The Psychological Basis of Aesthetic Preferences: Insights from Facial Attractiveness and Architectural Appreciation

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Declaration

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The psychological basis of aesthetic preferences: insights from facial attractiveness and architectural appreciation

Aesthetic experience is personal and yet universal. It has long been an intriguing subject of interest for philosophers and psychologists alike. Though even without consciously contemplating beauty, our aesthetic preferences influence many of our day-to-day choices beyond pure hedonism – from purchase decisions of products, selecting a partner, to voting behaviour in elections; all of which have real-world consequences. The main goal of the research described in this thesis was to advance empirical understanding of the factors that influence aesthetic judgements. The research focussed on of two ubiquitous categories of stimuli in our visual world, human faces and built environments. As such, this thesis consists of two main themes, facial attractiveness and architecture appreciation.

First impressions are thought to be formed within fractions of a second when seeing an unfamiliar face. Some researchers even argue that facial attractiveness judgements occur in a mandatory manner alongside other aspects of face processing, even when attractiveness is irrelevant to the task at hand. Once formed, these judgements persist and are difficult to inhibit. It has long been established that a number of invariant, or unchangeable facial features such as symmetry, averageness, and sexual dimorphism play a role in attractiveness. However, mounting evidence has shown that transient, or changeable facial properties such as gaze direction, head orientation and facial expression also modulate perceived attractiveness. For instance, faces which display a combination of a direct eye gaze at the observer and happy expression are known to be perceived as more attractive than those with an averted gaze and negative expression (e.g. sad or angry). These effects and their possible causal effects are described in Chapter 1. It is unclear, however, whether different social cues to attractiveness affect those judgements

in an integrated or independent manner. Moreover, previous studies on facial attractiveness might not reflect typical social interactions in which gaze direction, head orientation and facial expression are constantly changing. As such, the first question addressed in this thesis, and described in Chapters 2 and 3, concerns the role of dynamic social cues and their interaction on facial attractiveness. Specifically, the study described in Chapter 2 investigated whether the effect of facial expression on attractiveness was modulated by a dynamic gaze shift; and the study in Chapter 3 investigated the role of head turns. The second question addressed in the issue of serial dependency in which the rating provided to the stimulus in the current trial may be affected by the rating provided in the previous trial in a manner that is distinct from a response bias. The study described in Chapter 4 tested whether serial dependency occurs both within and across categories of stimuli (faces vs. built environments) in aesthetic rating tasks. Serial dependency was found in aesthetic judgements thus expanding previous findings of serial dependency in perception to higher levels of visual interpretation.

Unlike facial attractiveness, in which faces are an important social stimulus, aesthetic judgements for architecture appears to show greater individual differences. Nevertheless, some features appear to universally enhance aesthetic preferences in objects and scenes. The study described in Chapter 5 examined the effects of visual features, such as curvature, on the aesthetic judgements of architecture (both outdoor and indoor). Furthermore, the role of personality dimensions on these judgements was also investigated. Finally, in Chapter 6, the role of eye movements was investigated to determine regions of interest when participants are required to aesthetically evaluate exterior images of buildings.

A summary of the findings and their implications are discussed in detail in Chapter 7. The overall findings of this thesis have demonstrated that facial attractiveness judgements

are affected by a combination of factors, including social (e.g. expressions and eye gaze) as well as visual (particularly dynamic changes). Moreover, aesthetic preferences in architecture are determined by both visual properties of the buildings such as curvature, ceiling height, window-to-wall ratio, as well as personality traits of the observer. The thesis argued that in order to gain deeper understanding of aesthetic processing, more ecologically valid paradigms and stimuli are required (e.g. real models for facial attractiveness, and full immersion in 3D environments for architecture appreciation) that reflect better the real-world scenario of aesthetic evaluation. Recent technological advancements in virtual reality and mobile eye tracking offer promising avenues for future research on the topic.

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I need to thank my parents, my brother and my best friends back home in Hong Kong.

多謝你哋支持! 香港人加油。

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Chapter 1

General introduction

1.1 Abstract

The objective of this thesis is to report a series of empirical research conducted to investigate the psychological basis of visual aesthetics with the focus on facial attractiveness and appreciation for architecture. This chapter consists of six sections and start with an overview of the philosophical roots of aesthetics. In the second section, the historical context that marked the start of the field of experimental aesthetics are discussed, followed by the evaluation of some early theories in the field. In the third section, major theories in the studies of empirical aesthetics are evaluated. In the fourth section, an overview of theories in face perception is given, and findings regarding facial attractiveness are reviewed. The focus is then shifted to the perception of built environment in the fifth section, in which major theories of scene perception and preferences relevant to the aesthetic judgments of build environments are discussed. In the sixth section, some outstanding questions in the field which the current project was set out to address are highlighted. In the last section, the outline of the thesis is described.

1.2. The philosophical roots of beauty and early experimental aesthetics

"Beauty exists merely in the mind which contemplates; and each mind perceives a different beauty; and every individual ought to acquiesce in his own sentiment, without pretending to regulate those of others."

— David Hume, 1757 Of the Standard of Taste.

For centuries the nature of beauty remains one of the most debated and controversial topics among philosophers. The question "What is beauty?" is as captivating as beauty itself. One central issue in the philosophical inquiry of beauty revolves around whether beauty is subjective, as captured by the famous notion "Beauty is in the eye of the beholder" or objective, implicating a set of standards which govern universal beauty exist. This issue remains a topic of broad and current interest in experimental aesthetics. The current review only covers a small fraction of the discussion of aesthetics in philosophy that is significant to the discipline of experimental aesthetics.

1.2.1 Platonian beauty

For Plato, beauty was what he called a *Form* which could be understood as a perfect ideal, with the same status of justice or the circle (the mathematical ideal). It is associated with truth and the divine and is distinct from what we perceive as "physical beauty" (Pappas, 2017). While Plato acknowledged the beauty of physical objects such as that of a person, a flower, or the sunset, he considered it as a "*Mimêsis*" (or imperfect copy) of beauty itself (which is objective, yet invisible) because physical objects are mortal and subject to decay (Golden, 1975). Therefore, they are at best an imitation of the eternal and rational ideal. Following this logic, in his *Republic (Book X)*, Plato states that art is merely a copy

of the physical world, which in turn is a copy of true beauty. In addition, because art stirs up emotion, it affects our behaviour and has a dangerous potential to corrupt, and so it should be carefully censored (Pappas, 2017). It is perhaps very hard to be empathetic to such an emphasis on the negative potential of art and its separation from beauty as it is interpreted presently. However, it is in accordance to his notion that beauty as a virtue is to be associated with morality and goodness. Plato did not explicitly comment on facial attractiveness. However, in his *Symposium*, he related beauty of the body to 'love' and the desire to pursue the invisible, ideal *Form* of beauty through first finding physical beauty in the body, then beauty in the soul (e.g. the good and wisdom), and then ascending to the universal. It is unclear whether what Plato considered physically beautiful nor whether he meant physical was beauty subjective, although it was implied. However, Plato was a lot more forthcoming in regard to architecture – architecture should follow the exact measurements that represent the divine (or mathematical ideal) and promote the social good. In that sense, beauty in architecture is defined as the extent to which a structure conforms to perfect proportions, a concept that is akin to Vitruvius's virtues of architecture (Pappas, 2017).

1.2.2 Immanuel Kant's Critique of Judgment (Kant, 1922; first published in 1790)

Kant's Critique of Judgement (Kant, 1922) is perhaps the most influential book written on aesthetic appreciation in philosophy. According to Kant, aesthetic judgements consisted of the judgement on the agreeable (i.e. liking), the judgement on the beautiful and the judgement on the sublime. The judgement on the beautiful had the following characteristics that are of particular interest to this thesis. First of all, judgements on the beautiful are *disinterested*, which means they are made impartial to personal interests in

the object. Interest is defined as gaining pleasure from the existence of the object in question and so a judgement with interest is a judgement on the agreeable, not beautiful. *Disinterestedness* is often interpreted as 'liking without wanting' in the neuropsychology of aesthetics (Chatterjee, 2010, 2015; Belke, Leder, & Carbon, 2015) However, in their recent paper on the analysis of Kant's work and the interpretations made by empirical researchers in aesthetics regarding his work, Hayn-Leichsenring, & Chatterjee (2019) has warned that this interpretation is unlikely to be what Kant intended for *disinterestedness* to mean. Secondly, accordingly to Kant, beauty is universal because the same cognitive faculties are shared universally (Hayn-Leichsenring, & Chatterjee, 2019), what is subjective is the experience and pleasure that follows the perception of a beauty object. Thirdly, beautiful objects possess *purposiveness without an end (or purpose)*, whereby *an end* could be what the object is meant to be used for (*external end*) or what the object is meant to be like (*internal* end). In other words, beautiful objects appear purposive without actually serving a purpose.

So far, Kant's concepts of beauty appear incompatible with the purpose of this thesis, which is to investigate facial attractiveness and aesthetic judgements in architecture. While it can be assumed there might be some universal aesthetic preferences in both domains, *disinterestedness* and *purposiveness without an end* appear almost impossible to achieve, for faces are intrinsically, socially meaningful stimuli and the perceptual processing of faces serves the very purpose and an interest in social communication (see section 1.4); and for architecture, the built environments possess purposiveness with an obvious end, yet the contemplation of beauty in architecture is universal across cultures and civilisations. This can only be reconciled by recognising the differences in terminology commonly used in the empirical studies of aesthetics and the specific concepts referred to in philosophical writings (Hayn-Leichsenring, & Chatterjee, 2019.

Beauty judgements, for example, are defined as a sub-category of aesthetic judgements within Kant's philosophical framework while in experiments of empirical aesthetics, beauty, attractiveness, aesthetic judgments are often used interchangeably.

1.2.3 Fechner's psychophysical view of aesthetics

It wasn't until 1757 when aesthetics became a stream of philosophy, following the first use of the word *aesthetics* by Alexander Baumgarten. Major enlightenment thinkers maintained that aesthetic experience and the perception of beauty are too subjective to admit scientific inquiry. The first formal and documented study of aesthetics in the history of psychology can be traced back to the work of Gustav Fechner in the late nineteenth century (Fechner, 1876), who was better known as the father of experimental psychology and psychophysics. As a psychophysicist, Fechner believed that aesthetic preferences could be studied experimentally in ways similar to the psychophysical measurement of perception, in which there is a measurable correspondence between the physical properties of stimuli and the sensations they caused (Fechner, 1876) During his endeavour to test the veracity of the Golden Section hypothesis, Fechner introduced three key experimental methods which are still widely adopted in the empirical studies of aesthetics nowadays, namely, the method of choice, which involves subjects choosing between a number of alternatives to indicate their aesthetic preferences; the method of production, which involves instructing subjects to produce an object that possesses the features or properties that deemed most aesthetically pleasant; and the method of use, which involves the researcher examining the properties of existing objects to determine whether they conform to a specific hypothesis (Phillips, Norman, & Beers, 2011). The establishment and refining of these methods have made scientific inquiry into aesthetic

experiences very promising and have marked the birth of psychological aesthetics (Fechner, 1876).

1.2.4 Arnheim's beauty of Gestalt

Gestalt psychology offered an alternative to the bottom-up, elemental approach to perception in the early 20th century (Shimamura, 2012). Psychologist Rudolf Arnheim was strongly influenced by this holistic approach to perception, according to which a visual scene is made up of groups of organised features and perception is the interpretation of this organised sum, but not its elemental parts. Arnheim applied Gestalt principles to the investigation of visual aesthetics, in particular, the creation and appreciation of film and art. Viewing of paintings, natural scenery or any objects being subject to aesthetic appreciation is an active exploratory process, rather than a passive recording of elemental features (Arnheim, 1969, 1974). Arnheim also spoke of metaphorical terms such as "field" and "force" (borrowed from physics) to illustrate the dynamic structure of artworks (Vartanian, 2014). He argued that artists induced "perceptual forces" through balance, harmony, and object placement (composition). These forces then give rise to aesthetic experiences such as a sense of tenseness or calm (Shimamura, 2012).

1.2.5 Berlyne's psychobiological approach of aesthetics

Fechner (1876) and Arnheim (1969, 1974) both applied perceptual principles to aesthetic evaluations but did not address the affective and motivational aspects of aesthetic experience which differentiates an aesthetic experience from ordinary object perception. Daniell E. Berlyne proposed a theory which explained the effects of complexity and novelty on aesthetic preferences and arousal (Berlyne, 1960, 1970, 1974). Accordingly,

this relationship is in the form of an inverted-U curve, illustrating that maximum aesthetic pleasure is achieved by eliciting an optimal level of arousal (e.g. through novelty, surprise or incongruity in artworks) - not too low that the stimulus appears uninteresting but not too high that it causes excess arousal, confusion and discomfort (Berlyne, 1971).

Vartanian (2014) identified a number of shortcomings of Berlyne's model. Firstly, Berlyne's prediction of an inverted-U relation between arousal and aesthetic pleasure was not supported by empirical evidence. Rather, aesthetic preference was shown to positively correlate with meaningfulness (Martindale, Moore, & Borkum, 1990). Similarly, Martindale (2007) pointed out the theory implied that any two stimuli that bring about the same level of arousal must by definition trigger the same level of aesthetic pleasure. This simply cannot be true. An extension of the model was proposed to account for a full range of physical arousals that qualitatively differ, including negative aesthetic arousals that are not associated with pleasure (Silvia & Brown, 2007).

Nevertheless, the shortcomings of the inverted-U model do not undermine the profound contributions that Berlyne has made to empirical aesthetics. Importantly, Berlyne has provided a theoretical framework under which the beholder's experience can be taken into account in the understanding of aesthetic experience. Indeed, contemporary models of aesthetics strive to encompass both the perceptual and affective aspects of aesthetic experience.

1.3 Contemporary theories in experimental aesthetics

Even though the empirical studies of aesthetics in psychology can be dated back to near the birth of experimental psychology and psychophysics (Fechner, 1876), the hegemony

of behaviourism that followed, during which aesthetics was no longer a central topic of interest in the field, had halted the development of empirical aesthetics (Martindale, 2007). It was not until a century later in the 1970s when a unified theoretical framework started to emerge. Berlyne (1974) proposed his psychobiological model of aesthetics as discussed previously. In this section, three main theories of aesthetic experience proposed in recent years are reviewed.

1.3.1 Processing fluency theory

The processing fluency theory of aesthetics was proposed by Reber, Schwarz, & Winkielman (2004). Their central idea was intuitive - the more fluently perceivers can process an object, the more positive their aesthetic responses are. The processing fluency model is based on the following four assumptions. Firstly, objects differ in the extents to which their features facilitate fluent processing. By fluency, Reber, et al. (2004) was referring to the common experience of processing ease characterised by the speed and accuracy of the processing. This processing fluency can be enhanced at the perceptual level, the conceptual level, or both. Some of the core objective features of beauty such as symmetry, goodness of form and prototypicality all enhance fluent processing (Reber, et al., 2004). Secondly, "processing fluency is itself hedonically marked" and high processing fluency elicits a subjective and positive experience because it is associated with success in stimulus processing, recognition and interpretation. High processing fluency might also elicit positive feelings because it indicates that an external stimulus is familiar and likely to be harmless (Zajonc, 1968, 1998). Thirdly, the processing fluency feeds into the observer's aesthetic judgements because people often draw on their subjective feelings when making an aesthetic evaluation instead of assessing the stimulus content in a rational manner (Reber, et al., 2004). This is known as the "affect as

information framework". In other words, the positive feeling that emerges from processing fluency is wrongly attributed to some aspect of the stimulus (Reber, et al., 2004).

Lastly, the impact of processing fluency on affective experience is moderated by expectations and attribution. The effect of processing fluency is particularly strong if the source of the positive affect is unknown or attributed to an irrelevant source and fluency comes as a surprise (Reber, 2012). It has been reported that even a subjective feeling of fluency can enhance aesthetic pleasure (Forster, Leder, & Ansorge, 2013).

An abundance of empirical evidence supported the processing fluency theory (Alter & Oppenheimer, 2009; Chenier & Winkielman, 2009). First of all, the existence of processing fluency was supported by findings from studies in which prototypical or close-to-average stimuli are processed with greater speed and efficiency than novel, non-prototypical stimuli (Vartanian, 2012) and processing fluency was enhanced by procedures such as repeated exposure and priming, elicit positive reactions (Reber et al., 2004). Furthermore, the positive relationship between aesthetic liking and processing fluency was confirmed through manipulating stimulus properties in terms of contrast, clarify, and symmetry (Reber, Winkielman, & Schwarz, 1998; Reber, 2002; Reber, Wurtz, & Zimmermann, 2004; Wurtz, Reber, & Zimmermann, 2008); as well as through modifying the perceiver's perceptual experience e.g. repeated exposure, exposure duration and perceptual priming (Bornstein & D'Agostino, 1994; Reber et al., 1998).

However, contradictory findings have also been reported. These findings generally found an increase in aesthetic liking in low-processing-fluency stimulus characteristics such as complexity (Landwehr, Labroo, & Herrmann, 2011) and novelty (Hekkert, Snelders, & van Wieringen, 2003).

Armstrong & Detweiler (2008) also argued that high processing fluency creates mild, subtle feeling, such as the small pleasure of recognising of an object, but strong aesthetic feelings entail beyond merely successful perceptual processing (e.g. recognition, categorisation). Secondly, it is unclear how processing fluency interacts with other evaluative processes beyond mild aesthetic pleasantness (e.g. interestingness and meaningfulness). Furthermore, considering the mere exposure effect, while processing fluency can explain the increase in aesthetic preference upon repeated exposure, it cannot account for the increase in disliking for repeatedly exposed stimuli which are initially disliked (Silvia, 2012).

1.3.2 The Leder, Belke, Oeberst, & Augustin (2004) Model of aesthetic appreciation and aesthetic judgements

Leder, Belke, Oeberst, & Augustin (2004) proposed an aesthetic processing model which aimed to explain why people are attracted to art. Specifically, they argued for an extension of existing approaches to empirical aesthetics in order to account for the positive aesthetic experience arisen through cognitive challenges, for example, in the appreciation of abstract art and other conceptual, complex and multidimensional stimuli. By doing so, the findings in which complexity and novelty enhanced aesthetic liking, which the processing fluency failed to account for, can be explained. According to their model, aesthetic emotion and judgements are the outputs of five processing stages, which are:

1) Perceptual analyses - stimulus characteristics including colour, contrast, symmetry, complexity, grouping and order are extracted through a bottom-up and effortless process although this process is time sensitive. Restricting the time of stimulus

presentation differentially affect the processing of these characteristics (Leder, et al., 2004).

