that *valid – invalid* effect on evaluation observed in Experiment 1 could be replicated. Second, we aimed to understand whether this effect was *positive* (valid patterns will receive higher ratings than *invalid* and *no-cue*) or *negative* (invalid patterns receive lower ratings than *valid* and *no-cue*). In Experiment 2 all participants overtly oriented their attention to the patterns as soon as they appeared.

3.4.1 Method

3.4.1.1 Participants

Thirty participants (undergraduates from the School of Psychology; 9 males, 3 left handed, aged 18-26; mean = 19.4) took part in the experiment. None of them participated in any similar study.

3.4.1.2 Procedure

The experiment was similar to Experiment 1. However, this time there was a third *no-cue* condition. After the initial fixation period (ITI 1000ms-2000ms), the cue could flash at the left or the right of fixation for 100ms (*cue* condition, identical to Experiment 1). In the *no-cue* condition, the fixation screen remained for the same amount of time. The Inter- stimulus interval (ISI) was 50ms. The target-pattern was presented either at the left or the right side of the fixation cross, and remained on the screen for 1500ms. In 33.3% of trials, pattern location was the same location indicated by the cue (*valid* location). On other 33.3% it appeared at the opposite location of the cue (*invalid* location). The remaining 33.3% corresponded to the *no-cue* condition, in which attention was not cued to any specific location. Participants were required to keep fixation and to perform a saccade towards the patterns as soon as it appeared. Participants were instructed to respond to pattern regularity as fast and accurately as possible.

3.4.1.3 Design

The experiment consisted of 144 trials, 48 of which were *valid*, 48 *invalid* and 48 *no-cue*. Each of the validity condition contained 24 symmetric pattern and 24 random patterns. The location of cues and patterns on the left and right of fixation was balanced. No participant ever saw the same pattern more than once. However, the same patterns and patterns location were balanced across conditions and participants. In other words, pattern A was presented on *valid*, *invalid* and *no-cue* conditions, and both on the left and the right side of the screen.

3.4.1.4 Data Analysis

A 3X2 repeated measure ANOVA was performed with Validity (invalid, valid, not-cued trials) and Pattern regularity (random vs. symmetry) as within-subject factors. Mean saccadic latency, manual reaction times (MRTs) and accuracy from each subject were computed and analysed to assess exogenous cuing effects on performance. Likewise, patterns ratings were analysed to investigate exogenous cuing effect on preference formation.

Data cleaning. In the analysis of the manual response data, trials in which MRTs were below 150ms were considered as anticipation and excluded from the analysis (0% of trials). Trials in which no response was given before the 1500ms of pattern exposure were considered as misses and discarded (2.4% of trials). Criterions of exclusion on oculomotor responses were the same applied in Experiment 1 (overt condition). Data loss due to movement artefacts or eye blinks was 3.4% of trials. Deviations from fixation during the cue period, and in the time window between cue-offset and 100ms after pattern-onset, were excluded (2.5% of trials). Finally, trials in which no overt saccadic response was performed before 1000ms from pattern onset were considered as misses and excluded (1.25% of trials).

In total, 3820 trials, which correspond to 88.4% of the original trials, were considered in the analysis. Note that although the proportion of excluded trials was considerable, the average proportion of trials on each condition was similar (random 80.0%, symmetry 88.8%, *invalid* 87.6%, *no-cue* 90.6%, *valid* 88.8%).

3.4.2 Results

Cuing effect on performance

Oculomotor Responses: Saccadic Latency. The main effect of Validity was significant ($F_{(1,29)} = 125.215$; $p < .001$, $\eta^2_p = .812$). A *valid* > *no-cue* > *invalid* linear trend was significant ($F_{(1,29)} = 161.870$; $p < .001$, $\eta^2_p = .848$). Results are shown in **Fig. 4A**. Pairwise comparisons showed significant *invalid – valid* effect (82ms, SE= 6, p < .001). Moreover significant *invalid – no-cue* effect (15ms, SE= 4.8, p = .011) and *no-cue – valid* effect (67ms, SE= 5, p < .001) were also observed. No other main effects or interactions were observed (p > .1).

Manual Responses: Error Rates. Overall 98.3% of responses were correct. No significant main effects or interactions were found ($p > .1$)

Manual Responses: Reaction Times. The main effect of Validity was significant on MRTs ($F_{(1,29)} = 30.709$; $p < .001$, $\eta^2_p = .514$), and there was a significant linear contrast ($F_{(1,29)} = 62.781$; $p < .001$, $\eta^2_p = .684$), suggesting a *valid* > *no-cue* > *invalid* trend. Results are shown in the **Fig. 4B**. Pairwise comparisons revealed: significant difference *valid – invalid* (- 61ms, SE= 8, $p < .001$); significant difference *valid – no-cue* (- 41ms, SE= 8, $p < .001$); marginal difference *no-cue – invalid* (- 20ms, SE= 8, $p = .06$). No other main effects or interactions were observed ($p > .1$).

Cuing effect on Preference

Only the trials in which pattern regularity was correctly classified were analysed. The main effect of Validity was significant ($F_{(1,29)} = 6.251$; $p = .003$, $\eta^2_p = .177$). Significant linear contrasts (*valid* > *no-cue* > *invalid*) were observed on preference ratings ($F_{(1,29)} = 7.739$; $p = .009$, $\eta^2_p = .21$). Results are shown in the **Fig. 4C**. Pairwise comparisons confirmed significant *valid – invalid* difference (.29, SE= .1, $p = .03$). The difference *valid – no-cue* was not significant (.17, SE= .07, $p = .08$). Also, the difference between *invalid – no-cue* was not significant (-.12, SE = .06, $p = .2$). The main effect of Pattern regularity was significant: Random was liked less than symmetry ($F_{(1,29)} = 58.707$; $p < .001$, $\eta^2_p = .669$). The interaction between Validity and Pattern regularity was not significant ($F_{(1,29)} = .601$; $p = .551$, $\eta^2_p = .020$).

Simon spatial compatibility effect

The effect was investigated both on manual reaction time and preference evaluation. In both cases the interaction between pattern position and pressed-key position was not significant and there were no main effects (all ps > .1).

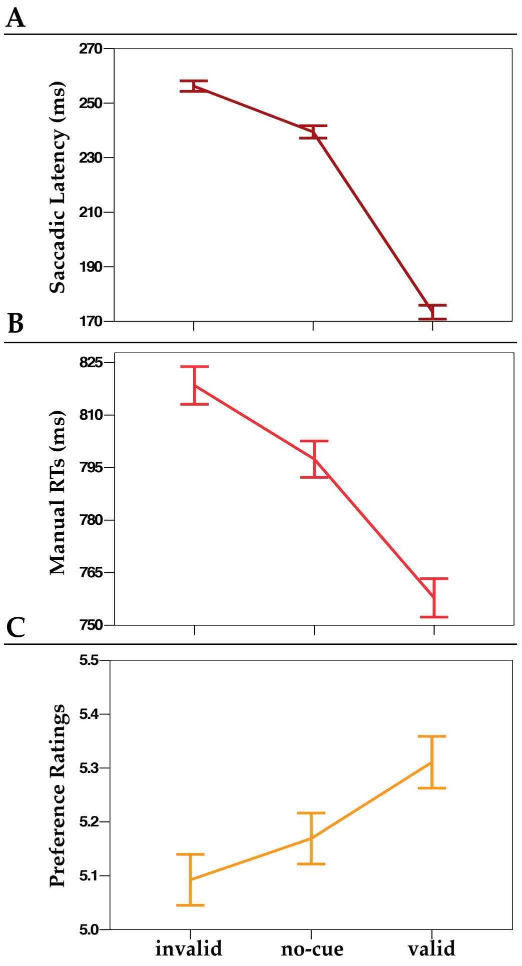

Figure 4. Results from Experiment 2 for invalid, no-cue, and valid conditions. (**A**) Saccadic latency; (**B**) manual reaction times (MRTs); (**C**) preference ratings. Error bars: ± 1 SE.

3.4.3 Discussion of Experiment 2

Experiment 2 was similar to Experiment 1. The additional *no-cue* condition allowed us to test the *valid – invalid* effect on preference against a baseline. The *valid – invalid* difference emerged on saccadic latency, manual reaction times, and preference evaluation. Specifically, two main findings emerged. First, exogenous cuing was confirmed to modulate attentional orienting and this was reflected on preference evaluation. Second, the presence of a baseline condition (*no-cue*) highlighted the nature of this effect. It has been suggested that the overall cuing effect is not simply a boost of attention and facilitation towards the cued location. Some costs of (re)-orienting attention to the opposite location may be involved (Posner, 1980).

For all three dimensions analysed there was a similar trend across cuing conditions: *valid* < *no-cue* < *invalid*. Pairwise comparisons suggested that both positive (*no-cue - valid*) and negative (*invalid - no-cue*) effects were significant on saccadic latency. Therefore overt orienting benefited from pre-cuing of target location. In invalid conditions a saccade might be activated in response to the cue. This might involve the inhibition and reprogramming of a new saccade towards the location of the target leading to a cost in latency. For manual reaction times a clear facilitation on valid trials was observed, as *valid – invalid* and *valid – no-cue* differences were both significant. The difference *no-cue – invalid* was only a marginal tendency, instead. This is in line with previous cost-benefit analyses of effect of exogenous cues on manual response times (Lambert & Duddy, 2002; Tepin & Dark, 1992). It suggests that cue-to-target validity facilitates perceptual processing of targets (Chica, Lasaponara, Lupiáñez, Doricchi, & Bartolomeo, 2010). In preference evaluation the linear trend was similar to that observed in performance but there was no clear dominance of a positive effect (*valid – no-cue*) over the negative effect (*no-cue – invalid*).

Although a full discussion of the integration of motor responses in attentional orienting goes beyond the scope of this study, it is necessary to highlight this aspect, as it is relevant for preference evaluation. Exogenous cuing favoured gaze orienting to cued locations but delayed saccadic responses to other locations. Manual responses mainly benefited from valid cueing. Instead, the difference in time required for responding to invalid patterns and baseline patterns was only marginal. The effect on preference was thus more similar to the effect on saccadic responses than the effect on manual responses, showing a combination of benefits and costs affecting liking evaluation.

For the second time the results obtained revealed two important findings: First, the *valid – invalid* effect on preference reflects the *valid – invalid* effect observed on performance. Second, facilitation on manual reaction times is not directly linked to the *valid – invalid* effect on preference. Oculomotor movements are a sensitive and reliable measure of attentional orienting in both cognitive and applied research (see Glaholt & Reingold, 2011). Manual responses were given after saccadic response and also required a conscious processing of the stimulus. Therefore MRTs may represent a secondary effect of attentional orienting. We will come back to this in the General Discussion.

Experiment 2 confirmed that exogenous cuing triggers attention towards one location, with both beneficial and detrimental consequences. As observed in Experiment 1, preference evaluation is affected by gaze orienting behaviour, and not necessarily by modulation on manual responses.

3.5 General Discussion

People are frequently confronted with new stimuli that influence and direct their behaviour. How the human brain uses attention in relation to emotional decisions has been the focus of recent research. In this study we showed that exogenous manipulation of attention affects people's preference evaluation of abstract objects presented at cued locations.

Our study presented substantial differences from previous tasks employed to study attention effects on (preference) choices. In our paradigm participants were not confronted with two (or more) stimuli at the same time. Therefore our procedure was designed to avoid a situation in which two stimuli were present in one trial, and thus subjected to contrasting effects of attention and classification. Instead, we tested the effect of bottom-up attention on evaluation of a stimulus that was cued (in some trials) or uncued (in other trials). In Experiment 1 we asked one group of participants to overtly shift their attention to the target, whilst other participants maintained fixation through the whole experiment. Overall, patterns were liked more when they appeared at the cued location. However, this *valid – invalid* effect was present only when participants overtly attended the patterns. Although the cueing effect on manual reaction times persisted in *covert* conditions, the cueing effect on preference was not present. Experiment 2 added a *no-cue* condition as a baseline. We found a significant linear tendency (*valid* > *no-cue* > *invalid*) in all the dimensions analysed (preference evaluation, saccadic responses, and manual reaction times).

Overall our results support the theory that attention has a causal effect on preference formation (Fenske et al., 2005; Fenske & Raymond, 2006; Hare et al., 2011; Huang & Hsieh, 2013; Lim et al., 2011; Martiny-Huenger et al., 2014; Schonberg et al., 2014; Simion & Shimojo, 2006, 2007; Yagi et al., 2009). This study enriches current knowledge by evidencing that the effect of attention on preference manifests also in absence of competing stimuli.

These experiments confirmed that peripheral cues affect emotional responses similarly to that observed with eye-gaze cues, and unlike central arrows (Bayliss et al., 2006). Although exogenous cues have no social value, they share an important aspect with gaze cues that central arrows do not have. They trigger a reflexive oculomotor response. Similarly, observing eye-gaze shifts can elicit (oculo)-motor brain activity (Pierno et al., 2006; Pierno, Becchio, Tubaldi, Turella, & Castiello, 2008). Corneille, Mauduit, Holland, & Strick (2009) employed dogs' heads in order to cue attention towards target objects. Heads could be either oriented toward the target (*valid*) or looking straight ahead (*no-cue*) or oriented away from target (*invalid*). Authors measured valence acquisition (positive – negative) of the stimuli as a function of cue orientation. Similarly to our results, a linear trend *toward* > *ahead* > *away* was observed. Hence orienting gaze to exogenous cues presented interesting similarities with perceiving others' gaze orientation in the modulation of affective responses.

Moreover, our results confirmed that some degree of affect emerges from the reflexive and involuntary involvement of sensorimotor processes (Shimojo et al., 2003). This was observed in Experiment 1, in which covertly attending to the patterns, in contrast to overtly attending with a saccade, cancelled the cueing effect on preference evaluation. Also in Experiment 2 the effect on preference reflected the effect on oculomotor processes.

It was interesting that, in Experiment 2, invalid cue-to-target contingencies delayed saccadic responses. In an invalid trial the attentional focus is directed towards the cued location, until the pattern appears at the opposite location. At this point, a prepared oculomotor program must be inhibited and a new program is formulated. Research has shown that the process of redirecting attention on invalid trials triggers the specific activation of a right lateralized fronto-parietal cortical network (see the review from Corbetta, Patel, & Shulman, 2008). The involvement of prefrontal cortex (ventrolateral and dorsolateral) in the inhibition and redirection of responses is believed to affect judgments (Doallo et al., 2012; Fenske et al., 2005; Fragopanagos et al., 2009). Moreover, attention reorienting after invalid cues has been suggested to trigger the activation of the Orbito-frontal cortex, a well-known brain area in emotional regulation (Nobre et al., 1999).

At this stage we can confirm that manipulation of attention alters the affective (liking) value attributed to visual stimuli, in that patterns at the focus of attention were liked more than stimuli outside the focus of attention. We also can highlight a close similarity between oculomotor responses and preference formation. Perhaps gazing towards the source of repeated stimulation (valid location) was critical in enhancing preference. Alternatively, the inhibition and redirection of the oculomotor response in invalid trials might have led to devaluation.

With respect to the validity effect on preference, one could argue that a *valid – invalid* effect may depend either on a direct effect (the orienting system is responsible for affective response) or an indirect effect of attention (attention facilitates performance of the task eliciting a sense of fluency, which is attributed to the target). The concept of perceptual fluency as a source of hedonic experience (Pitor Winkielman, Schwartz, Reber, & Fazendeiro, 2003) suggests that any perceptual factor that leads to facilitation (as measured by speed or accuracy) has a positive effect on preference (Reber et al., 1998; Reber, Wurtz, et al., 2004). Faster manual reaction times at cued location indicate that stimuli were processed and recognized more easily. This perceptual improvement might lead to enhanced preference. However, if this were the case, we should have observed a valid – invalid in the *covert* condition of Experiment 1. Moreover, we should have observed a clear preference for valid patterns over invalid and over no-cue patterns in Experiment 2. It is unlikely that preference modulation resulted entirely from fluent processing of pattern regularity at valid locations. Therefore, we suggest that modulation of liking was implicitly connected with orienting mechanisms. On the contrary, mere cuing facilitation on perceptual processing of the patterns was not causative of the effect.

Finally, our paradigm avoided any artefact due to categorization of stimulus identity (see Dittrich and Klauer, 2011) or better memorization/recognition of the attended stimulus (Yagi, Ikoma & Kikuchi, 2009) at the time of evaluation. In this study patterns were evaluated immediately after response and were all labelled as targets. Therefore we can argue that attention was the only factor influencing preference (in addition to regularity).

Our results provide evidence that orienting attention to a peripheral cue can enhance the value of an abstract pattern shown at the same cued location. With an exogenous cuing paradigm we observed that people rated abstract patterns at cue location more positively. Our findings have useful implications for cognitive and applied research, as they suggest that attention can modify people's affective responses to objects. Our study paves the way for future research, as this approach needs to be tested and replicated with other types of stimuli and might be integrated to designs usually employed in decision-making and visual selection research.

3.6 Control: Experiment 3a, 3b

The exogenous shift of attention is transient, unless top-down control is used to keep attention in place at the cued location. After a while attention is disengaged from the cued location and oriented toward novel locations in the visual field. Moreover, an inhibitory process might be instantiated, preventing attention from returning to the previously attended location (inhibition of return, IOR) (see reviews from Klein, 2000; Lupianez, Klein, & Bartolomeo, 2006). Experiment 3a and 3b explored the relation between attention and preference by increasing the duration of the Inter-stimulus interval (ISI). The experiment was designed to be as similar as possible to Experiment 1a. Only one ISI interval was employed in each experiment. In Experiment 3a ISI was 475ms, in Experiment 3b ISI was 900ms. Like in Experiment 1a (this refers to the *overt* condition of Experiment 1), participants executed a saccade towards the pattern as soon as it appeared on the screen before responding to regularity. After this, they reported a preference rating.

We expected the magnitude of the valid – invalid effect on SRTs and MRTs to decrease or disappear with increasing ISI, and this should reflect on preference evaluation. At long ISI, inhibitory mechanisms might be also activated, preventing attention from returning to previously cued locations (Inhibition of return, IOR). In this case we might expect faster orienting towards the invalid locations and possibly enhanced preference for invalid patterns.

3.6.1 Method

Forty participants (undergraduates from the School of Psychology) performed this study (6 males, 5 left handed, aged 17-22 μ=19). Stimuli, design and procedure were identical to Experiment 1a. This time the inter-stimulus interval (ISI), between the offset of the cue and the onset of the pattern, was increased. The exogenous cue was flashed for 100ms, similarly to previous experiments. In Experiment 3a, the inter-stimulus interval (ISI) between cue offset and pattern onset was 475ms. In Experiment 3b ISI was

900ms. Patterns remained on the screen for 1500ms like in the previous experiments.

For each experiment 2X2 repeated measure ANOVA was performed with two within-subject factors, Validity (invalid trials vs. valid trials) and Pattern regularity (random vs. symmetry). Performance analysis was conducted on mean manual reaction times (MRTs), accuracy and saccadic reaction times (SRTs). Analysis of aesthetic evaluation was conducted on mean ratings.

Data cleaning - Experiment 3a [ISI 475ms]. In total 2283 trials, corresponding to 89% of the original data, were considered in the analysis. The number of excluded trials was distributed homogeneously across conditions (random 88.5%, symmetry 89.8%, invalid 87.4%, valid 90.9%).

Data cleaning - Experiment 3b [ISI 900ms]. In total 2405 trials were analysed, which correspond to 93.9% of the original trials. The number of trials on each condition was similar (random 93.5%, symmetry 94.3%, invalid 94.6%, valid 93.8%)

3.6.2 Results

Figure 5 shows the magnitude of the 'validity effect' on preference ($VE_{preference}$: valid – invalid mean ratings) and 'validity effect' on saccadic latency (VE_{SRT}) and manual reaction time (VE_{MRT}) (invalid – valid mean reaction times). Effects from Experiment 3a (middle plot) and Experiment 3b (bottom plot) are compared with Experiment 1a (top plot).

Experiment 3a [ISI 475ms]. Preference ratings were not affected by cuing with this ISI ($F_{(1,19)}$ = .867; p= .36, η^2_p = .044). The only significant difference was between ratings for symmetry (mean 6.2 ± SE .24) and random (4.1 ± .16) ($F_{(1,19)}$ = 52.04; p < .001, η^2_p = .733). Pattern regularity and Validity did not interact (p > .1). Accurate responses were 95.3%. Accuracy on valid trials (95.1% ± 1.3) did not differ from accuracy on invalid trials (94.19% ± 1.6) ($F_{(1,19)}$ = .073; p= .79, η^2_p = .004). Similarly, there was neither facilitation nor IOR on MRTs (in*valid – valid:* 4ms ± 20ms; $F_{(1,19)}$ = .301; p= .59, η^2_p = .016). Also SRTs were not affected by attentional cuing (in*valid – valid:*

13ms ± 10ms; $F_{(1,19)}$ = 1.337; p= .26, η^2_p = .066). There were no other main effects or interactions (p > .1).

Experiment 3b [ISI 900ms]. Preference for patterns at valid locations were not significantly different to those at invalid locations (*valid* 5.06 ± .09; *invalid* 5.1 ± .11) ($F_{(1,19)}$ = .680; p= .420, η^2_p = .035). The difference between random (4.02 ± .18) and symmetry (6.15 ± .14) was significant ($F_{(1,19)}$= 69.649; p = .001, η^2_p = .786). No other main effects or interactions were found (p > .1). 95.6% of manual responses were correct. There was no main effect of validity either on accuracy (*valid* 95.6 ± .67; *invalid* 95.45 ± 1.1; $F_{(1,19)}$ = .031; p= .863, η^2_p = .002) or MRTs (in*valid – valid:* 9ms ± 8ms; $F_{(1,19)}$ = 1. 439; p= .245, η^2_p = .07) or SRTs (in*valid – valid:* 9 ± 16ms; $F_{(1,19)}$ = .278; p= .604, η^2_p = .014). No other main effects or interactions were found (p >.1).

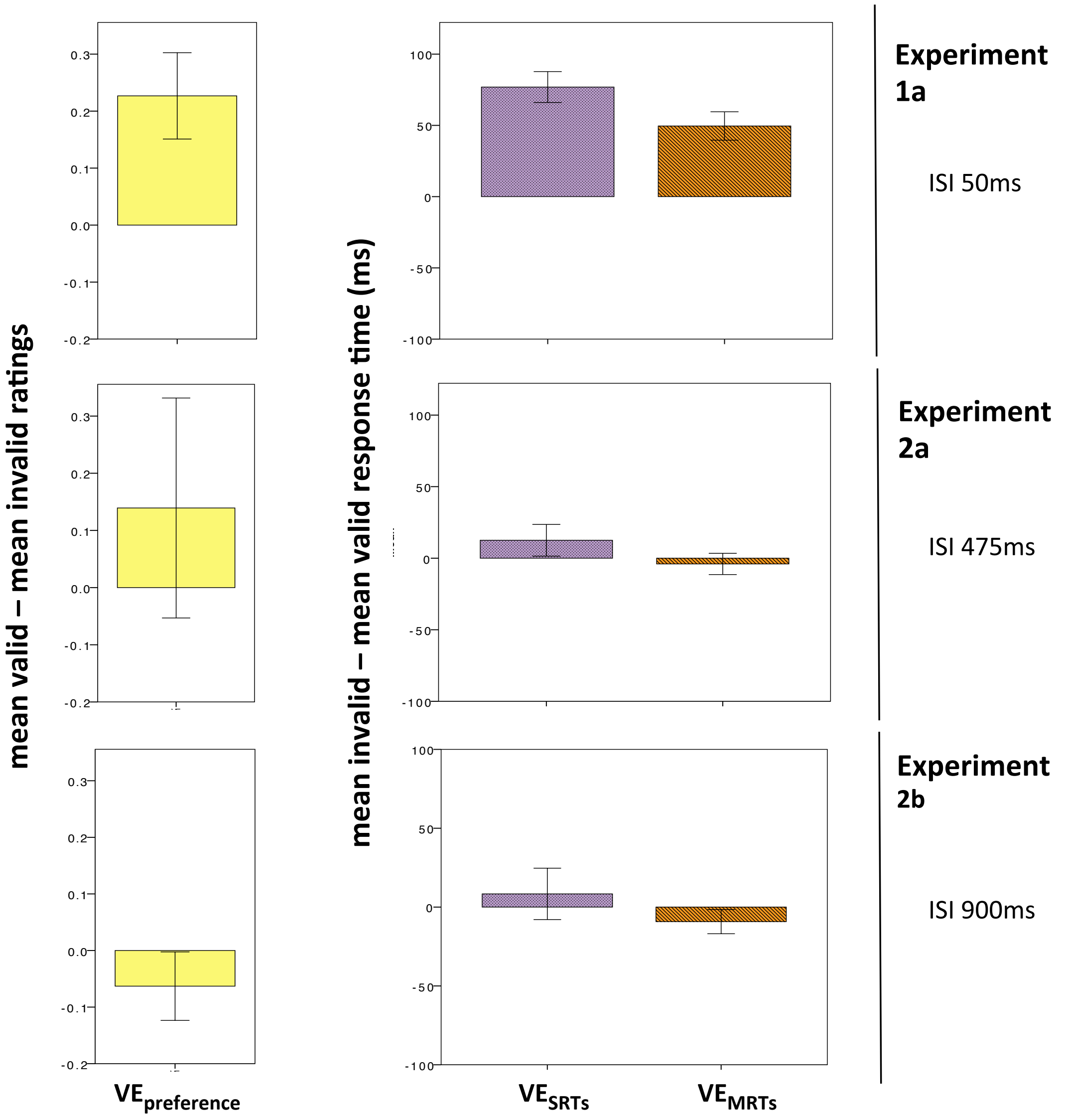

Figure 5. Bar graph showing the magnitude of validity effects (VE) separately for Experiment 1a (**top**), Experiment 3a (**middle**) and Experiment 3b (**bottom**). Left: validity effect on preference evaluation (mean ratings on valid – mean ratings on invalid trials). Middle: validity effect on saccadic reaction times (mean SRTs on invalid – mean SRTs on valid trials). Right: validity effect on manual reaction times (mean MRTs on invalid – mean MRTs on valid trial).

3.6.3 Discussion of Experiment 3a, 3b

In both experiments there was no valid-invalid difference in any of the variables analysed. This confirmed a transient orienting of attention towards the cued location: if nothing happens after cue offset, attention is removed from the cued location. These preliminary results suggested that attentional focus was reset to baseline, as neither facilitation nor inhibition of return was observed. Importantly, this experiment demonstrated that mere cueing to the left or right was in itself not sufficient for generating a preference effect. Hence the effect observed in Experiment 1a was unlikely to be due to a general cuing bias, in which observers tend to rate more positively patterns that appeared at cued locations. There is instead evidence that preference modulation was tightly linked with the engagement of (overt) attention at cued location, which depended on the duration of the interval between cue and pattern.

No inhibition of return (IOR) was observed. This may be not surprising for two reasons. First, only one ISI was used in each experiment. The intention of this was to keep the global design as similar as possible to Experiment 1a. There is evidence that IOR is sensitive to the number of ISI employed within the same experiment (Cheal & Chastain, 2002). Second, IOR is also sensitive to the type of task and emerges later with more difficult target processing tasks (R M Klein & Taylor, 1994; Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997; Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001; Terry, Valdes, & Neill, 1994; Van der Lubbe, Vogel, & Postma, 2005). In fact, an ISI of 900ms was presumably too short, given the nature of the stimulus set-up and task demands, for producing cuing effects (positive or negative) that could be reliably detected. Given average manual RTs around 800ms in Experiment 1a and Experiment 2, the chosen cue-target ISI of 900ms remained close to the expected crossover point (i.e., the point showing no difference in RTs to cued vs.

uncued items) (Klein, 2000). Hence, future studies should propose a design in which a greater range of ISIs, going well before (for positive cuing effects) or well after (for negative cuing effects) the crossover point, is used within the same experiment.

Since inhibitory processes associated with an event (i.e. cueing) are likely to be encoded into memory until the appropriate retrieval of the original event (i.e. target appearance) (Tipper, Grison & Kessler, 2006), it would be important to examine whether inhibition applied to the cued location can reverse the preference effect observed in Experiment 1a and 2, and lead to devaluation at valid locations. This would be in line with findings suggesting that inhibition of distracting information leads to devaluation when the distractor is presented again (e.g. Fenske & Raymond, 2006). Moreover, it would provide evidence of attention inhibition effects on preference evaluation avoiding the problem of prior stimulus categorization biases (Dittrich & Klauer, 2012).

4 Preference modulation elicited by exogenous cueing extends to non-target stimuli presented at target location

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4.1 Abstract

There is growing interest in the role of attention on preference formation. This study employed a spatial cueing procedure to study the link between exogenous cueing and preference. The onset of a peripheral uninformative cue preceded the appearance of a target (circle). Participants reported the location of the target (left/right), and then an abstract pattern appeared immediately after response. Participants rated how much they liked the pattern on a 9-points Likert scale. In Experiment 1 patterns were presented at the same location as the target (either valid or invalid). In Experiment 2 the patterns appeared at fixation. Cue-to-target validity (cue and target at the same location) elicited more positive ratings of patterns only when patterns appeared at the same location as the target (Experiment 1). Experiment 3a, 3b replicated the design of the two previous experiments respectively. This time participant maintained eyes at fixation through the whole experiment. No modulation of preference was observed. This study confirmed that the exogenous manipulation of attention influence explicit preference evaluation, and it highlighted a crucial role of gaze orientation in this mechanism.

4.2 Introduction

The attentional and emotional systems interact and influence human behaviour (Vuilleumier, 2005). Research has mainly focused on how emotional stimuli capture attention and affect attentional processing (see Phelps, Ling, & Carrasco, 2006; Yiend, 2010). Recently, a bidirectional relationship between attention and emotion has been suggested. It has been observed that the value of objects depends on how attention is deployed to specific stimulus features (Goolsby, Shapiro, & Raymond, 2009; Hare et al., 2011; Milosavljevic et al., 2012; Orquin & Mueller Loose, 2013; Raymond et al., 2003) as well as the whole stimulus entity (Armel et al., 2008; Glaholt, M. G, Wu, M., & Reingold, 2009; Huang & Hsieh, 2013; Kovach, Sutterer, Rushia, Teriakidis, & Jenison, 2014; Krajbich et al., 2010; Lim et al., 2011; Martiny-Huenger et al., 2014; Schonberg et al., 2014; Simion & Shimojo, 2007; Yagi et al., 2009). Attention thus seems to implicitly drive people's choices and preference. One theory suggests that emotional consequences of attention emerge from top-down inhibition of distracting information (Fenske & Raymond, 2006; Fragopanagos et al., 2009; Martiny-Huenger et al., 2014; Veling et al., 2007). Other studies have observed positive affective evaluation for selected items compared to unattended or novel items (Huang & Hsieh, 2013; Yagi et al., 2009). Partially in line with these studies, a role of exogenous manipulation of attention has been proposed (e.g. Shimojo et al., 2003). One theory attributes to (overt) attentional orienting a causative role in the construction of preference (Armel et al., 2008; Krajbich et al., 2010; Shimojo et al., 2003). Moreover, attention capture by bottom-up salient visual features play an important role in biasing choices/preferences (Lohse, 1997; Milosavljevic et al., 2012; Navalpakkam et al., 2012; Schonberg et al., 2014).

The studies mentioned so far demonstrated how attention affects preference by experimentally manipulating the relative amount of attention that people allocate on two (or more) alternatives. Fewer studies have tested preference for isolated items, which are not confronted with alternatives. Bayliss, Paul, Cannon, & Tipper (2006) conducted a pioneering study in which attention was drawn towards a peripheral location by uninformative social cues (i.e. eye gaze). Centrally presented faces could look either at right or left location 500ms prior to the appearance of a neutral object (kitchen/garage tools). The eye-gaze cues produced an attention-orienting effect, measured by manual reaction times. Participants reported their preference for the target objects on a Likert's rating scale, and rated more positively objects presented at the location indicated by the eye-gaze cue. This preference modulation effect was replicated in other studies employing human faces (Bayliss et al., 2007; Bayliss, Griffiths, & Tipper, 2009; Bayliss & Tipper, 2006; Capozzi et al., 2014; Manera, Elena, Bayliss, & Becchio, 2014; Ulloa et al., 2014), and even dog heads (Corneille et al., 2009). However, the liking effect of gaze cues may not be related to attentional allocation toward the cued direction. Eye-gaze cues may influence affective responses through a mechanism of 'mimetic desire' (see Corneille et al., 2009) , in which people like what is perceived to be the object of attention of others. It is interesting that endogenous central cues, like pointing hands (Ulloa et al., 2014) or central arrows (Bayliss et al., 2006), have not produced a similar liking effect in spite of a robust attention-orienting effect on manual reaction times. Central arrows or pointing gestures have an impact on attention orienting because people can easily learn their meaning. However, these types of cues may fail to elicit a spontaneous affective response because of their communicative role, which needs to be interpreted and voluntarily followed or ignored.

In Chapter 3, I showed a liking effect with exogenous peripheral cues in a simple attention-orienting paradigm. An abstract pattern could appear either at the valid (cued) location or invalid (opposite to cue) location. Participants classified the degree of regularity of the pattern (symmetry/random) and evaluated their preference for the pattern on a rating-scale immediately after response. Patterns presented at the valid location were rated more positively than patterns at the invalid location. Exogenous cues were thus found to affect liking similarly to what observed with social cues, like eye-gaze or head orientation. The brain is tuned to salient peripheral stimuli, as these indicate the presence of important information in the environment. Similarly to eye gaze, abrupt onsets are dynamic stimuli with a high biological relevance, which show adaptive benefits that do not depend purposely on communication (e.g. Franconeri et al., 2005; Hollingworth, Simons, & Franconeri, 2010).

Importantly, I controlled oculomotor responses associated with the shift of attention. When participants were required to maintain fixation on the central cross throughout the trial, the cuing effect on preference was absent in spite of a cuing effect on manual reaction times. In a further experiment a no-cue condition was added as a baseline. Participants overtly directed their attention to the pattern onset. Results from both saccadic latency and preference ratings showed a similar *valid* > *no-cue* > *invalid* trend, suggesting that preference formation was associated with oculomotor responses.

Hence, overt gazing seems to play a role in preference formation, either it originates from passive observation of other faces, or it is an active process of decision between alternatives, or a reflexive response triggered by sudden onsets.

Précis of current experiments

Preference might depend on reflexive orienting mechanisms triggered by the onset of either a valid or invalid peripheral cue. A valid cue produced a strong initial activation of the oculomotor map encoding response in the direction indicated by the cue. The onset of the pattern fostered this activation, triggering the execution of the saccade. In the case of invalid cueing, the onset of the pattern triggered a suppression of the prepared saccade and the redirection of a new saccade to the pattern. These mechanisms might have implicit influence on liking evaluation.

On the other hand, it is possible that the cuing effect on preference originated from increased perceptual fluency (e.g. Reber et al., 1998; Winkielman & Cacioppo, 2001) in valid conditions. Because exogenous cues enhance the activation of early-perceptual processes (e.g. Chica, Lasaponara, Lupiáñez, Doricchi, & Bartolomeo, 2010), it is possible that valid patterns were perceptually more fluent. The conclusions in Chapter 3 were not in favour of the latter hypothesis. When participants shifted attention covertly, manual RTs were faster at valid location, but preference evaluation was unaffected. This suggested that mere cuing facilitation on the perceptual processing of pattern regularity was not sufficient to enhance preference. However, the absence of foveation in this *covert* condition may reduce perceptual fluency itself and cancel any beneficial effect of exogenous cuing. For this reason the possibility of a cuing effect on the perceptual fluency of regularity needs to be further investigated.

This study consisted of three experiments. In Experiment 1, an uninformative cue flashed at one of two possible locations (right/left). A circular target appeared immediately afterwards. Participants shifted their gaze towards the target and reported the location as fast and accurately as possible (target detection task). Immediately after response, an abstract pattern replaced the target at the same location. Participants observed the pattern and then evaluated it. For the valid condition in Experiment 1, the location of cue, target and pattern was the same (cue=target=pattern, C=T=P), whereas for the invalid condition, target and patterns had opposite locations to the cue (cue≠ target=pattern, C≠ T=P). The structure of Experiment 2 was similar, but the pattern appeared always at fixation instead of target location (valid condition: cue=target ≠pattern or C=T≠ P; invalid condition: cue≠ target≠ pattern or C≠ T≠ P) (See **Fig. 1**).

The design of the experiments allowed us to test two hypotheses.

(1). Fluency hypothesis. Exogenous cuing may increase perceptual fluency of the target and this may cause an enhancement in preference. In this experiment the target processed after cue offset was a circle, whereas the to-be-evaluated pattern appeared after the target. The effect of fluent perception on affect can be either direct or indirect. A direct effect implies that the fluently processed stimulus acquires more positive value. If this was the case, the effect observed in Chapter 3 should not be replicated, as processing the pattern cannot benefit from the transient perceptual enhancement caused by exogenous cueing. Alternatively, processing facilitation might lead to a general subjective sense of fluency (e.g. fluent target processing; fluent orienting of attention; fluent cue-to-target contingency), which would indirectly bias evaluation (Constable et al., 2013). Fluency can manifest indirectly, as a secondary consequence of fluent processing (Forster, Leder, & Ansorge, 2012). A positive experience of fluency also emerges when motor responses are facilitated (e.g. Cannon, Hayes, & Tipper, 2009). Finally affective responses are elicited by either congruent or incongruent stimulus contingencies (Phaf & Rotteveel, 2009;). There are a number of putative mechanisms leading to subjective experience of fluency in a valid cue –target

contingency. In this case, the evaluated stimulus would not need to be the processed stimulus. As targets and patterns were different but shown in close continuity, a positive fluency effect may be misattributed to the pattern. In the case of indirect fluency, more positive rating should be observed for valid trials in both experiments, irrespective of whether target and pattern share the same location.

(2). *Gazing hypothesis*. In the C=T=P condition (cue = target = pattern, valid condition) of Experiment 1, overt attention was exogenously oriented towards the cue and dwelled at the cued location until an explicit rating was required. In the invalid C≠T=P condition (cue ≠ target = pattern, invalid condition), attention was initially prompted in the direction of the cue, then suppressed and reoriented to target=pattern location. We expected more positive ratings for C=T=P than C≠T=P, in line with findings reported in Chapter 3. In Experiment 2 the stimulus contingencies were: C=T≠P (cue = target ≠ pattern, valid condition) or C≠T≠P (cue ≠ target ≠ pattern, invalid condition). Attention was initially oriented towards either valid or invalid locations (where target was presented). In a second stage, gaze was oriented back to fixation where patterns were presented in all trials. If preference emerges from implicit orienting mechanisms (Shimojo et al. 2003), we should not observe any difference between the two conditions, as attention was directed towards fixation for the to-be-evaluated pattern in all trials.

Finally, Experiment 3 aimed to replicate the results observed in Chapter 3, *covert* condition. In that experiment half of the participants made a saccade to target (pattern) location; the other half kept eyes at fixation throughout the whole experiment. There was a significant *validity effect* on preference judgements only in the overt condition. The design of Experiment 3a was identical to Experiment 1 (target and pattern positions were the same). Experiment 3b had same design of Experiment 2 (patterns at fixation in all conditions). The crucial difference was that participants never moved eyes from fixation in Experiment 3a/b.

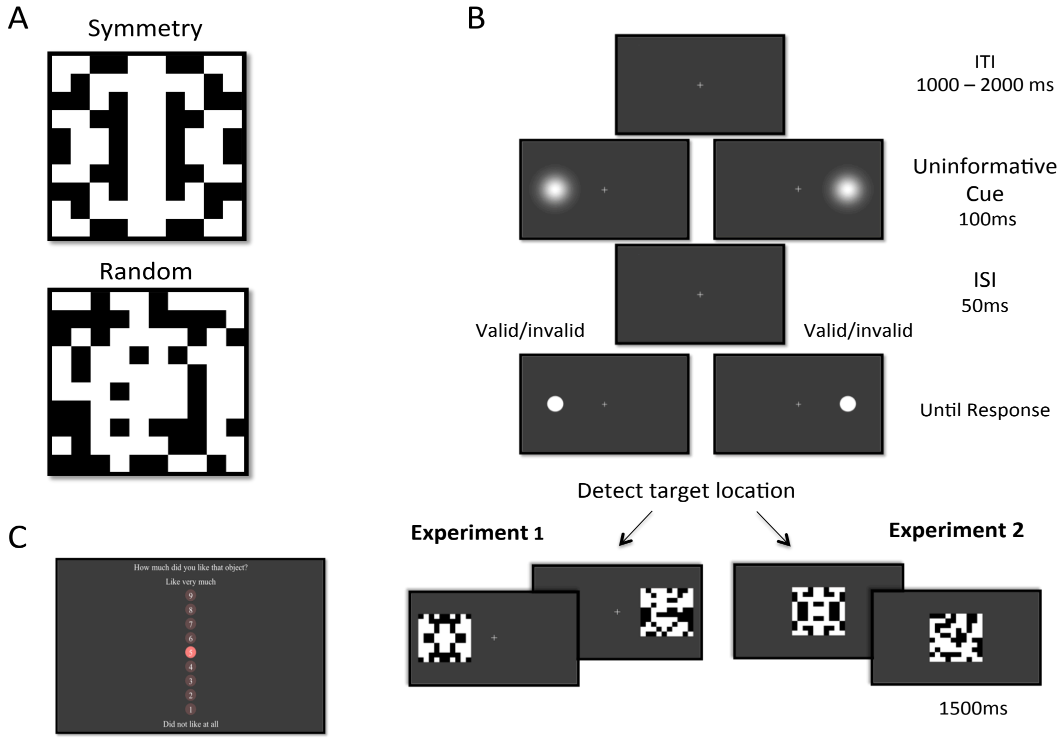

Figure 1. A) Examples of a symmetric and a random pattern. The number of black dots was the same in all patterns, but the configuration was different in every trial. Thus, a participant never saw the same pattern twice. **B**) A trial started with a fixation cross on a grey screen for a randomized period (1000 – 2000 ms). An uninformative cue flashed (100ms) either on the left or right of fixation. After an interval of 50ms the target appeared (50% of the times on the left and 50% on the right). If target location was the same of cue location, the trial was 'valid'. If target and cue had opposite locations, the trial was 'invalid'. Participants pressed the left/right button of a gamepad to report the location of the target. The target went off immediately after response. An abstract pattern appeared and remained on the screen for 1500ms. In Experiment 1the pattern appeared at the same location as the target. In Experiment 2 the pattern was presented at fixation. In Experiment 1 participants performed a saccade towards the target (and the pattern appeared soon after). In Experiment 2 participants performed a saccade to the target and a saccade back to centre at pattern onset. **C**) The 9-point Likert rating scale asking 'How much did you like the object?' (9= like very much; 1 = did not like at all).

4.1. Experiment 1

In this experiment a bright cue indicated the location of a target (white circle) on half of the trials. Participants overtly shifted attention toward the target and reported its location as fast and accurately as possible. Immediately after response, the target disappeared and was replaced by the pattern. The abstract pattern could have either random or symmetrical configuration. Participants evaluated patterns using a rating scale.

Participants were instructed to perform a saccade to the location of the target. The pattern appeared at that same location immediately after response. In valid conditions attention was exogenously triggered and endogenously maintained to the same location in which cue, target and patterns were presented (cue = target = pattern, C=T=P). In invalid conditions (or C≠T=P: cue ≠ target = pattern) attention was exogenously triggered toward one location, and redirected to the opposite location for target and pattern processing.

4.2.1 Method

4.2.1.1 Participants

Twenty-four naïve participants took part (6 males, 2 left handed, aged 18-30, mean=21.7). Participants were either volunteers or undergraduates from the School of Psychology and received formative credits for their participation. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008)

4.2.1.2 Apparatus and Stimuli

Participants saw the stimuli on a 16-in LCD monitor with resolution 1280X1024 pixels at 75Hz. It was positioned 57cm from a chin rest attached to the desk, which helped to keep subjects' head steady throughout the experiment. An ASL Eye-Tracker D6 (Applied Science Laboratories, Bedford, MA) infrared eye-monitoring camera, mounted below the screen, sampled participants' left eye movement at 120 Hz.

Stimuli were generated using python and the Psychopy software (Peirce, 2007). The main background screen was dark grey (RGB -0.7, -0.7, -0.7 decrement from grey). Fixation point consisted of a white cross of 2° of visual angle, presented on the centre of the screen. The fixation cross was presented continuously. Exogenous cues were generated from an increase in brightness modulated by a Gaussian envelope, with size 400 pixels (~ 12.8°). Target stimuli consisted of white circles with radius 50 pixels (~ 3°). Targets and cues were presented either at the left or the right of the fixation cross, at an eccentricity of 300 pixels (~ 9.6°). The to-be-evaluated patterns consisted of a black and white checkerboard (10 X 10) and measured 320 pixels (~ 10.3°).

The patterns could have either random or two-folded bilateral symmetric configuration (**Fig. 1A**). Participants never saw the same pattern more than once. This eliminated any potential mere exposure or familiarity effects on preference formation (Bornstein, 1989; Zajonc, 1968). Patterns were presented at target location, with the centre falling at the same eccentricity as cues and targets (300 pixels, ~ 9.6deg), immediately after participants responded to the target.

Preference ratings were recorded with a 9-point rating scale presented at the centre of the screen **(Fig. 1C).** There was a text on the top of the screen with the question "How much do you like that object?". Numbers were columned from 9 to 1, headed by the words "Like very much" at the top and the words "Did not like it at all" at the bottom. Participants used a gamepad with 8 buttons and 4 direction-arrows to give their responses. They used the left and right bottom-shoulder buttons (9 and 10) for target detection task. The upward and downward directional arrows were used to move along the rating scale and button 1 was used to confirm the choice.

4.2.1.3 Procedure

The sequence of events in a trial is shown in **Figure 1B**. Each trial started with a variable inter trial interval (ITI) from a minimum of 1000ms to a maximum of 2000ms. The exogenous cue immediately followed and lasted for 100ms either on the left or on the right of the fixation cross. After an Inter-stimulus interval (ISI) of 50ms, the target was presented at the same location as the cue (Valid location) in 50% of trials, or at the opposite location (Invalid location) on the remaining 50% of trials. The task consisted in reporting target location using the gamepad. Participants kept fixation until target onset, then they executed a saccade toward the target as soon as it appeared. Participants produced a manual response as fast and accurately as possible. The target remained on the screen until response, or for a maximum of 1000ms if no response was recorded. Immediately after, the target was replaced by the pattern. Participants observed the pattern until it went away.

Patterns remained on the screen for 1500ms. The rating scale followed the patterns at the end of each trial. Participants chose a value by moving on the scale with the directional up/down buttons of a gamepad, and pressed another button to confirm their choice. Participants were instructed to give a response as spontaneously as possible using a gut feeling. After 500ms, the fixation screen was presented and a new trial started. The experiment consisted of 128 trials. There was a break every 32 trials, in which participants could rest and disengage the eyes from the screen.

To familiarise participants with the task, a practice session of 32 trials preceded the experiment. The patterns were not presented during the practice, and participants were told about the evaluation task only before starting the proper experiment. In the practice session the target-circles remained on the screen for a maximum of 700ms. If participants were not able to respond before this time, the target disappeared and a message "too late" was presented for 500ms. This procedure trained participants to be fast and accurate and to concentrate on the task.

At the end of the experiment participants received a questionnaire in which they were asked to report their opinion about the experiment's purpose. This procedure allowed us to confirm that participants did not understand the aim of the experiment.

4.2.1.4 Design

The experiment consisted of 128 trials, 64 of which were *valid* and 64 *invalid*. Each of the validity conditions involved 32 symmetric pattern and 32 random patterns. Cues and target position was balanced, so that both appeared on the left and right side of the screen the same number of times. No participant ever saw the same pattern more than once. On the other hand all participants saw the same patterns, and patterns appearance was balanced across conditions and participants. In other words, *pattern A* was presented both after a valid and after an invalid trial, and both after a left target and after a right target. Therefore, differences in evaluation between valid and invalid conditions involved the same patterns.

4.2.1.5 Data Analysis

T-test analysis was conducted to compare saccadic latency, manual reaction times (MRTs), and accuracy on valid and invalid trials. A 2X2 mixed

ANOVA was conducted on the analysis of evaluation, with Pattern regularity (random, symmetry) and Validity (valid, invalid) as within-subject factors.

Data cleaning. Manual responses faster than 150ms (1.2%, of trials) were considered as anticipations, whereas responses slower than 1000ms (0.13% of trials) were considered as misses. Analysis of eye data was performed with Matlab. Trials in which eye data were lost because of movement artefacts or eye blinks were excluded from the analysis (2.66%. of trials). Anticipatory saccadic responses (50ms from target onset) to the cue were discarded (4.3%). A time-window was defined starting at target-onset and extending at target-offset. We controlled that the coordinates of the position in this time-window were at the correct location of the target. Trials in which eyes remained at fixation were discarded (4%). In total 2715 trials, which correspond to the 88% of the original trials, were taken in consideration for the analysis. The proportion of analysed trials remained balanced across conditions and locations.

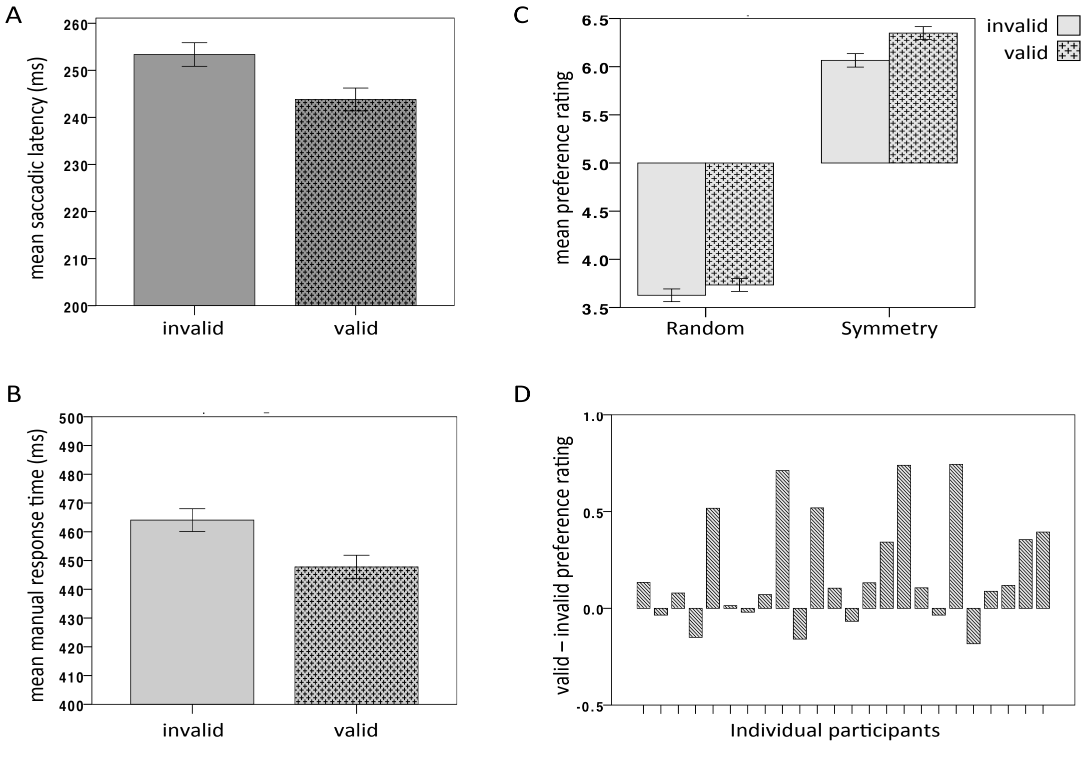

Figure 2 Results from Experiment 1. (**A**) Bar chart showing saccadic reaction times on valid and invalid trials. (**B**) Bar chart showing manual reaction times (MRTs) on valid and invalid conditions. (**C**) Bar chart showing mean preference ratings on valid and invalid trials. (**D**) Bar chart showing difference between ratings on valid trials – ratings on invalid trials for each participant. Values above zero indicate a tendency to evaluate valid patterns more positively.

4.2.2 Results

Results are shown in **Fig. 2**.

Overall Performance.

Significant cueing-effect on saccadic latency was observed, with mean reaction time on valid trials faster than reaction time on invalid trials (mean difference= 11ms; SE= 3ms; $t_{(23)} = 2.958$, $p = .007$, d= 1.21).

No significant effect of Validity on percentage of incorrect responses (mean difference= 1%; SE= .6; $t_{(23)} = 1.731$, p= .09, d= .72). The analysis on MRTs was conducted on trials in which responses were correct (96%). It revealed only a marginal difference between valid and invalid trials (mean difference= 16ms; SE= 8ms; $t_{(23)} = 1.969$, $p = .06$, d= .82).

Preference evaluation

Preference ratings were measured on trials where correct response was performed. The effect of Validity was significant ($F_{(1,23)}= 11.662$, $p = .002$, $\eta^2_p = .34$). Ratings on valid trials were more positive than ratings on invalid trials. A significant main effect of Pattern Regularity ($F_{(1,23)}= 46.578$, $p < .001$, $\eta^2_p = .67$), showed symmetry was liked more than random patterns. The interaction Pattern regularity X Validity ($F_{(1,39)}= 2.223$, $p = .15$, $\eta^2_p = .08$) was not significant.

4.2.3 Discussion of Experiment 1

In this experiment, a circular target followed an exogenous cue. An abstract pattern was presented immediately after response, and participants evaluated their preference for the pattern on a 9-points rating scale. Faster saccadic latencies on valid trials confirmed that valid cuing facilitated the orientation of saccades toward the location of the target. However, the same effect was only marginal on manual responses. Although this might be unexpected, it is not surprising. Target detection happens before the saccade is completed. Therefore, a manual response in this case is not indicative of the attentional benefit elicited by the cue. It has been observed that when the discrimination of the target is too easy cuing effects on reaction times are reduced or even absent (Macea, Abbud, Lopes-de-Oliveira, Fuga, & Ribeiro-do-Valle, 2006). Moreover, knowing that the stimulus of interest (the to-be-evaluated pattern) is going to appear immediately after the target may be distracting for the detection task.

Importantly, patterns presented after a valid target were evaluated more positively than patterns presented after an invalid target. In line with what observed in Chapter 3, exogenous cueing enhanced preference formation. Pattern regularity strongly influenced preference ratings. Ratings values below 5 were consistently attributed to random patterns, whereas rating values greater than 5 were commonly given to symmetry. Interestingly, the cuing effect on preference did not interact with pattern regularity. This confirmed that exogenous cuing affects liking evaluation of both disliked and liked patterns, as observed in Chapter 3.

Let us consider how this result applies to the initial hypotheses.

(1). *Fluency hypothesis.* It is unlikely that preference evaluation for the pattern directly originates from increased perceptual fluency. Exogenous cues activate early perceptual processes (e.g. Hopfinger & West, 2006). This is transient and is applied to the stimulus presented within a short interval immediately after cue offset. Patterns appeared at target offset (approximately 450ms after target onset), a time window in which cuing facilitation on early neural activity might have extinguished. Because cuing effect on preference was observed after valid targets, we can rule out the hypothesis of a *direct perceptual fluency effect* on preference evaluation after exogenous cuing. However, an affective value could be attributed to patterns, even if these were dissociated from the cuing task. The possibility of an *indirect fluency effect* of exogenous cuing that is misattributed to the pattern is still open. Although the cuing effect on manual RTs was marginal, oculomotor mechanisms significantly responded to cuing. Experiment 2 tested this second possibility. This experiment presented targets and patterns on different locations. If valid cue-to-target contingency generates a general sense of fluency that causes preference modulation, more positive ratings should be recorded in valid conditions also in Experiment 2.

(2). *Gazing hypothesis.* Exogenous cuing was found to affect preference even when the to-be-evaluated patterns were irrelevant for the cuing task. In valid conditions attention was exogenously triggered and endogenously dwelled at cued location. In line with findings of Chapter 3, this result supported an implicit role of gaze orienting on preference formation (see also Armel, Beaumel & Rangel, 2008; Shimojo et al., 2003).

In Experiment 2, a voluntary shift of gaze from target location to central location was required in all conditions in order to observe the pattern before evaluation. If the gaze orienting of attention elicited by exogenous cuing is crucial in the modulation of preference, this effect should be neutralized by the endogenous redirection of gaze towards the center in the next experiment.

4.3 Experiment 2

Experiment 2 was similar to Experiment 1. However, this time patterns were presented at fixation. After cue offset, the target appeared and participants looked at the target and manually reported its location as fast and accurately as possible. Then the target disappeared and, simultaneously, the pattern replaced the central fixation cross. Participants gazed back to the centre and observed the pattern for 1500ms before rating their liking for the pattern on the rating scale.

4.3.1 Method

4.3.1.1 Participants

Twenty-four naïve participants took part in this study (5 males, 2 left handed, aged 18-43, μ=24.8), in exchange for university credits. None of them participated either in Experiment 1 or any other similar study.

4.3.1.2 Design and Data Analysis

Stimuli, design and procedure are described in detail in the method section of Experiment 1. The only difference is that this time the to-be-evaluated patterns were presented at fixation, immediately after participants responded to the target. Participants executed a saccade toward the target as soon as it appeared. Then they performed a saccade back to the centre and observed the pattern until it disappeared. T-test analysis was conducted to compare saccadic latency, manual reaction times (MRTs), and accuracy on valid and invalid trials. A 2X2 mixed ANOVA was conducted on the analysis of evaluation, with Pattern regularity (random, symmetry) and Validity (valid, invalid) as within-subject factor.

Data cleaning. Manual responses faster than 150ms (1.4%), and slower than 1000ms (0.1%) were rejected. Trials in which eye data were lost because of movement artefacts or eye blinks were excluded from the analysis (3.6%). Trials in which eyes remained at fixation during target presentation were discarded (3.2%). Anticipatory saccadic responses (50ms from target onset) to the cue were discarded (5.4%). In total 2725 trials, which correspond to the 89% of the original trials, were taken in consideration for the analysis. The proportion of analysed trials remained balanced across conditions and locations.

4.3.2 Results

Results are shown in **Fig. 3**

Overall Performance.

Significant cueing-effect was observed on saccadic latency, with mean reaction time on valid trials faster than reaction time on invalid trials (mean difference= 11ms; SE= 3ms; $t_{(23)} = 3.097$, p = .005, d= 1.29).

No significant effect of Validity on percentage of incorrect responses (mean difference= 1%; SE= .6; $t_{(23)} = 1.714$, p= .10, d= .71). The analysis on MRTs was conducted on trials in which responses were correct (97%). No significant difference between valid and invalid trials was observed (mean difference= 12ms; SE= 9.5ms; $t_{(23)} = 1.287$, p = .21, d= .54).

Preference evaluation

Preference ratings were measured on trials where correct response was performed. The effect of Validity was not significant ($F_{(1,23)}= 1.100$, p = .305, $\eta^2_p = .05$). Ratings on valid trials were more positive than ratings on invalid trials. A significant main effect of Pattern Regularity ($F_{(1,23)}= 7.863$, p = .01, $\eta^2_p = .25$), showed symmetry was liked more than random patterns. The interaction Pattern regularity X Validity ($F_{(1,39)} = .734$, $p = .40$, $\eta^2_p = .03$) was not significant.

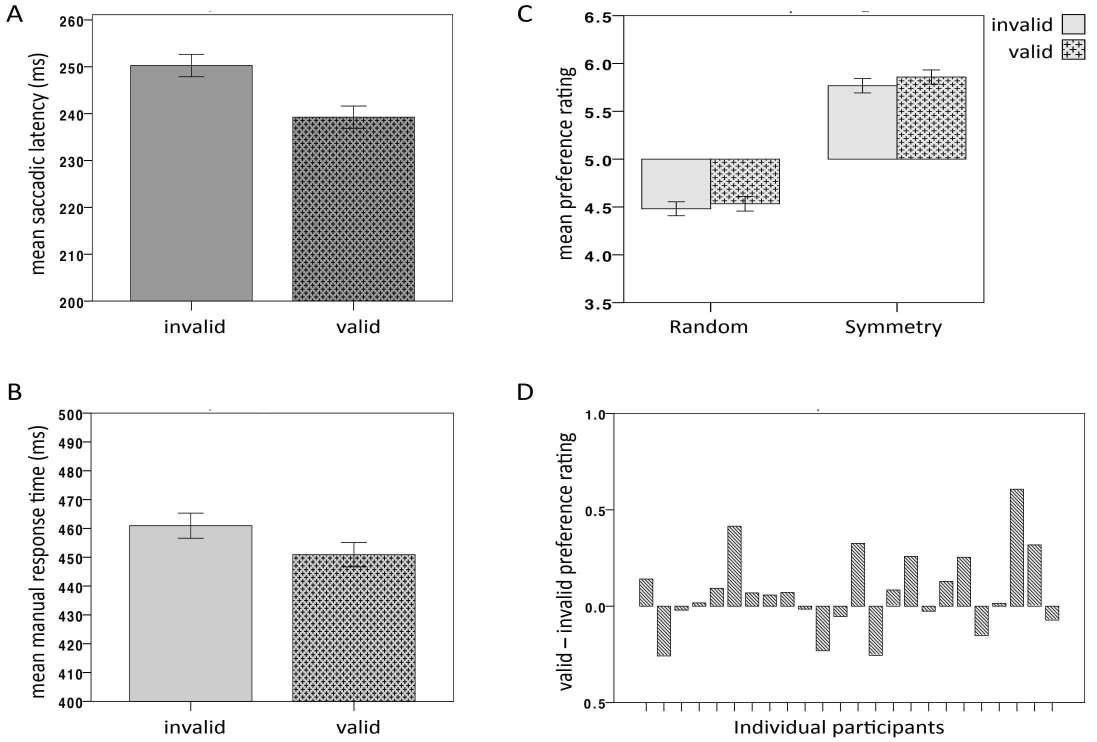

Figure 3 Results from Experiment 2 (**A**) Bar chart showing mean saccadic latency on valid and invalid trials. (**B**) Bar chart showing mean reaction times (MRTs) on valid and invalid conditions. (**C**) Bar chart showing mean preference ratings on valid and invalid trials. (**D**) Bar chart showing difference between mean ratings on valid trials – mean ratings on invalid trials for each participant. Values above zero indicate tendency to evaluate valid patterns more positively.

4.3.3 Discussion of Experiment 2

In this experiment the cueing task was the same as in Experiment 1: participants responded to targets at either cued or un-cued locations. The difference was pattern position, which was at fixation instead of target location. The analysis of preference evaluation showed that in this experiment mean preference ratings were similar in both valid and invalid conditions. Pattern Regularity was the sole factor controlling preference evaluation, as participants liked symmetry more than random patterns.

(1). Fluency hypothesis. The hypothesis that valid exogenous cuing elicits a general sense of fluency that is misattributed to the pattern was ruled out. Although a cuing effect was not observed on manual reaction times, the valid cue-target contingency was processed and facilitated gaze orienting on

valid trials (evidenced by saccadic latency). However this had no effect on preference formation. We can therefore conclude that, in light of the results obtained in Experiment 1 and Experiment 2, preference modulation elicited by exogenous cuing is not due to increased fluency.

(2) *Gazing hypothesis*. This experiment highlights the role of cuing in the activation of the orienting system and its intimate connection with preference formation. In this experiment, the evaluative process was similar in both valid and invalid trials. Patterns were dissociated from cued or un-cued location and all shared the same location. Participants voluntarily shifted their attention from target location to the centre in all trials. This resets any cuing effect on the final evaluation.

4.4 Experiment 3

Experiment 3 replicated the previous two experiments. The design of Experiment 3a was the same as Experiment 1, and the design of Experiment 3b was the same as Experiment 2. The difference was that participants maintained central fixation during the whole experiment. One group of participants (Experiment 3a) did not move the eyes toward target and pattern location. Therefore they attended and evaluated patterns presented in the periphery of their visual field. The other group (Experiment 3b) did not move the eyes to the target, but they observed the patterns foveally.

4.4.1 Method

Forty naïve participants took part in this study (7 males, 6 left handed, aged 18-34, μ=22.3), in exchange for university credits. None of them participated in the previous studies.

4.4.1.1 Design and Data Analysis

Stimuli, design and procedure are described in detail in the method section of Experiment 1 and Experiment 2. The only difference was that this time participants did not execute a saccade toward the target as soon as it appeared. They maintained fixation through the whole experiment. Twenty participants performed Experiment 3a, which was identical to Experiment 1. They observed both target and pattern covertly. Twenty participants performed Experiment 3b, which was identical to Experiment 2. They observed target covertly but patterns overtly. For each experiment, a t-test was conducted to compare saccadic latency, manual reaction times (MRTs), and accuracy on valid and invalid trials. A 2X2 mixed ANOVA was conducted to analyse evaluation, with Pattern regularity (random, symmetry) and Validity (valid, invalid) as within-subject factor.