2)   Implicit memory integration. The processing of familiarity, prototypicality and the search for essential features in arts rely on the use of implicit memory and depends on a top-down knowledge and experience of the observer (Elder, et al., 2004).

3)   Explicit classification. Analyses on this level are deliberate and are concerned with content and style. This is the stage when the observer's expertise and art knowledge come into play. An art novice's output at this stage is in terms of what is simply depicted; whereas with an increase in knowledge, the artwork, its historical importance, the artist's background or intention also become the content of the aesthetic object. For an expert, the processing of prototypicality overlaps with this stage of processing due to the knowledge of prototypes concerning a particular style, school or artist (Leder, et al., 2004; Cupchick, 1992).

4)   Cognitive mastering and evaluation. These two processes are closely linked and form a feedback-loop during which the results of the cognitive mastering stage are evaluated in relation to their success in revealing an understanding of the artwork, or changes in the level of ambiguity. Subject experience of failure in the evaluation further initiates information processing through the backwards-loop (Leder, 2004). This is also another stage during which expertise guides the aesthetic process, having extracted perceptual properties and placed it within self-referential (implicit memory integration) and explicit contexts, we make sense of the artwork (Vartanian, 2012).

5)   Affective and emotional processing. In the final stage, Leder, et al.'s (2004) model goes beyond perceptual and cognitive processes. Although this stage is placed as the last stage, the affective aspect of an aesthetic experience runs parallel with the

perceptual and cognitive processing stages. The affective state of the observer is constantly influenced by the results of each stage. The initial affective state when the observer enters an art-related situation is typically positive. Ongoing successful cognitive mastering, for instance, then builds up on the positive affective state of the observer in terms of cognitive appraisals.

The information processing model provides a more comprehensive explanation to aesthetic experiences, shifting the research focus away from single-factor explanations such as fluency (Reber, 2004), complexity (Eysenck, 1941), arousal (Berlyne, 1971), or prototypicality (Martindale, Moore, & West, 1988). It is unlikely that one single factor could account for aesthetic experience to a large extent given the complexity and multidimensionality of the way we interact with artwork and aesthetic objects. Recently, Leder & Nadal (2014) published a review paper on the developments in empirical aesthetics since their information processing model was proposed more than 10 years ago. In the review paper, the authors acknowledged the importance of investigating the underlying neural correlates of aesthetic experiences and understanding aesthetic experiences from an ecological perspective, which their model had not originally addressed. This model is one that is dedicated to explaining the aesthetic experience when viewing art. Therefore, while the aesthetic judgement and emotion elicited when viewing architecture can likely be accounted for by this model, its relevance to facial attractiveness is not as high, since the two stages of explicit classification and cognitive mastering and evaluation are not applicable for viewing of human faces. Nonetheless, this information processing model proposed by Leder, et al. (2004) marked a very important breakthrough in the empirical studies of aesthetics.

1.3.3 Redies (2015) A unifying model of visual aesthetic experience

Redies (2015) proposed a model of aesthetic experience that unified the contextual effects that give rise to individual differences as well as the universal preferences in visual stimuli. The stimulus in question, unlike in Leder, et al.'s (2004) model, can be any object of aesthetic interest, and coveys two pieces of information, its *form* , which refers to how something is depicted, and its *content*, which refers to what is depicted; both are presented or created in a *context*. Altogether, the stimulus as external information is translated into an internal representation for sensory coding and perceptual and cognitive processing, which are subject to modulations by memory, social context, cultural experience, expertise, previous exposure, etc. The beauty-responsive mechanism refers to cortical sensitivity to 'beautiful' features such as fractal and other image properties. Compared to the model proposed by Leder, et al. (2004), this model does not assume hierarchical processing of stimulus where by perceptual processing precedes cognitive processing, instead, this model allows for the two processes to occur in parallel and aesthetic experience is elicited only if both processes are successful. As Redies (2015) pointed out, his model allows for stimuli of different domains, as well as different aesthetic emotions (e.g. sadness).
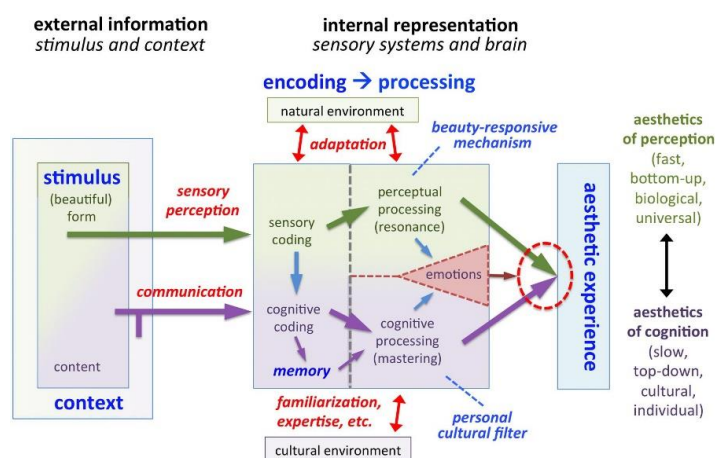
Figure 1.1 Model of aesthetic experience. Original diagram from Redies (2015)

1.4. Face perception and facial attractiveness

One of the prerequisites of aesthetic perception is perception. Therefore, judgements of facial attractiveness inevitably arise from face perception and likewise appreciation of architectural spaces is impossible without the ability to perceive spatial relations in scenes in the first place. The following sections aim to provide an overview of the most influential theories put forward to explain the perceptual and cognitive processing of faces and built environments.

1.4.1 The Bruce & Young (1986) Model of face recognition

The model of face recognition proposed by Bruce & Young (1986) remained to be one of the most influential theories of face perception. It is a functional model in which the processing of facial features serves an eventual goal of recognising familiar faces. In this model, there are seven types of information or "codes" that are extracted from a face during the process of face recognition, namely, the pictorial, structural, identity-specific, semantic, visually derived semantic, name, expression, and facial speech codes (Bruce & Young, 1986) and their inter-relationships and hierarchy of processing are illustrated in Figure 1.1 Accordingly, the first step of face perception was structural encoding during which two types of information were extracted: 1) view-centred features (or "pictorial code") such as configuration information due to facial muscle and lip movements that contributes to the visual appearance of a face at a given moment, specific to a given image and 2) expression-independent descriptions (or " structural code") that are invariant and represent the unchangeable internal feature configuration of a face that does not depend on face view or other incidental variations. Thereafter, the processing of facial expression and facial speech which rely on the former type of information and the recognition of

face identity which utilises the latter follow parallel routes. Bruce and Young (1986) drew comparison of this initial structural encoding to Marr's (1982) concepts of the primal sketch, 2½ sketch and 3D model in object recognition to stress the differentiation between changeable and unchangeable facial features. This information route map proposed by Bruce and Young (1986) implied that the processing of facial expression and speech-related and that of facial identity might be neurologically distinct (Calder & Young, 2005). This distinction gained much support by empirical evidence (Campbell, 1996; Calder, Young, Keane, & Dean, 2000; Etcoff, 1984; Young, Newbombe, de Hann, Small, & Hay, 1993) and was subsequently complemented by an equally influential neurological model of face perception proposed by Haxby, Hoffman, & Gobbini (2000). However, the model has also been challenged on the basis of the interdependence between identity and expression processing (Schweinberger, Stefan, Soukup, & Rüdiger, 1998; Kaufmann & Schweinberger, 2004; Atkinson & Adolphs, 2011).
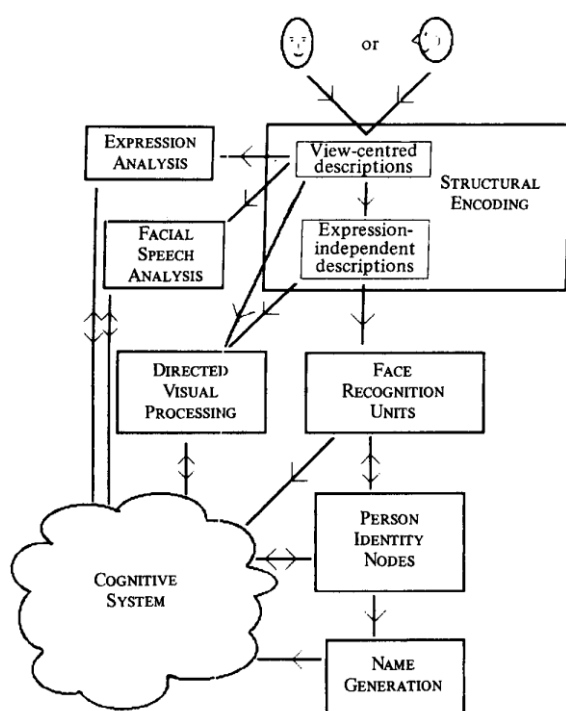
Figure 1.2 A schematic diagram illustrating the hierarchical processing of different information during face recognition. Original diagram from Bruce & Young (1986).

1.4.2 The Haxby, et al. (2000) distributed human neural system of face perception

Central to the neurological model of face perception proposed by Haxby, et al. (2000) was the division of the core system and the extended system. The core system contains the brain structures responsible for the visual analysis of facial features and the distinction in the neural representations between the changeable and invariant aspects of faces lies within this system. The extended system consists of additional brain regions which serve other cognitive functions but are involved in the further analyses of face signals. This is illustrated in Figure 1.2. Accordingly, after the initial feature processing in the inferior occipital gyri, changeable features such as expression, lip movement, and eye gaze are processed in the superior temporal sulcus (STS) in the core system and other areas in the extended system such as the amygdala and intraparietal sulcus for the purpose of emotion recognition and social communication; while the unchangeable features of faces are processed in the lateral fusiform gyrus in the core system and the anterior temporal regions in the extended system for the purpose of facial identification.
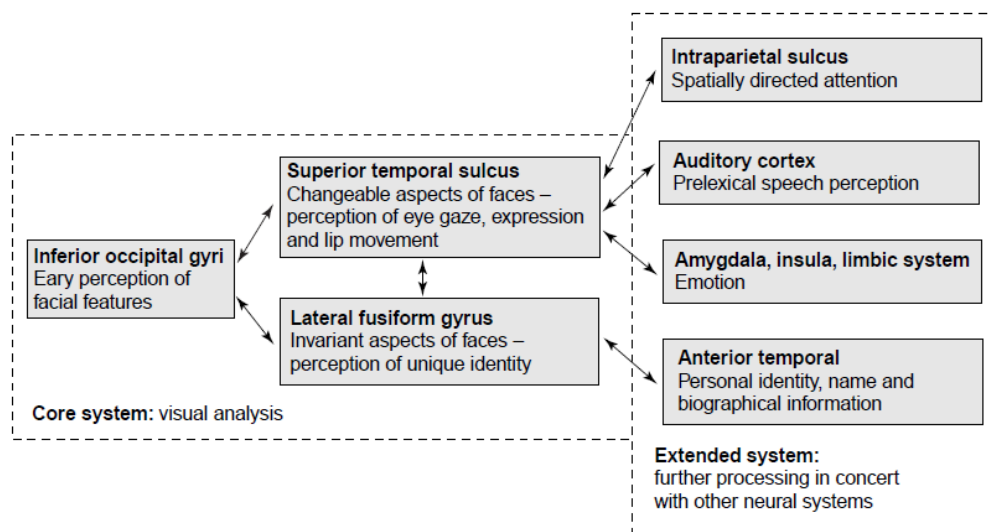
Figure 1.3 A schematic diagram illustrating the disturbed human neural system for face perception. Original diagram from Haxby, et al. (2000).

The two models proposed by Bruce & Young (1986) and Haxby, et al. (2000) only considered the perception of static face images but it is obvious that in real scenarios of social interactions, the perception of faces is dynamic. As a result, new models of face perception proposed were extended to include regions (e.g. motion-selective area MT) that are sensitive to face motion (O'Toole, Roark, & Abdi, 2002; Bernstein & Yovel, 2015). Furthermore, challenges to the two models proposed by Bruce & Young (1986) and Haxby, et al. (2000) mainly concern the inter-dependence between the processing of facial expression and identity, and, specifically to the neural model by Haxby, et al. (2000), there is new evidence of facial expression processing in regions the fusiform gyrus, indicating that the division of labour between STS and fusiform gyrus is not as precise as the model suggested (Bernstein & Yovel, 2015). The models proposed by Bruce & Young (1986), Haxby, et al. (2000) and O'Toole, et al. (2002) remain influential in the field of face perception. These models provided a framework in which facial attractiveness can be studied in respect to the processes involved in face perception. For example, both changeable and invariant aspects of faces have been shown to influence facial attractiveness. Changeable aspects of faces are processed for the purpose of social communication while invariant aspects of faces lead to face recognition in the case of familiar faces and a newly learnt identity in the case of unfamiliar faces. It follows that perceived attractiveness arose from these two types of information might be originated through different mechanisms.

1.4.3 The Todorov (2011) model of face perception and evaluation

Both models mentioned above are information processing models whereby different information extracted from faces undergo various pathways of hierarchical processing. Valentine (1991) proposed an alternative theoretical concept of face recognition whereby

each known face is stored within a multidimensional space called the 'face space'. Todorov and colleague (2011) adopted this concept and put forward to statistical model of facial attractiveness. The motivation underlying their model was to overcome the lack of explaining powers of two separate accounts of facial attractiveness based on averageness and sexual dimorphism respectively. The 50-dimensional (25-shape-dimensions and 25 reflectance-dimensions) face space model made more accurate predictions of attractiveness by taking into account the two factors of averageness and sexual dimorphism in conjunction. This interactionist approach of facial attractiveness provides a promising avenue to investigate the effects of different facial features on the evaluations of attractiveness.

1.5. Scene perception and architectural appreciation

1.5.1. Perception of architectural spaces

The perception of architectural spaces, indoor or outdoor, can be understood in terms of scene perception. The research in scene perception has two primary concerns: the time course of scene perception, usually referring to the rapid extraction of 'gist' information (Oliva, 2005; Oliva & Torralba, 2006), as well as the differentiation between the objects in the scene and the scene itself (Biederman, Mezzanotte, & Rabinowitz, 1982; Davenport & Potter, 2004). Both topics are relevant to the aesthetic processing of architecture. In order to evaluate the aesthetics of an indoor architectural space, it is necessary to perceive and visually explore the whole 'scene', gist information available early on can guide further exploration for aesthetic evaluation. On the other hand, when judging building exteriors, (e.g. "when asked, how beautiful is this building to you?"), it

is necessary to be able to differentiate between the building, which is now an object, from the background, which is the scene.

Scene gist can be extracted upon brief exposure to an image of a scene (Thorpe, Fize, & Marlot, 1996; Fei-Fei, Iyer, Koch, & Perona, 2007; Joubert, Rousselet, Fiz, & Fabre-Thorpe, 2007; Oppermann, Hassler, Jescheniak, & Gruber, 2012; Harel, Groen, Kravitz, Deouell, & Baker, 2016). The global spatial information necessary for scene category is extracted around 150 ms after stimulus onset (Thorpe, et al., 1996; Harel, et al., 2016). In a classic experiment by Potter (1976), participants were first shown a target picture and then asked to indicate whether they saw the same picture as they viewed a sequence of rapidly presented images, flashed for 250ms each. All observers reached a 100% accuracy. The concept of a saliency map was introduced by Itti, Koch, & Niebur (1998) to explain the role of local, low-level features in eye-movement guidance to achieve maximal computational efficiency in scene perception and object detection within a scene.

On the other hand, Oliva and Torralba (2006) proposed that scene perception is achieved by extracting global image features associated with specific types of scenes to provide the gist information required for further processing. Some holistic information, but not local object features is extracted during this stage, which included the spatial layout of the scene, the degree of openness, naturalness (i.e. urban or natural scene categorisation) and colour (Oliva, 2005; Oliva & Torralba, 2006).

1.5.2 Aesthetics in architecture

Throughout the history of civilisation, architecture has been one of the most profound reflections of culture. As modern human beings, our interaction with the built

environment is inevitable and to a certain extent, mundane that we might not be constantly contemplating the beauty of the environment we are in. Yet, conscious aesthetic considerations as well as automatic aesthetic responses (Mastandrea, Bartoli, & Carrus, 2011; Pavlović & Marković; 2012; Mullin, Hayn-Leichsenring, & Redies, 2017) arise readily for everyday objects and surroundings, which in turn lead to preferences that influence a wide range of decision-making and behaviour. Although aesthetics has been a major concern in architecture, there is thus far no models or theories specifically dedicated to the psychology of architectural aesthetics. While there has been limited and isolated studies in architecture and environmental psychology (with the work by architects such as Arthur Stamps III since the early 1990s being more comprehensive; Stamps, 1989, 1991, 1997a, 1997, 1999, 2000, 2010, 2013), the empirical studies of architectural aesthetics have only just begun to gain more attention in experimental psychology and neuroscience (Vartanian, Navarrete, Chatterjee, Fich, Leder, Modroño, Nadal, Rostrup, & Skov, 2013, 2015, 2017; Vecchiato, Tieri, Jelic, De Matteis, Maglione, & Babiloni, 2015; Coburn, Vartanian, & Chatterjee, 2017; Thömmes & Hübner, 2018; Ruta, Mastandrea, Penacchio, Lamaddalena, & Bove, 2018).

Nevertheless, Jay Appleton's Refuge and Prospect theory proposed in 1975 suggested that the preferences in landscape depends on a psychological need for safety and opportunity (to explore) at the same time. Therefore, the spatial arrangement of a preferred landscape should allow the occupant to "see without being seen". In essence, it is closely related to the approach-avoidance notion in psychology, both stems from an evolutionary origin (Dosen & Ostwald, 2013). Originally a theory of landscape preferences, it has been highly regarded in architecture. Translating the concept of "seeing without being seen" into the design of architectural spaces, architects strive to achieve an equilibrium of outlook and enclosure. Recently, this theory has been supported

for the first time using fMRI by Vartanian, et al. (2015), who reported that openness and high ceiling in indoor architectural spaces were rated as more beautiful and viewing enclosed spaces activated the brain regions that signal exit tendencies.

1.6. Research questions

1.6.1 Facial attractiveness

The first theme of this research project concerned the role of changeable features in facial attractiveness. The role of invariant features in facial attractiveness has been well studied. However, the effects of changeable properties such as eye gaze, face view, and expression, which are also socially important signals, were relatively underexplored. Even less forthcoming has been the interaction between these factors on attractiveness, especially in their dynamic forms. Therefore, to address these gaps in the research of facial attractiveness, the following research questions were formulated and tested in the experiments reported in Chapters 2 &3:

1) Do gaze shift and expression independently or, in an integrated manner, affect perceived attractiveness?