Data cleaning – Experiment 3a Trials in which MRTs were faster than 150ms (0.08%) and slower than 1000ms (0.03%) were discarded. Eye data loss due to technical issues or eyes blinks was 1%. Eyes were not allowed to move from fixation during a whole trial. Thus trials in which eyes moved beyond 2 degrees from average fixation position were excluded (3.16%). In total 2477 trials were considered for the analysis, which correspond to the 96.8% of the original number of trials.

Data cleaning – Experiment 3b Trials in which MRTs were faster than 150ms were discarded (1.95%); the same was for trials in which MRTs were greater than 1000ms (1.79%). Eye data loss due to technical issues or eye blinks was 1.20%. Eyes were not allowed to move from fixation during a whole trial. Thus trials in which eyes moved beyond 2 degrees from fixation position were excluded (2.02%). In total 2394 trials were considered for the analysis, which correspond to the 93.5% of the original number of trials.

4.4.2 Results

Results are shown in **Fig. 4**

Experiment 3a

Overall Performance.

There was a significant effect of Validity on percentage of incorrect responses (mean difference= -5%; SE= 2.2; $t_{(19)}$ = -2.290, p= .03, d= 1.05). The analysis on MRTs was conducted on trials in which responses were correct (95%). Significant difference between valid and invalid trials was observed (mean difference= 18ms; SE= 6ms; $t_{(19)}$ = -2.918, p = .009, d= 1.33).

Preference evaluation

Preference ratings were measured on trials where responses were correct. The effect of Validity was not significant ($F_{(1,19)}= 2.232$, $p = .15$, $\eta^2_p = .11$). A significant main effect of Pattern Regularity ($F_{(1,19)}= 50.13$, $p < .001$, $\eta^2_p = .72$), showed symmetry was liked more than random patterns. The interaction Pattern regularity X Validity ($F_{(1,19)}= 2.176$, $p = .16$, $\eta^2_p = .10$) was not significant.

Experiment 3b

Overall Performance.

Significant effect of Validity on percentage of incorrect responses (mean difference= 6%; SE= 1.7; $t_{(19)} = 3.467$, $p= .003$, $d= 1.59$). The analysis on MRTs was conducted on trials in which responses were correct (94.5%). Significant difference between valid and invalid trials was observed (mean difference= 33ms; SE= 10ms; $t_{(19)} = -3.500$, $p = .002$, $d= 1.61$).

Preference evaluation

Preference ratings were measured on trials where correct response was performed. The effect of Validity was not significant ($F_{(1,19)}= 1.848$, $p = .19$, $\eta^2_p = .09$). A significant main effect of Pattern Regularity ($F_{(1,19)}= 15.870$, $p = .001$, $\eta^2_p = .46$), showed symmetry was liked more than random patterns. The interaction Pattern regularity X Validity ($F_{(1,19)}= .997$, $p = .33$, $\eta^2_p = .05$) was not significant.

4.4.3 Discussion of Experiment 3

No cuing effect on preference was observed, as predicted. In a valid trial in Experiment 3a, attention was exogenously oriented and endogenously dwelled at the cue=target=pattern location similarly to Experiment 1. The difference is that attention was not accompanied by a shift of the gaze toward the attended location. This is similar to what observed in Experiment 1 of Chapter 3, and further highlights the important role of gaze orienting in preference evaluation (at least when this is required).

Surprisingly, in this experiment we observed a strong cuing effect on performance, both accuracy and manual reaction times. Covert attention may be a strategy the brain employs to respond to peripheral information.

Therefore, it is not surprising that the speed of manual detection of a white dot benefits from pre-cuing when eyes are maintained at fixation but not when a saccade to the target is required. Also the high proportion of errors in invalid trials suggests a strong bias in responding to the cue. It seems that gazing to the target helped in maintaining control over manual responses. Finally, this experiment further demonstrated that the presence of a facilitatory effect on manual responses is not (always) associated with a modulation of preference.

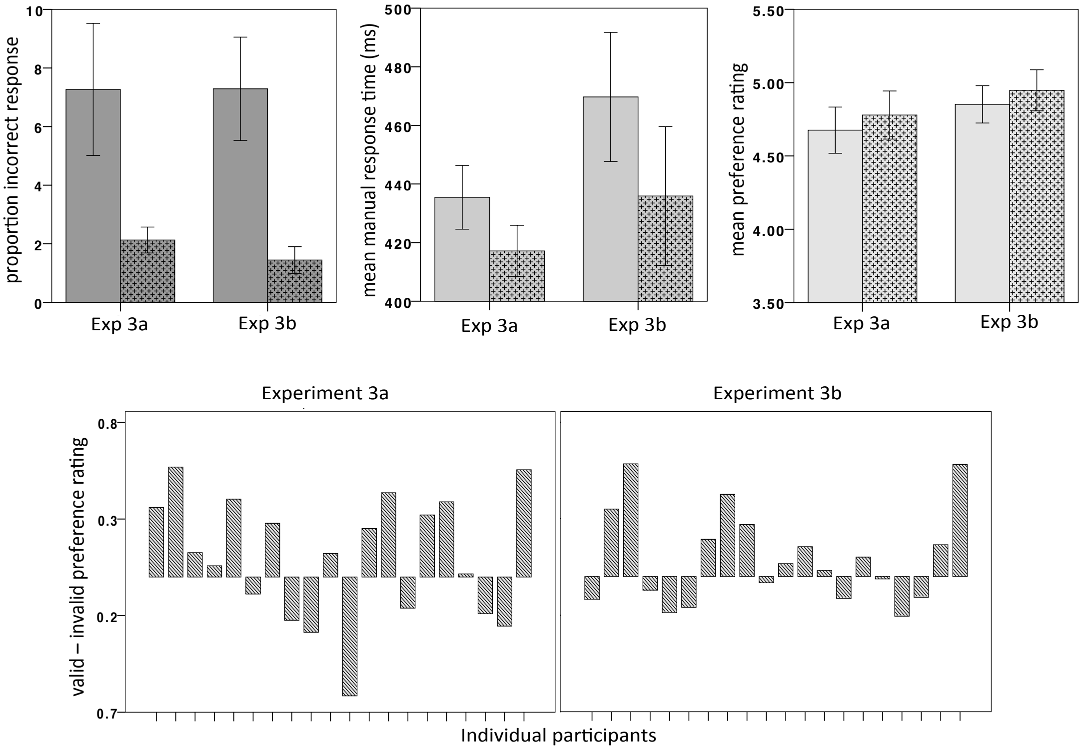

Figure 4. Results from Experiment 3. **Top plots.** Plain bar: invalid condition; Pattern bar: valid condition. All three plots show results separately for Experiment 3a and Experiment 3b. Left: proportion of incorrect responses; Middle: mean manual reaction times; Right: mean preference ratings. **Bottom plots**. Difference between mean ratings on valid trials – mean ratings on invalid trials for each participant in order of their recruitment (From left to right: Experiment 3a and Experiment 3b). Error bars represent ±1 standard error of the mean.

4.5 General Discussion

The present study investigated the effect of neutral exogenous cues on attention orienting and preference formation. Humans (and non-humans) constantly direct attention to interesting information in the environment. The orienting system is particularly tuned to emotional and biologically relevant exogenous stimuli. It has been proposed that a direct bidirectional route might connect the emotional and attentional systems (e.g. Fenske & Raymond, 2006), and the brain may rely on the orienting system in the construction of affective responses (Shimojo et al., 2003). Many studies investigating attention effects on preference have employed paradigms in which there were two or more alternatives. The attentional modulation of preference was measured by the relative amount of attention deployed to one of N (forced-) alternatives. By contrast, in this experiment we coupled a classic cueing paradigm (e.g. Posner, 1980) with a preference evaluation task for an isolated abstract pattern. This allowed testing attentional parameters and their benefits and costs on preference formation, in absolute rather than relative terms (see Palmer, Schloss, & Sammartino, 2013).

The patterns differed in the degree of regularity: highly regular (4-fold bilateral symmetry) and highly irregular (random). As expected, regularity split preference ratings in two: random were evaluated below neutral (5 to 1); symmetry was evaluated above neutral (5 to 9). Other than pattern regularity, the only factor influencing evaluation was attention.

Experiment 1 and Experiment 2 were similar: the salient abrupt onset of a peripheral cue was followed by the appearance of a circular dot-target. After detecting the target, a pattern was presented and participants reported how much they liked the pattern. The two experiments differed in one aspect. In Experiment 1, patterns were located at the target location. Therefore in valid trials cue, target and patterns had the same location (cue = target = pattern, C=T=P). In invalid trials target and patterns were presented at the opposite location of the cue (cue ≠ target = pattern, C≠T=P). In Experiment 2, patterns were located always at fixation. In valid trials cue and target still shared the same location (cue = target ≠ pattern, C=T≠P); in invalid conditions the three stimuli appeared in three different locations (cue ≠ target ≠ pattern, C≠T≠P). Oculomotor responses were controlled. In Experiment 1 participants maintained fixation until target appeared, than looked at the target as quickly as possible before giving manual response. They maintained gaze at target location as the pattern replaced the target. In Experiment 2 participants gazed back to the pattern at the centre after target offset. Experiment 3 replicated the previous two experiments, but this time participants never moved the eyes from fixation.

In Experiment 1 we observed a cuing effect on saccadic latencies, confirming that valid exogenous cuing mobilized attention toward the cued location. No cuing effect was observed on accuracy and the speed of manual responses in valid trials was only marginally faster. The weak effect on manual performance might not be surprising. On the one hand, the task was a simple target detection, and valid (or invalid) cuing has less impact on manual responses when task is too easy (e.g. Macea et al., 2006). This was combined with the fact that target detection happens before the eye lands on the location. Therefore manual response is not indicative of a cuing benefit on attention, whereas eye movements are a reliable response to cuing. The important result is that ratings for patterns at valid locations were more positive than for patterns at invalid location. In this experiment patterns were task-irrelevant, they appeared few hundreds of milliseconds after the cue and no explicit classification was required. However, the effect obtained was similar to the result of Experiment 1 in Chapter 3.

Importantly, performance in Experiment 2 (saccadic and manual responses) replicated that observed in Experiment 1 (although the cuing effect size on manual responses was even smaller). In fact, the task was identical in the two Experiments. However in Experiment 2, we did not observe any effect on preference ratings. Presenting the target at the centre instead of target location modulated preference.

Two possible hypotheses were tested in this study. Although the two hypotheses were both plausible, they rely on separate mechanisms. This study helped to clarify what mechanisms is more likely to play a role in the exogenous cuing effect on preference.

(1). *Fluency hypothesis.* Exogenous cuing triggers activation of early perceptual processes at the cued location prior to the appearance of the target (e.g. Hopfinger & West, 2006). This favours faster processing of the target, which usually is recorded by faster manual response time. Objects that are perceived more fluently than others are believed to be implicitly preferred (Reber et al., 1998; Rolf Reber, Schwarz, & Winkielman, 2004). It was conceivable to hypothesize that valid stimuli were liked more because more fluently processed. This could be the case in Chapter 3, as the to-be-evaluated patterns were presented immediately after the cue and the processing of pattern regularity might have been more fluent in valid than invalid conditions. We tested this direct perceptual fluency effect in this study. Here to-be-evaluated patterns were task irrelevant, and the target was a simple white dot. By the time the pattern was presented, the perceptual benefits elicited by the cue should be eliminated. No cuing effect on preference evaluation would be expected in this case. Experiment 1 showed instead that attentional modulation of preference could extend to task-irrelevant patterns. The hypothesis of a *direct perceptual fluency* effect was ruled out. Fluency could manifest indirectly, as a subjective sense of ease, which is misattributed to the patterns (e.g. Constable, 2013). The results from Experiment 1 did not discard the hypothesis of indirect fluency. However, if this hypothesis was valid, a modulation in preference should be observed in Experiment 2. If cue-to-target contingency elicits the experience of fluency and affective misattribution, then the location were the pattern is presented should be irrelevant. Therefore, in light of the results obtained in both experiments the hypothesis of a fluency effect was discarded.

(2). *Gazing hypothesis*. In the real world it is important to react efficiently to exogenous cues that can signal the presence of important information in the environment. The brain has an innate predisposition to react to these important biological stimuli, as they have not a purposely-communicative role. An impulse to gaze toward the location where the stimulus has appeared automatically joins the shift of attention. Gazing toward the location of interest seems to play a fundamental role in driving preference and choices (e.g. Shimojo et al., 2003). Although gaze allocation has not always proved to be causative of preference formation (Bird, Lauwereyns, & Crawford, 2012), eyes movements are the principal indicator of the attentional effect on (preference) choices (Glaholt & Reingold, 2011; Kovach et al., 2014; Orquin & Mueller Loose, 2013; van der Laan, Hooge, De Ridder, Viergever, & Smeets, 2015). The human brain is tuned to respond to others' gaze from the first months of life (e.g. Hoehl, Wiese, & Striano, 2008), and observing others' gaze implicitly influence the value that people attribute to objects (Bayliss et al., 2006; Corneille et al., 2009) . Hence, gazing is linked with emotional responses either as passive observation or active performance. In this study we obtained further evidence of a link between eyes movements and affective responses.

In Experiment 1 preference ratings for valid patterns were more positive on average than ratings for invalid patterns. So preference for objects that were presented at the cued location was higher. In a valid trial the eyes were directed to a location where the target and the pattern of interest appeared (in sequence). Therefore the orienting system was exogenously activated by the cue, and target appearance boosted this activation. Gaze shifted to target location and pattern appeared. In an invalid trial the cue pre-activated the response to the incoming target at the indicated location. This was then suppressed and reactivated for performing the saccade to the opposite location. In Chapter 3, a baseline no-cue condition showed that the cuing effect on preference might depend on a combination of benefits and costs elicited by the cue (similar to that observed for saccadic responses). Also in this case the difference in evaluation between valid and invalid patterns might be related to combined effects.

In Experiment 2, the patterns were always presented at fixation. An endogenous shift of attention from target location to pattern location wiped out the cuing effect on preference rating. Preference ratings were only modulated by pattern regularity. This suggests that gazing has a role, as the mere gazing back to fixation is sufficient to eliminate the effect of cuing.

Experiment 3 confirmed the important role of gazing. It replicated the design of Experiments 1 and 2 but participants maintained fixation throughout the whole trial. Therefore, attention was triggered by the cue and shifted towards target location similarly to what happened in the previous experiments. The difference was the absence of an overt gaze toward the location where the pattern was due to appear. Shifting attention is necessary but not sufficient to affect preference formation. The brain includes sensorimotor mechanisms in the construction of preference. Gazing and foveating the stimulus is a necessary condition in the formation of preference, and needs to accompany the shift of attention in order for attention to be able to modulate preference.

Finally, this experiment highlighted the fact that manual reaction times are not linked directly with preference modulation, and they might not even be a good estimation of attention. In Experiment 3 we observed strong cuing effect on RTs, but no effect on preference. A marginal valid – invalid difference on speed of manual responses was recorded in Experiment 1.

However, target detection happened correctly, as saccades were faster in valid conditions. Eye movements are considerably faster than movements of the hand, and they require less deliberate effort to execute. Manual RTs represent an artificial response that may not be always a reliable measure of an attentional phenomenon. Eye responses are spontaneous and more accurate indicators of attentional processes.

Overall this study provides evidence that orienting attention affects explicit measures of preference. Specifically, it suggests that both gaze orienting and dwelling attention at the cued location affect preference. We confirm that bottom-up stimulation can enhance affective responses towards stimuli, even when the salient feature capturing attention is not part of the object under evaluation.

5 Modulation of preference ratings with predictive and counter-predictive exogenous cues

5.1 Abstract

Predictability can modulate the extent to which certain visual stimuli come to be preferred over others. This study explored the effect of learned predictability and violation of expected contingency on preference evaluation by using peripheral exogenous cues, which I found to affect preference evaluation. In Experiment 1 the cue indicated the valid location of the incoming pattern on 80% of the trials (predictive cues). In Experiment 2 the proportion of valid:invalid was reversed (20% valid 80% invalid) (counter-predictive cues). These preceded the appearance of either abstract symmetric or random patterns, and we asked participants to rate their liking for the patterns. In the first case endogenous expectation and exogenous cueing synergistically cooperated. As expected response reactions and preference were enhanced for stimuli appearing at validly cued (and predicted) locations. In the second case endogenous and exogenous dimensions had opposite directions. The valid – invalid difference was cancelled in this experiment. This study showed that endogenous control overwhelmed exogenous influence. However, learned predictability did not lead to more positive evaluation for invalid conditions in Experiment 2. These results suggest that exogenous cueing influences preference formation when the attentional set is prepared to favour integration of cue and incoming pattern at same location.

5.2 Introduction

The bidirectional interplay between visual attention and visual preference guides the visual system in the process of prioritization of incoming information. Visual attention modulates visual preference through both endogenous (e.g. Fenske & Raymond, 2006; Huang & Hsieh, 2013; Yagi et al., 2009), and exogenous mechanisms (e.g. Armel et al., 2008; Shimojo et al., 2003).

The visual system selects information through learning and prior experience. Extracting repeated configurations from the complex visual environment enables the attentional and visual systems to anticipate upcoming stimuli enhancing visual performance (Chun & Jiang, 1998; Fiser & Aslin, 2002; Turk-Browne & Scholl, 2009). The learned predictability of stimuli affects early responses in primary visual processing (O'Brien & Raymond, 2012), probably by reducing the neural activation required to process the predictable visual stimuli (Alink, Schwiedrzik, Kohler, Singer, & Muckli, 2010; de-Wit, Machilsen, & Putzeys, 2010).

This parsimonious strategy of the brain allows attentional resources to be preserved and used for efficiently reacting to possible mismatches between top-down prediction and bottom-up evidence. Being vital for attentional processing, predictive coding has important consequences on emotional responses (see Van de Cruys & Wagemans (2011) for an exhaustive illustration of the relationship between predictive coding and emotion).

It has been suggested that predictability may modulate the extent to which certain visual stimuli come to be preferred over others. Ogawa & Watanabe, (2011) showed participants sequences of predictive displays (target embedded among distractors), in which the configuration of distractors and position of the target were maintained constant in every presentation. These predictive-displays were compared to non-predictive displays (the configuration of the distractors was fixed but target position changed). Participants reported the goodness of the previously seen displays and novel displays. Ratings were more positive for predictive-displays than non-predictive or novel displays, and the result could not be accounted for by memorization of the predictive-displays (as recognition of the predictive displays was not greater than the other displays). This study demonstrated that the predictive value of a stimulus can be learned during the task and implicitly modulate the affective evaluation of the stimulus itself. Another example was reported by (Bayliss & Tipper, 2006) who investigated whether the perceived trustworthiness of a face could be modulated by its predictive value. In a simple cuing task, some faces consistently gazed towards the target location, whereas other faces always directed gaze to the opposite location of the target. Predictive faces were rated as more trustworthy than counter-predictive faces, and were also preferred.

Learned predictiveness of an outcome enables an efficient reaction to the stimulus, which can be encoded as rewarding. On the other hand, failure in predicting an outcome may produce a "punishment signal" which reflects on negative evaluation (Oganawa & Watanabe, 2010).

Evidence that (counter)predictability and emotion are connected has been also provided by neuroimaging studies. Norbre et al. (1999) used an exogenous cuing procedure that manipulated either temporal or spatial orienting toward the periphery and recorded brain activity with functional magnetic resonance imaging (fMRI). Different types of cues could either validly predict spatial location (left or right) or time of appearance (after 300ms or 1500ms) or both dimensions. The proportion of valid:invalid conditions was 80:20. They observed that invalid trials triggered the activation of the lateral premotor cortex and orbitofrontal region, irrespective of cue dimension. The authors suggested that activity in these regions reflected a change in the expected cue-to-target contingency, playing a critical role in encoding deviations from a familiar sequence of events. The Orbitofrontal cortex is known to be a crossroad in the interface between cognitive functions and emotions (e.g. Pessoa, 2008; Rolls & Grabenhorst, 2008), and is active in the inhibition to inappropriate responses (e.g. Elliott, Friston, & Dolan, 2000). Doallo et al., (2012) used fMRI to record brain activity during a Go/No-Go task, in which participants performed a motor response when Go faces were presented and inhibited this response when No-Go faces where presented. The same faces were subsequently evaluated on a trustworthiness scale. Activity in the prefrontal cortex, indicating motor inhibition, and Orbitofrontal cortex, reflecting emotional response to changes, systematically correlated with the explicit evaluation of the No-Go faces. In other words, the more a face was evaluated untrustworthy, the greater activity in these areas was observed. This result demonstrated a tight connection between attentional inhibition of automatic motor responses and affective explicit evaluation.

In another fMRI study, Schonberg et al. (2014) manipulated attention towards items with a Go/No-Go procedure. In a *cue-approach condition*, participants saw a series of food images and were instructed to press a button as fast as possible when they heard an infrequent auditory cue (25% of trials). The previously seen items were then presented in pairs and participants made a preference choice. Authors observed that cued (Go) items were consistently preferred over no-Go items and this behavioural pattern was associated with stronger activation of ventro-medial prefrontal cortex. The important aspect is that the cue represented an unpredictable and rare event, interrupting a familiar sequence of events (passive observation of the food items). Go-signals triggered a response in prefrontal areas associated with encoding the affective value of items. However, in this circumstance cueing required the activation of a positive motor response (approach), and not inhibitory control or redirection of attention, modulating explicit affective responses accordingly.

According to Mandler (2003), rare events that interrupt familiar responses and conflict with expectations trigger the activation of emotional mechanisms. This can be seen as an automatic response to changes in the environment that require a reaction. This emotional response is subsequently encoded as positive or negative, depending on the context or task requirements.

In a further experiment Schonberg et al. (2014) tested the role played by cue-avoidance in food item choices. Participants pressed the button every time they saw an image, unless they heard a tone (25% of trials). One might expect that a Stop-signal, requiring inhibition of the automatic input of pressing the button, would reflect on negative encoding of the no-Go items. Curiously, in this *cue-avoidance condition*, there was no difference in preference between no-Go and Go items.

In this study I used either predictive (Experiment 1) or counter-predictive (Experiment 2) exogenous cues. These preceded the appearance of either abstract symmetric or random patterns, and I asked participants to rate liking of the patterns. In Experiment 1 the cue indicated the valid location of the incoming pattern on 80% of the trials. In Experiment 2 the proportion of valid:invalid was reversed (20% valid 80% invalid).

Orienting to abrupt-onset cues is a spontaneous response, unaffected by an individual's ability to control attention (e.g. Vecera & Rizzo, 2004, 2006). When cues are predictive of incoming target location, the automatic response activated by the cue is summed with the endogenous expectation of finding the target at the valid (cued) location. The predictability of the cue allows the perceiver to adopt specific attentional settings that lead to fast and efficient orienting. Moreover, learned predictiveness facilitates early perceptual mechanisms (O'Brien & Raymond, 2012) – which is likely to ease the processing of pattern regularity at cued location.

Orienting to the opposite location indicated by an abrupt-onset (invalid cueing) requires voluntary inhibition, which results in some re-orienting and performance costs (Posner, 1988, 1980). The behavioural consequences of this inhibition are evident when cues are uninformative of target location. In the context of highly predictive cues, invalid cueing would require a stronger top-down inhibitory control.

Chapter 3 of the present thesis describes results showing that preference evaluation of abstract patterns was modulated by uninformative exogenous cues indicating the valid or invalid location of a target (pattern). In Experiment 3, a baseline condition in which no cue anticipated pattern appearance was included. The results (both in performance and preference evaluation) suggested that the valid – invalid difference was due to a combination of benefits associated with valid cueing and costs associated with invalid cueing.

In Experiment 1 of the current study, this combination should be amplified thanks to the endogenous component added to it. Therefore, I expected to observe greater preference for the patterns at valid locations compared to patterns at invalid locations.

In Experiment 2, the exogenous cues indicated the opposite location of the target on most of the trials. Participants could learn to use the cue to predict target location, however, this learning process conflicted with the spontaneous response to the cue. It has been demonstrated that experimental manipulation of voluntary control can modulate involuntary orienting to abrupt-onsets, even at short cue-to-target interval (interstimulus interval, ISI) (Tipples, 2008). Thus participants can learn the predictive value of the invalid cue and exploit this information to orient and respond to the invalid location. Valid cueing represents in this context the rare unpredictable event that disrupts the familiar association between cue and outcome. Considering the positive effects of predictability on evaluation previously discussed, the preference evaluation of valid vs. invalid patterns might be reversed. In other words, patterns presented in valid conditions (rare trials) would be rated more negatively than patterns shown in invalid trials (frequent trials). If this were the outcome, I would have further support for the hypothesis that implicit knowledge of predictability facilitates a preference for visual stimuli (e.g. Ogawa & Watanabe, 2011).

On the other hand, the ability of voluntarily control the response to invalid cues requires the inhibition and redirection of an automatic response, which only in rare events (valid cueing) can be fluently performed. In Chapter 3 I speculated that preference evaluation of the patterns emerged from the implicit involvement of sensorimotor processes triggered by the cue, as mere covert orienting of attention towards the target was sufficient to cancel the valid – invalid preference effect (see Experiment 1, Chapter 3). In the current study, I chose to use an ISI interval of 50ms (+100ms cue duration). Tipples (2008) used exogenous counterpredictive cues and showed that with a short ISI interval, responses to cued location were significantly slower. In that study the author tested responses on valid and invalid trials against a no-cue baseline. He observed that the valid – invalid difference in attentional performance was due to slower response on valid conditions but no facilitatory effects were observed at predicted locations.

Therefore, this suggests that in the case of counterpredictive cues a constant inhibitory control is applied to the reflexive response to the cue. Schonberg et al. (2014) observed preference enhancement for items in which a positive motor response to an infrequent cue was performed. It is possible that valid cue-to-target contingencies represent the rare event in which an approach towards the cued location can be preformed. Taking this evidence into consideration, preference ratings might be expected to be more positive for validly cued patterns (as observed with uninformative cues), despite slower (oculo)-motor responses at valid locations.

Finally, it is important to mention that in this chapter, patterns are different from Chapter 3 and Chapter 4. I wanted to see whether increased complexity and aesthetic content of the patterns would dominate, and affect the cueing influence, on evaluation.

5.3 Experiment 1

In Experiment 1 I used salient predictive peripheral cues to drive attention towards one of two locations were an abstract pattern was about to appear. Cue predictability was violated only on 20% of trials. Here I tested whether preference evaluation would increase for patterns presented in the highly predictable condition compared to patterns in invalid conditions.

5.3.1 Method

5.3.1.1 Participants

Twenty naïve participants took part (0 males, 1 left handed, aged 18-32, μ=19.4). Participants were either volunteers or undergraduates from the School of Psychology and received formative credits for their participation. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008)

5.3.1.2 Apparatus and Stimuli

Participants sat 57cm in front of a 16-in LCD monitor with resolution 1280X1024 pixels at 75Hz refreshing rate. A chinrest aligned to the centre of the screen constrained head position. The left eye movements were sampled at 120Hz using an ASL Eye-Track D6 (Applied Science Laboratories, Bedford, MA) infrared eye-monitoring camera mounted below the screen.

Stimuli were generated using the Psychopy software (Peirce, 2007) and controlled by a PC running Windows XP – 32bit. Stimuli were presented on a dark-grey background (RGB -0.7, -0.7, - 0.7 decrement from grey). The fixation mark consisted of a light blue small circle (.2° of visual angle). The fixation point was presented continuously, with the exception of the evaluation task, in which the rating scale was superimposed. Two landmark circles were located at either the left or right of the central fixation point (diameter: 8.6°; line of width: .1°; distance of the centre of the landmark circle from the centre of fixation point: ~ 9.6°). Exogenous cues consisted of a local brightness increase (modulated by a Gaussian envelope) with size 400 pixels (~ 12.8°).

Target stimuli consisted of abstract patterns with two possible degrees of regularity: four-fold reflection symmetry or random (**Fig. 1**). Elements forming the patterns were circles with three different possible diameters: .1°, .2°, 4° and a distribution of 25%, 60% and 15% respectively. All elements were constraint to fall within the boundary of the landmark (8.6° diameter). Elements fell within a grid of 0.13 X 0.13° cells, some of which were occupied with an element. The distance between the centres of 2 adjacent elements was 0.13°. The stimulus generation had two stages. First a single segment was generated, with a single axis of symmetry (**Fig. 1**). Cells in the first segments were filled basing on a loop going through each position, and deciding whether to place a dot in the cell or not. If a dot was placed in the cell on the left of the axes, another was automatically placed in the cell on the right of the axis. For each cell, the density parameter set the probability of the pair being occupied or not. The density was 40%. This means that on average, 40% of all grid positions were occupied. In stage 2, the segments were reproduced in other positions. The random patterns also had four axes and segments, although each segments was generated afresh. The selection of each element across an axis was independent.

Pattern and cue were presented either at the left or the right of fixation, at an eccentricity of 300 pixels (~ 9.6 °). The same pattern was never repeated within the same experimental session. Preference ratings were recorded with a 9-point rating scale presented at the centre of the screen. Numbers were columned from 9 to 1, headed by the words "Like very much" at the top and the words "Did not like it at all" at the bottom. Nine corresponded to the most positive rating and 1 was the most negative rating value. Participants used a gamepad with direction-arrows to give their responses.

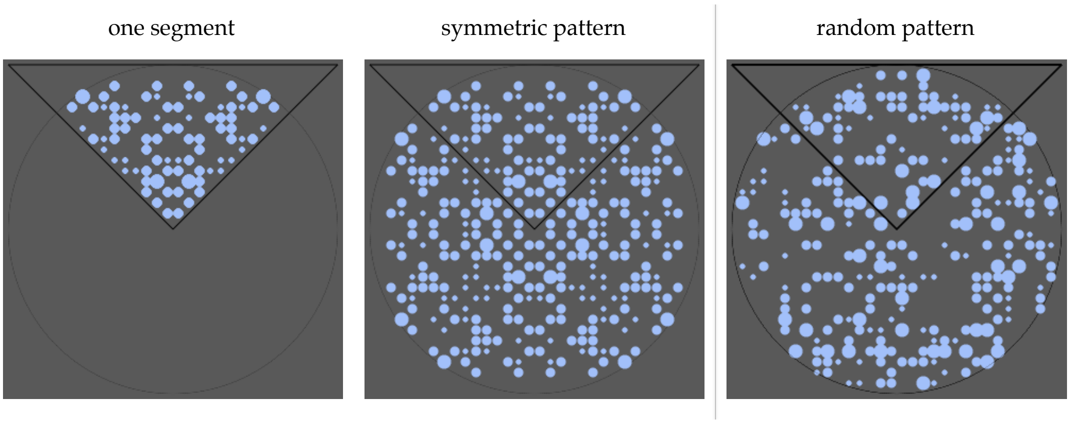

Figure 1. Examples of the patterns employed in this study. Every pattern was generated afresh at the beginning of each trial. First, one segment was generated, which was reproduced in all other segments in symmetric patterns. In random patterns all segments were generated independently.

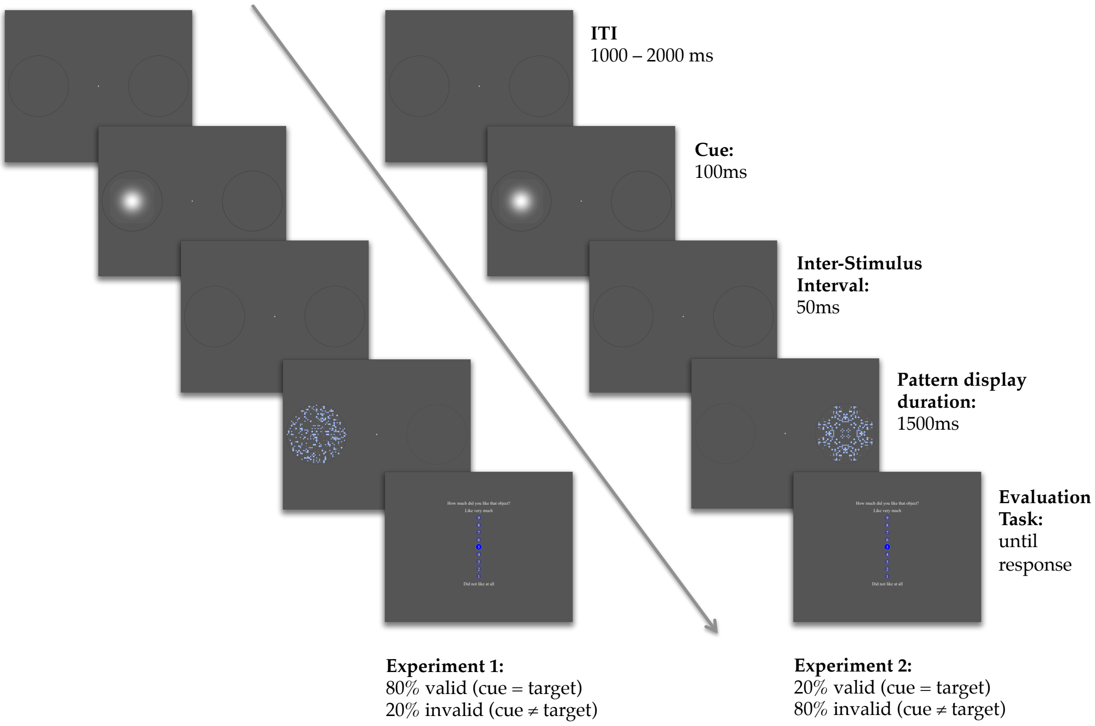

Figure 2. Sequence of events for each experimental trial. After a randomised inter-trial interval (ITI) the cue flashed either on the left or on the right. In Experiment 1, the cue was predictive of target location in 80% of trials. In Experiment 2 the cue was counter-predictive and indicated the opposite location of the incoming target on 80% of trials. Between cue offset and target onset there was an inter-stimulus interval (ISI) of 50ms. The target stimuli remained on the screen for 1500ms. During this time participant discriminated the degree of regularity of the pattern (random, symmetry) and reported it as fast and accurately as possible. Note that in both experiments participants kept fixation until patterns appeared, then they performed a saccade towards the pattern before giving their response. A 9-point rating scale (9- like very much; 1- did not like at all), was presented after pattern offset and remained on the screen until participants confirmed their selection.

5.3.1.3 Procedure

The sequence of events in a trial is shown in Figure 2. Each trial started with a variable inter trial interval (ITI) from a minimum of 1000ms to a maximum of 2000ms. The exogenous cue immediately followed and flashed for 100ms either on the left or on the right of the fixation cross. After an Inter-stimulus interval (ISI) of 50ms, the target-pattern was presented at the same location indicated by the cue (Valid location) 80% of trials, and at the opposite location of the cue (Invalid location) on the remaining 20% of trials. Participants were required to keep fixation until the pattern appeared. They performed a saccade towards the pattern as soon it appears on the screen. Participants were instructed to respond as fast and accurately as possible to pattern regularity. Reponses were given by using the bottom-shoulder buttons of a gamepad. Half of the participants pressed left button for 'symmetry' and right button for 'random'; the other participants did the opposite. Patterns remained on the screen for 1500ms. I ensured all patterns were seen for the same amount of time before being evaluated. The rating scale followed immediately the patterns. Participants moved on the rating scale with the directional up/down buttons of the gamepad, and pressed another button to confirm their choice. After 500ms, the fixation screen was presented and a new trial started. The experiment consisted of 128 trials. There was a break every 32 trials, in which participants could rest and disengage the eyes from the screen.

A practice session of 32 trials preceded the experiment, to ensure participants familiarized with the stimuli. They did not rate the patterns during practice, and they were told about this task only before starting the proper experiment. Moreover, in the practice session patterns remained on the screen for 1000ms. If participants did not manage to respond before that time, patterns were replaced by the message "too late" at the centre of the screen for 500ms.

5.3.1.4 Design

A whole experiment consisted of 140 trials. There were 70 symmetric patterns and 70 random patterns. Twenty participants performed the task with predictive cues: 80% of trials (112 trials) were valid, 20% of trials (28 trials) were invalid. Cues and patterns position was balanced, so that both appeared on the left and right side of the screen the same number of times.

No participant ever saw the same pattern twice. It is important to note that a new pattern was generated at the beginning of each trial. One participant never saw the same pattern twice and all participants saw different patterns. This last point is different from other similar studies (e.g. those described in Chapter 3 and Chapter 4) in which the same patterns were used for all participants and counterbalanced across conditions. Given the unbalanced nature of the current design, I considered more appropriate to generate 140 different patterns x 20 participants (the patterns used in the practice session were the same for all participants and different from any of the patterns employed in the experimental session).

5.3.1.5 Data Analysis

A 2 X 2 mixed ANOVA was conducted on the data. Cue validity (valid, invalid) and pattern regularity (symmetry, random) were the within subjects factors. The dependent variables analysed were: saccadic latency, error rates, manual reaction times and preference ratings.

Data cleaning. Data, in which the recording of eye movement was subjected to artefacts or eye blinks, were discarded (0.4%). Saccades performed before 100ms after target onset were considered responses to the cue (time-window taken in consideration began at cue-onset and extended 100ms after target appearance (200ms, 24 samples)). Anticipatory saccadic responses (5.2% overall) were excluded from analysis. Trials in which eyes never moved from fixation during pattern display were also discarded (0.4%). Eyes position was calculated by averaging samples within a time window going from 100ms after pattern onset and 1000ms after pattern onset (108 samples). This value needed to be at least greater than 2° from average fixation to be considered as valid. Criterions of exclusion for manual reaction times regarded anticipations (RTs < 150ms: 0%) and misses (no response: 2.4%).

In total 2592 trials (92.6%) were included in the analysis (93% of valid trials, 90.3% of invalid trials, 92.3% of symmetry and 91.2% of random).

5.3.2 Results

Results are illustrated in **Fig. 3**.

Saccadic Latency. Main effect of Validity was significant ($F_{(1,19)}$ = 70.354, p< .001, η^2_p = .787), with shorter latencies on valid conditions than invalid condition. The main effect of pattern regularity was significant ($F_{(1,19)}$ = 5.135, p= .035, η^2_p = .213), with faster saccadic response to symmetry than random (μ difference 8ms ± SE 3). The interaction between Validity and Pattern Regularity was significant ($F_{(1,19)}$ = 6.073, p= .023, η^2_p = .242). Paired t-tests analysis showed no difference in saccadic latency between symmetry and random in valid trials (mean difference= 1.78ms, SD= 17.8ms; $t_{(19)}$ = .446, p= .661, d=0.2). In invalid trials, faster saccades were performed when patterns were symmetric (mean difference= -17.38ms, SD= 27.5ms; $t_{(19)}$ = -2.821, p= .011, d= -1.29).

Accuracy. There were no significant main effects or interactions. Correct responses in valid trials were 96.6% and in invalid trials 96.7%.

Manual Reaction Times. Main effect of Validity was significant ($F_{(1,19)}$ = 32.519, p< .001, η^2_p = .631), with faster responses on valid conditions than invalid condition. Other main effects or interactions were not significant.

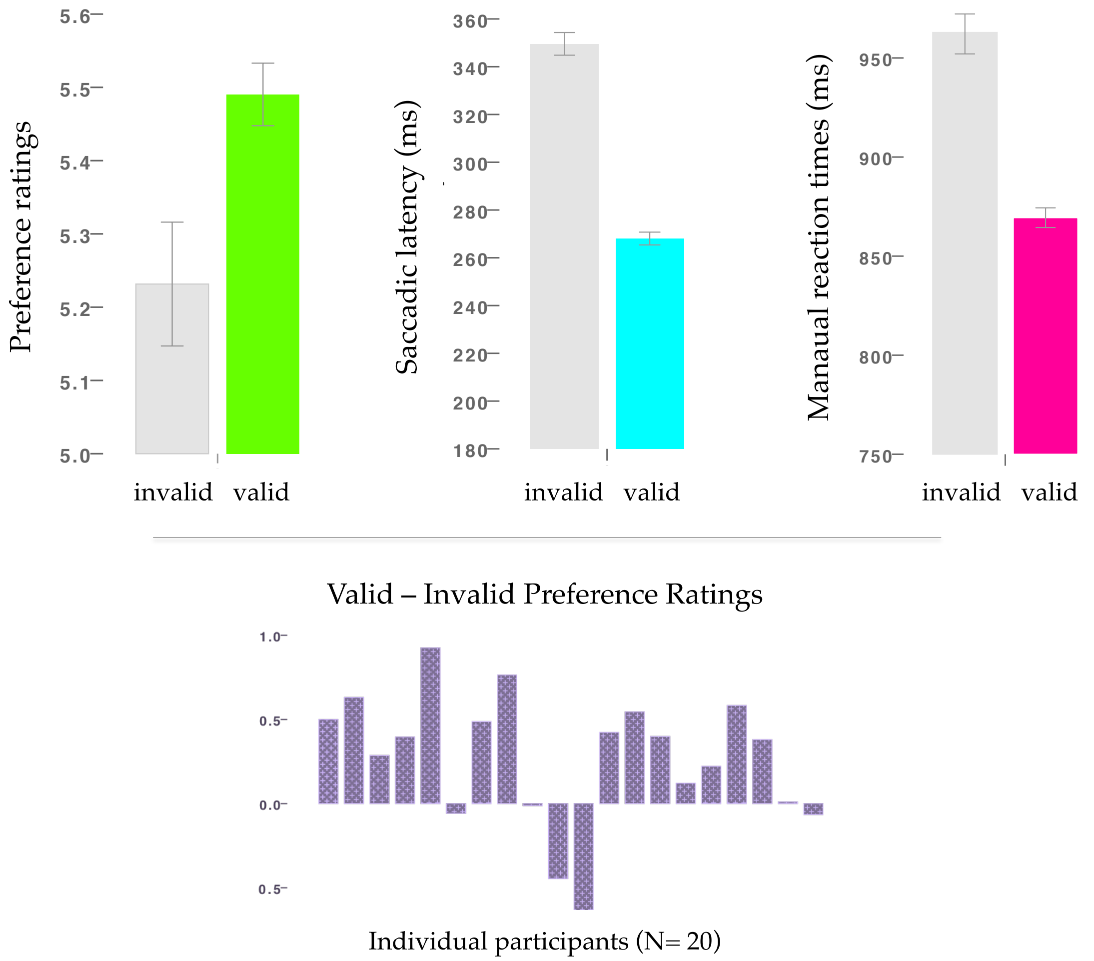

Figure 3. Bar graphs showing results from Experiment 1. **Top left**. Preference ratings, Top middle: Saccadic latency, **Top right**: Manual reaction times. Coloured bars indicate valid conditions, whilst grey bars indicate invalid conditions. Error bars indicate ± 1 SE. Bottom-plot reports rating-biases shown by individual participants (in the order in which they were recruited). Bars above zero indicate that a participant rated valid patterns more positively than invalid patterns.

Preference ratings. A significant main effect of Validity was obtained ($F_{(1,19)} = 9.117$, $p= .007$, $\eta^2_p = .324$) with patterns on valid conditions generally rated more positively than patterns on invalid conditions. The main effect of Pattern Regularity was also significant ($F_{(1,19)} = 56.551$, $p< .001$, $\eta^2_p = .749$), with symmetry liked more than random patterns (see top plot in Fig 2A). There was also a weak interaction between Validity and Pattern Regularity ($F_{(1,19)}= 5.303$, $p= .045$, $\eta^2_p= .196$). T-test analysis revealed that the difference valid – invalid ratings was significantly greater than zero for symmetry (mean difference= .36 ± SE .09; $t_{(1,19)} = 3.969$, $p = .001$, d= 1.82), but not for random (mean difference= .14 ± SE .1; $t_{(1,19)} = 1.390$, $p = .181$, d= 0.6).

5.3.3 Discussion Experiment 1

Predictable cues led to faster oculomotor and manual responses at valid locations. Preference ratings were more positive on valid trials than invalid trials. The synergistic action of exogenous and endogenous factors elicited by predictable cues influences attention and preference formation in favour of the expected stimulus contingency. This effect on preference may be associated with an increase in preference when endogenous predictions are confirmed (e.g. Ogawa & Watanabe, 2011). Alternatively, violated predictions and suppression of inappropriate responses may produce "punishment signals" and might have a negative impact on the evaluation (e.g. Doallo et al., 2012; Nobre et al, 1999).

In Experiment 2 I reversed the predictable nature of the cue, so that it indicated the opposite location of the incoming target on the 80% of times. In this case, endogenous and exogenous dimensions did not cooperate but instead had opposite directions. This experiment was intended to highlight what factor plays the crucial role of influencing preference evaluation. If learned predictability enhances preference when predicted stimulus contingencies are confirmed, I should observe more positive values for patterns at locations opposite to the cue.

In the present experiment I also observed that in invalid trials saccadic latencies were even slower if the pattern was random. Salient stimulus features (like symmetry in this case) can elicit strong saccadic responses (van Zoest, Donk, & Van der Stigchel, 2012). This suggests that if the pattern at the invalid location was symmetric and more salient, the process of re-orienting was probably facilitated. However, this specific effect was not part of our hypotheses and did not reflect on preference modulation, which instead appeared to be more marked for symmetry.

5.4 Experiment 2

In this experiment I tested how preference evaluation of abstract patterns was influenced by counter-predictive cues. Please note that I will still refer to *valid condition* as the condition in which the cue indicates the correct location of the target (unpredicted condition). Conversely, *invalid* *condition* refers to the condition in which the cue indicates the opposite location of the target (unpredicted condition).

In invalid condition, the cue has a predictable value and can be used to predict the location of the incoming target and efficiently respond to it. However, an abrupt onset in the periphery automatically triggers the activation of the orienting system towards its location and inhibitory mechanisms come into play for re-orienting attention to the expected target location.

Faster responses at the opposite side of the cue would indicate that the learned (counter)predictability of the cue has been encoded and voluntarily used to efficiently enhance performance. There are three different possible outcomes that could be obtained on preference ratings.

1. *Invalid* > *Valid*. Valid – invalid effect on preference might reflect the effect observed in attention orienting. If preference ratings will be more positive at the predicted location I could argue that predictability is associated with higher preference.
2. *Invalid = Valid.* No difference between conditions might be obtained. Every time that exogenous cuing triggers the activation of specific orienting mechanisms, this has to be inhibited to promote a response to the opposite side. The inhibition is applied in every trial irrespective of whether the cue will turn out to be invalid or valid. If top-down inhibitory control is the critical factor in evaluation, no difference will be observed between the two conditions.
3. *Invalid < Valid.* A positive valid – invalid effect on preference might persist, despite what observed on attention orienting. This result is unlikely to happen, as the endogenous orienting mechanisms would be directed toward the likely loci (i.e., opposite the cue) before target presentation. However if modulation of preference is strictly linked to orienting mechanisms activated (and inhibited) by exogenous stimulation, ratings should be more positive for patterns at validly cued locations.

5.4.1 Method

Stimuli, Apparatus and Design were the same as Experiment 1. The critical difference in this experiment is that a group of twenty participants (age:18-

30; average:19.4; 4 males; 1 left handed) performed the task with counter-predictive cues: 80% of invalid trials and 20% of valid trials.

Like in experiment 1 data from each dependent variable (saccadic latency, MRT, preference ratings) were analysed with a 2 (valid, invalid) X 2 (symmetry, random) mixed ANOVA.

Data cleaning. Eye artefacts and blinks were the 0.8%. Eyes responses to the cue were 4.6%. Missed saccadic responses were 1.3%. Anticipatory manual responses were 0% and misses were 3%. A total of 2590 trials (92.5%) were analysed (92.5% of valid trials, 92.5 % of invalid trials, 92.7% of symmetry and 91.4% of random).

5.4.2 Results.

Results are shown in **Fig. 4**.

Saccadic Latency. No main effect of Validity was observed ($F_{(1,19)} = 1.814$, $p= .194$, $\eta^2_p = .087$), and no any other significant main effect ($p> .1$).

Accuracy and Manual Reaction Times Accurate responses were 97% in all conditions. There was no difference in manual reaction times between valid and invalid trials ($F_{(1,19)} = .064$, $p= .80$, $\eta^2_p = .003$). No main effects or interactions were observed ($p> .3$).

Preference ratings. The main effect of Validity was not significant ($F_{(1,19)} = 3.407$, $p= .08$, $\eta^2_p = .152$). Symmetry was rated more positively than random ($F_{(1,19)} = 70.483$, $p< .001$, $\eta^2_p = .788$). No significant interaction between Validity and Pattern Regularity was found ($F_{(1,19)} = .189$, $p= .669$, $\eta^2_p = .010$).

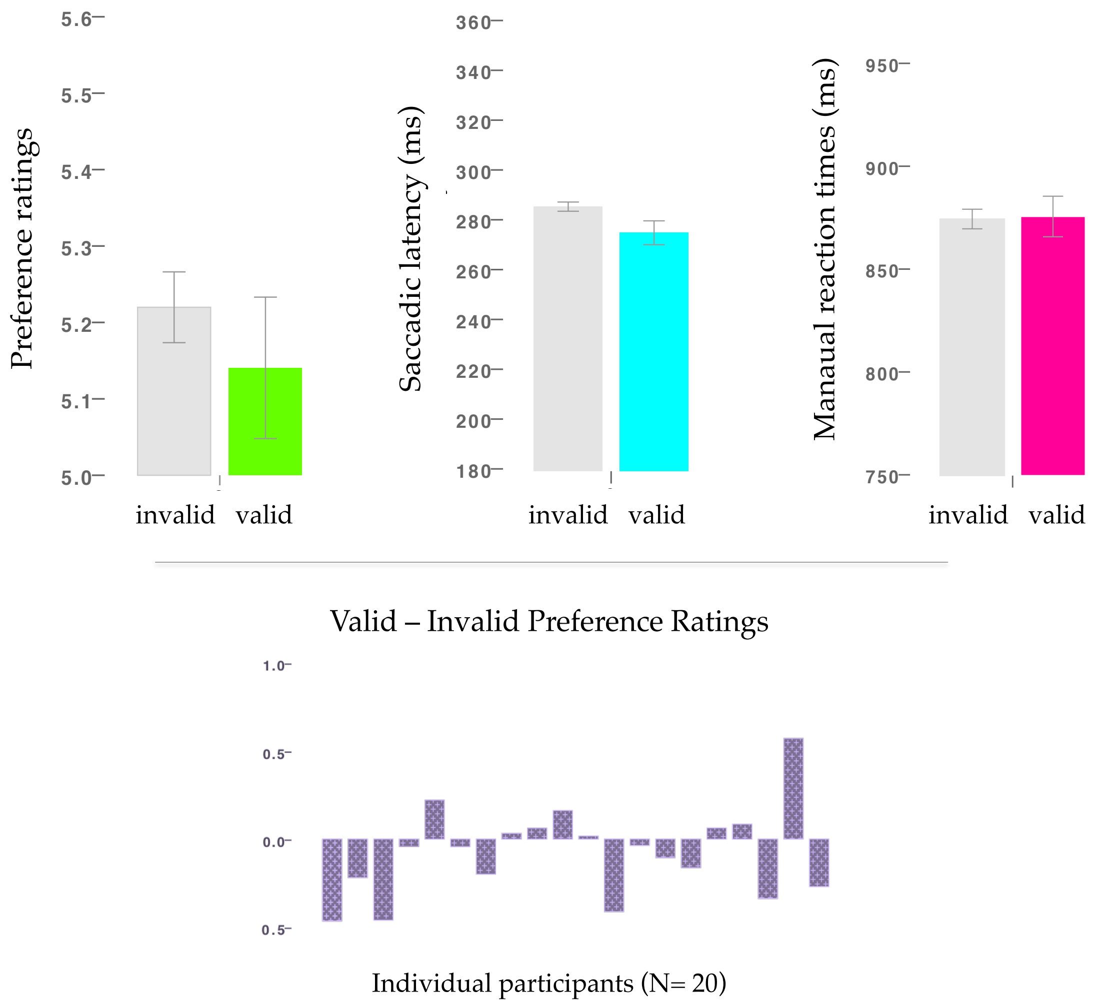

Figure 4. Bar graphs showing results from Experiment 2. **Top left**. Preference ratings, Top middle: Saccadic latency, **Top right**: Manual reaction times. Coloured bars: valid conditions, grey bars: invalid conditions. Error bars indicate ± 1 SE. **Bottom-plot** reports rating-biases shown by individual participants (in the order in which they were recruited). Bars above zero indicate that a participant rated valid patterns more positively than invalid patterns.

5.4.3 Discussion of Experiment 2

In this experiment I observed no difference between invalid and valid trials in any of the dimensions analysed (saccadic latency, manual response speed and preference evaluation). Here endogenous and exogenous factors activated attentional orienting towards opposing directions. This null result showed that voluntary control cancelled orienting to peripheral cues when participants were actively encouraged to counteract the effects of such cues (Spence & Driver, 1994; Tipples, 2008).

The absence of effect on preference evaluation might be a consequence of the top-down suppression that was constantly applied to the cue (irrespective of whether it will turn out to be valid or invalid). This result was one of the possibilities I predicted (2. *Invalid = Valid*). However, it is problematic to base strong conclusions on a null result. The intention of this experiment was to observe a reversed valid – invalid effect on attention orienting (due to voluntary orienting towards the opposite location of the cue). Without the evidence of such an effect, it is not conceivable to argue that an actual inhibition was applied on the cue and this was reflected on evaluation.

Therefore these data are only preliminary and warrant further investigation. There are some methodological weaknesses in this experiment that should be addressed in future studies. For simplicity and consistency with the design applied in Experiment 1, I used only one Stimulus Onset Asynchrony (SOA, interval going from cue onset to target onset) of 150ms. Spence & Driver (1994) used counterpredictive auditory abrupt-onset cues. SOA between cue and target could be either 100ms, 400ms, or 1,000ms. At short (100-msec) SOA between cue and target, participants prevented orienting to counterpredictive abrupt-onset cues (involuntary effects were eliminated, similarly to our case). However, reorienting effects did not emerge until a cue-to-target SOA of 400 msec. These findings suggest that a SOA of 150ms in the present experiment presumably did not allow sufficient time for a shift of endogenous attention away from the cue. If longer SOA was employed faster responses at predicted locations might be observed. This would confirm that information associated with the cue has been encoded and used to construct a prediction regarding target appearance. In such condition, increased preference for patterns on predictive (invalid) trials might be observed. That said, it could be possible that mere increment in power in the current design is sufficient to reveal an effect on preference, despite the absence of effect on performance. There was a small tendency towards more positive ratings on invalid trials in the current experiment (p = .08). Although, 150ms SOA is too short for a visible attentional orienting effect on response speed, this does not preclude the perceiver to encode efficiently the predicted (or unpredicted) cue-to-target contingency later on (note that the pattern remained on the screen for 1500ms before rating was required). Finally, the current design might have benefited with the addition of a baseline condition. In Tipples (2008), targets appeared in either the opposite (predicted) location of the cue (on 75% of trials), or the same (cued) location as the cue (on 8% of trials), or in a location that was neither predicted nor cued (NP–NC) on the remaining trials. The presence of a baseline condition was critical for testing the direction of the voluntary/involuntary effects at the different SOAs. The author observed that at 105ms SOA, manual responses at cued locations were significantly slower than at predicted location (effect that I did not replicate) and significantly slower than NP-NC conditions. This last effect reflected inhibitory action of endogenous control. The effect of voluntary reorienting (and encoding of cue predictability) against the baseline was observed only at 600ms SOA. Adding a NP-NC condition in both the designs of Experiment 2 and Experiment 1 might provide a suitable baseline against which the effect of the two opposing mechanisms on performance and preference can be tested. These expedients may improve the quality of the design and the results obtained. However, it is important to bear in mind that an increment in the number of variables would affect the statistical power of the different conditions. This implies the necessity of increasing considerably either the number of trials or sample sizes. The first options is inconvenient, as long experiments are more likely to increase the level of fatigue and boredom, leading to loss of commitment and unreliable evaluations. It is therefore paramount in future studies to employ larger sample sizes to detect differences between conditions.

Overall this experiment did not provide evidence of voluntary attentional re-orienting on response speed, and how this influences preference. However, these preliminary data suggest that when the two putative types of orienting are set against each other, they cancel each other out. Exogenous factors may be important in influencing attention orienting and preference formation, but they depend on endogenous control. In the General Discussion I will speculate about how endogenous and exogenous attention synergistically cooperate and affect preference accordingly.

	Experiment 1				**Experiment 2**			
	invalid		**valid**		**invalid**		**valid**	
	mean	**SE**	**mean**	**SE**	**mean**	**SE**	**mean**	**SE**
Saccadic Latency	350ms	13.6	268ms	16.5	290ms	6.7	276ms	9.4
Manual RTs	970ms	.03	873ms	.03	878ms	.02	881ms	.03
Preference Ratings	5.22	.15	5.48	.14	5.2	.08	5.1	.09

Table 1. Mean saccadic latencies, RTs and ratings and SE in Experiment 1 and 2.

5.5 General Discussion.

Being able to make predictions about the where, when and what of future events is an evolutionary adaptive behaviour. This ability allows the brain to efficiently encode sensory information, and save costly resources that serve for reacting to unexpected evidences. It is likely that emotions are tightly connected with predictive coding in guiding behaviour towards positive outcomes (see Van de Cruys & Wagemans, 2011).

It is possible that correctly predicted stimulus contingencies are rewarding and lead to positive affect (Ogawa & Watanabe, 2011). Conversely, when learned and expected stimulus associations are violated, negative affective responses may arise. There is evidence showing that unpredictability triggers the activation of brain areas involved in the encoding of emotional responses (e.g. den Ouden, et al. 2010; Herry et al., 2007; Nobre et al., 1999). In an fMRI study, Nobre and colleagues (1999) manipulated spatial or temporal orienting of visual attention toward peripheral stimuli by using predictive exogenous cues. The presence of invalid trials increased activations in premotor cortex around the orbital sulcus. Engagement of orbitofrontal cortex (OFC) in inhibiting prepared motor programs was also reported with fMRI studies using go/no-go response choices (Doallo et al., 2012; and Elliott, Friston, & Dolan, 2000 for a review). Importantly, Doallo et al (2012) observed that activation of OFC activity during response inhibition was reflected in subsequent devaluation.

In this study I manipulated the predictability of exogenous cues. In Experiment 1, a predictive exogenous cue indicated the correct location of an incoming abstract pattern on the 80% of trials. Participants were instructed to look at the patterns and quickly report whether the pattern was symmetric or random. As soon as the pattern disappeared, they also rated the pattern on a 9-points scale. In this experiment the exogenous evidence (bottom-up capture of attention and activation of the orienting system) boosted endogenous expectation (using information associated with the cue to predict target appearance).

Oculomotor responses were on average 82ms (SE=9.8) faster on valid trials than invalid trials. The discrimination of pattern regularity was also

98ms (SE=17) faster at valid locations. These large effect-sizes clearly reflected a synergistic interaction between bottom-up and top-down component. Given the predictable nature of the cue, attention allowed to efficiently reacting to the cue anticipating the appearance of the target at the same location. When an invalid trial was presented, the inhibition of this anticipatory mechanism, and reprogramming of a new response towards the opposite location, was effortful and time-consuming.

Importantly, more positive ratings for validly cued patterns (predicted event) than invalid patterns (unpredicted event) were observed. This suggests that endogenous shifts of attention, initiated strategically in response to an informative cue, influence pattern evaluation in favour of patterns that appear at the focus of attention.

This result is in accordance with the view that violation of expectation leads to suppression of inappropriate responses resulting in low emotional ratings during subsequent affective evaluations (Doallo et al., 2012; Nobre et al, 1999). However, the same result can be seen from another perspective. Preference for predictive (valid) contingencies might have developed. This could be interpreted as evidence that implicitly learned knowledge of predictability enhances preferences for visual stimuli (Ogawa and Watanabe, 2011).

Experiment 2 employed counterpredictive cues, which indicated the incorrect location of the target on 80% of trials. In this study, instead of a synergistic action between endogenous and exogenous components, top-down predictions were inconsistent with bottom-up influences. The cue could be voluntarily used to anticipate the incoming target (learned predictions). On the other hand abrupt onset activated orienting mechanisms on every trial (exogenous evidence). I observed that the two types of orienting set against each other levelled off the difference between valid and invalid. As discussed in previous paragraph, the interval between cue and target onset was presumably too short to allow re-orienting and preparation of a voluntary response at the likely target location. Nevertheless, absence of a difference between valid and invalid conditions provided evidence of efficient top-down control applied on the cue prior to target appearance. Ratings were consequentially low and similar in both conditions.

Table 1 summarises mean results for the three dimensions analysed in both experiments. Saccadic and manual responses in invalid trials in Experiment 1 were much slower than in other conditions. In the context of the infrequent invalid trials, top-down inhibitory processes participated both in the redirection of the response based upon a violation in stimulus contingencies and in possible changes of emotional state. I speculate that, as a consequence of these effortful processes, patterns at invalid locations were penalised and evaluated more negatively in Experiment 1.

Finally, the present results have another important implication. They demonstrate that subjects can modulate their sensitivity to exogenous influences by adopting specific attentional mind-set. In previous studies (described in Chapter 4 and Chapter 5 of the present thesis) employing uninformative cues (which in theory are exempt from top-down predictions), I observed a modulation of preference evaluation. Preference ratings for validly cued patterns were more positive than for invalidly cued patterns, similar to that observed in the present Experiment 1.

It is interesting that uninformative and predictive cues have been shown to produce similar valid – invalid effects, whilst counterpredictive cues failed to overcome endogenous control. Previous research has shown that the ability of abrupt-onset cues to affect participants' responses is contingent on the specific attentional control settings adopted by the perceiver (see Santangelo & Spence, 2008). This means that for an exogenous cue to trigger a spontaneous and efficient response, the subject has to be prepared to respond to an incoming cue-to-target contingency. Presumably, the mechanisms that control attention orienting and preference evaluation with highly predictive cues are the same as those triggered by uninformative exogenous cues.

6 Testing whether dwelling gaze for a longer period in valid conditions causes preference modulation

6.1 Abstract

Preference for abstract patterns is affected by valid or invalid cueing of location. This study tested the impact of pattern exposure duration on preference modulation observed in our previous studies. Because of the shorter latency in the oculomotor response, dwell time was longer over patterns (targets) at locations previously indicated by a peripheral cue. This was due to the fact that patterns were displayed for a fixed amount of time (1500ms). The processing time thus depended on the speed for a saccade to reach the pattern. In this study, a gaze-contingent method allowed to control the exact amount of dwell duration over the pattern. Results showed preference modulation for valid vs invalid conditions even if gaze dwelled over patterns for the same amount of time. A role of exposure duration on the preference effect elicited by exogenous peripheral cues was ruled out.

6.2 Introduction

In this manuscript I report data from an experiment in which exogenous cuing was employed to test preference evaluation, and the time that to-be-evaluated patterns were fixated was controlled. Results discussed in Chapters 3 – 5 have demonstrated that uninformative exogenous cues not only affect attention orienting and perceptual processes (i.e. target discrimination and detection) but also influence the way the target (i.e. an abstract dot-pattern) is evaluated in terms of liking. The design of these experiments consisted on a variation of a classic exogenous cuing task (Posner, 1980), in which the target was an abstract pattern and participants had to report their liking for the pattern at the end of each trial.

The abrupt-onset of a peripheral cue immediately triggers the activation of a complex orienting system towards its direction, which includes the preparation of (oculo)motor responses for the localization and processing of the incoming target (Ludwig et al., 2008). If the target appears at the same location of the cue, this programmed response can be finally executed. This leads to attentional benefits that can be reliably recorded as faster response latencies at cued locations. In the opposite invalid cue case, the target appears at the opposite location to the cue. If the interval between cue offset and target onset is very short (in our case 50ms) this second input reaches the orienting system in the moment in which this is still involved in the response to the cue. This second stimulation triggers immediate inhibition of the previous response in order to re-orient attention to the opposite location. This process normally entails some attentional costs that are recorded as slower latency.

In our experiments patterns that were validly cued were recognised faster and rated as more beautiful. I believe that preference evaluation was modulated by a combination of beneficial and inhibitory processes mediating the executive control of oculomotor and manual responses at the cued location. Consequentially, more positive values were more often attributed to valid patterns and more negative values were more likely to be chosen in an invalid trial.

This validity effect (valid – invalid) on preference was observed in more than one experiment, except when participants were required not to gaze at the pattern and covertly attended to it (see Experiment 1, Chapter 3). In this specific case, pattern discrimination at valid location still benefited from the shift of attention induced by the cue. However, preventing gazing towards the pattern eliminated the valid – invalid difference in preference ratings. This led to the conclusion that the process of gazing (activated exogenously by the cue and reinforced by target onset) or inhibition and re-orienting of gaze (induced by target onset at a different location) were primarily involved in the modulation of preference.