2) What is the more important attribute of a gaze shift to facial attractiveness, is it the direction of a gaze shift (which indicates the direction of social attention allocation), or the relative duration of the view of direct gaze compared to, the averted gaze during a gaze shift (which reflects the amount of social attention received by the observer)?

3) Can the effect of gaze on attractiveness be dissociated from that of face view (head orientation)? If so which factor exerts a greater influence on facial attractiveness?

4) Does facial expression interact with face view (and head turn) on facial attractiveness?

5) Similar to Question 2), does attractiveness of a face depend more on the direction of head turn or the relative duration of the front-facing view during head turn?

1.6.2 Serial dependence and perceptual categorisation

Serial dependence refers to an assimilative pull on the judgement response to a current stimulus towards those viewed in recent perceptual history. This is relevant to researchers in experimental aesthetics who routinely use rating or two (or multiple)-alternative-forced-choice tasks in the studies of aesthetic preferences and evaluations in which participants are required to make trial-by-trial aesthetic judgements, often within the time frame where serial dependence operates. It has been reported that indeed facial attractiveness judgements were susceptible to the effects of serial dependence too, but the effect was attenuated when the sex and race categories changed across consecutive trials and some researchers argued that the serial dependence observed in these studies were in fact merely a response bias. Therefore, a number of experiments were conducted in the current project in order to address the following questions:

1) Does serial dependence exist in facial attractiveness judgements?

2) If so, is the magnitude of serial dependence sensitive to a change in sex categories across trials?

3) Can serial dependence be found in the aesthetic evaluation of scenes of built environments too?

4) If so, is the magnitude of serial dependence sensitive to a change in scene categories across trials?

5) Do attractiveness judgements assimilative across trials in which stimuli of different domains were presented?

1.6.3 Beauty in architecture

The third theme of this thesis concerns the aesthetic judgements in architecture. Although an abundance of research in the area of architecture and environmental psychology have considered the aesthetics of architecture from a functional perspective, and usually adopted a qualitative approach with case studies (Stamps, 1989, 1991, 1997a, 1997, 1999, 2000, 2010, 2013), the experimental studies of architectural aesthetics has only begun recently, by considering the effects of a small number of properties at a time (Vartanian, et al., 2013; 2015; 2017). On the other hand, the aesthetic preferences in architecture could be confounded by other valence-related preferences such as the perception of intimacy, which is an important consideration in the design practice in architecture. The motivation behind this thesis was to take the next step in furthering the field of empirical architectural aesthetics by conducting a larger-scale study and considering more factors, both stimulus-related and personal-related, into the investigation. As such, in the large-scale behavioural study reported in Chapter 5 and an exploratory eye movement study reported in Chapter 6 the following research questions were asked:

1) What are the effects of curvature, ceiling height, and space openness on the perception of architectural beauty and the perception of intimacy in indoor architectural spaces?

2) Are these effects modulated by personality measurements and level of expertise in architecture?

3) What are they effects of curvature, building height, and window-to-wall ratio on the perception of architectural beauty and the perception of intimacy in building exteriors?

4) Are these effects modulated by personality measurements and level of expertise as well?

5) What do people look at when they judge the aesthetic appeal of a building? Do they pay more attention to aesthetically pleasing features? Do they look longer at aesthetically pleasing buildings?

1.7. Outline of this thesis

The primary aims of the experiments reported in Chapters 2 to 6 are outlined as follows.

1.7.1 Changeable facial features and facial attractiveness

Chapter 2 documents three experiments in which the effects of dynamic gaze and facial expression on perceived attractiveness were investigated by varying the direction and temporal dynamics of the gaze shift of faces during a series of attractiveness rating tasks. Pictures of expressive faces with different gaze directions were presented in pairs in quick succession to simulate gaze shift and participants were to rate these faces on their attractiveness. In the three experiments reported in Chapter 3, the role of face view in its static and dynamic forms on facial attractiveness was examined using similar experimental paradigm to that in Chapter 2.

1.7.2 Perception categorisation, serial dependence, and aesthetic evaluation

It is well documented that our percept at any given moment is influenced not only by the physical stimulus at present, but also by recent perceptual history. As such, some features, including attractiveness, of the current percept are biased towards those of previous ones. This is referred to as serial dependence. Chapter 4 documents three experiments conducted on the effects of perceptual categorisation on the magnitude of serial dependence during attractive judgements of faces and scenes. In a series of attractiveness rating tasks, images of faces and scenes were presented and rated by the participants in

rapid succession and the extent to which attractiveness judgements depended on preceding stimuli was measured.

1.7.3 Factors affecting the aesthetic evaluation of built environment

Chapters 5 and 6 were dedicated to the investigation of architectural aesthetics using an empirical approach. Chapter 5 documents a large-scale study in which more than 2000 participants made beauty and intimacy judgements of building exteriors and indoor architectural spaces. Among these participants, some are self-identified professional architects, some are students in architecture, and most were non-experts. They were also asked to fill in a personality questionnaire that measured their personality traits in the Big-five (OCEAN) dimensions. The inter-relationship between beauty and intimacy judgements, personality traits and level of expertise was examined.

Chapter 6 reports an exploratory eye-tracking study in which the eye movements of participants during the viewing of building exteriors, for the purpose of aesthetic evaluation, were recorded and examined.

Chapter 2

The effects of eye gaze on the perceived attractiveness of expressive faces

2 The effects of eye gaze on the perceived attractiveness of expressive faces

2.1. Abstract

The aim of the experiments reported in this chapter was to investigate whether attractiveness ratings of expressive faces would be affected by gaze shifts towards or away from the observer. In all experiments, effects of facial expression were found, with higher attractiveness ratings to positive over negative expressions, irrespective of effects of gaze shifts. In the first experiment faces with gaze shifts away from the observer were preferred. However, when the dynamics of the gaze shift was disrupted, by adding an intermediate delay, the effect of direction of gaze shift disappeared. By manipulating the relative duration of each gaze direction during a gaze shift, it was found that higher attractiveness ratings were given to faces with a longer duration of direct gaze, particularly in the initial exposure to a face. These findings suggest that although the temporal dynamics of eye gaze and facial expressions influence the aesthetic evaluation of faces, these cues appear to act independently rather than in an integrated manner for social perception.

2.2. Background

Social interaction relies on the ability to rapidly determine the intention, the focus of attention and the emotional state of others, often in the absence of verbal communication. In particular, at any one moment, complex information perceived from a face, especially the eye region, is encoded and processed in a fluid and instantaneous manner. Dynamic, non-verbal social cues such as expression and eye gaze can be detected and discriminated within fractions of a second with impressively high accuracy and acuity (Gibson & Pick, 1963; Cline, 1967; Anstis, Mayhew, & Morley, 1969; Argyle & Cook, 1976; Grossmann, Johnson, Farroni, & Csibra, 2007; Hall, Andrzejewski, Murphy, Mast, & Feinstein, 2008). These non-verbal cues communicating social interest are each known to influence the formation of first impressions, social judgements and preferences for different faces (Lau, 1982; Mueser, Grau, Sussman, & Rosen, 1984; Kleinke, 1986; Reis, Wilson, Monestere, Bernstein, Clark, Seidl, Franco, Gioioso, Freeman, & Radoane, 1990; Ambady & Rosenthal, 1993; Mason, Tatkow, and Macrae, 2005; Ewing, Rhodes, & Pellicano, 2010). However, very little is known about the interaction between information from the eyes connoting social attention, such as gaze shifts and direction, and other social information determined from expressions on our preferences for faces. The aim of the current study was to investigate whether dynamic eye gaze information and facial expression directly influence each other or act as independent cues in modulating the attractiveness judgements of unfamiliar faces.

It is argued that the evaluation of facial attractiveness involves two criteria, namely aesthetic beauty and rewarding beauty, that are dissociated behaviourally and differentially represented in the brain (Aharon, Etcoff, Ariely, Chabris, O'Connor, & Breiter, 2001; Senior, 2003; O'Doherty, Winston, Critchley, Perrett, Burt, & Dolan, 2003). The former refers to the disinterested response associated with perceiving faces

that are of high aesthetic value but of little, or no, social relevance to the observer. On the other hand, beautiful faces can be rewarding in that they entail the adaptive value as potential targets of further social interaction (e.g. mates).

Given that expressive and attentional cues from faces can communicate social interest and engagement with the observer very effectively, it is possible that these cues might also enhance the perceived attractiveness of the target face. For example, studies on face perception suggest the early development of sensitivity to the eye region, in that infants show a preference for looking at faces with a direct gaze (Farroni, Csibra, Simion, & Johnson, 2002; 2007a). Moreover, other studies have implicated eye gaze as an important cue to the attentional state of another (as in joint attentional tasks, e.g. Frischen, Bayliss & Tipper, 2007). This preference for eye gaze direction may, in turn, extend to the evaluation of facial attractiveness. Indeed, gaze direction has been found to influence attractiveness judgements in adults. For example, Ewing et al., (2010) used a forced-choice paradigm and reported that static images of faces with eye gaze directed at the observer were preferred over faces with averted gaze (and all faces conveying a neutral expression). However, they also found that when participants rated individual images of faces, attractiveness ratings were higher for faces with direct gaze compared to those with gaze averted to the left but, interestingly, not the right. The authors attributed the asymmetric results to the greater difficulty of discriminating the direction of gaze when it is averted to the right (see Calder, Jenkins, Cassel, & Clifford, 2008). The findings suggest that faces with direct rather than averted gaze, are perceived to be more attractive but only when the gaze direction can be detected unambiguously. Moreover, Ewing et al., (2010) ruled out a role for symmetry as the effect of gaze direction on both face preference and perceived attractiveness of faces was not found when the images of the faces were inverted.

A preference for faces with eye gaze directed at the observer was also reported using dynamic stimuli. For example, Mason et al. (2005) used highly stylised images of female faces, all presented with neutral expressions and either displaying gaze shifts away or towards the observer. They reported higher likeability ratings to faces when the direction of gaze shifted towards, rather than away from the observer. However, the effect of gaze shift towards the observer on the perceived attractiveness of the face was found only among male participants. The shift of gaze direction towards the observer acts as a salient cue for social engagement and is perceived as positive in general, as reflected in the higher likeability ratings in Mason's et al. (2005) first experiment. Mason et al. argued, however, that the effect of gaze shift on perceived attractiveness is dissociable from likeability, possibly reflecting the different factors underpinning aesthetic and rewarding beauty, since a preference for gaze shift towards the observer affects attractiveness ratings only when the social engagement is relevant to the observer, in this case male observers rating female faces.

There are a number of possible explanations as to why a face that directly gazes on an observer is perceived as more attractive than a face with an averted gaze. First, Reber, Schwarz, and Winkielman (2004) proposed the 'processing fluency' hypothesis of aesthetic experience, which predicts that the more fluently a stimulus is processed by the perceptual system, the more positively it is evaluated aesthetically. Extending this to the evaluation of facial attractiveness, some studies have reported evidence that direct gaze facilitates the perceptual processing of faces and this may, in turn, lead to a higher aesthetic evaluation of these faces. For example, in studies using a visual search task a target face is typically detected more rapidly if the eye gaze of the face is directed at the observer than if the gaze is averted, known as the 'stare-in-the-crowd' effect (von Grünau & Anston, 1995; Senju, Hasegawa, & Tojo, 2005). Indeed, Senju and Hasegawa (2005)

demonstrated that direct gaze in a face captures the allocation of spatial attention. They reported that the presence of a face in which the eyes are gazing directly at the observer hinders the detection of peripherally placed targets compared to a face with an averted gaze. Conversely, averted gaze is thought to induce a reflexive shift of attention away from the target face and initiate joint attention towards a third location of interest (Schuller & Rossion, 2001). Other evidence also supports the 'processing fluency' effect of direct eye gaze. For example, face images with direct than averted gaze are associated with better person memory encoding (Mason, Hood, & Macrae, 2004; Smith, Hood, & Hector, 2006) and better discrimination of the invariant properties of the face such as its biological sex and identity (Macrae, Hood, Milne, Roour, & Mason, 2002). Relatedly, neuroimaging studies have found that viewing static images of faces shown with direct rather than averted gaze is associated with greater BOLD activation in the fusiform gyrus (George, Driver, and Dolan, 2001), a region known to be associated with face perception, and that faces with a gaze shift towards, rather than away from the observer elicit both an increase in activation in the right posterior superior temporal sulcus (pSTS, an area known to be involved in processing eye gaze information) and in its functional connectivity with the right fusiform gyrus (Ethofer, Gschwind, & Vuilleumier, 2011).

However, evidence in support of the 'processing fluency' hypothesis has been inconsistent with regard to the role of eye gaze on facial attractiveness. First, the results of some studies suggest that direct gaze does not always enhance the perceptual processing of faces. For instance, Vuilleumier, George, Lister, Armony & Driver, (2005) reported that the ability to discriminate the sex of a face was better for faces with averted gaze. Moreover, Adams & Kleck, (2003) found faster response times in identifying certain emotional expressions of faces with averted, rather than direct gaze. In reference to the 'stare-in-the-crowd' effect (Senju et al., 2005), Cooper, Law, & Langton (2013)

argued that the faster detection of faces with direct gaze among distracters in visual search tasks could be due to the failure to control for the similarity among the distracter items, and that a target face with a direct gaze is more likely to pop-out among more homogenous distracters. Second, it is unclear how attention to face images with direct gaze is enhanced relative to averted gaze, given that participants are typically required to pay attention to each face image during attractiveness rating experiments, prior to making judgements (Mason et al., 2005; Ewing et al., 2010).

An alternative proposal to the 'fluency' hypothesis is that the effect of direct gaze on facial attractiveness lies in its social reward value to the observer. For example, when the eye gaze of another face is directed at oneself, it signals social interest and willingness to approach or engage in further interaction (Patterson, 1982; Kleinke, 1986). The findings of Kampe, Frith, Dolan, & Frith, (2001) provide supporting neuroimaging evidence, in that viewing attractive faces with a direct gaze activated brain regions associated with the reward processing system, particularly the ventral striatum. Additionally, other studies have reported that viewing faces with direct and averted gaze differentially activated the approach-avoidance motivational circuitry in the brain (Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008) even when the participant viewed a real person (Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). Moreover, Harmon-Jones et al. (2006) also reported larger skin conductance responses indicating physiological arousal during direct gaze. Arousal is associated with enhanced judgements of attractiveness regardless of arousal type (see review by Foster, Witcher, Campbell, & Green, 1998). Consequently, the arousal elicited by viewing faces with direct gaze might contribute to the higher perceived attractiveness of those faces.

Facial expression is an important social cue signalling the emotional state of another, and many studies have provided evidence supporting an association between positive

expressions, (e.g. smile) and facial attractiveness (Lau, 1982; Mueser et al., 1984; Reis et al., 1990; Otta, Lira, Delevati, Cesar, & Pires, 1994; Otta, Abrosio, & Hoshino, 1996; Mehu, Little, & Dunbar, 2008; Tracy, & Beall, 2011; Morrison, Morris, & Bard, 2013; Golle, Mast, & Lobmaier, 2014; Ueda, Kuraguchi, & Ashida, 2016). In particular, studies which compared the perceived attractiveness of smiling and neutral expressive faces found a preference for smiling faces, irrespective of whether the task involved ratings using a Likert scale or 2-alternative forced choice (Reis et al., 1990; Otta et al. 1994, 1996; Mehu et al., 2008; Golle et al., 2013). Moreover, O'Doherty et al. (2003) reported that viewing smiling faces was associated with greater activation in regions of the brain associated with reward-processing, particularly the orbitofrontal cortex (OFC). This finding suggests that, similar to the role of direct gaze, viewing faces with smiling expressions increases the reward value of faces thus enhancing their appeal. Furthermore, if a similar reward network in the brain is activated by both gaze direction and facial expression, this may mediate an interaction between these factors when evaluating faces. Although the effects of eye gaze and facial expression on perceived attractiveness have been examined separately in the laboratory, our every-day social interactions are more likely to be based on a combined percept. For example, during naturalistic social interactions, the combination of both cues may be required to effectively interpret the intentions and emotional states of another. Accordingly, Adams & Kleck (2003, 2005) proposed the 'shared signal' hypothesis which states that eye gaze and facial expression are processed in an integrated manner, particularly for the purpose of the target's approach-avoidance disposition. For example, both direct gaze and positive expressions (but also anger) are both associated with an individual's intention to approach the observer. Detection of both cues in this case is enhanced to allow the observer prepare an appropriate response. As such, the decoding efficiency of a particular combination of

gaze direction and expression would be expected to increase when the two cues are consistent in the approach-avoidance dimension compared to when they are not.

In support of their hypothesis, Adam & Kleck (2003) reported that happy and angry facial expressions were discriminated more accurately and rapidly when each was coupled with direct rather than averted gaze, whereas averted gaze facilitated the processing of fear and sad expressions. Both of these effects may be underpinned by an adaptive advantage to be alert to approach-avoidance related signals in order to efficiently respond. For instance, happy and angry expressions communicate an intention to positively engage or an imminent attack respectively, and evidence suggests that both of these expressions elicit an approach response (Carver & Harmon-Jones, 2009; Wilkowski & Meier, 2010). Such cues are, consequently, more relevant to the observer when coupled with direct eye gaze than when gaze is averted. Alternatively, fearful and sad expressions could signal a potential threat in the vicinity to be avoided, particularly when coupled with an averted gaze that suggests an attention shift for the observer towards an external location.

The judgement of facial attractiveness also seems to be modulated by similar approach-avoidance mechanisms that are determined by an interaction between gaze direction and facial expressions. For example, Jones, DeBruine, Little, Conway, & Feinberg (2006) found that images of faces with direct gaze were judged to be more attractive when smiling than when shown with a neutral expression whereas faces with a neutral expression were preferred over faces with a smile when gaze was averted. Jones et al., (2006) also reported that gaze direction affected the perceived attractiveness of smiling faces only, and did not have an effect on how attractive a face appeared when the expression was neutral. In a later study, Conway, Jones, DeBruine, & Little (2008) reported a similar interaction between gaze direction and expression on facial attractiveness when participants judged faces conveying happy or disgusted expressions,

especially for faces of the opposite sex. Taken together, the evidence suggests that facial attractiveness is modulated by facial cues such as eye gaze direction and emotional expressions that signal their social relevance to the observer (Mason et al., 2005; Jones et al., 2006; Conway et al., 2008).