One important aspect in these studies is that exposure duration was fixed at 1500ms, independently of response speed. This strategy was adopted to ensure that stimuli were exposed for the same amount if time, as exposure duration is known to be a factor influencing preference evaluation. With subtle variations of the stimulus presentation duration, Reber, Winkielman & Schwarz (1998) observed that participants liked a stimulus more the longer it was exposed. They presented black-and-white square patterns at fixation for different periods of time (100, 200, 300, and 400 ms) and asked participants to report how much they liked the pattern on a rating scale from 0 to 9 immediately after exposure. They observed a linear increase in preference ratings with increasing exposure duration. The authors concluded that people like objects that are presented for longer times more than objects that are presented for shorter times, presumably because longer exposure facilitates the processing of the stimulus ("*perceptual fluency hypothesis*": visual stimuli that are more efficiently processed are more likely to be preferred; see Reber, Schwarz, Winkielman, 2004 and Winkielman, Schwarz, Fazendeiro, & Reber, 2003).

The duration of stimulus presentation is critical for the extraction of information from stimuli (Mackworth, 1963). With longer presentation duration more visual information can be acquired, increasing the likelihood of fluent processing and higher preference. This takes into account that the stimulus needs to be foveated in order for exposure duration to have an impact on processing and preference.

Although in previous experiments the objective duration of the patterns on the screen was fixed, there was no control for the actual amount of time spent foveating the pattern. This varied across trials, conditions and subjects, and depended either on saccade latency or how long gaze dwelled on the pattern before moving back to fixation. In valid trials, saccades to the patterns were faster than in invalid trials. This led to the possibility that patterns in valid trials were foveated for longer periods of time than patterns in invalid trials, because eyes reached the patterns in a shorter period of time. Differences in dwell duration over valid/invalid locations might have biased evaluation, as participants might be slightly less likely to extract enough information from less foveated patterns. This would have some important implications on the way in which the valid – invalid effect on preference has been interpreted.

The current study addresses the possibility that differences in the gaze dwelling duration between valid and invalid trials could have biased preference evaluations in our previous studies.

The first section briefly reports eye-data from three of our previous experiments (Experiment 1, Chapter 3; Experiment 2, Chapter 3; Experiment 1, Chapter 5), showing mean difference in gaze dwelling time on both valid and invalid conditions.

The second section reports on a new experiment, in which the duration of the pattern on the screen was controlled with a gaze-contingent manipulation. Uninformative peripheral cues were employed to indicate either the correct (*valid*) or opposite (*invalid*) location of an abstract pattern, with either symmetric or random configuration. Participants performed a saccade towards the pattern as soon as it appeared on the screen and were required to look at the pattern until it disappeared. Immediately afterwards they were required to report how much they liked the pattern on a 9 points rating scale.

The important aspect of this experiment is that pattern presentation was 1500ms starting at the moment in which eyes reached the pattern. In this way each pattern could be foveated for the same amount of time, irrespective of saccadic latency. By updating the display based on the viewer's gaze position, it is possible to precisely control over exposure to individual stimuli. This method gave us the possibility to control effectively for possible biases in preference evaluation due to differences in exposure duration.

6.3 Previous Studies

Analysis of gaze duration over the target in previous studies testing the effect of exogenous cueing on preference evaluation

Gaze duration on patterns presented at either valid (cued) or invalid (un-cued) locations was analysed using the data recorded in three previous experiments (described in the present thesis: Experiment 1, Chapter 3; Experiment 2, Chapter 3; Experiment 1, Chapter 5).

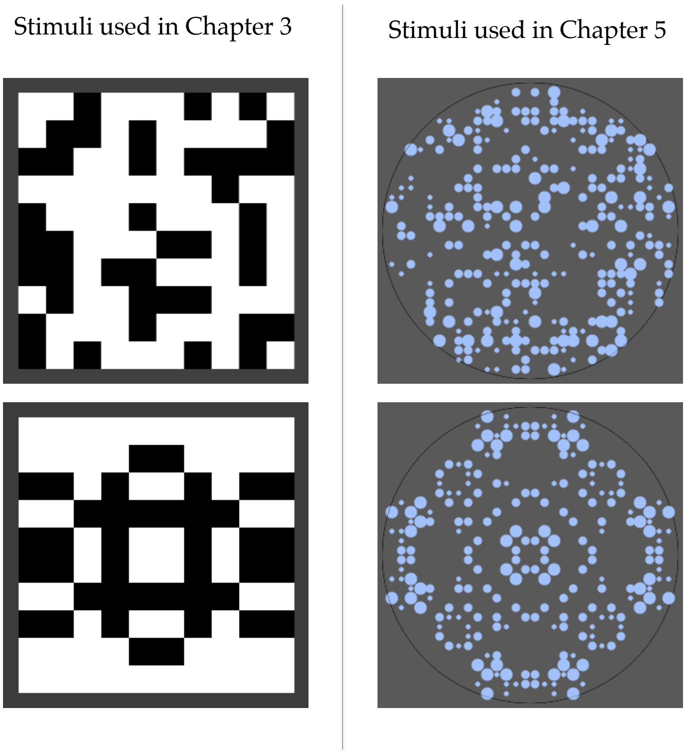

Figure 1. Examples of the stimuli employed in previous studies. **Left column**. Stimuli employed in Experiment 1 and Experiment 2 of Chapter 3. Top: random pattern, bottom: symmetric pattern. **Right column**. Stimuli employed in Experiment 1 of Chapter 5. Top: random pattern, bottom: symmetric pattern.

6.3.1 Method

In all experiments the left eye movements were sampled at 120Hz using an ASL Eye-Track D6 (Applied Science Laboratories, Bedford, MA) infrared eye-monitoring camera mounted below the screen. Stimuli were generated using the *Psychopy* software (Peirce, 2007) and controlled by a PC running Windows XP – 32bit.

Figure 1 shows examples of the target stimuli employed in the previous studies. In all experiments stimuli were presented within a grey background, with a fixation cross in the middle. After a randomised interval between 1000-2000ms, a bright cue appeared at either the left or right of fixation. Cue remained on the screen for 100ms followed by an inter-stimulus interval of 50ms. The pattern appeared either at cued location (valid) or location opposite to the cue (invalid). In Experiment 1 of Chapter 3, cues could be either valid or invalid and were uninformative. In Experiment 2 of Chapter 3, there was an additional condition in which no cue preceded pattern onset; cues were still uninformative. Experiment 1 of Chapter 3 used predictive cues (80% valid and 20% invalid). In all experiments, participants were instructed to wait for the pattern to appear, and then they gazed to the pattern and reported pattern regularity by pressing a button on a gamepad as quickly and accurately as they could.

Eye-data analysis. Gaze duration over a pattern was defined as the number of samples in which the coordinates of the left eye were recorded over the area occupied by the pattern (area of interest, AOI). For each trial the number of samples was counted starting from the first sample in which the left eye coordinates were included in AOI until the first sample in which it moved back to fixation. The number was multiplied by 8.333333ms (1000ms/120Hz) in order to obtain the time eye remained over the pattern on each trial. We considered only trials in which a correct saccade to the pattern was made, according to criteria applied on eye data and described in detail in the Method session of each experiment.

In most of the cases eyes dwelled at pattern location while the pattern remained on the screen. This was confirmed in the 62% of trials in Experiment 1, Chapter 3, in 59% of trials in Experiment 2; Chapter 3, and in the 98% of Experiment 1, Chapter 5. In the remaining trials, eyes left the pattern before pattern offset.

6.3.2 Results and discussion

Experiment 1, Chapter 3. A mixed 2 (valid, invalid) X 2 (symmetry, random) ANOVA was conducted. This revealed a significant difference between valid and invalid trials (F (1,29) = 21.84, $p < .001$, $\eta^2_p = .43$), with longer gaze dwell duration over valid locations (mean difference = 44ms, SE 9.3) (**Fig. 2**A). There was no significant effect of regularity (F (1,29) = 3.379, $p < .076$, $\eta^2_p = .10$), although gaze tended to dwell for longer time over symmetry than over random (mean difference = 18.6ms, SE = 10). No interaction was observed (F (1,29) = .006, p = .9).

*Experiment 2, Chapter 3***.** A 3 (valid, no-cue, invalid) X 2 (symmetry, random) mixed ANOVA revealed significant validity effect (F (1,29) = 17.968, $p < .001$, $\eta^2_p = .38$). Gaze dwelled for longer time over the patterns in valid trials than no-cue (mean difference = 63ms; SE= 12; $p < .001$) and invalid trials (mean difference = 56ms; SE= 13; $p < .001$). The difference between no-cue and invalid was null (mean difference = 6.8ms; SE= 9; p = 1). No other effect or interaction was recoded (all ps > .3).

*Experiment 1, Chapter 5***.** A mixed 2 (valid, invalid) X 2 (symmetry, random) ANOVA was conducted. The main validity effect was significant ($F_{(1,19)} = 68.94$, $p < .001$, $\eta^2_p = .78$), with longer gaze duration over valid locations (mean difference = 81.6, SE= 9.8). Gaze dwelled over symmetry for a longer time (mean difference= 8ms, SE= 3; $F_{(1,19)}= 5.98$, p = .024, $\eta^2_p = .24$). There was also significant interaction between validity and regularity ($F_{(1,19)} = 6.26$, p = .022, $\eta^2_p = .25$). Eyes dwelled over symmetry for longer time than random only on invalid trials ($t_{(19)} = 2.96$, p = .008).

For all experiments (re-)analysed gaze dwelled over the patterns for a significantly longer time on valid trials. These results may reflect that observed for saccadic latencies. Differences depended mainly on the speed eyes reached the pattern, as pattern duration was limited to 1500ms. For example, gaze dwelled for longer time over symmetric patterns than random patterns (see Experiment 1, Chapter 5) presumably because saccadic responses were faster towards symmetry than towards random in that experiment.

Mean differences in gaze duration between valid and invalid conditions measured 44ms (Experiment 1, Chapter 3), 55 and 63 (Experiment 2, Chapter 3) and 82ms. (Experiment 1, Chapter 5). It has been observed that increments of few milliseconds in stimulus exposure duration can affect preference for a previously presented polygon over a novel polygon

(Seamon, Marsh, & Brody, 1984). In these experiments, evaluation was purposely made on each single pattern immediately after exposure. In the absence of a comparison between stimuli, biases related to different levels of exposure duration should be avoided. However, Reber, Winkielman and Schwarz (1998) found linear relationship between longer exposure and preference ratings using a paradigm in which liking for square patterns was measured immediately after stimulus presentation.

The current study explored whether a different gazing duration over validly or invalidly cued patterns played a role in the validity effect on preference.

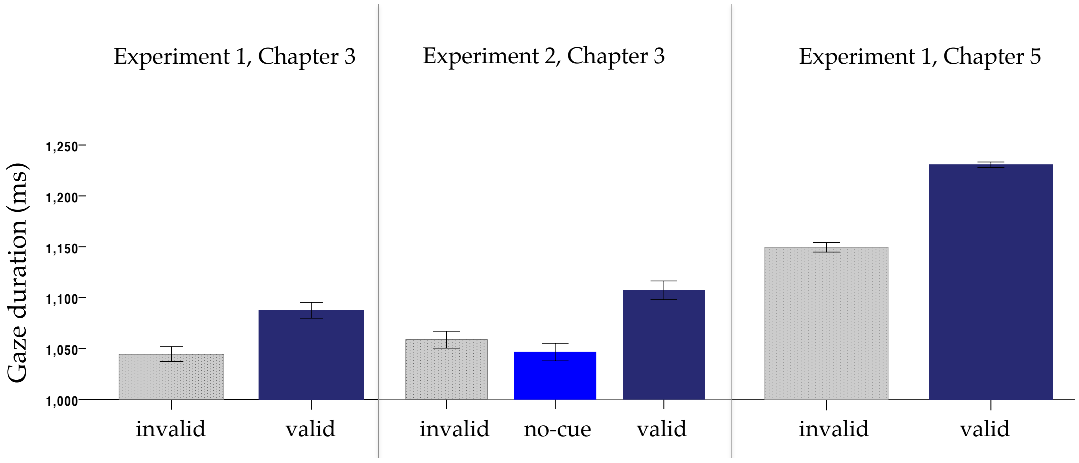

Figure 2. Bar graphs showing results from previous studies on gaze-dwelling duration. **Left plot**: Experiment 1, Chapter 3 (uninformative peripheral cues; 2 conditions: invalid, valid). **Middle plot**: Experiment 2, Chapter 3 (uninformative cues; 3 conditions: invalid, no-cue, valid). **Right** plot: Experiment 1, Chapter 5 (predictive cues on 80% of trials; 2 conditions: valid, invalid). Error bars represent ±1 SE.

6.4 Current study

The current study employed a gaze-contingent method in which pattern display time on each trial varied according to saccadic latency. On each trial a pattern appeared after an uninformative cue, either at a valid or invalid location, similarly to aforementioned previous studies. The pattern remained on the screen until a saccade over its location was made. As soon as eyes landed over the area of interest (AOI) delimited by the pattern, an additional display period of 1500ms began, at the end of which the pattern disappeared. All patterns could thus be foveated for the exact same amount of time, unless a saccade back to fixation was made before pattern offset. This allowed also to test whether cue validity biases gaze-dwelling behaviour (Glaholt, Wu & Reingold, 2009)

Finally, in this experiment participants did not discriminate pattern regularity and did not perform any other manual response. They gazed at the pattern as soon as it appeared and passively observed it until it went away. Our previous studies excluded an association between cuing effect on manual responses and preference. However, it has not been explored whether exogenous cueing can influence evaluative responses in absence of an explicit processing of the target (and therefore of the cue-to-target contingency).

6.4.1 Method

6.4.1.1 Participants

Twenty participants from the cohort of psychology students at the University of Liverpool took part in this experiment (aged 18-28, mean 19.5, 3 males, 0 left handed). They received formative credits in return for their participation. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

6.4.1.2 Apparatus and Stimuli

Participants sat at 57cm from a 17-inch ViewSonic monitor with resolution 1024 X 768 pixels at 60 Hz. A chin rest was employed to keep the head still and at the correct distance through the whole experiment. Eyes positions were measured using an EyeLink 1000 plus at a sampling rate of 500 Hz. Stimuli were generated using PsychoPy software (Peirce, 2007) on a 15-inc MacBook Pro with resolution 1280 X 800 and exported in BMP format. The experiment was constructed using Experiment Builder 1.10.1241. Exogenous cues consisted of a blue stimulus (modulated by a Gaussian envelope) with size ~12. Stimuli consisted of abstract patterns with two possible degrees of regularity: four-fold reflection symmetry or random. Elements forming the patterns were circles with three different possible diameters: .1°, .2°, 4° and a distribution of 25%, 60% and 15% respectively.

Elements were constrained to fall within the boundary of a virtual circle with 8.6° diameter. Moreover there was a grid of 0.13 X 0.13° cells, some of which were occupied with an element. Therefore the distance between centres of 2 adjacent elements was 0.13°. The stimulus generation had two stages. First a single segment was generated, with a single axis of symmetry. Cells in the first segments were filled with on a loop going through each position, and deciding whether to place a dot in the cell or not. If a dot was placed on the left of the axes, another was placed on the right of the axis. The same constraint was applied to colour. The colour of each element of the first segment was generated using RGB values. A number between -1,0,1 was randomly selected for each hue (red, blue, green), so that there were 3x3x3 = 27 possible colour combinations. However, white (RGB 1,1,1) was excluded. Therefore one of 26 colours could be assigned to each element. The element placed in the mirrored position of the axis assumed the same colour. In stage 2, the segments were reproduced in other positions. The random patterns also had four axes and segments, although each segment was generated afresh. The selection of each element across an axis was independent. Similarly colour selection of each element was unconstrained. Examples of stimuli are shown in **Fig. 3**.

Pattern and cue were presented either at the left or the right of fixation (2°) over a white background (RBG 1,1,1). Distance of the stimuli from fixation was 300 pixels (~ 9.6°). The same pattern was never repeated within the same experimental session. Preference ratings were recorded with a 9-point rating scale presented at the centre of the screen (see **Fig. 1C**). Numbers were columned from 9 to 1, headed by the words "Like very much" at the top and the words "Did not like it at all" at the bottom. Nine corresponded to the most positive rating and 1 the most negative rating value.

6.4.1.3 Procedure

At the start of each trial a fixation dwell time of 500ms triggered an interval, which was randomly generated on each trial and varied between 500-1500ms. The cue immediately followed and was displayed for 100ms either on the left or on the right of the fixation cross. After an Inter-stimulus interval (ISI) of 50ms, the target-pattern was presented at the same location indicated by the cue (Valid location) 50% of trials, and at the opposite location of the cue (Invalid location) on the remaining 50% of trials. Participants were required to keep fixation until the pattern appeared, then they gazed immediately at the pattern. A gaze-contingent display updated the position of the eyes. When gaze reached the area of interest (AOI) delimited the pattern stimulus, an additional display time of 1500ms was triggered. After this period pattern disappeared. The rating scale was presented at fixation immediately afterwards. Participants reported the rating value by voice and the experimenter recorded it manually. Participants were instructed to follow their immediate gut reaction in judging the patterns.

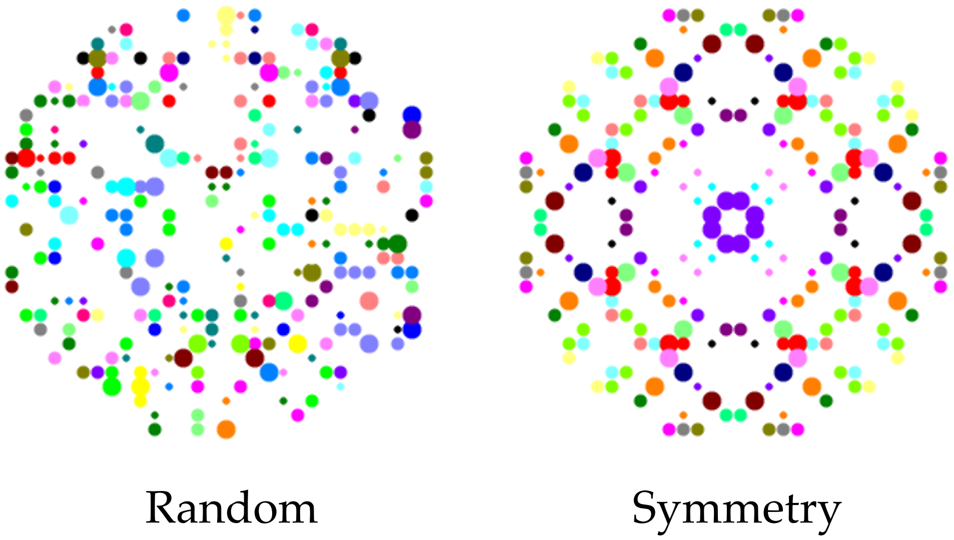

Figure 3. Examples of random (left) and four-fold symmetric (right) stimuli employed in the current study.

6.4.2 Design and Data Analysis

A whole experiment consisted of 128 trials, 64 of which were *valid* and 64 *invalid*. Each condition contained 32 symmetric pattern and 32 random patterns. Cue and pattern position was balanced, so that both appeared on the left and right side of the screen the same number of times. A new pattern was presented on each trial. However, pattern presentation was counterbalanced across participants, so that the same pattern was presented in every possible condition.

A 2 x 2 mixed ANOVA with validity (valid, invalid) and pattern regularity (symmetry, random) was conducted on saccadic latencies, gaze-dwelling duration and preference ratings.

Data cleaning. Data, in which the recording of eye movements was subjected to artefacts or eye blinks were discarded (0.2%). Saccades performed before 100ms from target onset were considered responses to the cue and rejected (4.3%). Trials in which eyes never moved from fixation through a whole trial were also discarded (0.4%). In total, 2432 trials were considered in the analysis, which correspond to the 95% of the original trials. The proportion of rejected trials was uniformly distributed across conditions.

6.4.3 Results

Saccadic Latency. Main effect of Validity was significant (F (1,19) = 84.937, $p < .001$, $\eta^2_p = .87$). Main effect of Regularity and interaction between the two factors was not significant ($p > .5$).

Gaze duration. Results showed no difference in gaze dwelling duration at either the valid or invalid location (F (1,19) = .982, p = .3, $\eta^2_p = .05$), although gaze left the patterns before pattern offset in 65% of trials. Also gaze duration was not affected by pattern regularity.

Preference evaluation. Main effect of Validity (F (1,19) = 4.759, p = .04, $\eta^2_p = .2$) and main effect of regularity were significant (F (1,19) = 7.792, p = .01, $\eta^2_p = .3$). There was no interaction between the two factors (p = .3).
Results are illustrated in **Fig. 4**.

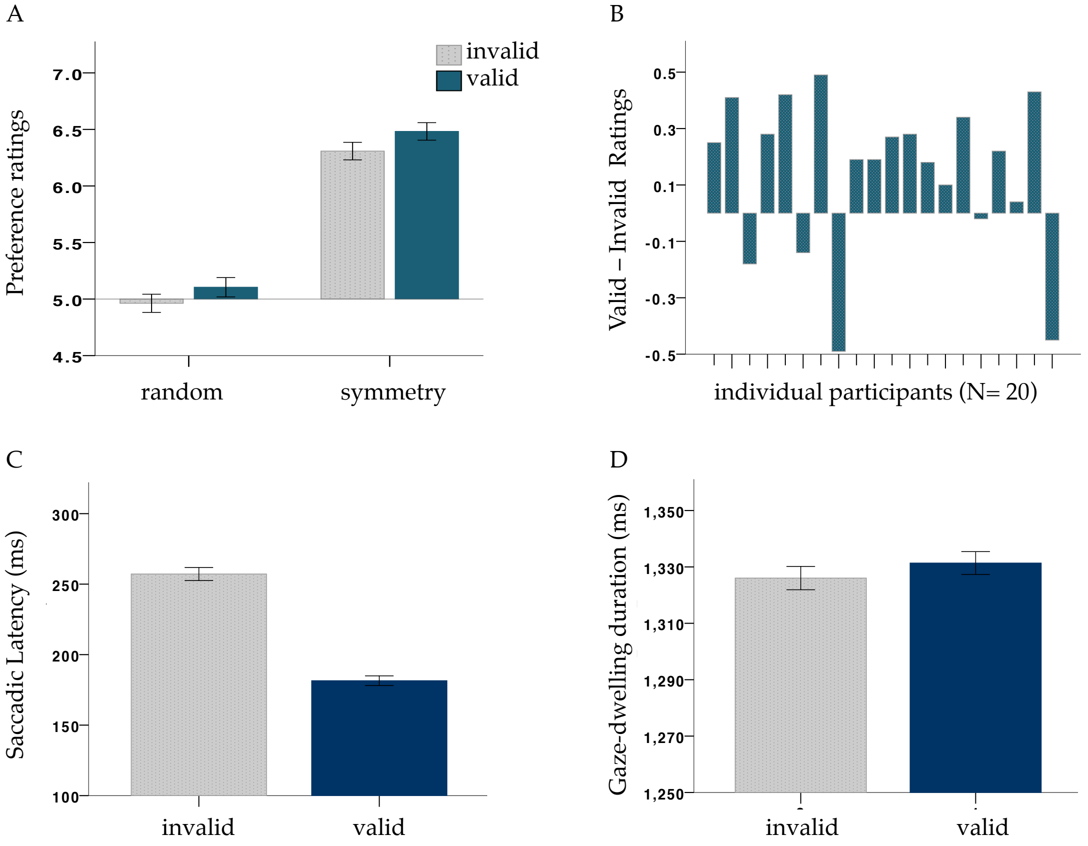

Figure 4. A. Bar plot showing results on preference ratings separately for random and symmetry. **B**. Rating-biases shown by individual participants (in the order in which they were recruited). Bars above zero indicate that a participant rated valid patterns more positively than invalid patterns. **C.** Mean saccadic latencies on invalid and valid conditions. **D.** Mean gaze-dwelling duration on valid and invalid conditions. Error bars indicate ±1 SE.

6.5 Discussion

The exogenous cuing effect on preference evaluation was confirmed. In previous studies, described in the previous chapters, I observed that gaze consistently dwelled for longer time over patterns at valid locations than over patterns at invalid locations. This might have been due to methodological issues: pattern display time was fixed for 1500ms, and participants gazed at the pattern as soon as it appeared on screen. The time in which gaze dwelled over the valid/invalid location depended on the time required for a saccade to be initiated varied as a function of cue validity. Longer stimulus exposure duration is known to facilitate the extraction of more information from stimuli (Mackworth, 1963), and it has been suggested to increase experienced fluency and, in turn, affective responses (i.e. liking evaluation and preference choices) (Bonanno & Stillings, 1986; Reber et al., 1998; Seamon et al., 1984).

The duration of the stimuli on the screen was controlled with a gaze-contingent method. In the moment in which eyes reached the AOI delimited by the pattern, a fixed display time of 1500ms started. This ensured that each stimulus in every condition could be accessible to foveal processing for very similar amount of time. Nevertheless, participants were allowed to saccade back to fixation at any moment before pattern offset. Therefore, the substantial difference with our previous studies was that here gaze-dwelling duration depended entirely on arbitrary decision. Gaze dwelled over the patterns until pattern offset only in 35% of trials. This implies that gaze-dwelling durations still differed among patterns. However, neither validity nor pattern regularity was found to influence gaze-dwelling duration (at least with a display time of 1500ms). Assuming that people look longer at stimuli they like (Birch, Shimojo, & Held, 1985; Fantz, 1964), it may be conceivable to think about a bidirectional effect. These preliminary results suggest that factors that influence preference do not necessarily increase the likelihood of longer gaze duration.

This experiment confirms that a difference in the exposure time of the pattern at foveal processing cannot be accounted for the valid – invalid effect on preference. Moreover, in this study a manual response for the discrimination of pattern regularity was not required. This is the first of our studies in which there was no explicit manual response to target. Although absence of explicit response does not exclude processing facilitation at valid locations, mere facilitation in manual responses does not play a role in the effect on preference elicited by peripheral cueing, a result consistent with previous studies (Chapter 3 and Chapter 4).

This experiment rules out a role of (foveal) exposure duration and a role of mere facilitation in manual responses as candidates for the valid – invalid effect on preference elicited by peripheral cues. This strengthens the conclusion that the manipulation of active orienting towards (or away) the source of visual stimulation is the critical factor influencing observers' preference (at least, when abstract stimuli, in absence of distracting information, are involved).

Part 3

Symmetry detection and symmetry evaluation across retinal eccentricity

7 The role of eccentricity on preference for abstract symmetry

* This study has been submitted for publication as: Rampone, G., O'Sullivan, N. & Bertamini, M. The role of eccentricity on preference for abstract symmetry.

7.1 Abstract

This study tested preference for abstract patterns, comparing random to a 4-fold bilateral symmetry. Stimuli were presented at random locations in the periphery. Preference for bilateral symmetry has been extensively studied in central vision, but evaluation at different locations had not been systematically investigated. Patterns were presented for 200ms within a large circular region. On each trial participant changed fixation and were instructed to select any location. Eccentricity values were calculated a posteriori from ocular coordinates at pattern onset and coordinates for the centre of the pattern. Experiment 1 consisted of two Tasks. In Task 1, participants detected pattern regularity as fast as possible. In Task 2 they evaluated their liking for the pattern on a Likert-scale. Results from Task 1 revealed that with our parameters eccentricity did not affect significantly symmetry detection. However, in Task 2, eccentricity predicted more negative evaluation of symmetry, but not random patterns. In Experiment 2 participants were either presented with symmetry or random patterns. Regularity was task-irrelevant in this task. Participants discriminated the proportion of black/white dots within the pattern and then evaluated their liking for the pattern. Even when only one type of regularity was presented and regularity was task-irrelevant, preference evaluation for symmetry decreased significantly with increasing eccentricity, whereas eccentricity did not affect the evaluation of random patterns. We conclude that symmetry appreciation is higher for foveal presentation in a way not fully accounted for by sensitivity.

7.2 Introduction

Bilateral symmetry is a ubiquitous structural property of objects, which is salient both for humans and for other animal species (e.g. Delius & Nowak, 1982; Rodríguez, Gumbert, Hempel de Ibarra, Kunze, & Giurfa, 2004; J P Swaddle & Pruett-Jones, 2001; John P. Swaddle & Cuthill, 1994; Tudor & Morris, 2009). It has been suggested that the visual system is particularly tuned to bilateral symmetry and uses this property as a perceptual cue in figure-ground discrimination (e.g. Machilsen, Pauwels, & Wagemans, 2009; see Treder, 2010a; Van Der Helm, 2011 for a review). Bilateral symmetry in clouds of dots is accurately distinguished from random dot patterns of similar size and density at brief exposure times (Barlow & Reeves, 1979; A. M. Herbert & Humphrey, 1996; Wenderoth, 1994), even when embedded in noise (Barlow & Reeves, 1979; Gurnsey et al., 1998; Jenkins, 1983). As bilateral symmetry is *effortlessly* extracted (Julész, 1981), it has been suggested that it acts as a visual primitive and it has been incorporated as a Gestalt property (Palmer, 1990; Pomerantz & Kubovy, 1986)

The association between symmetry (and in particular bilateral symmetry) with beauty is longstanding. Many animal species, included humans, use symmetry as a biological signal of mate quality (Johnstone, 1994; Little, Jones, & DeBruine, 2011; A. Møller & Thornhill, 1998; John P. Swaddle & Cuthill, 1994; Thornhill & Gangestad, 1999; Wignall et al., 2006). Ramachandran & Hirstein (1999) proposed symmetry as a basic principle of aesthetics and artistic experience. In fact, symmetry is a good predictor of preference when people explicitly evaluate the aesthetic appeal of abstract patterns (e.g. Cárdenas & Harris, 2006; Jacobsen & Höfel, 2003). Moreover, there is evidence of automatic association between symmetry and positive valence (Pecchinenda, Bertamini, Makin & Ruta, 2014; Bertamini, Makin & Rampone, 2013; Makin, Pecchinenda, Bertamini, 2012; Rampone, Makin & Bertamini, 2014).

This strong, and possibly innate (Rentschler, Jüttner, Unzicker, & Landis, 1999), aesthetic appreciation of symmetry may derive from the ease of its processing (*perceptual fluency hypothesis*, Winkielman, Schwarz, Fazendeiro & Reber, 2003).

Bilateral symmetry is the optimal stimulus to activate a regularity-specific extrastriate visual network, although it is unlikely that a symmetry-specific area exist (Bertamini & Makin, 2014). Moreover, there is no evidence that symmetry is extracted by low level-visual mechanisms (like V1 and V2; Makin, Rampone, Pecchinenda, & Bertamini, 2013; Makin, Wilton, Pecchinenda, & Bertamini, 2012; Sasaki, Vanduffel, Knutsen, Tyler, & Tootell, 2005; Tyler, Baseler, Konstevich et al., 2005). When the regularity around the axis of symmetry is less accessible, the saliency of symmetry drastically reduces. For example, symmetry detection is possible in extra-foveal vision but with reduced sensitivity (Barlow & Reeves, 1979; Herbert & Humphrey, 1996; Masame, 1983; Jukka Saarinen, 1988). Symmetry detection declines rapidly as a function of increasing retinal eccentricity (although appropriate size scaling removes the eccentricity dependence) (Barrett et al., 1999; Gurnsey et al., 1998; Sally & Gurnsey, 2001; Tyler & Hardage, 1996).

If increasing eccentricity gradually impairs detection of symmetry, it would seem plausible that aesthetic appreciation of symmetry decreases with a similar trend. Because foveal perception is important for fluently extracting the information around the bilateral axis of symmetry and constructing the representation of shape, people would need to look at bilateral symmetry foveally to appreciate it. However, to the best of our knowledge there has been no systematic study of the change in aesthetic appreciation of bilateral symmetry across retinal eccentricities.

It is generally accepted that beauty can be easily detected in extrafoveal vision (e.g. Kuraguchi & Ashida, 2015 and Guo, Liu, & Roebuck, 2011 conducted studies on detection of beautiful faces in the periphery), and beauty in the periphery captures attention even when it is task irrelevant (Sui & Liu, 2009). It is possible therefore that symmetry is detected and preferred to non-symmetry in the periphery (as long as it can be discriminated). The aim of this study is to compare the affective value that people attribute to the same type of regularity presented at different levels of eccentricity. Moreover, we wanted to test the link between the decrement in preference with increasing eccentricity and the difficulty in processing symmetry (measured by manual reaction times and proportion of incorrect responses).

We used abstract patterns made of black dots. These could have either bilateral symmetry (with both vertical and horizontal axes of reflection) or random configuration. On each trial, one pattern (4.6° of visual angle) appeared for 200ms at a random location within a large circular region (25.6°). In order to reduce the artificiality of the experiment, participants autonomously chose a fixation point (not marked) within the circle prior to pattern onset. The participant changed fixation at the beginning of each trial. Hence, the distance from the centre of the pattern and the fovea was not controlled by the experimenter and could not be predicted by the participant. The value of retinal eccentricity was calculated a posteriori and varied across trials and across participants. However, for all participants, the final eccentricity values ranged approximately between 0 and 18 degrees of visual angle. Experiment 1 was divided in two tasks. In Task 1 participants classified the regularity of the patterns (as "random" or "symmetry") immediately after pattern offset. In the second task (Task 2) participant did not classify pattern's regularity but rated the pattern on a 9-point liking scale after pattern offset. Note that patterns presented in Task 1 were different from those presented in Task 2. In this way we eliminated any bias due to familiarity (*mere exposure effect*; Zajonc, 1963)

In Task 1 manual reaction times and response errors were recorded. These were used as measures of the perceptual impairment caused by retinal eccentricity. We expected an increase in response errors and latency with increasing eccentricity. In addition, Task 1 allowed participants to familiarize to the type of patterns and reduce the effort required to discriminate regularity in Task 2. We were aware that in this experiment patterns at larger eccentricities might be misclassified (e.g. symmetry could be confounded with random, or vice versa) and misevaluated accordingly. The practice in Task 1 helped to maximise correct discrimination of regularity at the farthest eccentricities.

We can distinguish three possible outcomes.

(1) Eccentricity may fail to predict evaluation. Participants might rate symmetry more positively (ratings from 5 to 9) than random (ratings form 5 to 1) at any eccentricity. This category-based evaluation would suggest that regularity is the sole predictor of preference modulation, whereas the reduced saliency caused by eccentricity does not influence preference.

(2) Eccentricity may cause a decrease in rating only for symmetry, but not for random. This would suggest that the aesthetic appreciation of symmetry benefits from foveal processing.

(3) Finally, another possible outcome would be that eccentricity generally predicts more negative evaluations for all stimuli. This would imply a general preference for central presentations.

Experiment 2 was conducted to test the effect of eccentricity on the evaluation of symmetry (and random) presented in isolation and not confronted with its counterpart. The experimental design was similar to Experiment 1. One group of participants observed only symmetric patterns and the other group observed random patterns. Patterns this time were made of black and white dots and participants were asked to report whether the pattern contained more black or more white dots. Immediately after a response, participants evaluated their liking for the pattern on a 9-points rating scale. If retinal eccentricity is a predictor of liking for regular patterns but not for random patterns, a linear relationship between ratings and eccentricity might be observed only in the group that saw symmetric patterns. Another advantage of this task was to measure evaluation of symmetry when symmetry was task-irrelevant.

To summarise, this study aimed to answer the following questions: (Q1). Is retinal eccentricity a general predictor of lower preference or is it specifically detrimental for the aesthetic appreciation of regular shapes (bilateral symmetry)? (Q2). Does eccentricity affect evaluation by impairing the discrimination of symmetry at peripheral locations?

7.3 Experiment 1

To investigate the effect of eccentricity on the appreciation of symmetry, participants were presented with abstract patterns made of black dots, with either two-fold bilateral symmetry or a random configuration. On each trial one pattern was presented for 200ms inside a large grey circle in the centre of the screen. The coordinates for the position of the pattern were randomly generated on each trial. Participants were asked to change fixation on each trial arbitrarily. Eccentricity values were calculated a posteriori, and a different array of eccentricity values was obtained from each participant.

This method was employed to reduce the artificiality of the experimental design. Task 1 tested manual response speed and accuracy in symmetry detection as a function of retinal eccentricity. The same participants performed Task 2. In this task participants did not perform a classification task. They evaluated their liking for each pattern on a 9-points Likert rating scale. This second part tested whether increasing eccentricity predicted a reduction in preference for patterns.

In order to avoid familiarity influences on aesthetic evaluation, we ensured that patterns were generated afresh on each trial and they differed in Task 1 and Task 2. Therefore participant never saw the same pattern twice. Eccentricity was calculated as the distance from eyes coordinates at pattern onset and the coordinates of the centre of the pattern inside the circle.

7.3.1 Method

7.3.1.1 Participants

Twenty participants from the cohort of psychology students at the University of Liverpool participated in both experiments (age 18-31 years, mean age 19 years, 1 male, 2 left handed). All were naïve in respect to the experimental hypotheses and had normal or corrected to normal vision. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

7.3.1.2 Apparatus and stimuli

Participants sat at 57cm from a 16-inch LCD monitor with resolution 1280 X 1024 pixels at 75 Hz. To prevent loss of data due to head movements, a chin rest was employed to keep the head still. Participants' eye movements were measured using an ASL Eye-Trac D6 (Applied Science Laboratories, Bedford, MA) at a sampling rate of 120 Hz.

Stimuli were generated using PsychoPy software (Peirce, 2007) and consisted of abstract black-dots patterns with either symmetrical or random configuration. Each pattern was composed of 60 dots arranged within a region delimited by two virtual circular perimeters (as indicated by the red lines within the pattern in **Fig. 1B** and **1B′**). The radius of the internal small circle was 0.2° of visual angle; the radius of the external circle was ~1.5°. Therefore the global size of the patterns was approximately ~3°. Each dot had radius 0.1°. Symmetric patterns were constructed by randomizing the arrangement of the dots in one of four quadrants. Each quadrant contained 15 dots. In this way we obtained bilateral symmetry both on the vertical and horizontal axis, to maximize the regularity of the pattern (**Fig. 1B**). For random patterns the arrangement of the dots inside each quadrant was unconstrained (Fig 1B′).

Stimuli were presented within a grey circle (RGB 0,0,0) with radius 12.8°. Coordinates of stimulus position were randomly generated on each trial. The pattern could appear at any position within the circle. Because pattern position changed on each trial, it could not be predicted. Participants used a gamepad to report their response accordingly to task instructions.

The experiment was divided in two tasks. In Task 1 participants pressed the two top-bottom shoulder buttons of the gamepad (7 - 8) to report pattern regularity (symmetry or random). In Task 2 a Likert vertical scale was presented after stimulus appearance at the centre of the screen. It consisted of a column of numbers from 9 to 1, headed by the messages “Like it very much” at the top, and “did not like at all” at the bottom. Participants could move up and down on the scale using the arrows on the gamepad. The position on the scale was indicated by a change in opacity of the circle surrounding the specific number. Participants confirmed their final response by pressing button 1 on the gamepad.

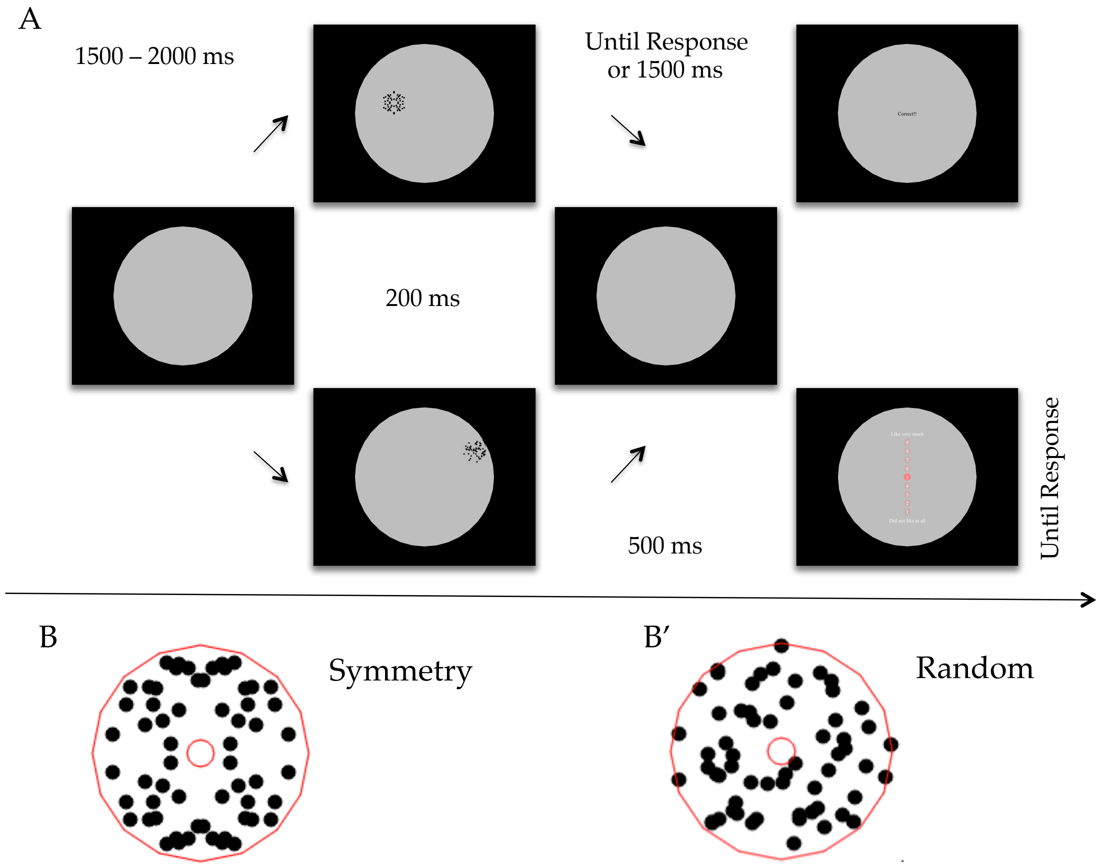

Figure 1. (**A**) Experimental procedure of Experiment 1. Each trial started with an interval between 1500ms and 2000ms. During this interval the participant could look at any location within the central large circle, and chose a point where maintaining the gaze. After the interval an abstract pattern appeared at a random location. The pattern could be either symmetry or random, and remained on the screen for 200ms. Participants were encouraged to control the reflexive response to look at the pattern and maintain fixation on the point they chose. Task 1: Immediately after pattern offset, participants reported whether the pattern was symmetry or random. If no response was given within 1500ms from pattern offset, the trial was considered null and a new trial started. Task 2: After 500ms from pattern offset, a 9-points rating scale was presented. Participants moved the cursor up/down on the rating scale to assign a preference value to the pattern (9 = like very much; 1= do not like a t all). They were encouraged to give a response relatively fast and using a gut feeling. (**B**) Example of a symmetry pattern. (**B′**) Example of a random pattern. Red lines indicate the virtual circles used to construct the patterns. These were not visible to the participants and are shown here for illustrative proposes.

7.3.1.3 *Procedure*

Figure 1A illustrates the experimental procedure. A large grey circle over a black background delimited the area of interest. Each trial started with a variable interval of 1500 to 2000ms. During this interval participants were required to choose arbitrarily any point within the grey circle and keep fixation on that point. An abstract pattern appeared at an unpredicted position within the grey circle. Participants were instructed to try to control reflexive saccadic responses to pattern onset. In Task 1, participants classified the pattern as symmetry or random as fast and accurately as possible. One group of participants pressed a left button for symmetry and right button for random. The other group did the opposite. Response screen was displayed until response. A feedback word ("correct" or "incorrect") was displayed for 500ms immediately after response, then a new trial started. Task 2 was identical except that participants did not classify pattern regularity and maintained fixation until a vertical 9-points rating scale was presented. Participants were encouraged to base their evaluation on a first spontaneous reaction to the pattern.

Each task consisted of 144 trials, divided in four blocks of 36 trials. Between each block participants were allowed to rest and disengage the eyes from the screen. The two tasks followed one after the other with a break (~5/10 min) between them and always with the same order. The order of the two tasks was not counter-balanced. Task 1 always preceded Task 2. This was intentional in order to facilitate sensitization to symmetrical stimuli for the preference task. A practice session of 20 trials preceded Task 1, whereas a practice session of 10 trials preceded Task 2. These reproduced the procedure of the incoming Task, in order to ensure participants understood the instructions. A questionnaire was provided at the end of both experiments asking participants their personal opinion about the purpose of the study. This was used to ensure participants did not understand the real experimental aims.

7.3.1.4 *Analysis*

Calculation of eccentricity values

Spatial coordinates of stimulus position were calculated as the distance between the ocular coordinates at target onset and the coordinates of the centre of the circular region in which patterns were embedded. Eccentricity values ranged approximately between 0 and 18 degrees of visual angle (Task 1 M= 8.85; SD= 3.8; range=17.99; Task 2 M= 8.88; SD= 3.9; range=18.121). We discarded trials in which eyes' signal was not recorded (Task 1 5.6%, Task 2 10%, of total trials), or incorrect eye movements were performed during pattern presentation (Task 1 4.4%, Task 2 6%, of total trials). In Task 1 10% of total trials were excluded from the analysis, In Task 2 we excluded 14% of total trials. However, the average proportion of excluded trials in the symmetry and random conditions did not differ in both experiments.

Multilevel linear model

Multi-level linear modeling is a statistical approach for hierarchical data sets in which data is sampled at different levels of a hierarchy. In our study experimental trials (the lowest level of the hierarchy) were nested within participants (the highest level of the hierarchy). In contrast to a standard regression model in which the dependent variable is a measure of central tendency that is detached from the variance around that score, a multi-level model includes estimates of the variance at each level of a hierarchical data-set, adjusting the estimates of other parameters in the model accordingly. Random effects in the model relate to the extent that variance in the DV can be attributed to variance at a particular level in the hierarchy (e.g. a random effect of participant; a random effect of trial). Fixed effects in the model relate to the extent that variance in the DV can be attributed to a manipulated variable. Through partitioning the variance in this way within the context of one model, the parameters that are estimated for the fixed effects are statistically unbiased by, for example, variability across participants.

Fixed factors in our analysis were eccentricity, pattern regularity, and two parameters that we called Mean Individual Eccentricity (MIE) and Mean Individual Inverse Efficiency Score (MIIES). MIE corresponds to the mean distance from eyes at which patterns were presented, calculated for each participant. As eccentricity values were not pre-set and balanced, each participant might have been exposed to patterns at different eccentricity. Taking this variable into account as fixed variable of our model, allowed us to control for individual differences in eccentricity exposure.

MIIES corresponds to the mean "inverse efficiency score" (Townsend and Ashby, 1978; 1983) for each participant. MIIES integrates the average proportion of correct responses (PC) and latency of correct responses (reaction times, RTs) in a unique variable, in order to weight the impact of speed and accuracy. For each participant mean RT was divided by mean PC, the value obtained corresponds to MIIES and it is expressed in ms (like RT).

This variable was included in the model employed for the analysis of preference evaluation. Including MIIES allowed controlling for the effect of individual efficiency in performing Task1 on preference evaluation.

Two multilevel linear models were employed to analyse reaction times (Task 1) and preference ratings (Task 2). Accuracy (Task 1) is a binary dependent variable; therefore a binary logistic model was performed. Correct responses were coded as 1, and incorrect responses as 0. The model for RTs included only trials in which a correct response was made. Each DV was analysed as a function of increasing eccentricity and pattern regularity. All models revealed that random factors (participants and trials numbers) generated significant variability in the data (all ps < .05). However, we were not interested in testing the role of random factors on the final outcome. Therefore these will not be discussed any further. The analysis was carried out in MLwiN (Rasbash, Charlton, & Browne, 2009).

7.3.2 Results

Task 1

Table 1 shows results from the model used for analysis of RTs. Overall both eccentricity and pattern regularity were unrelated to variability in reaction times (see **Table 1** and **Fig.2**).

	β	SE	t	p
Intercept	0.67	0.03	23.89	< .001
MIE	0.03	0.03	0.83	0.42
Eccentricity	0.002	0.002	1.00	0.33
Pattern regularity (symmetry)	0.02	0.01	1.70	0.11
Eccentricity x Pattern regularity	-0.002	0.003	-0.67	0.51

Table 1. Results from Multilevel Linear Model for analysis of reaction times as a function of visual eccentricity in Experiment 1 (Task 1).

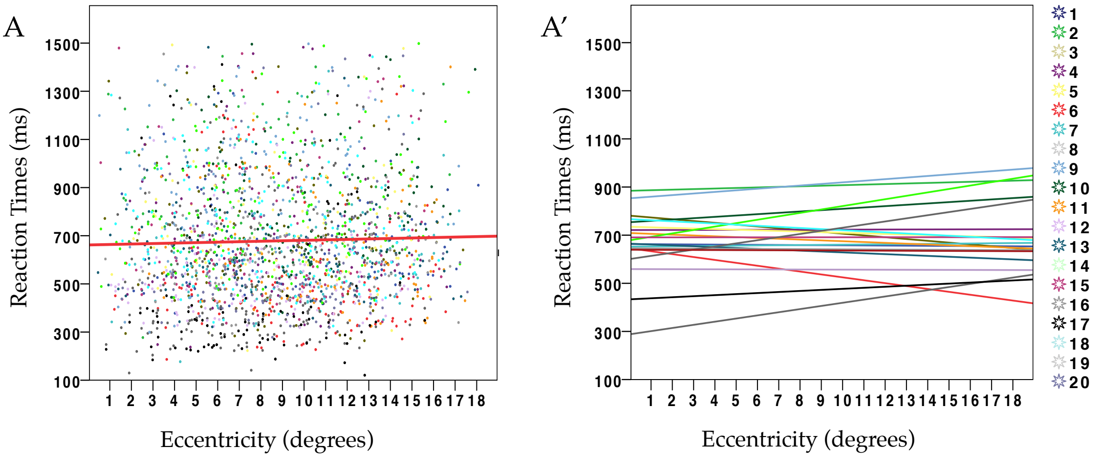

Figure 2. (**A**) Scatterplot showing the relationship between manual reaction times (RTs) and retinal eccentricity, and regression line (red) (R2= .0007). (**A'**) The same plot showing linear regression lines from each individual.

Response correct were the 85.5%. **Table 2** shows results from the Binary Logistic Model for the analysis of correct responses as function of eccentricity. Increasing eccentricity did not affect the odds of correct responses (OR= .96, $t_{(19)}$= -1.96; p .07). Instead, the odds of correct responses significantly decreased when symmetry was presented (OR= .78, $t_{(19)}$= -2.23; p .04), suggesting a possible bias in classifying the patterns as random. However, this bias was generalized at any eccentricity level. In fact, the exposure to symmetry at increasing eccentricities was not associated with lower odds of correct responses (OR= .98, $t_{(19)}$= - .7, p .5).

	β	SE	Odd Ratio	prob	*Xsq*	t	p
Intercept	1.94	0.15				12.71	< .001
MIE	0.30	0.18	1.35	0.95	3.23	1.69	0.11
Eccentricity	-0.04	0.02	0.96	0.87	3.66	-1.96	0.07
Pattern regularity (symmetry)	-0.25	0.11	0.78	0.85	5.00	-2.23	0.04
Eccentricity x Pattern regularity	-0.02	0.03	0.98	0.87	0.51	-0.70	0.49

Table 2. Results from Binary Logistic Model for analysis of correct responses as a function of visual eccentricity in Experiment 1 (Task 1).

Task 2

We ran one model using liking ratings as dependent variable. This model included one more fixed factor: MIIES (see Analysis session). Results are shown in **Table 3**. The model suggests that Pattern Regularity was a good predictor for preference evaluation ($t_{(19)}$= 37.37, p < .001). Increasing eccentricity was not a predictor of preference formation overall ($t_{(19)}$= .08, p .94). However, there was an interaction Eccentricity * Pattern Regularity ($t_{(19)}$= -4.94, p < .001). It is evident from Scatterplots in **Fig. 3A-A′** that preference for symmetry decreased with increasing eccentricity. Scatterplots in **Fig. 3B-B′** show that the same was not true for random stimuli.

MIE significantly affected preference. This suggests that participants that were more often exposed to patterns at larger eccentricities tended to use higher ratings overall.

	β	SE	t	p
Intercept	3.62	0.09	39.29	< .001
MIE	0.16	0.07	2.19	0.04
MIIES	< .001	0.001	< .001	1.00
Eccentricity	0.001	0.01	0.08	0.94
Pattern regularity	2.65	0.07	37.37	< .001
Eccentricity x Pattern regularity	-0.09	0.02	-4.94	< .001

Table 3. Results from Multilevel Linear Model for analysis of preference ratings as a function of visual eccentricity in Experiment 1 (Task 2)

7.3.3 Discussion

Results from Task 1 revealed that eccentricity did not affect either accuracy or reaction times. The gradual decline in the saliency of symmetry did not affected speed and accuracy of manual response. This is not in agreement with previous findings (Julesz, 1971; Jukka Saarinen, 1988; Sally & Gurnsey, 2001), but it is possible that the type of design was not ideal for recording manual response speed. We will discuss this aspect in the General Discussion. Results from Task 2 showed that Eccentricity did not predict lower ratings in general. A significant Eccentricity X Pattern Regularity interaction showed, instead, that eccentricity differently modulated the evaluation of the two types of regularity. Ratings for symmetry decreased to more negative values with increasing eccentricity, whereas ratings for random patterns remained unvaried. This supports the hypothesis that proximity to the fovea is important for the aesthetic appreciation of bilateral symmetry.

However, an important caveat upon this result is that evaluation may have been subject to a regression to the mean. Because symmetric and random patterns were interleaved, it is possible that patterns at farther distances were more often misclassified and rated accordingly (i.e. symmetry was confounded and rated as random and vice versa). There was no significant evidence of a regression to the mean in the ratings for random patterns (i.e. evaluation for random patterns did not gradually become more positive with eccentricity). However, as shown in **Fig. 2A'/2B'**, the regression lines for both categories suggest (descriptively) a weak tendency toward converging. We also observed that in Task 1 participants were significantly more prone to classify patterns as random in case of doubt, although this classification bias did not interact with eccentricity.

For these reasons we conducted a second experiment. Experiment 2 was similar to Experiment 1. This time one group of participants saw only symmetric patterns, whereas the other group saw only random patterns. In this way any confound due to misclassification of Pattern Regularity was avoided.

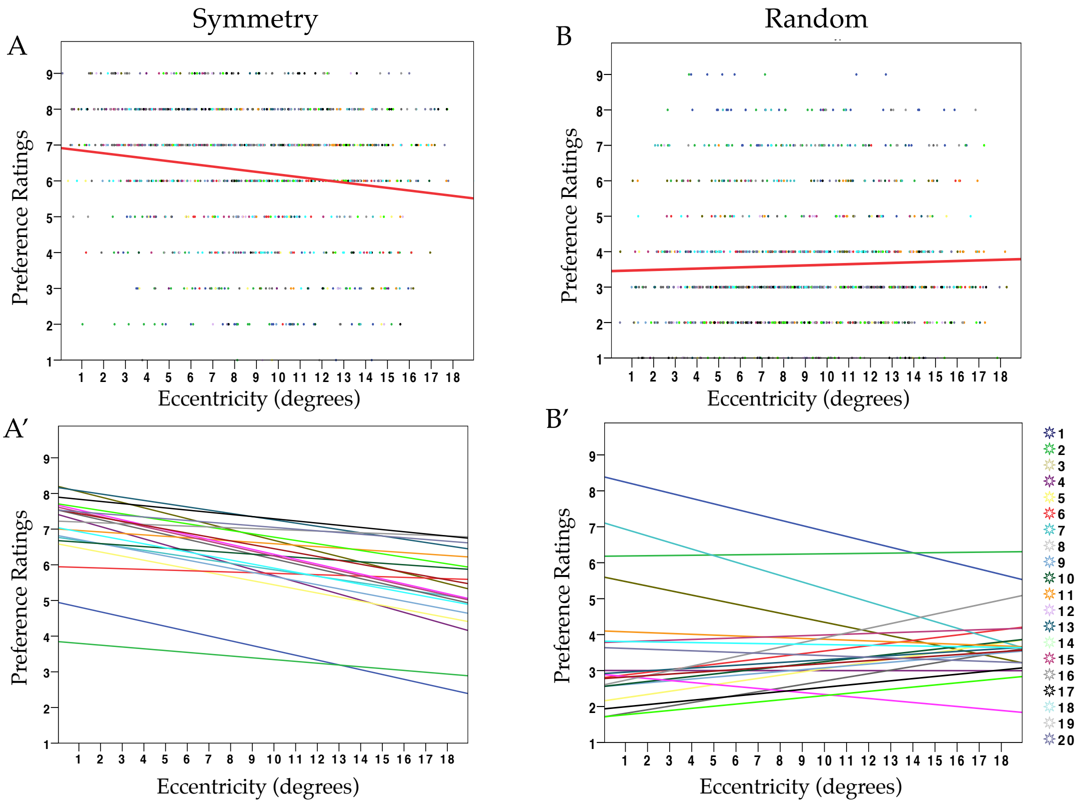

Figure 3. (**A**) Scatterdot plot showing preference ratings (1-9) for symmetry in relation to retinal eccentricity, and regression line (red) (R2 = .03). **(A′)** Same plot showing individual regression lines. **(B)** Scatterdot plot showing preference ratings (1-9) for random in relation to retinal eccentricity, and regression line (red) (R2 = .002). **(B′)** Same plot showing individual regression lines.

7.4 Experiment 2

Experiment 1 suggested that increasing eccentricity leads to devaluation of symmetry, but not random patterns. However, it is possible that symmetry at farther retinal locations was more often confounded and evaluated as random. The second experiment was conducted to investigate this possibility. We introduced four important changes. First, one group of participants saw only symmetry (Experiment 2a), whereas the other group saw only random (Experiment 2b). Second, patterns were made of a random number of black and white dots. Participants reported whether the pattern contained more black dots or more white dots. Third, the evaluation task was included in the same experiment. Immediately after responding to black/white proportion, participants rated how much they liked the patterns that they had just seen. Four, the starting point of the rating scale was moved from 5 (central value on the rating scale) to 1 (lowest value of the rating scale). In this way we assumed that evaluation was made following a criterion of 'gradual distance from the starting point'. Note that the detection task served to disguise participants from the real aim of the experiment. No predictions were made regarding the evaluation of different proportions of black/white dots.

Forty people took part in Experiment 2 (aged 18 to 22, 6 males, 4 left handed). They were all first year students from the School of Psychology of the University of Liverpool, and received course credits for their participation. Twenty participants took part in Experiment 2a, the other participants did Experiment 2b.

7.4.1 Experiment 2a

7.4.1.1 Method

The design was similar to Experiment 1, although both stimuli and procedure presented some important differences (See **Fig. 4**). Patterns were made by black and white dots. The proportion of black and white dots was randomly generated on each trial and was never 50-50%. In Experiment 2a all patterns were *4-fold bilateral symmetry*. In the Method session of Experiment 1, we mentioned symmetric patterns were constructed by mirroring the structure of one quadrant of the shape in the other three quadrants. In the same way, the number of black and white dots was randomized only within one quadrant. Therefore there were limited possible configurations, based on black/white proportions. Ten different types of black/white configurations were generated (12/48, 16/44, 20/40, 24/36, 28/32, 36/24, 40/20, 44/16, and 48/12). The frequency of appearance of the configurations was distributed with a bell-shaped configuration, as shown in **Fig. 4**.

Each trial started with a variable inter-trial interval (between 1.5 and 2 s) in which participants chose arbitrarily a fixation point. Similarly to Experiment 1 the pattern could appear at any position within the grey circle. Patterns remained on the screen for 200ms. Participants pressed one button if the pattern contained more black dots and the other button if the patterns contained more white dots. Ten participants pressed left button for 'more blacks' and right button for 'more whites', whereas the others did the opposite. Participants were asked to be as fast and accurate as possible. Immediately after response, participants evaluated the pattern aesthetically on a rating scale from 9 to 1. If no response was given after 1500ms, the rating scale was presented and the trial considered null. In this Experiment, the starting point of the rating scale was the lowest number (1), instead of the central (neutral) point (5) that was used in Experiment 1.

Note that if preference depends on eccentricity the lowest number would be used to rate the pattern at the farthest position and the highest number would be used for the foveal position. Therefore the scale works in a counter-directional manner compared to pattern position (rating the closest pattern would require to move to the farthest position on the rating scale). One might point out that starting from the highest number (9) would be more intuitive. However this would risk making the task too obvious (and a leading question). Moreover, moving the cursor from the most positive value to more negative value, would represent a devaluation process instead of an evaluation process.

Each participant did an introductory session, in which 10 examples of the patterns were shown. This was followed by a practice session of 36 trials. In the practice session, feedbacks reporting the real number of black/white dot and correct/incorrect response were shown in order to help participant to familiarize with the patterns. Because we expected participants would find the task difficult, we encouraged them to try to be as accurate as possible without worrying too much about the quality of their performance. Participants were not told about preference evaluation task until the beginning of the experimental session.

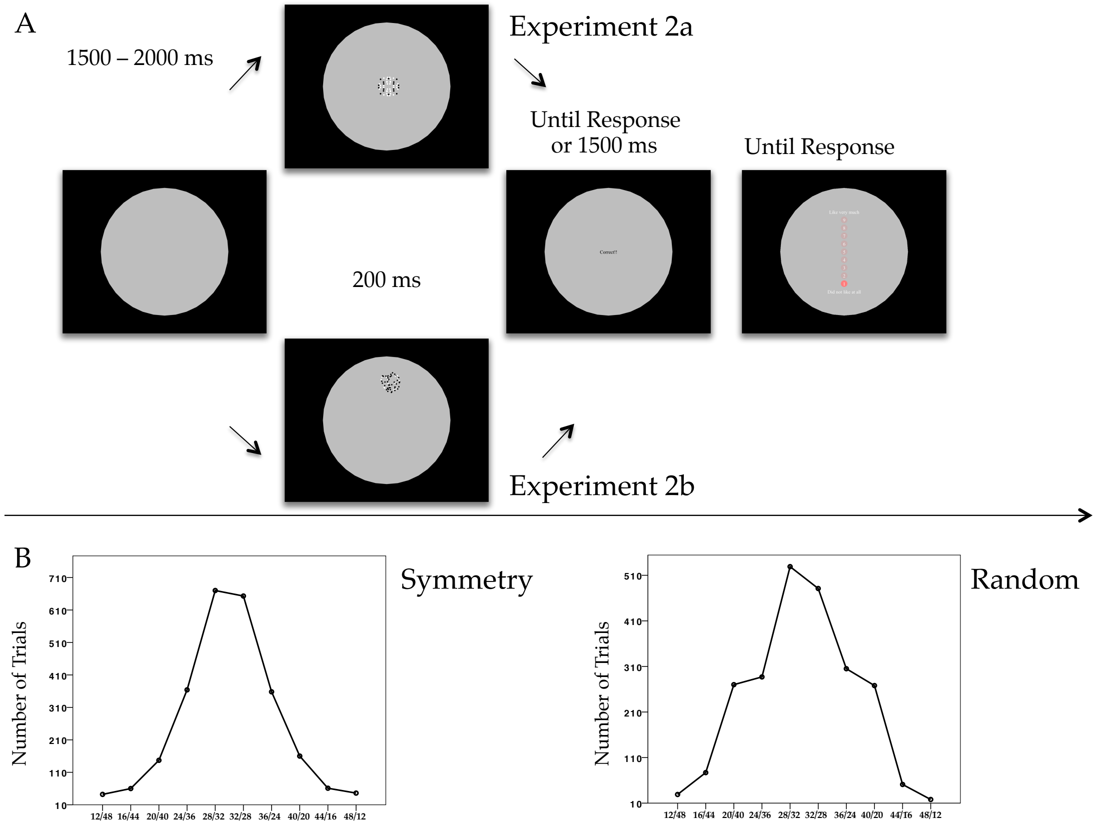

Figure 4. (A) Experimental procedure of Experiment 2a and Experiment 2b. Each trial started with an interval randomized between 1500ms and 2000ms. During this interval the participant could look at any location within the central large circle, and chose a point where maintaining the gaze. After the interval an abstract pattern appeared at a random location within the circle. Experiment 1a: The pattern was symmetry; Experiment 1b: The pattern was random. Patterns remained on the screen for 200ms. Participants were encouraged to control the instinct of attempting to look at the pattern and maintain fixation on the point they chose. Immediately after pattern offset, participants reported whether the pattern contained more black or more white dots. If no response was given within 1500ms from pattern offset, the trial was considered null. Immediately after pattern offset, a 9-points rating scale was presented in the centre of the screen. Participants moved the cursor to select a value (1= do not like at all; 9 = like very much). **(B)** Line graphs showing the number of trials in which different proportions of black/white dots were presented within the patterns. The program randomly generated black/white dots proportions. Ten possible configurations were generated and their frequency of appearance assumed a bell-shaped configuration. Left plot shows the black/white proportions frequency for symmetry patterns (Experiment 2a). Right plot shows the black/white proportions frequency for random patterns (Experiment 2b).