Previous studies have mainly used static images of faces to investigate the effects of eye gaze and expression on perceived attractiveness. However, the nature of both eye gaze and expression information in a naturalistic setting is dynamic. In particular, a gaze shift can signal a change in attentional and intentional states, therefore conveying a more socially meaningful cue than a static gaze. It remains unclear, however, whether facial expressions can affect attractiveness judgements when the eye gaze shifts, or whether one source of social information dominates over the other. The following experiments were conducted to investigate the interactions between gaze shift and facial expression on the perceived attractiveness of unfamiliar faces. If gaze shift and expression act as integrated cues, faces with a gaze shift towards, rather than away from the observer would be rated as more attractive only when the face was shown with a smiling rather than neutral expression. Previous studies used a range of expressions, from neutral to smiling, on attractiveness judgements. In order to investigate the role of expression, the intensity of the facial expression was also manipulated to test its effect on facial attractiveness when coupled with shifts in eye gaze.

2.3. Experiment 1a

2.3.1 Introduction

The aim of the following experiment was to assess whether gaze shift and facial expression integrated to modulate attractiveness ratings or whether the two cues independently contributed to attractiveness. Based on Mason et al. (2005), the first

prediction was that faces in which the eye gaze shifted towards the observer would be rated as more attractive than gaze shifts away from the observer. Furthermore, if facial expression modulated perceived attractiveness, another prediction was that higher attractiveness ratings to faces with positive (smiling) expressions than those with neutral expressions and that an increase in the intensity of the expression (slight smile to full smile) would further enhance those ratings. On the other hand, if gaze shift and expression affected attractiveness ratings independently, then the effects on attractiveness would be dominated by one of these cues (e.g. higher attractiveness to smiling faces irrespective of the direction of a gaze shift). The intensity of facial expressions was manipulated by including neutral, slight smile and full smile (with a closed mouth). The 'slight smile' was created by morphing between the neutral and smiling expressions of each individual face.

2.3.2 Method

Participants

One hundred and eighty-four participants (75 females; mean age = 37.4 years, *SD* = 9.38) from the USA were recruited online through Amazon's Mechanical Turk (Woods, Velasco, Levitan, Wan, & Spence, 2015). All were naïve to the purpose of the study and were awarded approximately €1.00 for participating in the experiment. The study (and all subsequent experiments) was approved by the Research Ethics Committee in the School of Psychology, Trinity College Dublin, University of Dublin. Accordingly, all participants gave informed consent by proceeding with the experiment upon reading an introduction about the study.

Stimuli and apparatus

Face images of 34 faces were taken from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015) in order to create the stimulus set for this study. All images were of Caucasian, female faces, presented from a front facing viewpoint. None of the faces were famous and were therefore unfamiliar to the participants. For the purpose of this experiment, two different versions of each face identity from this original database were used: one showing a neutral and the other a happy expression. The happy expression consisted of a face with a full, close-mouthed smile (see Figure 1). To examine the effect of expression intensity on attractiveness ratings, an intermediary expression of a smile was also included. This expression was created for all face identities by morphing the neutral expression with the corresponding smiling expression for each facial identity to create a slight smile stimulus (see Figure 2.1). In total, three images of each of the 34 facial identities were obtained for the stimulus set; with each image conveying a neutral expression, a slight smile (averaged) or a closed-mouth smile.
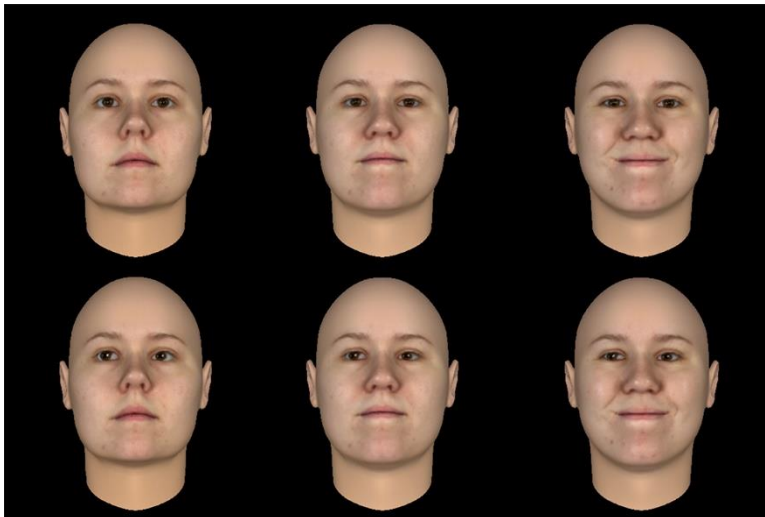
Figure 2.1 Example of the face stimuli used in Experiment 1a and 1b. The top row shows faces with direct eye gaze conveying (from left to right) an increase in expression intensity from a neutral expression, a slightly smiling expression (morphed between neutral and close-mouthed smile) to a full (close-mouthed) smiling expression. The bottom row shows the corresponding facial expressions with an averted eye gaze.

The original face images, and images of the morphed expression, were edited using FaceGen software. First the original face images were uploaded onto the 'FaceGen Modeller' and processed through its 'PhotoFit' function. All hair information was removed, and faces were presented from the neck up in each image. 'FaceGen' allowed images of the faces with different eye gaze directions (direct or averted left or right) to be created, for each of the three expressions of each face identity. The gaze direction for averted gaze was either to the left or right (randomly assigned to each face image and counterbalanced across all images) such that each face image was associated with one direction of an averted gaze.

Each image was positioned in the centre of a black background and all were matched for contrast and luminance. The sizes were adjusted such that each image was approximately 400 x 400 pixels in dimension.

An example of a trial sequence is illustrated in Figure 2.2. A shift in gaze in each face was simulated by adapting the paradigm previously described by Mason et al. (2005). Specifically, gaze shift of the eyes was achieved by presenting two face images in rapid succession to simulate apparent motion of the eyes. The first face stimulus (S1) differed from the second face stimulus (S2) in gaze direction only, whilst maintaining the same expression. This manipulation resulted in one of two possible gaze shift directions (towards or away from observer) for each of the three facial expressions.
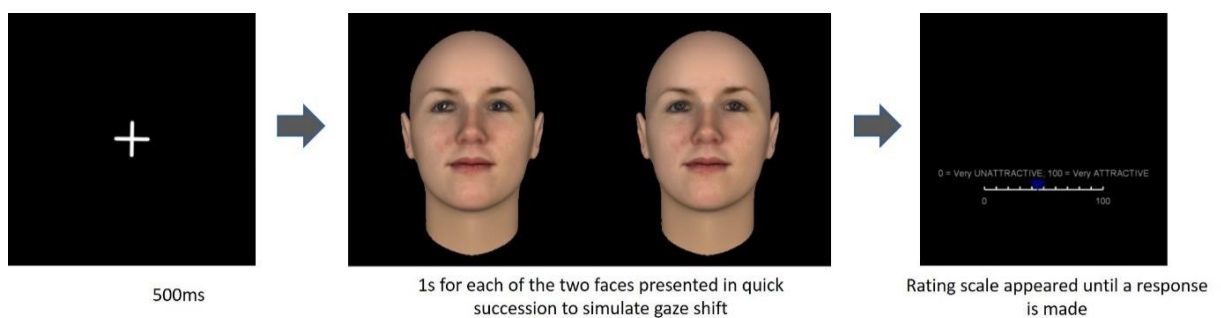
Figure 2.2 An illustration of the structure of a trial in Experiment 1a. Gaze shifts were simulated by presenting the face images in rapid succession. See text for more details.

Participants completed the experiment using their own desktop computers via the online research platform Xperiment (http://www.xperiment.mobi; Woods et al., 2015). The resolutions of the screens used were recorded and ranged between 800 x 600 and 2560 x 1440 pixels.

Design

A within-subject design with two independent variables was adopted, namely the direction of gaze shift (away or towards the observer) and facial expression (neutral, slight smile and full smile). The dependent variable was the perceived attractiveness ratings provided to each of the faces. Each participant was presented with a total of 68 trials, with each of the 34 face images shown twice, once with a gaze shift towards the observer and the other away from the observer. Although each participant saw all facial expressions, each of the 34 faces were depicted showing one of the 3 facial expressions only. Thus facial expression was counterbalanced across facial identity for all participants in the experiment. This design was adopted to ensure that each face image was presented to each participant a minimum number of times to avoid the 'mere exposure' effect (e.g. Peskin & Newell, 2004). All trials were presented in a random order across participants.

Procedure

Prior to the experiment, each participant completed a demographics questionnaire and was then provided with the instructions to the experiment. They were informed that images of female faces would be presented on the screen and their task was to rate the attractiveness of each face as soon as they were prompted.

A single practice trial was performed to allow the participants become familiar with the trial structure (as illustrated in Figure 2) and the nature of the response. The experiment

could not proceed unless the participant indicated they understood what they were expected to do during the experiment and completed this initial practice trial. A trial began with the presentation of a white fixation cross, centred on a black background, which remained on screen for 500 ms, followed by a 30-ms blank screen. Then, in the centre of the screen, two face stimuli appeared in rapid succession for 1000 milliseconds each (i.e. a total of 2000 milliseconds). The end of a trial was marked by a response cue which indicated to the participant to provide an attractiveness rating of the face they had just viewed. A sliding scale was used to provide this rating, which ranged from very unattractive (0) to very attractive (100). The participant was instructed to make a response as quickly as possible and to utilize the whole scale. Participants moved the indicator along the scale, using a mouse press, to indicate their preferred rating of the attractiveness of the face stimulus they had just seen. The entire experiment took approximately ten minutes for each participant to complete.

2.3.3 Results

Participants' mean attractiveness ratings to the faces for each of the gaze shifts and neutral, slight smile and full smile facial expressions were first calculated and are shown in Figure 2.3. Because of a concern that face images created using 'FaceGen' software may alter their characteristics relative to the original photo images of the faces, the attractiveness ratings obtained in the present experiment (averaged across both directions of gaze shift) were first compared with those obtained from the corresponding facial identities reported in the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015, N=34). A significant correlation (Pearson's $r = 0.863$, $p < 0.001$) between the attractiveness ratings indicated that the edits made to the face images (using FaceGen) did not differentially affect their relative attractiveness. However, the ratings obtained in

the current study ($M = 38.8$, $SD = 10.3$) were significantly lower than those normative ratings in the database ($M = 48.2$, $SD = 12.4$; mean difference = 9.33, $SD = 6.27$, t (33) = 8.67, p < 0.0001, Cohen's $d = 0.825$).
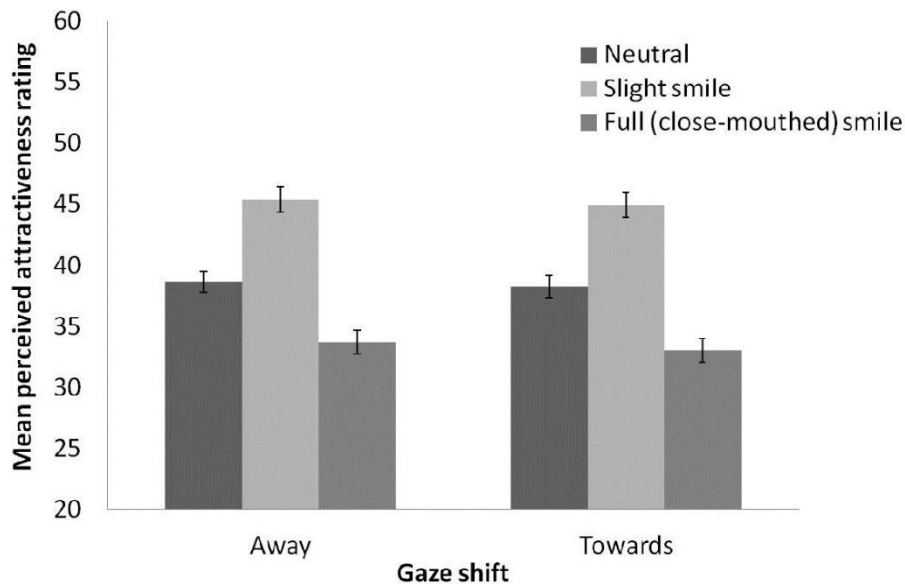
Figure 2.3 Plot showing the mean perceived attractiveness ratings to faces shown in Experiment 1a. For each facial expression, the mean attractiveness ratings for gaze shift towards or away from the observer are shown. Error bars represent ±1 standard error of the mean.

Although the current study did not set out to compare ratings between male and female participants, a preliminary data analysis was carried out on the basis of previous findings (Mason et al., 2005). This analysis failed to show evidence for an effect of the sex of the participant on ratings of attractiveness of the female face images [$F_{(1, 182)} = 2.32$; $p = 0.13$, $\eta_p^2 = 0.013$]. The ratings from male ($M = 37.9$, $SD = 11.9$) and female ($M = 40.6$, $SD = 11.9$) participants did not differ significantly and the sex of the participant was not taken into account in any of the subsequent analyses.

A 2x3 repeated-measures ANOVA was performed on the mean attractiveness ratings with direction of gaze shift (towards and away) and expression (neutral, slight smile, and full smile) as within-subject factors.

In this data analysis (and those of subsequent experiments), degrees of freedom were corrected using the Greenhouse-Geisser method whenever the assumption of sphericity was violated. Effect sizes were reported in terms of partial eta squared for the effects of each independent variable and their interaction(s); and Cohen's *d* for mean differences respectively.

The results revealed a main effect of gaze shift [$F_{(1, 183)}$ = 5.30, *p* =0.023, η_p^2 = 0.028] with higher attractiveness ratings to faces to a gaze shift away from (*M* = 39.3, *SD* = 11.9), rather than towards (*M* = 38.7, *SD* = 12.2) the observer. A main effect of expression [$F_{(1.779, 325.6)}$ = 168, *p* <0.0001, η_p^2 = 0.478] was also found. There was no significant interaction between the direction of gaze shift and expression [$F_{(1.895, 346.8)}$ = 0.21, *p* = 0.799, η_p^2 =0.001].

Post hoc pairwise comparisons (with Bonferroni correction) on the effect of expression indicated that faces with a slight smile (morphed) (*M* = 45.2, *SD* = 13.8) were rated as significantly more attractive than those conveying either a neutral expression (*M* = 38.4, *SD* = 12.1; mean difference = 6.72, *SD* = 1.35, *p* < 0.0001, Cohen's *d* = 0.706) or a full (close-mouthed) smile (*M* = 33.4, *SD* = 13.01; mean difference = 11.8, *SD* = 1.4, *p* < 0.0001, Cohen's *d* = 1.17). Unexpectedly, attractiveness ratings were higher for faces conveying a neutral expression than those with a full smile (mean difference = 5.07, *SD* = 1.33, p < 0.0001, Cohen's *d* = 0.739).

2.3.4 Discussion

In contrast to the findings reported by Mason et al. (2005), the results of the current study showed that when the eye gaze shifted away from the observer this was associated with higher attractiveness ratings for faces than when the gaze shifted towards the observer. While social attention, indicated by a gaze shift towards the observer, has been shown to

enhance preferences for faces, the results here suggest that this effect may be context-specific. For instance, in Mason et al.'s (2005) study, a gaze shift towards the observer rendered the female faces more attractive to the male participants only, with no effect on the ratings provided by the female participants (Mason et al., Experiment 2). Thus, as Mason et al. (2005) argued, eye gaze shifts may be highly dependent on the specific social relevance of the face to the observer. In the current study, the sex of the faces presented might not have been apparent due to the lack of hair even though the participants were briefed before the experiment that the faces they were going to view were female faces. No difference was found between the ratings provided by the male and female participants; therefore, there was no evidence to suggest that the faces varied in their social relevance across these groups. Nevertheless, the ratings provided by the participants were generally low (less than 50%), suggesting that the effects of eye gaze found here may be specific to faces that are generally perceived as low in attractiveness. An alternative possibility is that the results were based on the initial exposure of the face stimuli and the direction of the gaze first encountered, and not on any shift in gaze direction. For example, Willis & Todorov (2006) reported evidence suggesting that an initial exposure of 100 ms was sufficient for a specific trait inference (including attractiveness) to be judged from an unfamiliar face, and that increasing the duration of the exposure to a face, from 500 to 1000ms, did not further affect attractiveness judgements. It is plausible, therefore, that the results from the current experiment reflected an impression formed upon initial exposure to the face in the first image, which was present for 1000 ms in each trial, rather than a preference for a gaze shift away from the observer. This idea was tested further in Experiment 1b.

Although a significant effect of facial expression on perceived attractiveness was found, with a preference for positive expression over neutral as previously reported (Mueser et

al., 1984; Reis et al., 1990; Otta, 1994, 1996; O'Doherty et al., 2003; Golle et al., 2014; Ueda et al., 2016), the results of the current experiment were somewhat unexpected. Specifically, previous findings in which facial attractiveness ratings increased with the intensity of a smiling expression were not replicated (Golle et al., 2014; Ueda et al., 2016). Rather the data here suggested that participants found the average or morphed facial expression to be more attractive than either the original neutral or full smiling expression. There are a number of possible reasons for this result. First, a full but close-mouthed smile may not sufficiently convey a happy expression, and in fact, some participants reported that it appeared 'unnatural'. Indeed, in a follow-up study in which 20 naïve participants were asked to identify the facial expression in single images of the faces used in this experiment, only 35% of the faces with closed smile were associated with a "happy" (or "content") expression. Second, without a direct comparison between different expressions conveyed by the same faces (e.g. by adopting a 2-AFC design as in Golle et al. 2014), the expression of some faces may have been relatively difficult to perceive from an isolated image. To mitigate against these possibilities, the effect of facial expression on perceived attractiveness was tested further in Experiment 2.

2.4. Experiment 1b

2.4.1 Introduction

In Experiment 1a, it was unclear whether the benefit of a gaze shift away from, rather than towards, the observer on attractiveness judgements was due to the initial exposure to the face image or to the dynamic direction of the gaze. The aim of this experiment was, therefore, to disambiguate the effect of the order of the gaze direction (i.e. the direction of the initial gaze viewed) from the direction of the gaze shift itself (i.e. towards or away) relative to the observer. To that end, a 500-ms delay was introduced between the

presentation of the first and second face images within each trial (i.e. S1 and S2) in order to disrupt the perception of a shift in gaze. Removing the shift in gaze should not change the results found in Experiment 1a (i.e. a preference for the 'away' gaze shift) if those ratings were based on first impressions only. However, if the gaze shift itself was the basis of the findings, then a disruption to the shift would likely change the results.

2.4.2 Method

Participants

Ninety-eight participants (59 females; mean age = 39.1 years, SD = 9.54) from the USA were recruited online through Amazon's Mechanical Turk. All were naïve to the purpose of the study and were awarded approximately €1.00 for participating in the experiment. All gave informed consent by proceeding with the experiment as described in Experiment 1a.

Stimuli and apparatus

The face stimuli were the same as those used in Experiment 1a. Participants used their own desktop computers and screens to complete the experiment via Xperiment, as in Experiment 1a. The resolutions of the screens used were recorded and ranged between 800 x 600 and 2560 x 1440 pixels.

Design and procedure

The experimental design was mainly the same as that of Experiment 1a with the only exception that the factor of shift in gaze direction was described as the initial gaze

direction viewed in the sequence of two images (i.e. direct gaze first vs. averted gaze first[1]). The task for the participant was as described in Experiment 1a.

2.4.3 Results

As in Experiment 1a, the mean ratings made by female ($M =40.5$, $SD = 11.8$) and male ($M =36.4$, $SD = 11.8$) participants did not differ significantly [$F_{(1, 96)} = 2.82$, $p = 0.096$, $\eta_p^2 = 0.029$] therefore the sex of the participant was not included in any subsequent analyses. The mean attractiveness ratings to each of the gaze direction and expressions are shown in Figure 2.4.
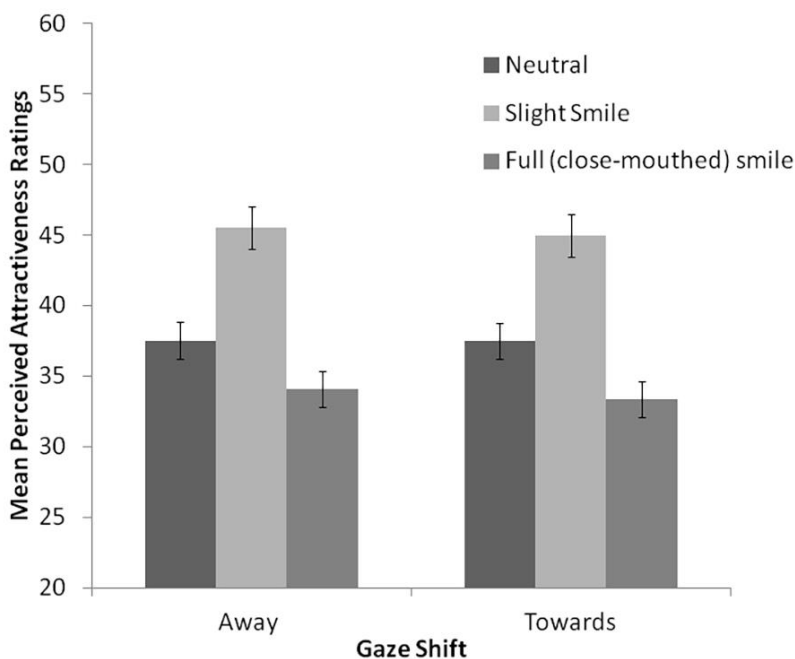
Figure 2.4 Plot showing the mean perceived attractiveness ratings to faces shown in Experiment 1b. The results are shown for each facial expression with either direct gaze or averted gaze first. Error bars represent ±1 standard error of the mean.

A 2 x 3 repeated-measures ANOVA was performed on participants' average ratings with initial gaze (direct or averted gaze first) and facial expression (neutral, slight smile, and

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[1] Note that here the 'direct gaze first' and 'averted gaze first' conditions were equivalent to the 'gaze shift away' and 'gaze shift towards' conditions respectively in Experiment 1a.

full smile) as within-subject factors. The order of presentation of the two gaze directions (i.e. mean ratings to direct gaze first = 39.03, SD = 12.1; averted gaze first = 38.6, SD = 11.9) did not have a significant effect on perceived attractiveness [$F_{(1, 97)}$ = 2.03, p = 0.158, η_p^2 = 0.02]. A significant main effect of expression [$F_{(1.74, 168.48)}$ = 72.3, p <0.0001, η_p^2 = 0.427] was found. The interaction between expression and order of presentation failed to reach significance [$F_{(2, 194)}$ = 0.515, p = 0.598, η_p^2 = 0.005].

Post-hoc pairwise comparisons (with Bonferroni correction) replicated the findings from Experiment 1a, with higher attractiveness ratings associated with the slight smile expression (M = 45.2, SD = 14.4) compared to either the neutral (M = 37.5, SD = 12.6; mean difference = 7.71, SD = 1.93, p < 0.0001, Cohen's d = 0.721) or full smile (M = 33.7, SD = 12.4; mean difference = 11.5, SD = 1.92, p < 0.0001, Cohen's d = 0.999) expressions. Attractiveness ratings were lower for faces with a full smile than those with a neutral expression (mean difference = 3.81, SD = 1.79, p < 0.0001, Cohen's d = 0.235).

2.4.4 Discussion

The results of this follow-up experiment suggest that the presentation order of two static images of the same face, in which either a direct or averted gaze was initially shown in the sequence of two images, did not affect the perceived attractiveness of the face. Therefore, the effect found in Experiment 1a for higher ratings to faces with an averted gaze shift was unlikely due to a preference for direct gaze during the initial exposure to the face stimulus (i.e. the initial face image in this gaze-shift condition was a direct gaze). It is unclear why a preference was found for an averted gaze in Experiment 1a, although it may still be possible that the initial exposure had an effect, if the gaze shift was not attended to under the particular timing conditions of the stimuli (i.e. in both experiments, each of the two face images within a trial was shown for the same amount of time).

Experiment 3 was designed to address this possibility by changing the relative timings of the exposure of each individual face image in the sequence.

The effect of facial expressions was consistent with that in Experiment 1a, with a preference for a slight smile (the morphed expression) over neutral or full smile expressions. Because of a concern that the closed smile was less discriminable as a positive expression than the morphed smile, the following experiment was designed to further investigate the role of facial expressions on the attractiveness judgements of faces.

2.5. Experiment 2

2.5.1 Introduction

The finding from Experiment 1, that the effects of gaze shift and facial expression do not interact, suggests that these are possibly independent cues that act separately to modulate the perceived attractiveness of unfamiliar faces. In particular, the results of Experiment 1a suggest that the effect of gaze shift was consistent for all facial expressions and did not seem to vary with an increase in the perceived intensity of the facial expression. This is in contrast to findings from previous studies reporting interactions between expression and eye-gaze direction (e.g. Jones, et al., 2006; Conway, et al., 2008), although some included negative facial expressions.

While attractiveness judgements have been found to be enhanced by expressions of happiness, including different forms of smiles (Lau, 1982; Mueser et al., 1984; Reis et al., 1990; Otta, Lira, Delevati, Cesar, & Pires, 1994; Otta, Abrosio, & Hoshino, 1996; Mehu, Little, & Dunbar, 2008, Golle et al., 2014), fewer studies have examined the effect of negative facial expressions on perceived attractiveness. When negative expressions are included, these studies typically reported lower attractiveness ratings (Tracy, & Beall, 2011; Morrison et al., 2013; Ueda et al., 2016). For example, Morrison et al. (2013)

reported that attractiveness ratings to faces with an angry expression were lower than those with a neutral or happy expression. It was therefore expected that an angry expression would negatively affect attractiveness ratings relative to a happy expression. Moreover, if expression and gaze-shift interact as cues for attractiveness, it was expected that the relative benefit of a happy expression on ratings may be further enhanced by a gaze shift towards the observer.

Because of a concern that the positive expressions used in the previous studies may have been ambiguous, the closed-smile expression was replaced with a happy facial expression that depicted an open-mouth smile. An open-mouth smile is also more consistent with previous studies on perceived emotion in faces (e.g. Ekman et al. 1987; Young et al. 1997).

2.5.2 Method

Participants

Ninety-nine participants (60 females; mean age = 28.7 years, SD = 7.22) were recruited online through the web-based participant recruitment platform 'Prolific.ac'. Participants were all native English speakers and were recruited from the U.S. (n = 14), U.K. (n = 82) and Ireland (n = 3). All were naïve to the purpose of the study and were awarded approximately €1.10 for participating in the experiment. All gave informed consent as described in Experiment 1a.

Stimuli and apparatus

The face stimuli were mainly based on the same identities as those used in Experiment 1a, except the face images now conveyed either a neutral, happy (open-mouthed smile) or angry expression (see Figure 2.5). An open-mouthed-smile version of two face

identities from the Chicago Face Database did not exist; therefore, images of two other face identities replaced those from the original set (taken from the same database). The new images underwent the same editing processes as all other stimuli using FaceGen. 75 % of these images were identified as a happy or elated expression in the same follow-up study mentioned in experiment 1a.
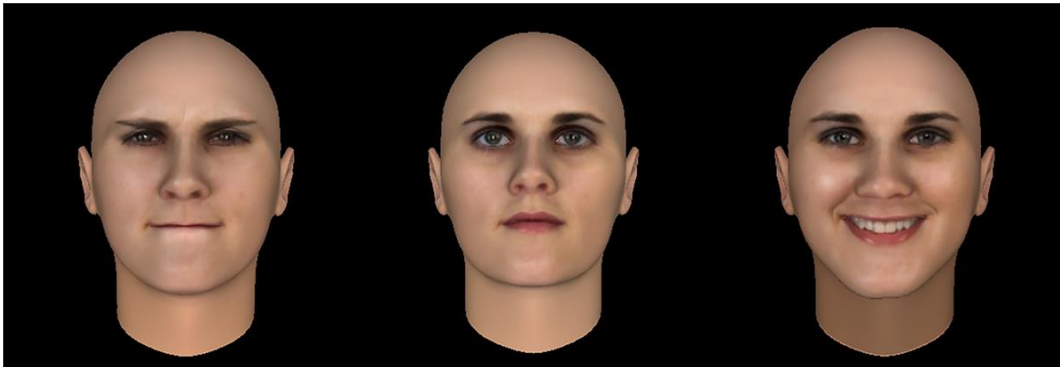
Figure 2.5 An example of face images representing the facial expressions used as stimuli in Experiment 2 with (left-to-right) angry, neutral and happy (i.e. open-mouthed smile) expressions.

Participants completed the experiment using their own desktop via Prolific.ac and the online experiment platform Gorilla (www.gorilla.sc). The resolutions of the monitors used by the participants were recorded and ranged between 1280 x 1024 and 2548 x 1282 pixels.

Design and procedure

The experimental design and procedure were identical to those described in Experiment 1a and b.

2.5.3 Results

As in the previous experiments, the mean ratings provided by female (M =35.6, SD = 12.4) and male (M =36.4, SD = 12.4) participants failed to reach statistical significance

$[F_{(1, 97)} = 0.085, p = 0.771, \eta_p^2 = 0.001]$ and the sex of the participant was not included in any further analyses. Figure 2.6 shows the mean attractiveness ratings for each facial expression and gaze shift directions.
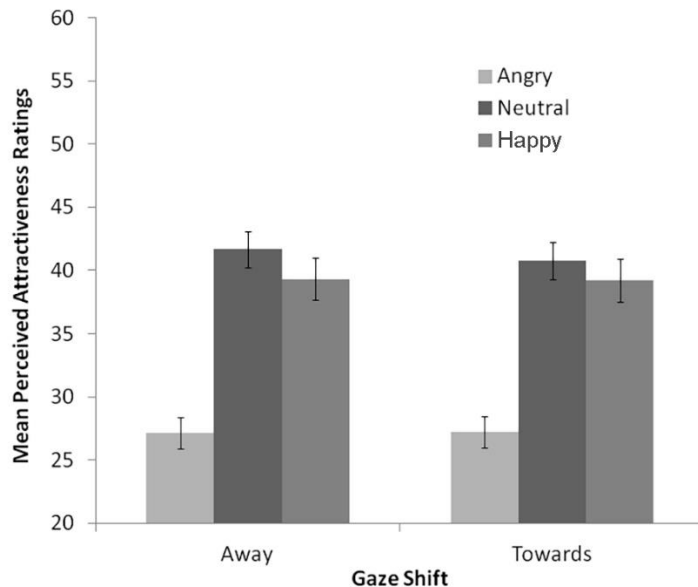
Figure 2.6 Plot showing the mean perceived attractiveness ratings to face images shown in Experiment 2 as a function of their facial expression (happy, neutral and angry) and gaze shift towards or away from the observer. Error bars represent ±1 standard error of the mean.

A 2 x 3 repeated-measures ANOVA was performed on participants' attractiveness ratings with direction of gaze shift (towards or away) and facial expression (angry, neutral, or happy) as within-subject factors. A main effect of facial expression was found $[F_{(1.671, 163.767)} = 65.5, p < 0.001, \eta_p^2 = 0.40]$. The mean rating for faces with gaze shift away from the observer ($M = 36.1, SD = 12.9$) or towards the observer ($M = 35.8, SD = 12.6$) were similar and the main effect of gaze shift failed to reach significance $[F_{(1, 98)} = 1.25, p = 0.267, \eta_p^2 = 0.013]$. There was no evidence for an interaction between gaze shift and expression $[F_{(2, 196)} = 1.28, p = 0.281, \eta_p^2 = 0.013]$.

Post hoc pairwise comparisons (with Bonferroni correction) on the main effect of expression indicated that faces with an angry expression ($M = 27.2, SD = 12$) were rated as significantly less attractive than faces with a neutral ($M = 39.3, SD = 16.8$; mean

difference = 12.1, SD = 1.93, p < 0.0001, Cohen's d = 0.958) or happy (i.e. open-mouthed smile; M = 41.2, SD = 14.3; mean difference = 14, SD = 2.13, p < 0.0001, Cohen's d = 1.5) expression. Although the neutral expression was rated as slightly more attractive than the happy expression, the difference in ratings failed to reach statistical significance (mean difference = 1.94, SD = 2.28, p = 0.417, Cohen's d = 0.141).

2.5.4 Discussion

The results of the current experiment further confirmed the effect of facial expression on perceived attractiveness. While an angry facial expression had a negative effect on attractiveness ratings compared to the neutral and happy expressions, the ratings for faces with neutral and happy expressions did not differ significantly. The failure to find a specific benefit from happy expressions on attractiveness ratings contradicts some previous reports that positive emotions enhance perceived attractiveness of faces (e.g. Lau, 1982; Mueser et al., 1984; Reis et al., 1990; Otta, Lira, Delevati, Cesar, & Pires, 1994; Otta, Abrosio, & Hoshino, 1996; Mehu, Little, & Dunbar, 2008, Golle et al., 2014). However, the current study differed from these studies with the inclusion of a negative facial expression. When negative expressions are considered, the results are consistent with those reported by Morrison et al. (2013) that angry facial expressions are rated as less attractive compared to those with happy or neutral expressions and, moreover, that neutral and happy expressions had a similar effect on perceived attractiveness.

With regard to gaze-shift, there was no evidence that it affected perceived facial attractiveness, which is in contrast to the findings of Experiment 1a in which a main effect of gaze shift was reported by consistent with Experiment 1b in which no effect was found. Given that the interaction between gaze shift and expression did not reach statistical significance, it is unlikely that the inclusion of the angry expression influenced the effect

of gaze shift on attractiveness ratings in the present experiment. However, due to the inconsistent findings between Experiment 1a, 1b and the current experiment, the role of the temporal aspects of the gaze shift in the formation of attractiveness judgements were further examined in the following experiment.

2.6. Experiment 3

2.6.1 Introduction

In Experiment 1a, a preference for an averted gaze shift which contradicted the prediction based on findings by Mason et al. (2005) was found. It is, however, known that the temporal dynamics of gaze also provides crucial information regarding its social meaning. In everyday situations, the eyes are in constant motion and individuals vary their gaze when interacting with others to signal intent: a quick glance at an individual could represent an acknowledgment of his/her presence, whilst prolonged eye gaze or frequent gaze shifts towards the observer could signify an exclusive allocation of attention to another, which could be perceived as social interest or intimacy. Indeed, sensitivity to the temporal parameters of eye gaze seems to arise early in development, indicating their importance for social development. For example, Einav & Hood, (2006) found that children as young as four years old could accurately and competently use both the gaze frequency (number of fixations on an image of an object) and duration (relative time spent fixating on one object image over another) to infer an actor's preference for one of three images of objects. Moreover, the children were able to justify their answers by stating that the preferred picture was either gazed at for longer, or more often than the other images.

Although it remains unclear if temporal differences during gaze shifts have an impact on other social judgements, such as attractiveness, some studies have found evidence in

support of an effect of gaze duration on likeability judgements (Kuzmanovic et al., 2009; Georgescu, Kuzmanovic, Schilbach, Tepest, Kulbida, Bente, & Vogeley, 2013). For example, Kuzmanovic et al. (2009) reported that likeability ratings of faces of virtual characters increased as a function of the duration of their direct gaze (1s, 2.5 s, or 4 s). Apart from the effect of direct gaze on attractiveness judgements (Jones et al., 2006; Conway et al., 2008; Ewing et al., 2010; Lawson, 2015), the duration of direct gaze is also likely to modulate these ratings. However, to the best of the author's knowledge, no studies have looked at the relationship between the temporal dynamics of perceived gaze and perceived attractiveness. As such, the following experiment was designed to test this relationship by manipulating the relative duration of each gaze direction during a gaze shift (i.e. the exposure ratio of direct to averted gaze). By doing so, this experiment aimed to disambiguate the effects of the order of the gaze direction during gaze shift from the shift itself on the results found in Experiment 1a. Hence, the hypothesis was that perceived attractiveness of a target should increase with the relative duration of direct gaze during a gaze shift.

Similar to Experiments 1a and b, this experiment tested whether the intensity of positive facial expression increased with perceived attractiveness by including the 'morphed' or slight smile expression as an inter-mediatory expression, as described in Experiment 1a, and the happy (open-mouthed smiling) expression used in Experiment 2.

2.6.2 Method

Participants

Ninety-three participants (53 female; mean age = 24.29 years, SD = 6) were recruited from the student population within Trinity College Dublin. They either received research credits or were paid €5.00 for their participation in the experiment. All were naïve to the

purpose of the experiment. All participants provided informed, written consent in accordance with ethical approval.

Stimuli and apparatus

The happy facial expression stimuli were the same as those used in Experiment 2 whereas the neutral and slight smile expressions of the same individuals were as described in Experiment 1a and b. Pairs of face images were presented in succession to simulate movement of eye gaze, as described in Experiment 1a (see also Mason et al. 2005). The total duration of exposure to an individual face within each trial was 2 seconds, similar to Experiments 1a and 2.

The experiment was programmed using PsychoPy (Peirce, 2007) and run on an Alienware AURORA R4 desktop computer. The stimuli were presented on a 34cm x 27.5cm HP monitor with a resolution of 1280 x 800 pixels at 60 Hz. Each face image subtended a visual angle of approximately 10° x 10° from a viewing distance of 60cm.