7.4.1.2 Data analysis

Similarly to Experiment 1, each eccentricity value was obtained by calculating the distance between the ocular coordinates at target onset and the coordinates of the centre of the pattern. Eccentricity ranged from a minimum of 0 to a maximum of 18.4 degrees of visual angle (M= 8.12; SD= 4.26; range= 18.401). The percentage of lost trials because of blinks and bad signal was 8.4%. The trials in which eyes movement were made during pattern presentation were removed (2.7%). In total 89% of original trials were included in the analysis.

Multilevel linear model and binary logistic analysis

We ran two multilevel linear models, for reaction time and preference formation respectively, and a binary logistic analysis for accuracy. Note that the models for RTs included only trials in which a correct response was made (84% of the trials), whereas the model for preference ratings included all trials. Random variables were participants and trial number. The fixed factors were: MIE, and Eccentricity.

In the analysis of preference ratings the factor MIIES was added. Moreover we also included the Number of black dots within the pattern, and the interaction Number of black dots X Eccentricity, to test whether any possible contribution of this factor on the evaluation.

7.4.1.3 Results and Discussion

Differently from Experiment 1, participants were exposed only to symmetric patterns and responded to another dimension (proportion of black/white dots within the pattern). Eccentricity did not predict the latency of correct responses ($t_{(19)}$= 1.50, p = .15; see **Table 4**).

	β	SE	t	p
Intercept	0.81	0.02	40.45	< .001
MIE	-0.002	0.02	-0.08	0.93
Eccentricity	0.003	0.002	1.50	0.15

Table 4. Results from Multilevel Linear Model for analysis of reaction times as a function of visual eccentricity in Experiment 2a.

Overall participants gave incorrect response on 16% of trials. We ran a Binary Logistic model for the analysis of accuracy, which showed that eccentricity did not predict lower odd ratio of correct responses (OR = .999; $t_{(19)}$= -.07, p = .9; see **Table 5**). The proportion of black/white dots did not affect the odds of responses overall.

	β	SE	Odd Ratio	prob	*Xsq*	t	p
Intercept	1.66	0.09				18.28	< .001
MIE	0.077	0.10	1.08	.844	0.75	0.74	0.47
Eccentricity	-0.001	0.01	1.00	0.84	0.01	-0.07	0.94

Table 5. Results from Binary Logistic Model for analysis of correct responses as a function of visual eccentricity in Experiment 2a.

This experiment challenged a possible interpretation of the results observed in Experiment 1: lower ratings for symmetry could be due to increasing difficulty in discriminating between random and symmetry. The results obtained in this experiment showed that eccentricity was a good predictor for preference evaluation ($t_{(19)}$= - 10.33, p < .001), even if only one type of pattern was employed (see **Table 6**). **Fig 5A** shows preference-ratings as a function of eccentricity, whereas **Fig. 5A'** illustrates the individual regression lines. There is a consistent tendency from more positive ratings to more negative ratings with increasing eccentricity. This result suggests that the distance of the symmetrical pattern from the point of fixation affected evaluation proportionally. This is in line with the hypothesis that liking of symmetry depends on the goodness of regularity processed around the axis of symmetry.

	β	SE	t	p
Intercept	4.63	0.10	44.57	< .001
MIE	-0.1	0.12	-0.82	0.42
MIIES	0.0001	0.001	0.10	0.92
N black dots	0.3	0.005	5.00	< .001
Eccentricity	-0.09	0.009	-10.33	< .001
Eccentricity * N black dots	0.001	0.001	1.00	0.33

Table 6. Results from Multilevel Linear Model for analysis of preference ratings as a function of visual eccentricity in Experiment 2a.

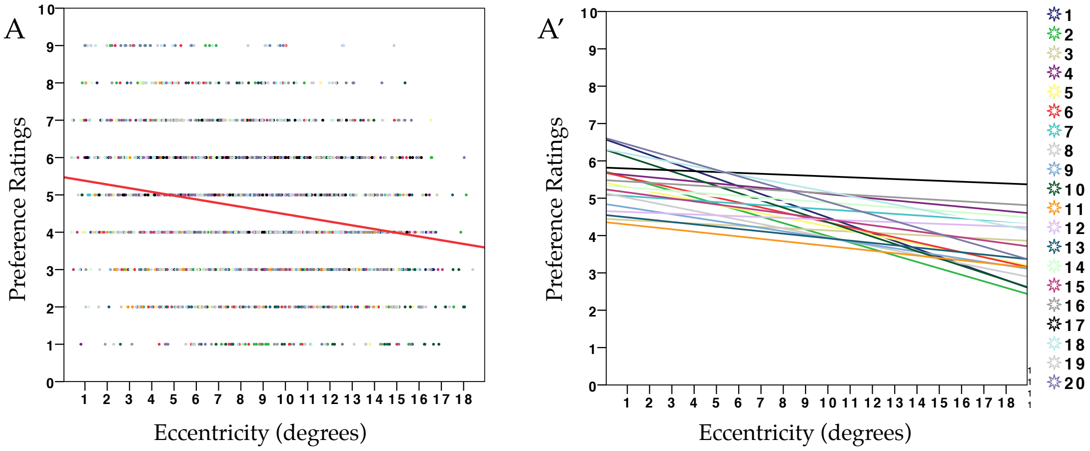

Figure 5. Results from Experiment 2a **(A)** Scatterdot plot showing preference ratings (1-9) in relation to retinal eccentricity, and regression line (red) (R2 .05). **(A')** Same plot showing individual regression lines.

Because participants were instructed to attend to proportion of black/white dots, this factor might have influenced ratings. In fact, the number of black dots was a good predictor of preference for the pattern ($t_{(19)}$= 5.00, p < .001). However, the interaction between Number of black dots and Eccentricity was not significant ($t_{(19)}$= 1.0, p .3).

This experiment supports the hypothesis of a close relationship between retinal eccentricity and evaluation of symmetry. However, here participants did not explicitly attend to symmetry and we observed that the proportion of black dots within the pattern significantly affected evaluation. Experiment 2b was conducted to test the evaluation of random patterns instead of symmetry by using the same design.

7.4.2 Experiment 2b

Another group of twenty participants performed the same experiment with a variation: patterns were always random. Similarly to what observed in Experiment 2a, eccentricity might predict a decrease in preference for random patterns. This would suggest that eccentricity induces more negative evaluation of abstract patterns (at least when a discrimination task is required), probably as consequence of reduced confidence. On the other hand, eccentricity might not affect evaluation for this type of pattern. This result would be in line with the hypothesis that eccentricity does not always affect aesthetic appreciation of meaningless patterns. On the contrary it specifically affects the aesthetic appreciation of symmetry.

7.4.2.1 Method

Design and apparatus were the same as Experiment 2a. The only change was on the type of patterns. The arrangement of dots within each quadrant was unconstrained to obtain a random configuration. However the proportion of black/white dots was controlled in order to have same number of black/white dots in each quadrant. The distribution of black/white dots was the same of for symmetric patterns in Experiment 2a (see Fig 3B). Ten different proportions of black/white dots were used (12/48, 16/44, 20/40, 24/36, 28/32, 36/24, 40/20, 44/16, and 48/12). The frequency of appearance of the different proportions had a bell shaped configuration, similar to Experiment 2a (See **Fig. 4B**).

7.4.2.2 Data Analysis

Eccentricity values were calculated with the same method used for previous experiments. Eccentricity ranged from a minimum of 0.1 to a maximum of 19.2 degrees of visual angle (M= 8.13; SD= 3.9; range= 19.1). The percentage of lost trials because of bad signal was 10.9%. The trials in which eyes movement were made during pattern presentation were removed (7.4%). In total, 83% of original trials were included in the analysis.

Multilevel linear model and binary logistic analysis

Two multilevel linear models (reaction time and preference formation) and a binary logistic analysis (accuracy) were conducted. The model for RTs included trials in which a correct response was made (76% of the trials), whereas the model for preference ratings included all trials. Random variables were participants and trial number. The fixed factors were: MIE, Number of black dots within the pattern, and Eccentricity. The interaction Eccentricity * N black dots and MIIES were included in the model for preference ratings.

7.4.2.3 Results and Discussion

Multilevel linear modelling on latency of correct responses did not reveal any effect of eccentricity ($t_{(19)}$= 0.50, p = .62) (**Table 7**). The overall percentage of incorrect responses was 24% of trials. This was significantly higher than in Experiment 2a ($t_{(19)}$= -5.615, p < .001). We ran a Binary Logistic model for the analysis of accuracy, which showed that eccentricity reduced the odds of correct responses significantly (OR= .947, $t_{(19)}$= -4.154, p < .001) (**Table 8**). This result is considerably different to what observed in Experiment 2a, in which the accuracy of responses was unaffected by eccentricity. Although pattern regularity was task irrelevant, it appeared to implicitly play a role on response accuracy. Possibly, in Experiment 2a, specular pairings of coloured dots facilitated the estimation of correct proportion of black/white dots, even when the pattern was far from fixation. In contrast, the random distribution of the dots in the patterns of Experiment 2b made the detection of correct proportions more difficult.

	β	SE	t	p
Intercept	0.73	0.02	31.78	< .001
MIE	-0.02	0.03	-0.68	0.51
Eccentricity	0.001	0.002	0.50	0.62

Table 7. Results from Multilevel Linear Model for analysis of reaction times as a function of visual eccentricity in Experiment 2b.

	β	SE	Odd Ratio	prob	*Xsq*	t	p
Intercept	1.18	0.08				14.96	0.000
MIE	0.05	0.09	1.05	0.78	0.19	0.61	0.553
Eccentricity	-0.05	0.01	.94	0.76	18.00	-4.15	< .001

Table 8. Results from Binary Logistic Model for analysis of correct responses as a function of visual eccentricity in Experiment 2b.

Although increasing retinal eccentricity significantly affected performance, the linear model on preference evaluation showed no influence of eccentricity on preference ratings (**Fig. 6A** and **6A'**). In this experiment, colour did not influence evaluation. Probably eccentricity did not predict devaluation because patterns were completely random and perceptually meaningless at all eccentricities. Also different proportions of black and white dots did not affect the aesthetic appearance of the pattern at any eccentricity. This null result further points out that retinal eccentricity is a predictor of aesthetic appreciation but only for symmetry (even if it is always present and task-irrelevant). **Table 9** shows the results.

	β	SE	t	p
Intercept	4.16	0.14	29.06	< .001
MIE	0.04	0.16	0.26	0.80
MIIES	-0.001	0.001	-1.00	0.33
N black dots	-0.006	0.004	-1.50	0.15
Eccentricity	0.005	0.007	0.71	0.48
Eccentricity * N black dots	0.001	0.001	1.00	0.33

Table 9. Results from Multilevel Linear Model for analysis of preference ratings as a function of visual eccentricity in Experiment 2b.

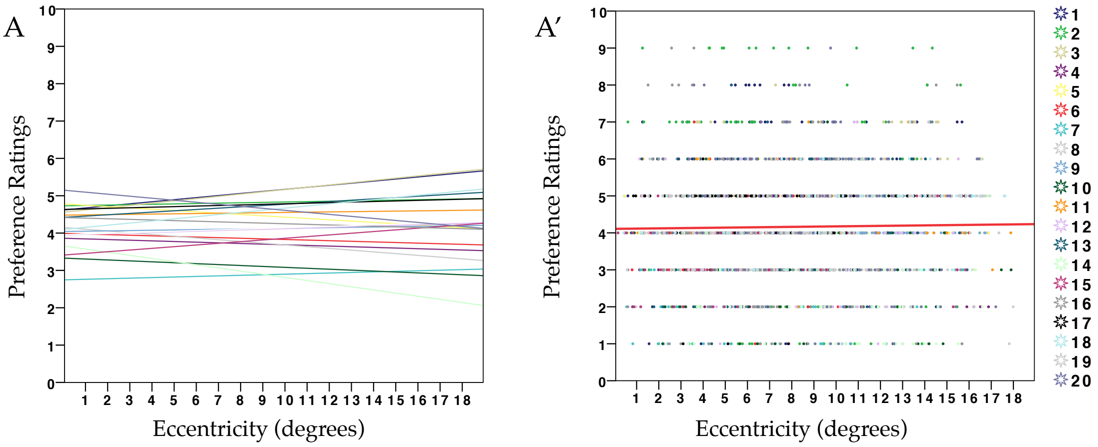

Figure 6. (A) Results from Experiment 2b **(A)** Scatterdot plot showing preference ratings (1-9) in relation to retinal eccentricity, and regression line (red) (R2 .0003). **(A′)** Same plot showing individual regression lines.

7.5 General Discussion

For abstract patterns, bilateral symmetry is a powerful predictor of aesthetic judgments. This is supported by a large literature, using either explicit measures (e.g. Cárdenas & Harris, 2006; Jacobsen & Höfel, 2003) or implicit measures (e.g. Makin, Pecchinenda & Bertamini, 2012a; Bertamini, Makin & Rampone, 2013). Symmetry is highly salient to the visual system, and therefore, a strong preference for symmetric configurations has been attributed to the ease of its processing (e.g. *The Perceptual Fluency Hypothesis*, Winkielman, Schwarz, Fazendeiro, & Reber, 2003). However, saliency of bilateral symmetry is sensitive to several parameters. One example is retinal eccentricity. The detection of symmetry is possible at different locations in the visual field (at least when pattern regularity is the focus of the task). However, the percept of symmetry drastically reduces even with small shifts from the center of the retina (e.g. Sally & Gurnsey, 2001). Increasing eccentricity leads to a gradual decrease in performance (e.g. discriminating symmetry from non-symmetry) (Tyler & Hardage, 1996; Saarinen, Rovamo, & Virsu, 1989; Sally & Gurnsey, 2001). In this study we investigated the role of visual eccentricity on the evaluation of symmetry. Preference for bilateral symmetry might depend on the perceptual information available when symmetry is processed at fovea. Because previous studies involving preference for symmetry were conducted in central vision, preference for symmetry at different location on the retina had not been systematically investigated. This study tested preference evaluation for highly regular patterns (mirror symmetry on both vertical and horizontal axis) and highly irregular pattern (randomly arranged dots) across retinal eccentricity.

The results obtained in this study helped to answer our initial questions. Q1). *Is retinal eccentricity a general predictor of lower preference or is it specifically detrimental for the aesthetic appreciation of regular shapes (bilateral symmetry)?* In two experiments (Experiment 1 and Experiment 2a) we observed that the evaluation of symmetry decreased with increasing eccentricity. On the contrary, abstract random patterns were similarly evaluated at all eccentricities (Experiment 1 and Experiment 2b) (Q2). *Does eccentricity affect preference evaluation through the impairment of symmetry discrimination at peripheral locations?* We did not obtain evidence of an effect of eccentricity on symmetry discrimination (Experiment 1), which was measured by response time and accuracy. Moreover in Experiment 2a, symmetry was task irrelevant. Therefore, the effect of eccentricity on evaluation cannot be explained by mere difficulty in processing pattern regularity in the periphery.

As previously mentioned it has been found that shifts of 1°-2° from the fovea cause a drastic drop in sensitivity to bilateral symmetry (e.g. Barrett et al, 1999; Gurnsey et al., 1998; Tyler and Hardage, 1995; Saarinen, 1988).

As the size of the patterns was maintained unvaried, we expected to observe a worsening in performance with increasing eccentricity. The experimental design probably played a critical role in cancelling any effect of eccentricity on performance. This approach is substantially different from other studies on the saliency of symmetry in the periphery, and a number of factors might affect the way in which participants distributed attention within the circle. Stimulus locations were not decided a priori; the fixation location changed at every trial; the fixation location was not set by the experimenter but chosen by the participant; there was no concrete fixation stimulus (e.g. a cross or a point) on which to concentrate attention. By randomizing the point of fixation as well as pattern location within the circle, participants could not make any prediction about the location of the incoming pattern. Further investigation may reveal that integrating any of these factors in the design can lead to a gradient of response speed as function of retinal eccentricity.

Although the design employed in this study cancelled any effect of eccentricity on performance, preference evaluation was sensitive to the retinal location of the (symmetrical) patterns. This is interesting. It suggests that visual eccentricity probably affects the perceptual processing of the pattern, even though this reduced saliency cannot be reported behaviourally.

The aesthetic appreciation of symmetry therefore is a function of the degree of regularity perceived around the axis. The gradual reduction of sensitivity caused by eccentricity is reflected in more negative evaluation of symmetry.

Experiment 2 showed that this happens even when symmetry is task-irrelevant. In fact, although participants attended to the colour of dots, symmetry was gradually disliked across the further peripheral locations. The goodness of processed symmetry was the critical factor affecting appreciation. On the contrary, irregular patterns (i.e. random) are perceptually meaningless at any distance from the point of highest visual acuity. For this reason, the task-relevant factor (i.e. colours of dot) was the only predictor of preference modulation in Experiment 2b.

This study shows that the link between symmetry and beauty is sensitive to its location on the retina. Although symmetry discrimination happens at any level in the periphery, symmetry appreciation is restricted to proximity to the fovea. This may explain why beauty is detected in the periphery, however it requires foveal observation in order to be appreciated and elicit an emotional response.

8 The role of the fixation cross in modulating symmetry detection speed at different eccentricities

8.1 Abstract

In this study, we investigated symmetry detection across visual eccentricity and compared two procedures, one in which observers arbitrarily selected where to look and one in which they were provided with a fixation mark. The display consisted of a large grey central circle in which an abstract dot pattern (bilateral symmetry or random) was presented for 200ms. The coordinates of pattern location were randomly generated. In Task-NoF participants arbitrarily choose any point within the circle. There was no physical stimulus to fixate, so participants maintained fixation on an empty space. Values of retinal eccentricity were calculated a posteriori by using the ocular coordinates and the coordinates of the centre of the pattern. Task-FC was identical, but a fixation cross was presented at different locations within the circle. Accuracy and manual reaction time were recorded. Accuracy decreased with increasing eccentricity. Hence, eccentricity was a good predictor of reduced sensitivity to symmetry overall. However, the effect of eccentricity on manual reaction times depended on the type of task. Increasing eccentricity predicted gradually slower RTs in Task-FC, but not in Task-NoF. Experiment 2 showed an eccentricity effect on RTs by using a central fixation mark, despite a reduced range of eccentricity values. This study shows that accuracy and RTs are separate measures of a perceptual process. It highlights an important role of the fixation-cross in the deployment of attention in the visual field, and how this affects responses to symmetry across the visual field. Moreover, it suggests that findings from traditional paradigms may not generalise to the case of a freely chosen fixation.

8.2 Introduction

The following study investigates the detection of bilateral symmetry across retinal eccentricity. Bilateral symmetry in abstract visual pattern is processed immediately and effortlessly in central vision (e.g. Barlow & Reeves, 1979; Jenkins, 1983). Although, foveation of the symmetry axis is not a prerequisite for correct symmetry detection (Barlow & Reeves, 1979), the saliency of bilateral symmetry strongly depends on its visual eccentricity. It has been demonstrated, with different parameters, that the detectability of symmetry considerably drops with axis eccentricity (Saarinen, 1988; Sally & Gurnsey, 2001; Barrett, Whitaker et al., 1999; Gurnsey et al., 1998). Scaling up stimulus size proportionally with eccentricity can compensate for the deterioration of symmetry processing (Tyler & Hardage, 1996). Symmetry detectability can be equated across eccentricities if stimuli are scaled with a factor $F = 1 + E/E2$, where E is eccentricity and $E2$ (~ 0.88° to 1.38° of visual angle) corresponds to the eccentricity at which the stimulus size must double in order to maintain foveal performance (Sally & Gurnsey, 2001). This signifies that, unless symmetry is scaled up, the detection speed should be gradually delayed with increments of 1°-2° of distance from foveal vision.

In the study described in Chapter 7, either 4-fold symmetric or random abstract patterns were presented at random locations within a large circular space. Participants kept fixation on a specific point they had selected arbitrarily at the beginning of each trial. Therefore the patterns could appear at any eccentricity within a range between 0° to ~18°/19°. Since patterns' size was maintained unvaried in every trial, it was expected that manual reaction time would be delayed, and accuracy would decline, as a function of increasing eccentricity. Results from this experiment showed that increasing retinal eccentricity did not predict response errors and did not even predict reaction times on correct trials. This was surprising considering what is reported in the literature.

In the same experiment, a second task, in which participants evaluated aesthetic appeal, showed that eccentricity predicted lower preference ratings for symmetric patterns (and not for random patterns). This result implied that some aspects of processing ought to be affected by eccentricity, leading to the devaluation of the symmetric stimulus. If symmetry evaluation benefited from foveal (or parafoveal) vision, and gradually decreased across the peripheral space, why was detection speed not sensitive to patterns' of eccentricity at all?

The design presented substantial deviations from traditional paradigms, I hypothesised that methodological factors should be imputed for the null eccentricity effect on response time and eccentricity. Several factors were likely to have affected the way in which participants reacted to the stimuli. These were, for example, the absence of a fixation mark, a continuous change of perspective caused by changing fixation on each trial, and the high level of unpredictability associated with pattern location.

The fixation mark plays a fundamental role in traditional experimental psychology studies, as it favours the engagement of attention on a specific point prior to target appearance. Keeping fixation on a small fixation-shape minimizes noise due to spreading of attention in the periphery and helps reducing the frequency of involuntary eye movements (although these are present with the majority of fixation marks employed in research, Thaler, Schütz, Goodale, & Gegenfurtner, 2013). When the fixation mark is removed, the deployment of (covert) attention to the periphery is facilitated (Fischer & Breitmeyer, 1987; Mackeben & Nakayama, 1993). Mackeben & Nakayama, (1992) used a circular stimulus array of 10° diameter. A vernier target occupied one of the 18 positions of the array (containing vertical bars). Participants' task was to identify the direction of the vernier offset without moving eyes from centre. In one condition a fixation mark was maintained at the centre of the array through the whole task. In the "gap" condition the fixation cross was removed prior to the appearance of the stimulus array. Discrimination performance in the vernier acuity task rose more quickly when fixation marker was removed prior target appearance. Authors confirmed that attentional disengagement at fixation caused the faster deployment of attention to the periphery.

The absence of a physical fixation point in our experiments is likely to have facilitated the employment of a strategy in which attention was spread evenly to the periphery. The attention receptive field expanded in order to fill a whole region delimited by the circumference of the circular region. This would be a version of the zoom-lens model of attention (Castiello & Umiltà, 1990; Eriksen & St James, 1986). In this case the efficient spread of attentional resources reduced the "attentional gradient" (i.e. difference in RT between farthest and nearest eccentricity).

Engaging attention on a fixation cross is more likely to favour the formation of an attentional gradient, as compared to a condition without fixation mark. This because processing the fixation stimulus automatically implies increased sensitivity on that area, at the expenses of peripheral areas.

In Experiment 1 I tested whether providing a fixation cross, instead of asking participants to freely choose where to look, made a difference in the RT of pattern discrimination. This experiment was divided into two tasks counterbalanced across participants. The first group of participants performed first a task in which they arbitrarily chose a fixation point (not marked) within a large circular region, and a pattern appeared at a random location within the circle (In Task-No Fixation (NoF)). Eyes position at target onset was recorded and memorized by the eye-tracker on each trial, together with patterns' location. The coordinates were used to calculate patterns of eccentricity. Importantly, eyes' position at target onset was also used in the following task (Task-Fixation Cross (FC)). Here, a fixation cross was provided. In each trial the position of the fixation-cross changed and corresponded to eyes' position at target onset in the first task. In other words, the fixation cross in trial-N of Task-FC was at the same location of the eyes' position at pattern onset in trial-N of Task-NoF. This method allowed controlling for individual strategies in choosing the fixation location, when no fixation point was provided. Some participants may tend to choose more central locations, others prefer to gaze at the borders of the circle, and others vary the position of the eyes considerably. Each participant was thus exposed to different eccentricity values. Because we specifically wanted to test the role of the fixation cross, it was important not to ignore this variability. In the second task participants did not choose where to fixate but their fixations were controlled experimentally by introducing a fixation cross. However, the fixation-cross reproduced the strategy they used in the previous task. At the end of the experiment we asked participants a series of question to clarify whether they understood the trick, and eventually told them about the design of the experiment. None of participants realized that the fixation cross was allocated at the same locations where they had looked before. This confirmed that participants did not use any specific strategy, or at least not consciously. The second group of participants performed the same task with reversed order. As this group performed task-FC first, the same fixation-cross positions for the previous group were used.

The primary aim of Task-NoF was to test whether the null-result of observed in Experiment 1 of Chapter 7 would be replicated. The secondary aim was to provide the coordinates for the position of fixation cross in Task-FC. Task-FC investigated whether adding a fixation-cross would be a critical factor for an effect of eccentricity on speed of manual responses and proportion of correct responses.

In the final experiment (Experiment 2) a central fixation point was employed and participants maintained fixation throughout the whole experiment. This reduced the level of unpredictability caused by randomised fixation and patterns positions. This experiment was more similar to traditional paradigms in which fixation point is generally at a fixed position and the number of possible target locations limited and controlled. Keeping fixation in the centre halved the range of possible eccentricities.

8.3 Experiment 1

8.3.1 Method

8.3.1.1 Participants

Forty participants from the cohort of psychology students at the University of Liverpool participated (age 18-28 years, mean age 20.5 years, 7 males, 2 left handed). All were naïve in respect to the experimental hypotheses and had normal or corrected to normal vision. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008). Data from one participant (subject number: 40) was not considered. For this participant the proportion of correct/incorrect responses was at chance level. Therefore the results in this session describe the data from 39 participants.

8.3.1.2 Apparatus and stimuli

Participants sat at 57cm from a 17-inch ViewSonic monitor with resolution 1024 X 768 pixels at 60 Hz. A chin rest was employed to keep the head still and at the correct distance. Eyes positions were measured using an EyeLink 1000 plus at a sampling rate of 500 Hz.

Stimuli were generated using PsychoPy software (Peirce, 2007) on a 13-inc MacBook Pro with resolution 1280 X 800 and exported in BMP format. Stimuli consisted of abstract black-dots patterns with either symmetrical or random configuration. Each pattern was composed of 60 dots arranged within a region delimited by two virtual circular perimeters (as indicated by the red lines within the pattern in **Fig. 1B and 1B′**). The radius of the internal small circle was ~0.2° of visual angle; the radius of the external circle was ~1.5°. Therefore the global size of the patterns was approximately 3°. Each dot had radius ~0.1°. Symmetric patterns were constructed by randomizing the arrangement of the dots in one of four quadrants. Each quadrant contained 15 dots. The other three quadrants were identical but specular in structure. In this way we obtained bilateral symmetry both on the vertical and horizontal axis, in order to maximize the regularity of the pattern. For random patterns the arrangement of the dots inside each quadrant was unconstrained. See **Fig 1B** for details regarding stimulus construction. No participant ever saw the same pattern twice. In total 288 images (144 symmetry and 144 random) were generated for the experiment and other 20 images (10 symmetry and 10 random) were used for the practice sessions. 10+144 images were used for Task-NoF and 10+144 images were used for Task-FC. The order of images was counterbalanced across tasks, so that all stimuli were either processed in a task in which participants chose the fixation point arbitrarily or in a task in which the fixation-cross was provided.

The experiment was constructed using Experiment Builder 1.10.1241. Stimuli were presented within a white circle with radius 12.4°. The first group of participants (N1-20) performed Task-NoF first, followed by Task-FC. The second group (N21-40) performed Task-FC first and Task-NoF second. Coordinates for the centre of the position of stimulus image were randomly generated on each trial. The pattern could appear at any position within the circle. Specific constraints were applied in order to avoid that the image would cross the border of the circle. For the first twenty participants, ocular coordinates at pattern onset in Task-NoF were saved, and these were used in the following task. In Task-FC a fixation cross was presented on each trial. The fixation cross was red and measured ~1.5°. The location of the fixation cross within the circle changed on each trial. The program used the ocular coordinates at pattern onset in Task1-NoF for determining the coordinates for the fixation cross. In other words, the fixation cross in trial-N (Task-FC) was located at the point of fixation that the participant chose in trial-N in Task-NoF. Since the second group performed Task-FC first, the fixation-cross coordinates of the same task in the previous group were used. Therefore the eyes-coordinates in Task-NoF of the first group were used to provide coordinates for Task-FC for both groups. Fixation-cross for Subject 21 had the same locations than fixation-cross for subject 1, and so on. Design of Task-NoF in the second group was identical to Task-NoF in the first group. Participants used a 2-buttons keypad to report their response accordingly to task instructions.

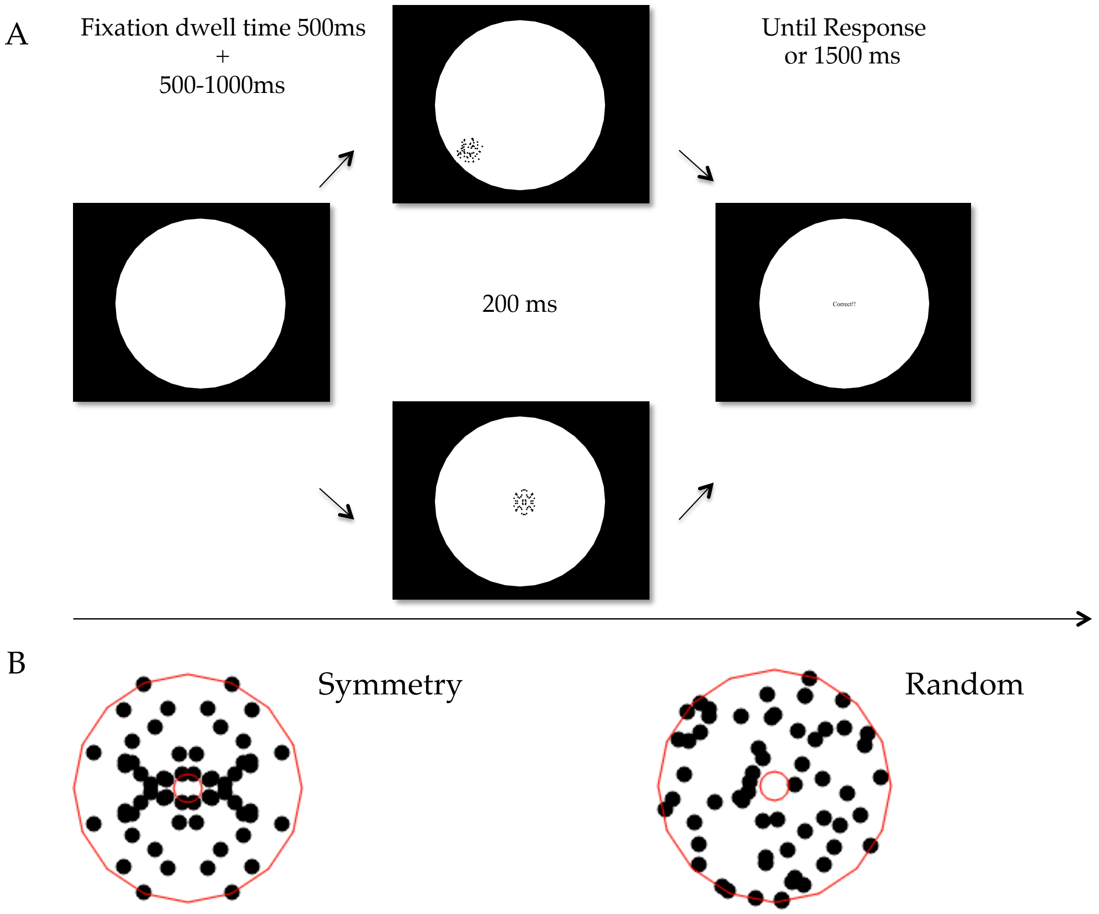

Figure 1. (A) Experimental procedure of Task-NoF. The participant could look at any location within the central large circle and choose a point on which to maintain fixation. Fixation lasted a random interval between 500ms and 1000ms. After the interval an abstract pattern appeared at a random location within the circle. The pattern could be either symmetry or random, and remained on the screen for 200ms. Participants were encouraged to control the reorienting reflex. Immediately after pattern offset, participants reported whether the pattern was symmetry or random as fast as they could. If no response was given within 1500ms from pattern offset, the trial was considered null and a new trial started. (**B**) Example of a symmetry pattern. (**B'**) Example of a random pattern. Red lines indicate the virtual circles used to construct the patterns. These were not visible to the participants and are shown here for illustrative proposes.