Design and Procedure

A 3-way mixed design was adopted in which the relative duration of exposure of each face image in a sequence was a between-subject variable, whereas both the direction of the gaze shift (towards or averted) and the facial expression (neutral, slight or open smile) were within-subject variables. The relative duration condition was created by varying the duration of the first face stimulus (S1) relative to the second face stimulus (S2) in each gaze shift sequence as follows 300ms:1700ms, and 1700ms:300ms to a total (S1+S2) exposure duration of 2000ms. a condition in which the timings were similar for both stimuli (i.e. 1000ms:1000ms) was also included in order to ensure that any differences in the particular protocols across experiments were controlled (i.e. testing on-line versus in a laboratory) and to allow for the results to be compared directly with those found in

Experiment 1a. Participants were randomly assigned to one of these three duration conditions.

The experiment took place in a darkened testing room within the Institute of Neuroscience, Trinity College Dublin. The experimental procedure and task was the same as described in Experiment 1a.

2.6.3 Results

Consistent with the previous experiments, initial comparisons of the ratings across male (M =37, SD = 12.3) and female (M =39.3, SD = 12.5) participants revealed no difference [$F_{(1, 87)}$ = 0.774, p = 0.381, ηp^2 = 0.009] and this factor was not included in further analyses.

The mean ratings to faces across all conditions are shown in Figure 2.7. A 3-way mixed-model ANOVA was performed on participants' attractiveness ratings with the direction of gaze shift (towards and away) and expression (neutral, slight smile and open-mouthed smile) as within-subject factors and S1:S2 gaze duration ratio (300:1700, 1000:1000 and 1700:300) as a between-subject factor. The mean attractiveness ratings for faces with gaze shift away from the observer (M =38.5, SD = 11.7) were similar to those for faces with gaze shift towards the observer (M =38.2, SD = 12.7) and no main effect of the direction of gaze shift [$F_{(2, 90)}$ = 0.909, p = 0.343, η_p^2 = 0.001] was found. There was also no evidence for a main effect of gaze duration ratio[2] [$F_{(2, 90)}$ = 2.92, p = 0.059, η_p^2 = 0.061]. A main effect of expression [$F_{(1.28, 115.60)}$ = 5.93, p = 0.01, η_p^2 = 0.062] was revealed.

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[2] Mean attractiveness ratings to the 300:1700 condition = 39.1, SD = 12.5; the 1000:1000 condition = 34, SD = 12.4; and the 1700:300 condition = 41.2, SD = 12.1.
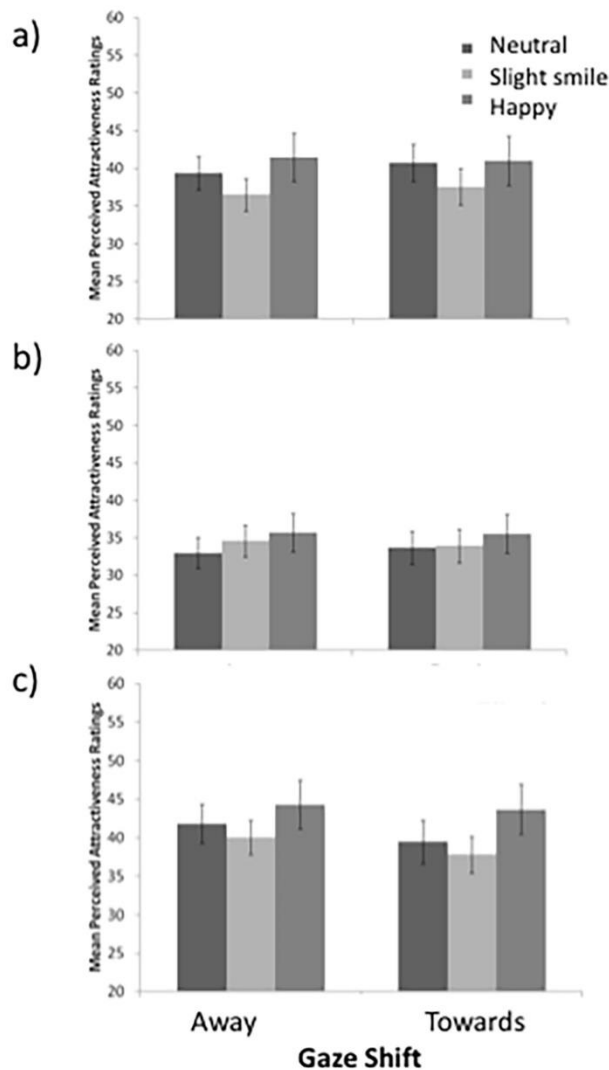
Figure 2.7 Plot showing the mean perceived attractiveness ratings to faces shown in Experiment 3 for each of the gaze duration ratio conditions: a) 300:1700; b) 1000:1000; & c) 1700:300), facial expression, and gaze shift conditions. Error bars represent ±1 standard error of the mean.

Post-hoc, pairwise comparisons (with Bonferroni correction) on the main effect of expression indicated that faces with an open smile (M = 40.3, SD = 15.1) were rated as significantly more attractive than those with a slight smile (M = 36.4, SD = 12.4, mean difference = 3.86, SD = 2.03, p = 0.001, Cohen's d = 0.367). Although attractiveness ratings were higher for the happy (open smile) than neutral expression (M = 38.3, SD = 13.1) this difference failed to reach significance (mean difference = 1.97, SD = 2.07, p = 0.541, Cohen's d = 0.135). Attractiveness ratings for faces with the slight smile

expression were significantly lower than those with a neutral expression (mean difference = 1.89, SD = 1.87, p = 0.034, Cohen's d = 0.281). The effect of facial expression did not interact with the direction of gaze shift [$F_{(2, 180)}$ = 0.179, p = 0.836, η_p^2 =0.002] nor the S1:S2 exposure ratio [$F_{(4, 180)}$ = 0.43, p = 0.787, η_p^2 = 0.009].

A significant interaction between the direction of the gaze shift and S1:S2 exposure ratio was found [$F_{(2, 90)}$ = 3.13; p =0.048, η_p^2 = 0.065] as shown in Figure 2.8. Post hoc, pairwise comparisons with Bonferroni correction were conducted on the direction of gaze shift for each of the three S1:S2 exposure ratio conditions. The results showed that for the 1700:300 condition, faces were rated as more attractive with a gaze shift away from the observer (M = 42, SD = 11.5) rather than towards the observer (M = 40.3, SD = 12.5, mean difference = 1.7, SD = 3.27, p = 0.016, Cohen's d = 0.141). However, there were no differences in attractiveness ratings between the two gaze shift directions for either the 300:1700[3] or 1000:1000 conditions.[4] The interaction between expression, direction of gaze shift and S1:S2 exposure ratio did not reach statistical significance [$F_{(4, 180)}$ = 1.26; p =0.288, η_p^2 = 0.027]

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[3] 300:1700 condition: mean rating for gaze shift away from observer = 39.1, SD = 21.4; mean rating for gaze towards the observer = 39.8, SD = 23.2; mean difference = 0.66, SD = 3.27, p = 0.341, Cohen's d = 0.03.
[4] 1000:1000 condition: mean rating for gaze shift away from observer = 34.44, SD = 17.78; mean rating for gaze towards the observer = 34.4, SD = 19.3; mean difference = 0.038, SD = 2.72, p = 0.947, Cohen's d = 0.0022.
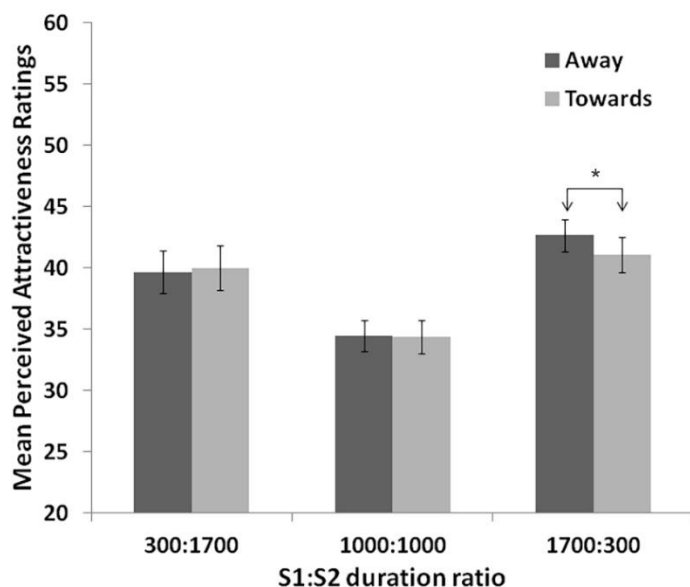
Figure 2.8 Plot showing the mean perceived attractiveness ratings for gaze shifts towards or away from the observer, across the gaze duration conditions in Experiment 3. Error bars represent ±1 standard error of the mean. [*p <0.05].

2.6.4 Discussion

Results from the current experiment suggested that neither the direction of gaze shift alone nor the S1:S2 exposure ratio (i.e. the timing of gaze shift) alone had an effect on judgements of attractiveness. Instead, the results revealed an interaction between these two factors. As suggested by the data plotted in Figure 2.8, no effect of eye gaze shift was found when each gaze direction was presented for the same duration of time (i.e. under the 1000:1000 condition). In contrast, a longer duration of a direct gaze seemed to be associated with an increase in attractiveness ratings. For example, the ratings in the 1700:300 'away gaze shift' were slightly higher than those to the 'towards gaze shift'. However, only the pairwise comparison in the 1700:300 condition reached statistical significance. The significant interaction between the gaze duration and gaze shift, and the significantly higher ratings to faces shown in the 'away gaze' condition when the initial gaze was a prolonged direct gaze, suggests that attractiveness ratings were affected by an initial exposure to a face, with higher ratings to faces with direct than averted gaze in this

initial exposure. These results are consistent with findings from previous evidence suggesting a role for the initial exposure to faces (Willis & Todorov, 2006) as well and other studies in which positive ratings were increased when the duration of exposure to direct gaze increased (Kuzmanovic et al., 2009; Georgic et al., 2013). The results therefore suggested that the temporal dynamics of eye gaze, including gaze duration and the initial direction of the shift itself, affect attractiveness ratings in a combined manner. On the other hand, the current findings also suggested that eye gaze and other social cues do not integrate to influence facial attractiveness. This finding is contrary to what Jones et al. (2006) found, but consistent with the results of Experiments 1 (a & b) and 2 in which facial expression affected perceived attractiveness of unfamiliar faces, regardless of the direction of gaze shift. Moreover, the results of the present study did not provide evidence to suggest that an increase in the intensity of the smile leads to higher attractiveness ratings for unfamiliar faces: although attractiveness ratings for faces with the open-mouthed smile were higher than those with a slight smile expression, these ratings were only marginally (but not significantly) higher than those conveying a neutral expression. Furthermore, faces with a neutral expression were rated as more attractive than those with the slight smile expression. In Experiment 1a and 2, in contrast, the images of slight smiles were associated with higher attractiveness ratings than the more intense (i.e. closed-mouth) smiles. This change in ratings to slight smiles across experiments suggests that the overall context of the face stimulus set may have had some effect on the ratings. Also, it is worth noting that although one of the duration conditions in the current experiment, that is the duration condition of 1000:1000ms, was similar to that tested in Experiment 1a, the finding in Experiment 1a of a preference for an averted gaze shift in Experiment 1a was not replicated. However, the preference for a gaze-shift away from the observer may have been influenced by the face expressions being

generally perceived as more negative than positive (i.e. the closed-mouth smile was not unambiguously perceived as 'happy'). The possible role of stimulus context is discussed in more detail in the following section. At the very least, the present findings suggest that the direction of gaze shift, or the duration alone has an effect on perceived attractiveness that was not influenced by the expression of the face.

2.7. General discussion

The aim of the experiments reported in this chapter was to investigate the role of socially-relevant cues, eye gaze and expression, on judgements of facial attractiveness and, in particular, whether such cues contribute in a combined or independent manner to the aesthetic evaluation of a face. The data do not support the shared-signal hypothesis of gaze and expression on attractiveness. Instead the results of the studies reported here suggest that gaze shifts and facial expression act as independent cues in influencing attractiveness judgements. In particular, across all experiments, the effect of gaze shift did not vary across facial expressions and the effect of expression was also independent of both the timing and the direction of the gaze shift.

This finding is seemingly in contrast to the findings of previous studies investigating the role of gaze direction on facial attractiveness. Specifically, Jones et al., (2006) found stronger preferences for attractiveness when faces were presented with direct gaze and a smile but not when they conveyed a neutral expression. In addition, they reported that attractiveness preferences were stronger when a neutral expression was coupled with an averted rather than a direct gaze. However, Ewing, Rhodes, & Pellicano, (2010) reported higher attractiveness ratings to a direct gaze over an averted face, even in faces with a neutral expression.

Although it is unclear why these studies report different effects of eye gaze direction on faces with a neutral expression, one possibility is that different experimental or stimulus contexts may play a role. In particular, the effect of facial expression on attractiveness appears to be sensitive to variations in the choice of stimulus materials and experimental procedures across studies, leading to inconsistent results across and even within studies. For instance, Mueser et al. (1984) found that using either a two-alternative-forced-choice (2AFC) task or a rating task based on individual face images using the Likert scale, yielded very different results although the same face images were used in both tasks. In the 2AFC task, faces with a sad expression were perceived as less attractive than faces with either a neutral or smiling expression, whilst no difference was found across expressions when ratings were provided to individual face images. Morrison et al. (2013) also reported no significant difference between neutral and happy expressions in attractiveness judgements, though both expressions were rated as more attractive than negative expressions such as sadness, fear, anger and disgust. The results of Experiment 2 reported here are consistent with Morrison et al.'s (2013) findings, in that the angry expression was rated as less attractive than both the smiling and neutral expressions, although attractiveness ratings did not differ between the latter two expressions.

Previous studies have provided evidence for a role of stimulus context on face perception. For example, the influence of other unrelated, interleaving emotional stimuli on the perception of facial expressions is nicely demonstrated in the Kuleshov effect (see e.g. Calbi, Heimann, Barratt, Siri, Umiltà, & Gallese, 2017). Recent findings on facial attractiveness also support a role for the context of the stimulus set. For example, there is evidence in support of the 'serial dependence' effect, whereby a response provided to a current-trial is biased towards that of the preceding trial (Kondo, Takahashi, & Watanabe, 2012; Pegors, Mattar, Bryan, & Epstein, 2015; Taubert, Van der Burg, & Alais, 2016).

Furthermore, unlike happy, sad and other emotional expressions, a neutral expression does not provide unambiguous information regarding another person's emotional state or intentions. It may, therefore, be more susceptible to contextual conditions such as the presence of other emotional expressions in order for it to be appropriately discriminated and perceived as neutral, rather than a negative emotion. As such, in the current experiments, integrating a neutral expression with gaze shift either away or towards the observer may not represent either a congruent nor an incongruent gaze-expression combination relevant for a social response (Adams & Kleck, 2003; 2005).

A second reason for the inconsistencies across these studies may lie in the fact that the face stimuli used in the present studies maintained a static facial expression which was present for the entire two-second presentation of the target face, and therefore may have served as a more reliable signal compared to a gaze shift, and thus expression may have dominated the ratings response. This raises the possibility that for gaze and expression to interact, the two social cues may have to be equivalent in perceptual saliency (e.g. either both static or dynamic or both presented for similar temporal durations). Since dynamic cues are reflective of social interactions in the real world, future research could help reveal the influence of the dynamic aspects of gaze shifts with changes in expressions in a more ecologically relevant display.

Although a positive, rather than a negative facial expression was associated with stronger attractiveness of an unfamiliar face in Experiment 2, there was no evidence of a consistent effect of an increase in expression intensity on stronger attractiveness judgements. Previous studies using both neuroimaging and behavioural measures (Mueser et al., 1984; O'Doherty et al., 2003; Golle et al., 2014; Ueda et al., 2016) provide supporting evidence that a smiling expression is associated with higher attractiveness ratings and enhanced activation in the medial orbitofrontal cortex (OFC), an area within the reward circuitry.

Here, inconsistent effects were found with an increase in smiling: in Experiment 1a faces with a closed-mouth smile expression were rated as less attractive than those with either a slight smile or a neutral expression; in Experiment 2, faces with a happy (i.e. open-mouthed smile) expression were not rated as more or less attractive than those with a neutral expression; and lastly, in Experiment 3, faces with a happy (open-mouthed smile) were rated as more attractive than those with the slight smile. Notwithstanding the influence of stimulus context discussed above, different forms of smiles might carry socially different meanings. For example, a broad open-mouthed smile might be perceived to signify happiness, but a close-mouthed or a milder smile might be perceived as a polite, amused, or even nervous smile (Ekman, & Friesen, 1982; Ambadar, Cohn, & Reed, 2009). In other words, while it was initially assumed that by manipulating the intensity of smile that the degree of positive emotion was also varied, the morphology of a smile may not represent a single continuum in terms of the perceived expression (see e.g. Calder, Young, Perrett, Etcoff & Rowland, 1996). Although some insight was gained by asking naïve participants to identify the facial expressions used in Experiment 1a, it remains nevertheless unclear whether those categories would be maintained within the context of the experiment itself (as suggested by the change in ratings to neutral expressions across experiments). Therefore, it can only be speculated that perceived attractiveness was enhanced when the expression represented an unambiguously happy and positive emotion (hence a clear social reward), as in the case of the open-mouthed smile in Experiment 2. The present results therefore provide supporting evidence for the role of positive facial expression in enhancing perceived attractiveness. Furthermore, this finding is consistent with the 'perceptual fluency' proposal that attractiveness ratings tend to be higher for stimuli that are relatively 'easy' to perceive (e.g. Reber et al, 2004).

Another main finding of the current study was that attractiveness ratings were unaffected by the direction of a gaze shift, which is contrary to the results reported by Mason et al. (2005). However, the effect of gaze-shift on ratings of attractiveness reported by Mason et al. (2005) did not appear to be robust in that it was dependent on the specific characteristics of the face images and the observer, namely that the images were of female faces and the raters were male. It should also be noted that the face images used in their study were of female models taken from fashion magazines, and therefore highly stylised to enhance their attractiveness and allure. It is therefore reasonable to suggest that male participants found viewing stylised faces as rewarding, especially when the gaze shifted towards the observer, with the consequence that male participants attended more to the features of those faces. In a similar vein, Jones et al. (2006) used images of composite faces as stimuli by averaging images from at least 15 female faces to create an 'attractive' and 'unattractive' prototype. Averageness is a well-known contributing factor to facial attractiveness (Langlois & Roggman, 1990; Rhodes & Tremewan, 1996; Rubenstein, Langlois, & Roggman, 2002; Valentine, Darling, & Donnelly, 2004) and, similar to the Mason et al. study, increased attractiveness may have enhanced participants' attention to the faces (Sui & Liu, 2009; Li, Oksama, & Hyönä, 2016). Indeed, Jones et al. reported higher attractiveness ratings overall (compared to the faces used in the current study) suggesting that their image manipulations were successful. The results reported here suggest it cannot be assumed that the use of less stylised, or original, images of faces would result in the same effect of eye gaze.

Indeed, the role of attention in combing the effects of facial expression and eye gaze may have had an important influence on the present results. For example, it is possible that the distinct facial expressions used in Experiment 2 relative to 1 had the effect of drawing attention away from the eye region of the face towards other, more expressive, facial

features such as the mouth region, thus limiting the role of gaze-shift on attractiveness in this context. Future studies based on eye movement recordings may help reveal the role of social intentions (i.e. male observers judging female faces) and experiment context (i.e. different facial expressions) on the nature of the facial features that are specifically attended. It is expected that such studies would add further support to the argument that facial expression and gaze shift provide independent sources of information for judging facial attractiveness.

A potential limitation of the current study is the use of computer-generated (CG) faces which may have resulted in the creation of 'unnatural' looking faces. The decision to use such images was based on the rationale that it allowed for the standardisation of stimulus properties such as lighting and skin texture, as well as the fine control of gaze direction in order to achieve the animation of gaze shift. Furthermore, hair features such as hairstyle and hair length were not of interest in the current study but were known to affect attractiveness judgements (Bereczkei & Mesko, 2007; Saegusa, Intoy, & Shimojo, 2015). The original face images from the Chicago Face Database came with different hairstyles, hair colours and hair lengths. Hence, just like in many previous studies which investigated facial attractiveness using CG faces, particularly FaceGen faces (Jones et al., 2006; Potter & Corneille, 2008; Bird, Lauwereyns, & Crawford, 2012; Ma, Xu, & Luo, 2015; Huang, Pan, Mo, & Ma, 2016), hair information was systematically removed during the process of creating the stimuli to avoid confounding the ratings. This, however, might have lowered the overall attractiveness of the stimulus set. Bald female faces are not the norm within Western culture and could be associated with illnesses (Cash, 1999). Previous studies have suggested that CG manipulations may affect face perception with such images reportedly perceived as "eerier" (MacDorman, Green, Ho, & Koch, 2009) and less trustworthy (Balas & Pacella, 2017). Although Crookes et al. (2015) argued that CG

faces fail to tap into the full extent of face expertise required to identify faces they also suggested that such images could still be appropriate for other aspects of face processing which do not involve identification. Indeed, a number of studies used 'FaceGen' software to generate face images in order to investigate aspects of facial attractiveness and produced consistent and comparable results to those in studies where photographic images of real faces were used (Potter & Corneille, 2008; Bird et al., 2012; Ma et al., 2015; Huang, et al., 2016). For example, Balas, Tupa, & Pacella (2018) used the 'Photofit' function within FaceGen to create images (as in the Experiments reported above) and compared social evaluations across the real and CG generated images of the same faces. They found that the social evaluation ratings given to both artificial and real faces were well-described by the two-factor model of 'social face space' (see Oosterhof & Todorov, 2008) based on valence and dominance (Balas et al., 2018), implying that the general principles underlying social evaluations of real and CG faces are at least similar. Consistent with this finding, in Experiment 1a, a high correlation between the attractiveness ratings obtained to the CG faces used in the current experiments and the corresponding ratings to photographic images of the same faces obtained from the Chicago Face Database (Ma et al., 2015) was found. Taken together, these consistent findings suggest that observers do not adopt different criteria across different image formats when rating the same facial identity for attractiveness. However, the overall lower ratings in the current study compared to the normative ratings in the database and those in previous research might have been the result of using CG faces with no hair. Further research will be required to address this limitation and to determine whether the effects found in the current study were specific to relatively unattractive, CG faces.

The main finding from Experiment 3 was that perceived attractiveness increased with the relative duration of direct gaze, regardless of facial expression. An image of a face,

smiling or otherwise, was rated as more attractive when eye gaze was directed at the observer for a prolonged period of time. Put differently, it was both the initial exposure and the amount of perceived attention (in terms of duration) directed at the observer that influenced attractiveness judgements. This finding for a preference for a direct eye gaze is consistent with previous studies (e.g. Kuzmanovic et al., 2009; Georgic et al., 2013). Prolonged eye gaze indicates social interest and engagement directed at the observer and has been found to be rewarding (Kampe et al., 2001). A recent study by Hesslinger, Carbon, & Hecht (2017) provided evidence suggesting that a prolonged duration of direct gaze (e.g. 10 second as opposed to a quick glance for 200ms), not only increased the observer's 'sense of being watched' but was also associated with a higher level of arousal. In accordance with the notion that facial attractiveness is associated (at least partly) with arousal, as well as the social reward perceived by the observer (Senior, 2003), face images with a relatively long duration of eye gaze directed at the observer should be rated as most attractive, which the data reported here have confirmed. This effect, however, appeared to be dependent on the order of gaze direction during gaze shift such that direct, prolonged eye gaze benefits attractiveness only when this direct gaze is present in the initial exposure to the face.

Finally, future research could consider the effects of top-down, contextual influences such as the individual differences among participants in cultural background, relationship status, sexual orientation, etc. on facial attractiveness which were outside the scope of the current investigation. It is possible that the social meanings of eye gaze and expression vary depending on those factors.

2.8. Conclusion

In summary, evidence consistent with previous findings that both facial expression and gaze information affect judgements of the attractiveness of faces was revealed. In particular, faces displaying a positive, rather than neutral or negative, emotional expression were associated with higher ratings of attractiveness as were faces that maintained a longer duration of eye contact with the observer. These results also provide new evidence to suggest that these cues appear to act independently of each other in the aesthetic evaluation of faces. The findings of this study add to growing evidence for a role of socially relevant cues on the evaluation of others and provide further insight into the role of these cues on perceptual processes underpinning judgements of attractiveness in faces.

Chapter 3

The effects of head orientation on the perceived attractiveness of expressive faces

3 The effects of head orientation on the perceived attractiveness of expressive faces

3.1. Abstract

Three experiments were conducted to investigate whether the perceived attractiveness of expressive faces was influenced by head view under static and dynamic conditions. In all experiments happy faces were consistently rated as more attractive than angry faces. Facial expression also modulated the effects of directional social cues such as static head orientation (Experiment 2a), eye gaze (Experiments 2b), and head turn (Experiments 1 & 3), which alone did not generally affect attractiveness. Faces with a happy expression facing or turning towards the observer received higher attractiveness ratings than those facing elsewhere or turning away from the observer. Such effect of head view, however, was not evident for angry faces. In Experiment 3, by manipulating the relative duration of the two head views (front-facing and averted at 15°) during a head turn, it was demonstrated attractiveness ratings for happy faces increased with the duration of front view; regardless of the direction of the head turn. These findings support previous studies indicating a preference for positive expressions on attractiveness judgements, which is further enhanced by the front views of faces, whether presented during a head turn or shown statically. In sum, these findings imply a complex interaction between cues of social attention, indicated by the view of the face shown, and reward on attractiveness judgements of unfamiliar faces.

3.2. Background

Human faces provide rich information to facilitate effective social interaction: eye-gaze direction, head orientation and facial expression are social cues to the attentional, intentional and emotional state of another (Argyle, & Cook, 1976; Ekman & Friesen, 1982; Langton & Bruce 1999; Camerlink, Coulange, Farish, Baxter, & Turner, 2018). Moreover, these individual cues can be accurately perceived within a fraction of a second thus facilitating the dynamic nature of changes to a person's affective state (Argyle, & Cook, 1976; Ekman, 1982; Langton, Watt, & Bruce, 2000; Wilson, Wilkinson, Lin, & Castillo, 2000; Adolphs, 2002). However, in the real world, social information from a face is often perceived from a combination of where the face is looking and its expression. Moreover, social interactions can involve moment-to-moment changes in gaze direction, face view and expression, often in combination. It is important, therefore, to establish how these cues interact under circumstances which are more reflective of the dynamic changes that occur during typical, everyday social interactions.

Cognitive and neural models of face processing (e.g. Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2002; Young & Bruce, 2011; O'Toole, Roark, & Abdi, 2002) have proposed that the processing of social or changeable aspects of a face, such as its emotional or attentional state, occurs independently to the processing of structural facial information for the purpose of recognition, such as the view of a face (Bruce, Valentine, & Baddeley, 1987; Langton & Bruce, 2000; Siéroff, 2001). Indeed, the results of neuroimaging studies have shown that eye gaze and facial expression activate distinct but hugely overlapping neural systems, particularly in the occipital face area (OFA) and superior temporal sulcus (STS) (Engell, & Haxby, 2007; Carlin & Calder, 2013), that comprise an extensive neural network for social attention processing (Nummenmaa, &

Calder, 2009). A number of behavioural studies have also reported early interactions between eye gaze and facial expression on perception (Adams & Kleck, 2003; 2005) although supporting evidence is not always consistent with some other findings suggesting independent processing of these cues (Graham & LaBar, 2012; Ho, Woods & Newell, 2018).

It is now well documented that although the accuracy of discriminating gaze direction is high (Gibson & Pick, 1963; Cline, 1967; Symons, Lee, Cedrone, & Nishimura 2004), this ability can be affected by the view of the face shown (e.g., Wollaston, 1824; Gibson & Pick, 1963; Cline, 1967; Anstis, Mayhew, & Morley, 1969; Langton, 2000; Langton, Honeyman, & Tessler, 2004; Seyama & Nagayama, 2005; Gamer & Hecht, 2007; Ricciardelli & Driver, 2008; Todorovic, 2006, 2009; Wilson, et al., 2000). For example, Wollaston (1824) was the first to report that the perceived direction of a gaze appeared to be biased towards the direction of the orientated face view, even if the image of the eye region was identical across the different orientations of the face depicted. In a further elaboration of what is now known as the "Wollaston Effect", Gibson and Pick (1963) reported a systematic error of approximately 2.9° in visual angle when observers were asked to judge the perceived direction of gaze when the observed face was averted by 30° to either side from the full-face view. In a similar study, but using mirrored views of faces, Cline (1967) reported that the perceived gaze direction was biased towards the perceived direction to which the gazer's face was oriented which, in this case, was the mirrored view of the face (Cline, 1967). Anstis, et al. (1969), just like Cline (1967), studied the effect of head rotation on perceived gaze direction using a triadic task in which the observer viewed the face through a TV screen and found a bias in perceived gaze direction away from the direction in which the face was oriented. Anstis, et al. (1969)

explained that this 'repulsive' effect was caused by the reduction in the sclera visible on either side of the iris as a consequence of the face view away from the observer.

A number of more recent studies, adopting a variety of paradigms, have presented evidence for both 'attraction' and 'repulsive' effects of perceived eye gaze with changes in face view (Maruyama & Endo, 1983; Maruyama, Endo, & Sakurai, 1985; Masame, 1990; Langton, Honeyman, & Tessler, 2004; Gamer & Hecht, 2007; Todorović, 2006; 2009; Kluttz, Mayes, West, & Kerby, 2009; Otsuka, Mareschal, Calder & Clifford, 2014; Otsuka, Mareschal, & Clifford, 2016; Balsdon & Clifford, 2017, 2018; Sweeny & Whitney, 2017). Otsuka, et al. (2014) proposed a model to account for the existence of two seemingly contradictory effects, known as the dual-route hypothesis. According to this model, the 'attractive' and 'repulsive' effects of head orientation on perceived gaze direction occur through two distinct routes such that the perceived gaze direction is a linear combination of eye orientation and head orientation. A 'repulsive' effect is observed when a 3D rotation of the head reduces the availability of information from the eye region (iris, sclera) thus reducing its effectiveness as cue for gaze direction. Alternatively, when identical eye region information is presented within the context of different views of faces (i.e. a 2D condition, such as in Wollaston's (1824) demonstration) only the orientation of the face serves as a cue to gaze direction leading to an 'attractive' effect on gaze direction towards the direction of the view of the face (Otsuka, et al., 2014; 2016). Moreover, errors in the perceived orientation of the face (Wilson, et al., 2000) or an incongruency between the directions of gaze and head (Langton, 2000), would consequently affect the accuracy of the perceived direction of gaze.

Although gaze direction has been shown to capture visuospatial attention (Senju & Hasegawa, 2005; Palanica & Itier, 2012), it can also affect the processing of face

information per se. For example, direct gaze facilitates the discrimination of the sex of a face (McCrae, Hood, Milne, Rowe, & Mason, 2002), facial expression (Adams & Kleck, 2003; 2005, although see Bindemann, Burton, & Langton, 2008; Ganel, Goshen-Gottstein, & Goodale, 2005), face recognition in infancy (Farroni, Massaccesi, Menon, & Johnson, 2007; Yamashita, Kanazawa, & Yamaguchi, 2012), and can enhance ratings of facial attractiveness (Kampe, Frith, Dolan, & Frith, 2001; Ewing, Rhodes, & Pellicano, 2010). Interestingly, certain facial expressions (e.g. sadness and fear) are detected more quickly when coupled with averted than direct gaze (Adams & Kleck, 2003; 2005; Milders, Hietanen, Leppänen, & Braun, 2011). Indeed Sander, Grandjean, Kaiser, Wehrle, & Scherer (2007) reported that angry faces were rated as angrier with direct, rather than averted, gaze and fearful faces as more afraid with averted than direct gaze. Neuroimaging evidence is consistent with these behavioural findings in that increased activation was observed in the amygdala, fusiform gyrus and medial prefrontal areas when viewing faces with an angry expression and direct gaze or a fearful expression with averted gaze (N'Diaye, Sander, & Vuilleumier, 2009).

However, cue interactions appear to be sensitive to different factors such as stimulus duration (Adams, Franklin, Kveraga, Ambady, Kleck, Whalen, Hadjikhani, & Nelson, 2011; Adams, Franklin, Nelson, Gordon, Kleck, Whalen, & Ambady, 2011), discriminability (Graham & LaBar, 2007), task demands and instructions (Graham & LaBar, 2007; Bindemann, et al., 2008; Ricciardelli, Lugli, Pellicano, Iani, & Nicoletti, 2016) and individual differences in cultural backgrounds (Adam, Franklin, Rule, Freeman, Kveraga, Hadjikhani, Yoshikawa, & Ambady, 2009) Therefore, the effect of gaze direction on face perception may not be robust.

In sum, previous findings suggest that information from gaze direction, face view and expression can interact with each other for the purpose of social evaluation of the state of

another person, although these interactions can be sensitive to experimental manipulations and viewing conditions as discussed previously. However, it remains unclear whether these cues interact to influence judgements of attractiveness. Moreover, many of these studies investigated the role of eye gaze, face view and expressions on attractiveness using static images of faces in which ecological relevance may be reduced.

Judgements of facial attractiveness are made as early as 100ms after the initial exposure of an unfamiliar face (Willis &Todorov, 2006). The effects of certain invariant facial features such as symmetry (Perrett, Burt, Penton-Voak, Lee, Rowland, & Edwards, 1999; Scheib, Gangestad, & Thornhill, 1999), averageness (Rhodes & Tremewan, 1996; Rubenstein, Langlois, & Roggman, 2002) and sexual dimorphism (Perrett, Penton-Voak, Rowland, Yoshikawa, Burt, Henzi, Castles, & Akamatsu, 1998; Rhodes, Hickford, & Jeffrey, 2000) on facial attractiveness are well documented. On the other hand, social cues which vary momentarily also influence attractiveness judgements and the rewarding values of faces. For instance, there is strong evidence to suggest that faces with happy expressions are perceived as more attractive than faces with neutral or negative emotional expressions (Lau, 1982; Mueser, Grau, Sussman, & Rosen, 1984; Reis, Wilson, Monestere, Bernstein, Clark, Seidl, & Radoane, 1990; Otta, Lira, Delevati, Cesar, & Pires, 1994; Otta, Abrosio, & Hoshino, 1996; Mehu, Little, & Dunbar, 2008; Tracy, & Beall, 2011; Morrison, Morris, & Bard, 2013; Golle, Mast, & Lobmaier, 2014; Ueda, Kuraguchi, & Ashida, 2016; Ho et al., 2018). Moreover, several studies report that faces with direct gaze are preferred and receive higher attractiveness ratings than the corresponding faces with averted gaze (Ewing, et al., 2010; Palanica & Itier, 2012; Kaisler & Leder, 2016). Direct gaze can enhance the rewarding value of attractive faces relative to averted gaze (Kampe, et al., 2001) possibly by increasing the saliency of self-relevance perceived by the observer (Senju & Hasegawa, 2005; Bublatzky, Pittig,

Schupp, & Alpers, 2017). Finally, Kaisler & Leder (2017) found that the three-quarter view of (neutral expressive) faces was rated as more attractive than the frontal view when viewing time was unlimited. However, this finding was not reported by Rule, Ambady, and Adams (2009) who found that ratings on attractiveness were consistent across different full-frontal, three-quarter and profile views of faces, even at brief stimulus presentation durations.

Although the above evidence suggests interactions between face view eye gaze and expression on face perception, the number of studies which have examined the interaction between these cues on attractiveness are few. For example, the results of Main, DeBruine, Little, & Jones (2010) suggest that the effect of face view on attractiveness may depend on facial expression. They found that the front-view was preferred over the three-quarter view when participants were evaluating the attractiveness of happy faces but preferred the three-quarter view when judging faces with a disgusted expression. In a similar vein, Jones, DeBruine, Little, Conway, & Feinberg (2006) presented evidence that gaze direction and expression interacted for the purpose of judgements of facial attractiveness. Specifically, they found that preferences for facial attractiveness were stronger for smiling faces with direct gaze than averted gaze and for neutral faces with averted than direct gaze. These results, in turn, supported the 'shared-signal' hypothesis whereby the effect of an approach-oriented emotional expression (i.e. happiness) is enhanced by an approach-oriented directional cue (i.e. direct gaze, front-facing head orientation). In other words, faces are perceived as more attractive when they face the observer with a positive expression (Main, et al., 2010; Sutherland, Young and Rhodes, 2017).

Most previous studies on the interactions between face cues on attractiveness used single, static images. Studies which have used more dynamic changes have reported effects of eye gaze shifts, with higher attractiveness ratings for gaze shifts towards the observer

than away (Mason, Tatkow, & Macrae, 2005) although these interactions appear to be dependent on the facial expression shown. For example, it was previously reported that shifts in eye gaze did not modulate attractiveness ratings of happy expressive faces (Ho, et al., 2018, and Chapter 2 of this thesis) suggesting that the effect of facial expression on attractiveness judgements was independent of the effect of gaze dynamics. However, when pitted together, facial expression may be a more salient signal of attractiveness than gaze shifts and hence the effect of expression dominated attractiveness judgements. A more salient directional cue might be a gaze shift coupled with a congruent head turn. The experiments reported in the current study were therefore designed to further investigate the nature of the interactions between changes in head view and gaze direction on the perceived facial attractiveness of expressive faces, using a more ecologically valid paradigm in which momentary changes to one or two cues could occur, as in social interactions in the real world.