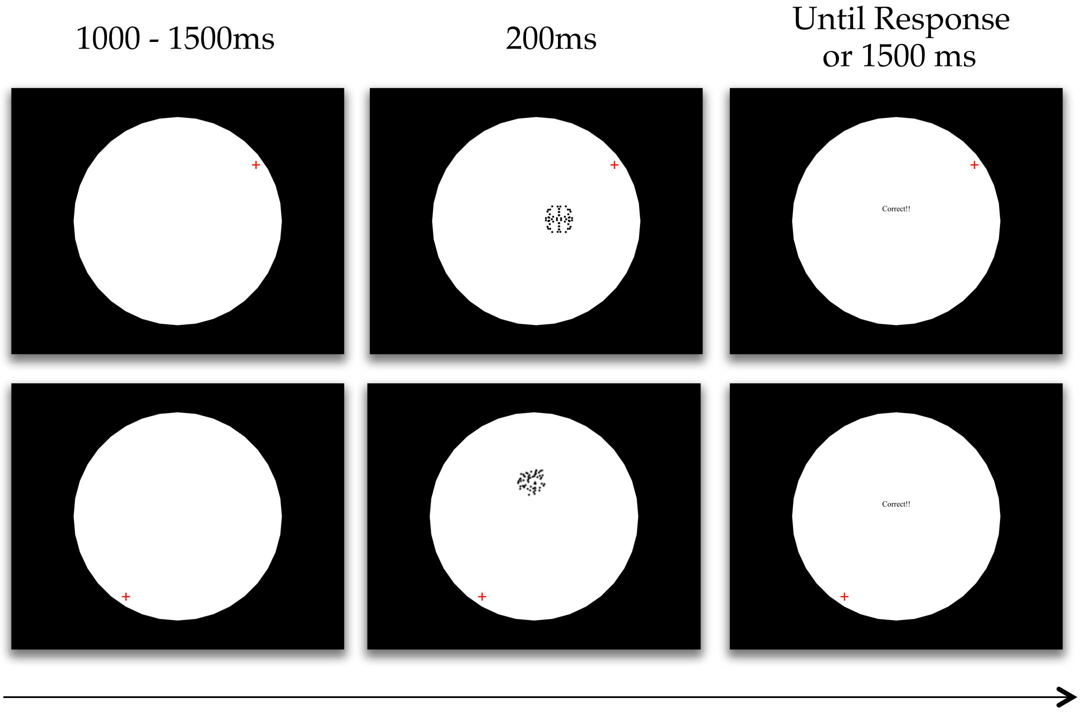

Figure 2. Experimental procedure of Task-FC. Participants were required to maintain fixation on the red fixation-cross presented within the circle. After the interval (between 500ms and 1000ms) an abstract pattern appeared at a random location within the circle. The pattern could be either symmetry or random, and remained on the screen for 200ms. Immediately after pattern offset, participants reported whether the pattern was symmetry or random as fast as they could. If no response was given within 1500ms from pattern offset, the trial was considered null and a new trial started.

8.3.1.3 Procedure

Fig. 1 shows experimental procedure of Task-NoF, and **Fig. 2** shows Task-FC. A large grey circle over a black background delimited the area of interest. At the beginning of each trial in Task-NoF, participants were required to chose arbitrarily any location within the circle and keep fixation on that point (see details about procedure in **Fig. 1**A). At the start of each trial a fixation dwell time of 500ms triggered an interval, which was randomly generated on each trial and varied between 500-1000ms. This was followed by pattern onset. The Last Point of Gaze (LPOG; ocular coordinates at the instant of pattern onset) was saved on each trial to be used in the following task. Patterns were presented for 200ms and could be either symmetric or random. Participants were instructed to control reflexive saccade to pattern onset and keep fixation on the location. Participants classified the pattern regularity (symmetry or random) as fast and accurately as possible. One group of participants pressed a left button for symmetry and right button for random. The other group did the opposite. The response screen was displayed until response. A feedback word ("correct" or "incorrect") was displayed for 500ms after response, then a new trial started. If no response was produced within 1500ms from pattern offset, the feedback word 'too late' was displayed for 500ms and a new trial initiated. The task consisted of 144 trials.

The first group of participants performed Task-FC after Task-NoF. They were required to keep fixation on a fixation-cross, and they were told the cross was presented in a random location within the circle. The fixation-cross was presented at the beginning of each trial and remained in position until a new trial started. The coordinates of the cross were not randomized. LPOG coordinates saved in Task-NoF were used to set the location of the cross within the circle. Therefore, the fixation-cross in Trial 1 of Task-FC was located at the same position where the eyes were fixating during pattern onset in Trial 1 of Task-NoF. Participants reported whether the patterns were symmetric or random as quick and accurately as they could. Patterns in Task-FC were different from patterns presented in Task1-NoF and the order of pattern appearance was randomized. Also pattern position was randomized. Therefore, for each trial, the fixation point was the same than in Task-NoF, but pattern eccentricity and pattern regularity were different. A questionnaire was provided at the end of both experiments asking participants their personal opinion about the purpose of the study. This was used to test whether participants did understand the experimental aims. None of participants was aware that fixation-cross position corresponded to eyes-positions in the previous task.

The second group of participants performed Task-FC first. They also were told that fixation cross and pattern location within the circle was random. Instead, the location of the fixation-cross was the same than in Task-FC in the previous group. Each task was preceded by a practice session of 10 trials, to ensure that participants understood the instructions, and was divided in two halves by a break. Here participants were allowed to rest and disengage eyes from the screen. Between the two tasks a longer break (~ 5/10min) was used to provide new instructions to the participant. All details regarding Task-NoF are in **Fig. 1**A, whilst Task-FC is described in **Fig. 2**.

8.3.1.4 Eye data analysis

Data Viewer (version 1.11.900) was used to export both ocular and behavioural data into excel file. In the 5.9% of trials eye data were lost. RTs shorter than 100ms were considered as anticipatory responses and excluded (1.7%). In total 10567 trials were included in the analysis, corresponding to the 94% of total trials. The average proportion of excluded trials in the symmetry and random conditions did not differ in both experiments. Retinocentric coordinates of stimulus position were calculated as the distance between the ocular coordinates at target onset and the coordinates of the center of the circular region in which patterns were embedded. Eccentricity values ranged between 0.1° and 19.8° (Task-NoF M= 8.22; SD= 4; range=19.7; Task-FC M= 9.0; SD= 4.1; range== 19.6).

8.3.2 Analysis

Multilevel linear model

Multi-level linear modeling is a statistical approach for hierarchical data sets in which data is sampled at different levels of a hierarchy. In the experiments here, experimental trials, the lowest level of the hierarchy, were nested within participants, the highest level of the hierarchy. In contrast to a standard regression model in which the dependent variable is a measure of central tendency that is detached from the variance around that score, a multi-level model includes estimates of the variance at each level of a hierarchical data-set, adjusting the estimates of other parameters in the model accordingly. Random effects in the model relate to the extent that variance in the DV can be attributed to variance at a particular level in the hierarchy (e.g. a random effect of participant; a random effect of trial). ‘Fixed effects’ in the model relate to the extent that variance in the DV can be attributed to a manipulated variable. Through partitioning the variance in this way within the context of one model, the parameters that are estimated for the fixed effects are statistically unbiased by, for example, significant variability across participants.

Fixed factors in our analysis were Mean Individual Eccentricity (MIE), task, pattern regularity and eccentricity. The interactions eccentricity X pattern regularity and eccentricity X task were included. MIE corresponds to the mean distance from eyes at which patterns were presented, calculated for each participant. As eccentricity values were not preset and balanced, each participant might have been more often exposed to patterns at a certain eccentricity. Taking this variable into account as fixed variable of our model, allowed us to control for individual differences in eccentricity exposure.

Two models were performed. One multilevel linear model was employed to analyse RTs. The model for RTs included only trials in which a correct response was made (Task-NoF 19%; Task-FC 21%). Accuracy is a binary dependent variable; therefore a binary logistic model was performed. All correct responses were coded as 1, and all incorrect responses were coded as 0.

All models employed revealed that random factors (participants and trials numbers) generated significant variability in the data (all ps < .05). However, the current work was not interested in testing the role of random factors on the final outcome. These will not be discussed any further. The analysis was carried out in MLwiN (Rasbash, Charlton, Browne et al., 2009).

8.3.3 Results and Discussion

Eccentricity affected the odds of correct responses ($t_{(38)} = -6.00$, $p < .001$), suggesting higher proportion of errors at greater eccentricities (see **Table 1**). Also Pattern regularity affected accuracy ($t_{(38)} = 3.08$, $p < .001$), which suggests a bias in classifying the pattern as symmetry in case of doubt. Possibly participants set up a strategy based on “detecting symmetry” instead of “discriminating regularity”. This bias, however, did not interact with eccentricity. Task did not affect accuracy of responses. More importantly, it did not interact with Eccentricity. This signifies that sensitivity to symmetry decreased with increasing eccentricity, irrespective of the presence/absence of a fixation-cross.

	β	SE	Odd Ratio	prob	*Xsq*	t	p
Intercept	1.55	0.11			4.81	13.61	< .001
MIE	-0.10	0.05	0.90	0.81	2.37	-2.17	0.03
Task	0.25	0.16	1.28	0.86	10.89	1.54	0.13
Pattern regularity	0.23	0.08	1.26	0.86	36.20	3.08	< .001
Eccentricity	-0.07	0.01	0.93	0.81	1.24	-6.00	< .001
Eccentricity x Pattern regularity	0.02	0.01	1.02	0.83	0.10	1.23	0.22
Eccentricity x Task	0.00	0.01	1.00	0.83	1.10	0.29	0.78
Task X Pattern regularity	-0.11	0.11	0.90	0.81	0.93	-0.96	0.34

Table 1. Binary Logistic model for analysis of correct responses (Experiment 1)

Results from the model used for analysis of RTs are shown in **Table 2**. The main effect of Eccentricity was not significant. This suggests that eccentricity did not affect responses speed. However, MIE was a predictor of slower responses. This suggests that responses tended to be slower for participants that more often processed patterns in the periphery. There was a main effect of Task ($t_{(38)}$ = -6.13, p < .001). This indicates that responses in Task-FC were generally faster (mean= 503.4, SD= 164) than in Task-NoF (mean= 524.2, SD= 183.05). Presumably the presence of a fixation-cross led to prompter responses overall. A significant main effect of pattern regularity ($t_{(38)}$ = -6.09, p < .001) also suggested that there was a bias to respond faster when patterns were symmetric. Possibly participants were focused on detecting symmetry within the pattern, leading to more prompt responses when this was correctly identified. Importantly, eccentricity interacted with Task ($t_{(38)}$ = -4.69, p < .001). Two separate models, one for each task, were then performed in order to explore this interaction (shown in **Table 3**). No other interaction was observed.

	β	SE	t	p
Intercept	542.76	3.78	143.70	< .001
MIE	4.12	1.68	2.45	0.02

Task	-33.14	5.41	-6.13	< .001
Pattern regularity	-31.90	5.23	-6.09	< .001
Eccentricity	1.32	0.84	1.56	0.12
Eccentricity x Pattern regularity	-1.22	0.91	-1.33	0.19
Eccentricity x Task	4.31	0.92	4.69	< .001
Task X Pattern regularity	10.27	7.47	1.38	0.17

Table 2. Multilevel linear model for analysis of reaction times (Experiment 1)

Multilevel analysis on RTs in Task-NoF showed that eccentricity was not a predictor of slower responses time. The analysis on RTs in Task-FC revealed instead that eccentricity significantly predicted gradually slower RTs ($t_{(38)}$ = 6.10, <.001). When fixation-cross was provided participants reaction times were affected by patterns location in the periphery (see **Fig. 3**)

	Task-NoF				Task-FC			
	β	SE	t	p	β	SE	t	p
Intercept	543.58	14.23	38.20	< .001	514.30	11.4	44.82	< .001
MIE	2.58	7.19	0.36	0.72	6.65	7.24	0.92	0.36
Pattern regularity	-32.36	4.95	-6.54	< .001	-22.67	4.66	-4.87	< .001
Eccentricity	0.56	0.94	0.60	0.55	5.27	0.86	6.10	< .001
Eccentricity x Pattern regularity	0.88	1.22	0.72	0.47	-1.75	1.15	-1.52	0.14

Table 3. Multilevel linear model for analysis of reaction times separately for Task-NoF and Task-FC (Experiment 1)

Some important suggestions can be extrapolated from these results. It was evident that the saliency of symmetry gradually decreased with increasing eccentricity, overall. The detection of symmetry was less accurate at farther distances from the fovea in both tasks. This confirms that sensitivity to symmetry drops off when symmetry is shifted to the periphery of the fovea, and this decline is proportional to increasing distance on the retina.

The interesting aspect is how response speed was modulated by eccentricity depending on the presence/absence of the fixation cross. A gradual effect of eccentricity on reaction times was evident and significant in Task-FC (fixation cross) but not in Task-NoF (free fixation). It is important to bear in mind that each participant looked at the same positions in both tasks. The two tasks differed for only two aspects: the presence/absence of fixation mark, and the fact of either actively choosing where to fixate (Task-NoF) or passively being directed to fixate a given point (Task-FC).

The absence of fixation-cross specifically affected the speed of manual reactions. This is likely to have attentional causes, reflecting a widespread distribution of attention within the circle when the fixation mark is absent. We will discuss this in the General Discussion.

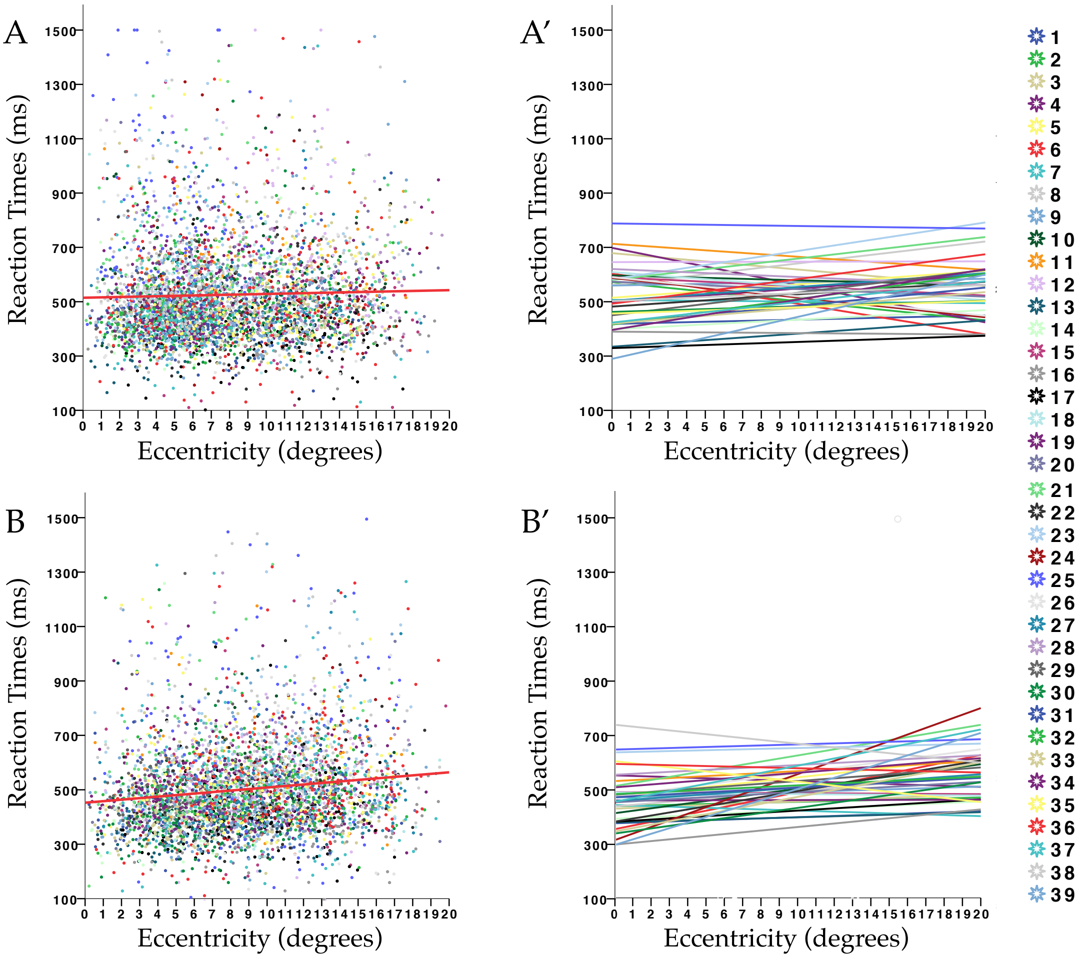

Figure 3. (A) Results from Task-NoF. Scatterplot shows the relationship between manual reaction times (RTs) and retinal eccentricity, and regression line (red) (R2 = .009). **(A′)** The same plot showing linear regression lines from each individual. **(B)** Results from Task-FC. Scatterplot shows the relationship between manual reaction times (RTs) and retinal eccentricity, and regression line (red) (R2= .02). **(B′)** The same plot showing linear regression lines from each individual.

8.4 Experiment 2

This control experiment tested manual responses as a function of eccentricity by keeping a central fixation throughout the whole task. In this experiment therefore the level of predictability of possible pattern eccentricities would increase even further as participants know the fixation point will not vary across trials. However, in this task the possible eccentricity values will have a reduced range, as there is not as much space available between the center and the circumference. It is therefore possible that the task will be too easy to give a reliable eccentricity gradient of reaction times

8.4.1 Method

8.4.1.1 Participants

Sixteen naïve participants took part in the experiment (age 17-31 years, mean 23.2 years, 6 males, 3 left handed).

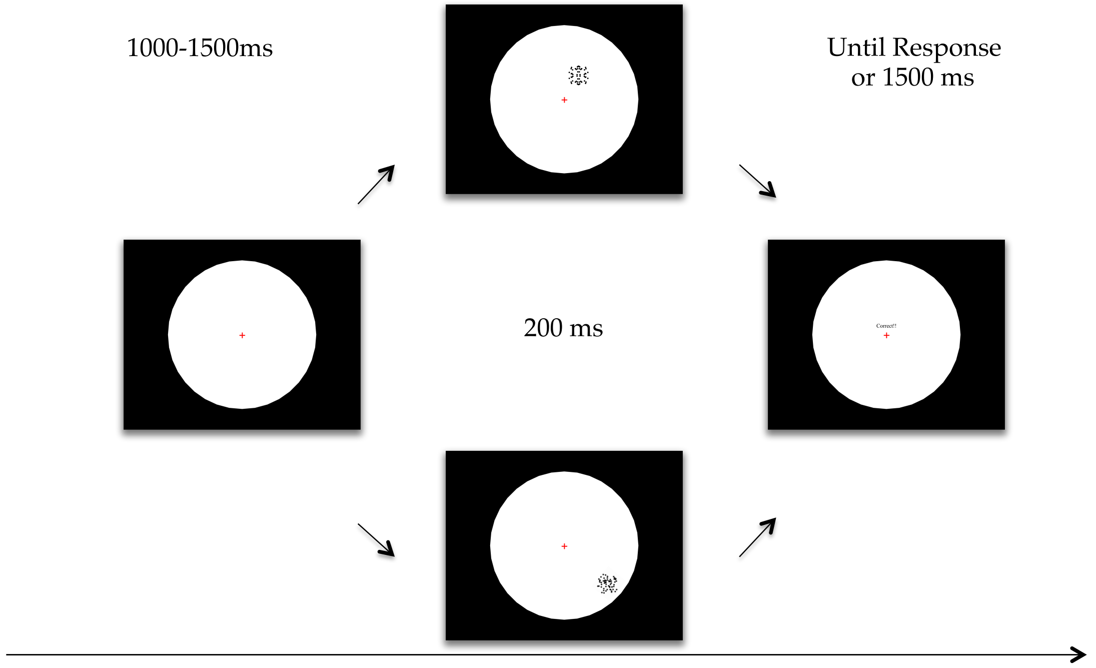

Figure 4. Experimental procedure of Experiment 3. Each trial started with a random interval between 1000ms and 1500ms. Participants were required to maintain fixation on at the red fixation-cross presented at the center of the circle. After the interval an abstract pattern appeared at a random location within the circle. The pattern could be either symmetry or random, and remained on the screen for 200ms. Participants reported whether the pattern was symmetry or random as fast as they could.

8.4.1.2 Apparatus and stimuli

Participants sat at 57cm from a 16-inch LCD monitor with resolution 1280 X 1024 pixels at 75 Hz. To prevent loss of data due to head movements, a chin rest was employed to keep the head still. Participants' eye movements were measured using an ASL Eye-Trac D6 (Applied Science Laboratories, Bedford, MA) at a sampling rate of 120 Hz. Both experiment and stimuli were generated using PsychoPy software (Peirce, 2007). Stimuli were constructed with the same principle adopted in the other experiments. However, these were not exported as images but generated afresh on each trial. Stimuli were presented within a white circle with radius ~12.4°. Coordinates of stimulus position were randomly generated on each trial. The pattern could appear at any position within the circle. Because pattern position changed on each trial, it could not be predicted. A red fixation cross was located in the center of the circle through the whole experiment. Participant used a gamepad to report their response accordingly to task instructions. They pressed the two top-bottom shoulder buttons of the gamepad (7 - 8) to report pattern regularity (symmetry or random).

8.4.1.3 Procedure

The experimental procedure was similar to the previous experiment (see **Fig. 4**). A large grey circle delimited the area of interest. Each trial started with a variable interval of 1500 to 2000ms. During this interval participants choose any point within the grey circle to fixate. An abstract pattern, either symmetrical or random, appeared at an unpredicted position within the grey circle. Pattern display duration on the screen was 200ms. Participants were instructed to control reflexive saccade to pattern onset.

Participants classified the pattern as symmetry or random as fast and accurately as possible. One group of participants pressed a left button for symmetry and a right button for random. The other group did the opposite. A response screen was displayed until response. A response feedback word (correct; incorrect) was displayed over the fixation cross for 500ms immediately after response.

The experiment consisted of 144 trials, divided in two blocks of 72 trials. Between each block participants were allowed to rest and disengage eyes from the screen. A practice session of 10 trials came first. This reproduced the procedure of the incoming experiment, in order to ensure participants understood the instructions.

8.4.2 Analysis

Retinocentric coordinates of stimulus position were calculated as the distance between the centre of the screen and the coordinates of the centre of the circular region in which patterns were embedded. Eccentricity values ranged approximately between 0.1 and 7.4 degrees of visual angle (M= 4.85; SD= 1.8; range=7.3). There were no anticipatory responses (RT < 100ms) and no odd eye-data were recorded. Therefore 2304 (100%) of trials were included in the analysis. Multilevel linear model was performed for the analysis of manual reaction times (only on correct trials: 12.2%) and Binary Logistic model was performed for the analysis of accuracy.

8.4.3 Results

Results are shown in **Table 4**. There was a significant effect of eccentricity on manual reaction times ($t_{(15)}$= 5.67, p < .001). The effect of pattern regularity on manual reaction times was not found in this experiment.

	β	SE	t	p
Intercept	0.544	0.025	21.76	< .001
MIE	0.003	0.175	0.17	0.87
Pattern regularity	0.001	0.008	0.13	0.90
Eccentricity	0.017	0.003	5.67	< .001
Eccentricity x Pattern regularity	-0.002	0.005	-0.40	0.69

Table 4. Multilevel linear model for analysis of reaction times as a function of visual eccentricity in Experiment 2

There was also a significant effect of eccentricity on the odds of correct responses ($t_{(15)}$= -1.98, p = .03), and a significant effect of pattern regularity ($t_{(15)}$

= -2.51, p = .01). This was similar to the results obtained in Experiment 1 and Experiment 2. No other significant result was observed (**Table 5**)

	β	SE	Odd Ratio	prob	*Xsq*	t	p
Intercept	2.15	0.15				14.65	< .001
MIE	0.82	0.93	2.27	0.95	0.78	0.88	0.38
Pattern regularity	-0.32	0.13	0.72	0.86	6.27	-2.51	0.01
Eccentricity	-0.12	0.06	0.89	0.88	4.67	-1.98	0.05
Eccentricity x Pattern regularity	0.08	0.08	1.08	0.90	1.06	1.03	0.30

Table 5 Binary Logistic model for analysis of correct responses as a function of visual eccentricity in Experiment 2

In this experiment the eccentricity range was halved as compared to the other experiment. However, we observed that responses speed to pattern regularity was faster when the patterns appeared closer to fixation. In this experiment the fixation cross was maintained in a fixed location through the whole experiment. It is possible to speculate that this might have amplified the focus on the fixation area, even though patterns appeared more often at the greatest eccentricities (see **Fig 6**). This favoured fast and accurate responses when patterns appeared in this central area.

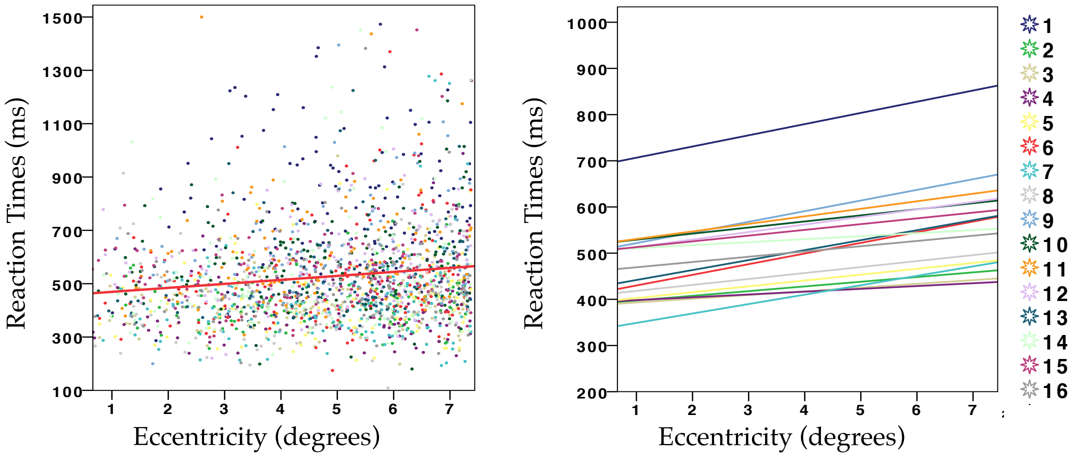

Figure 6. (A) Results from Experiment 2. Scatterplot shows the relationship between manual reaction times (RTs) and retinal eccentricity, and regression line (red) (R2 = .02). (**A'**) The same plot showing linear regression lines from each individual.

8.5 General Discussion

The perception of symmetry is known to be immediate in central vision but rapidly falls-off with retinal eccentricity (e.g. Sally & Gurnsey, 2001). The current set of experiments confirms that accuracy in symmetry detectability decreases as a function of eccentricity. However, eccentricity affects detection speed depending on the presence/absence of a fixation cross.

Task-NoF of Experiment 1 explored the detection of symmetry at different locations in the visual field with a novel design. Participants were asked to freely choose a location inside a large circle where directing their gaze. A stimulus (an abstract pattern with either symmetry or random configuration) was presented briefly at a randomly generated location within the circle. The stimulus was an abstract pattern with either symmetric or random configuration and participants classified the regularity of the pattern as fast and accurate as possible by pressing a button on a keypad. Eccentricity values were calculated a posteriori and randomly varied across participants. Although sensitivity to symmetry was significantly impaired (as results on discrimination accuracy demonstrated), detection speed was unvaried across the whole eccentricity spectrum. Task-FC replicated the exact same design with a difference: a fixation cross was provided. In this task retinal eccentricity predicted both worse accuracy and slower reaction times.

In this experiment there was also a significant tendency to give faster responses when patterns were symmetric. This might reflect an attentional preparation to detect symmetry within the pattern, leading to more prompt responses when this was correctly identified. There was also a significant tendency to misclassify random patterns as symmetric patterns. This bias overall suggests that participants may have adopted an attentional strategy, whereby the aim was 'detecting symmetry' instead of 'discriminating the type of regularity'. However, it is important to note that this attentional bias did not interact with eccentricity, and it is unlikely to have affected sensitivity to symmetry at the different locations.

Experiment 2 repeated the same design but further incremented the stability of the design by setting a constant fixation point location in the center of the circle. Although this halved the range of possible eccentricities, slower responses were more frequent with increasing eccentricity (as visible in **Fig. 6**). There was no response bias induced by pattern regularity in this experiment.

This study provided two important results. First, it confirmed that sensitivity to symmetry in abstract patterns decreases as a function of increasing eccentricity. Second, it showed how experimental factors can considerably affect the way participants perform a task. Specifically, it showed a role of the fixation cross in the speed of manual responses.

In Task-NoF participants were encouraged to explore the circle and change gazing location on each trial. In addition to a high level of unpredictability, the absence of a fixation-cross led participant to distribute attention evenly on a wide area. The presence of a fixation-cross favoured the formation of a gradient of responsiveness, with faster correct responses when the pattern was presented closer to the fixation point. In traditional experimental designs, the fixation point defines a starting position in which the eyes can anchor in preparation for the upcoming stimulus. It is likely that the focus of attention converges on the area defined by fixation creating a gradient of attention. The same pattern of results was observed if the order of the tasks was inverted, confirming that the fixation-cross played a critical role in the formation of a gradient of response time.

Attention is directed and distributed in the space in different ways. One of the most accredited models describes attention as a "spotlight" beam moving in space (Posner et al., 1980). The attentional spotlight results in an improvement of information processing in the attended area at the expense of other locations, in other words stimulus detection is faster and its discrimination more accurate (see Carrasco, 2011; Corbetta & Shulman, 2002; Michael I. Posner & Petersen, 1990). However, objects in the space have different dimensions and shapes. It is therefore important for the attentional focus to adjust its size according to the attended area. This "zoom-lens" model of attention (Castiello & Umiltà, 1990; Eriksen & St James, 1986) predicts that processing efficiency spreads evenly within the attended area. It is likely that both mechanisms of attention exist and interleave depending on context and task. In the current design, the "zoom-lens" model applied on the NoF condition. As no fixation mark was provided attention expanded and filled the whole region of the circle. In other words, the circle was the attended object and every point received the same attention. This happened, even if the eyes were maintained still on a specific position. The presence of a fixation-cross requires automatically the formation of an attentional "spotlight" around its area in order to process the stimulus, which is likely to subtract resources from the periphery and create an attentional gradient.

It is however important to bear in mind that discrimination accuracy was affected by eccentricity in both NoF and FC conditions. It thus suggests that the percept of symmetry benefited of pattern proximity to the fovea even when attention was widespread evenly within the circular region. Manual reactions were instead specifically affected by the presence/absence of the fixation cross. This also indicates that RT and accuracy are not always equivalent measures of the underlying processes involved in the recognition of visual stimuli (Prinzmetal, McCool, & Park, 2005), and responses depend on how attention is distributed in space.

Hence, this study provides important evidence that the way in which an experiment is designed can affect responses significantly. The outcome obtained may not always reflect the actual presence/absence of a phenomenon. Moreover, highly controlled experimental designs are likely to show effects that more ecological designs do not show.

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Notes

The research reported in this thesis has been carried out in the Bertamini Lab within the School of Psychology of the University of Liverpool (UK). Some of the work described in this thesis has been accepted or submitted for publication and/or has been presented at international conferences. All chapters have been written as separate articles in collaboration with Marco Bertamini, whose supervision has been of immense value to me. Alexis Makin, in quality of third supervisor, has been of critical importance for the realization of these studies. I also would like to thank Noreen O'Sullivan for her help on the statistical analysis of Chapter 7. Finally, I thank Naomi Brayshaw and Margaret Matich for their help in collecting some data as part of their third year graduation project.

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Rampone, G., Bertamini, M. & Makin, A., (2015) Exogenous cuing of attention increases preference for abstract shapes. ECVP, 24th -27th August.

Rampone, G., Bertamini, M. & O'Sullivan, N., (2015) Role of eccentricity on evaluation of abstract symmetry. VSAC, 22th – 23th August 2015.

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