3.3. Experiment 1

3.3.1 Introduction

The aim of this experiment was to investigate whether a change in face view and emotional expression modulated the perceived attractiveness of unfamiliar faces in an independent or combined manner. To that end, an attractiveness rating task was conducted, whereby participants judged the attractiveness of expressive faces during which the face view shifted in orientation either towards or away from the participant. Each face conveyed either a happy (i.e. an open-mouthed smile) or angry expression. Based on the findings from previous studies on facial expression and attractiveness (Lau, 1982; Mueser et al., 1984; Reis et al., 1990; Otta et al., 1994 & 1996; Mehu, et al., 2008; Tracy, & Beall, 2011; Morrison et al., 2013; Golle et al., 2014; Ueda et al., 2016), it was

expected attractiveness ratings to be higher for faces conveying a happy than an angry expression. Furthermore, other studies on social attention have suggested that self-referent signals of attention, such as shifts of eye gaze towards an observer (Mason et al. 2005) renders the observed face more attractive. It is unclear, however, whether both of these cues to attractiveness combine to influence attractiveness judgements, such that smiling faces in which the head turns towards the observer would be perceived as the most attractive. On the other hand, attractiveness judgements may be dominated by one cue with no evidence for integration of those cues (see e.g. Ho et al., 2018). For example, shifts in eye gaze direction may be perceived as a less salient visual cue than view changes of a face. As such, it remains possible that facial expression and head orientation may combine to influence judgements of facial attractiveness.

3.3.2 Method

Participants

Thirty volunteers (20 females; mean age = 22.7 years, *SD* = 6.9) from the student and staff population at Trinity College Dublin participated in this study. All were naïve to the purpose of the study and were compensated with research credits or €5 for their participation. The study (and all experiments reported here) received ethical approval from the School of Psychology Research Ethics Committee at Trinity College. In accordance with this approval, all participants gave informed, written consent prior to conducting the experiment.

Stimuli and apparatus

Images of 32 female Caucasian faces were taken from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015) in order to create the stimulus set. All original images were

presented from a front facing viewpoint. From this database, two versions of each face identity, one conveying a happy expression (an open-mouthed smile) and the other conveying an angry expression were used.

Each original face image was edited using the FaceGen software which allowed the images of the faces to be created from different orientations. First, each face image was uploaded onto the FaceGen Modeller and processed through its "PhotoFit" function. For the purpose of the current experiment, two views of each facial identity image (one front facing view and one view at 15° left or right from the front view) were created. The gaze direction of the eyes was not manipulated therefore eye gaze was always aligned with the orientation of the face in Experiment 1. Figure 3. 1 shows examples of the resulting images with different facial expressions and views. In each image, hair information was removed and faces were presented from the neck up. Each image was positioned in the centre of a black background. Image sizes were adjusted such that each face image was approximately 400 x 400 pixels and all were matched for contrast and luminance.
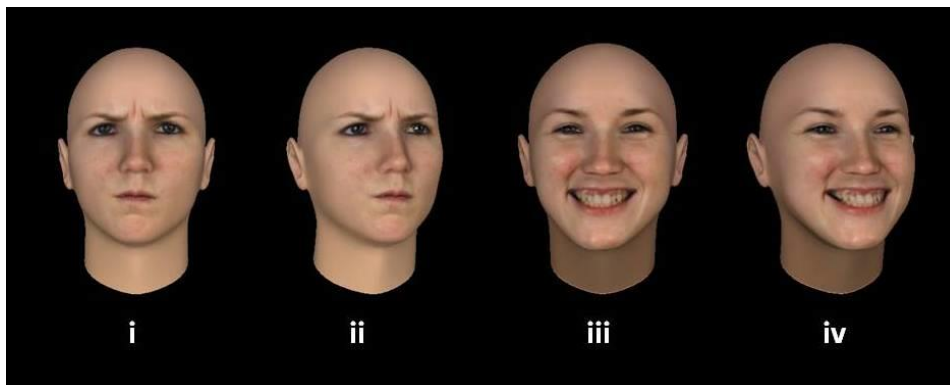
Figure 3.1 An example of face stimulus images used in Experiment 1. In this example, the same face identity is presented across different images consisting of the following combinations of face orientation and expression: i) front view, angry expression; ii) 15° view, angry expression; iii) front view; open-mouthed smile; iv) 15° view; open-mouthed smile.

Each trial in this experiment began with the presentation of a fixation point for 500ms followed by a 30-ms blank screen. Then, a face was shown in which the face orientation shifted towards or away from the observer. That is, each face was presented such that the face orientation changed from front facing to 15° to the left or right (i.e. the view of the face shifted away from the observer), or from 15° to the left or right to front facing (i.e. the view of the face shifted towards the observer). This apparent turn of the head was achieved by rapidly presenting two images of different head orientations in succession to generate the perception of illusory motion.

The experiment was programmed using PsychoPy (Peirce, 2007) and run on an Alienware AURORA R4 desktop computer. The stimuli were presented on a 34cm x 27.5cm HP monitor with a resolution of 1280 x 800 at 60 Hz.

Design

The experiment was based on a two-way fully factorial, within-subject design with two independent variables, namely the direction of the head turn (away or towards the observer) and facial expressions (angry or open smile). The dependent variable was the perceived attractiveness ratings of faces given by the participants. Each participant was presented with 64 trials, with each of the original 32 face identities shown twice, once with the head turned towards and once away from the observer. Although both facial expressions across each of facial identities were shown across all participants, for any one participant, each facial identity was shown either with a happy or angry expression only. The allocation of facial expression to facial identity was counterbalanced across participants.

Procedure

The experiment took place in a darkened testing room within the Institute of Neuroscience, Trinity College Dublin. Prior to the experiment, participants provided basic demographic information (e.g. age, sex, handedness) and were instructed on the task. Then the participant was seated at 60 cm away from the monitor onto which the facial images would be displayed. A single practice trial was performed in order for the participants to familiarise themselves with the trial structure and task. Each trial started with a white fixation cross, followed by a 30ms interval. Then, in the centre of the screen, two face stimuli appeared in rapid succession for 1000 milliseconds each (a total of 2000 milliseconds). The end of a trial was marked by a response cue for the participant to provide an attractiveness rating of the face just viewed. The participant responded by adjusting the location of a marker on a sliding scale which ranged from very unattractive (0) to very attractive (100). The adjustment was achieved by the participant using the computer mouse to drag the marker along the scale to their preferred rating of the attractiveness of the viewed face. The participant was instructed to make a response as quickly as possible and try to utilize the whole scale. The experiment took approximately ten minutes for each participant to complete.

3.3.3 Results

The mean attractiveness ratings were calculated for each of the face orientation and expression combination for each participant. The mean rating across these conditions is shown in Figure 3.2. A preliminary data analysis revealed no significant differences between the ratings made by female and male participants (F (1, 28) = 0.025; p = 0.875) and the sex of the participant was not considered in any of the remaining analyses.
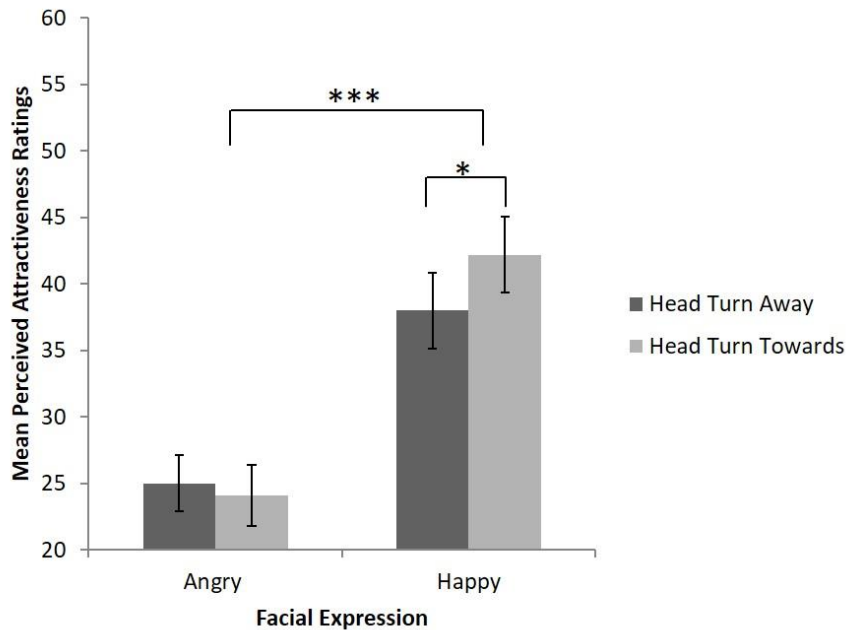
Figure 3.2. The plot shows the mean perceived attractiveness ratings for each of the head orientation (away or towards) and facial expression (happy or angry) of faces across participants in Experiment 1. Error bars represent ±1 standard error of the mean. [*p<0.05; *** p <0.001].

A 2x2 repeated-measures ANOVA was performed on the mean ratings with the direction of head orientation (away or towards the observer) and facial expression (angry or happy) as within-subject factors. The results revealed a main effect of expression (F (1, 29) = 55.6, p <0.0001, $\eta_p^2 = 0.657$): faces were rated as more attractive when conveyed with a happy than an angry expression (mean difference = 15.6, SE = 2.09). Although attractiveness ratings were slightly higher for faces presented with a head turn towards rather than away from the observer (mean difference = 1.63, SE = 0.878), this difference did not reach statistical significance (F (1, 29) = 3.43, p = 0.074). There was a significant interaction between the direction of head turn and facial expression (F (1, 29) = 5.17, p = 0.03, $\eta_p^2 = 0.151$), as shown in Figure 3. A post-hoc simple effects analysis (with Bonferroni correction) indicated a significant effect of head turn for happy faces (F (1, 29) = 4.83, p = 0.036, $\eta_p^2 = 0.143$) but not angry faces (F (1, 29) = 1.87, p = 0.182). That

is, attractiveness ratings for faces with a happy expression were significantly higher when the head turned towards, rather than away from the observer (mean difference = 4.17, *SE* = 1.90).

3.3.4 Discussion

First, the results of this experiment showed a robust effect of facial expression on perceived attractiveness and therefore concur with those from a number of previous studies (Lau, 1982; Mueser et al., 1984; Reis et al., 1990; Otta et al., 1994 & 1996; Mehu et al., 2008; Tracy, & Beall, 2011; Morrison et al., 2013; Golle et al., 2014; Ueda et al., 2016). Specifically, smiling faces were rated as more attractive than angry faces. On the other hand, the direction in which the head turned, either away from or towards the observer, did not significantly affect attractiveness ratings on its own. Given that eye gaze direction was aligned with the face view, this result is somewhat contrary to that of Mason, et al. (2005) in which they reported a benefit of a gaze shift towards the observer on perceived attractiveness. However, the effect of facial expression was modulated by a change in the view of the face, in that faces with a happy expression were rated as more attractive when the head turned towards, rather than away from the observer. In contrast, ratings for angry faces were unaffected by changes in the orientation of the face. This finding is consistent with a number of other reports that face view interacts with facial expressions to form impressions (Main, et al., 2010; Rule, et al., 2009; Sutherland, et al., 2017).

The interaction between facial expression and head turn on attractiveness ratings is consistent with the idea that social cues of attention integrate to influence attractiveness judgements (Main et al., 2009). These results suggest that the allocation of social attention directed at the observer (as indicated by a head turn in the current experiment),

coupled with an expression of positive emotional state, was associated with enhanced perceived attractiveness of that face. However, eye gaze is not always coupled with the direction of the view of a face, therefore the following experiment was designed to investigate the role of shifts in eye gaze with a constant face view, either full or a view averted by 15 degrees.

3.4. Experiment 2a

3.4.1 Introduction

In Experiment 1, the effect of head turn alone did not reach statistical significance, contrary to what was predicted by some previous studies on the role of social attention from eye gaze on attractiveness ratings (e.g. Mason et al., 2005). However, when gaze-shifts were presented with facial expression, it was previously reported that facial expressions dominated attractiveness judgements (Ho et al., 2018). The results of Experiment 1 are ambiguous on the relative contribution of head turns or shifts in eye gaze on modulating the effect of facial expression. The following experiment aimed to dissociate the effects of head view and eye gaze information on attractiveness judgments by pitting head orientation against shifts of eye gaze. To do so, gaze shift was manipulated while maintaining a static head orientation in the current experiment; and then subsequently in Experiment 2b, a head turn was displayed while maintaining a static gaze direction in the face image relative to the observer.

3.4.2 Method

Participants

Thirty-six volunteers (20 females; mean age = 26.3 years, *SD* = 11.2) from the student population of Trinity College Dublin participated in this study. All were naïve to the

purpose of the study and were compensated with research credits or €5.00. All gave informed, written consent prior to proceeding with the experiment.

Stimuli and apparatus

The face images from the Chicago Face database and the processes used to create the stimulus set in Experiment 1 were again used here (Figure 2). A shift in gaze was simulated by adapting the paradigm previously described by Mason et al. (2005) and Ho et al. (2018). Specifically, gaze shift of the eyes was achieved by presenting two face images in rapid succession to simulate an apparent motion of the eyes. The first face stimulus (S1) differed from the second face stimulus (S2) in gaze direction only, whilst maintaining the same expression and face view, resulting in two possible gaze shift directions (towards or away from the observer) for each combination of expression and face view.

Design and procedure

The experiment was based on a three-way, within-subject design with face orientation (full view or 15° view), the direction of gaze shift (away or towards) and facial expression (angry or happy) as factors. The dependent variable was the perceived attractiveness rating. Each participant was presented with 128 trials, with each of the face images shown four times, once in each of the four head orientation and gaze shift combinations. All participants were presented with faces shown in one or other of the facial expressions, such that each facial identity was presented with one facial expression only per participant. Facial expression was counterbalanced across facial identity for all participants. All other details of the experimental procedure were as described in Experiment 1.

3.4.3 Results

Participants' mean attractiveness ratings across all face images shown with different gaze shifts, head orientation, and facial expression are shown in Figure 3.3. Again, no significant differences were found between the ratings made by female and male participants (F (1, 34) = 0.133; p = 0.718) and participant sex was not taken into account further analyses.
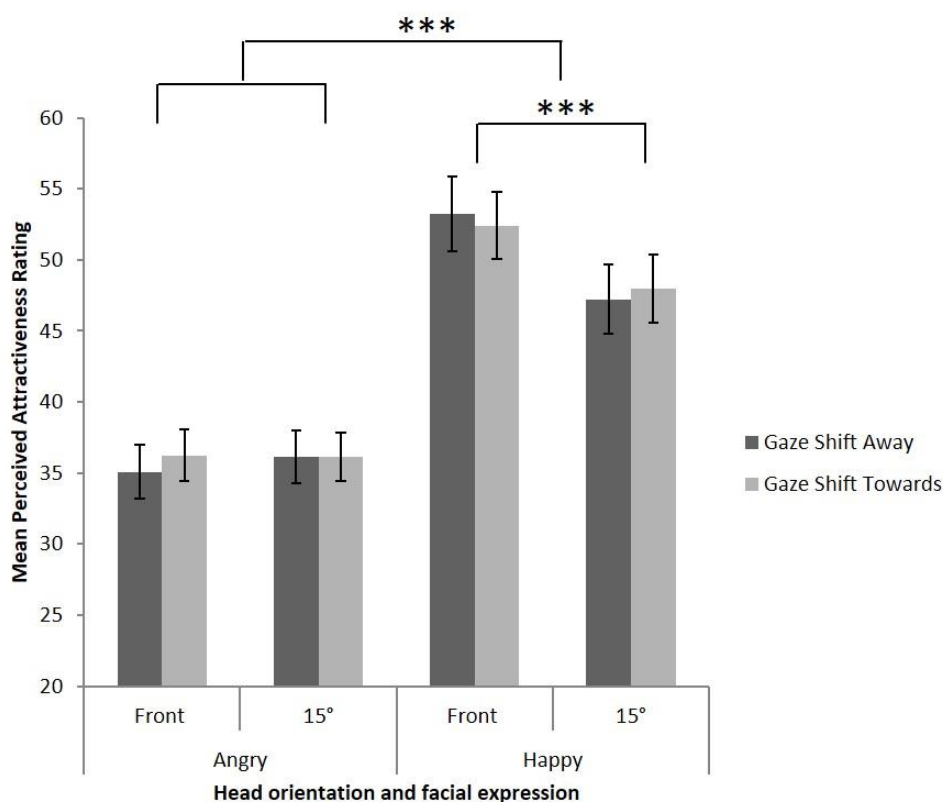
Figure 3.3 The plot shows participants' mean perceived attractiveness ratings for faces presented across different orientations, gaze shifts and expressions in Experiment 2. Error bars represent ±1 standard error of the mean. [*** p <0.001].

A three-way repeated-measures ANOVA was performed on the mean attractiveness ratings with face orientation (front view or 15° view), the direction of gaze shift (towards or away from the observer) and facial expression (angry or happy) as within-subject

factors. The results revealed a main effect of face view ($F_{(1, 35)} = 21.8$, $p < 0.0001$, $\eta_p^2 = 0.384$), with higher attractiveness ratings given to faces with the front view, rather the 15° view. A main effect of expression ($F_{(1, 35)} = 35.9$, $p < 0.0001$, $\eta_p^2 = 0.506$) was also found with higher attractiveness ratings to faces shown with a happy than angry expression. There was no evidence for an effect of gaze shift ($F_{(1, 35)} = 0.555$, $p = 0.461$).

A significant interaction between head orientation and facial expression ($F_{(1, 35)} = 44.2$, $p < 0.0001$, $\eta_p^2 = 0.558$) was found. Results of post-hoc simple effects analysis indicated no effect of head orientation on the attractiveness ratings of angry faces ($F_{(1, 35)} = 0.578$, $p = 0.452$) whereas, in contrast, faces with the happy expression were rated as more attractive from the front view, rather than at the 15° head orientation ($F_{(1, 35)} = 4.83$, $p < 0.001$, $\eta_p^2 = 0.606$).

There was no evidence for a two-way interaction between gaze shift and facial expression ($F_{(1, 35)} = 0.76$, $p = 0.389$), nor between gaze shift and head orientation ($F_{(1, 35)} = 0.058$, $p = 0.811$). The three-way interaction between the direction of gaze shift, head orientation and expression also failed to reach significance ($F_{(1, 35)} = 2.43$, $p = 0.128$).

3.4.4 Discussion

The effect of facial expression on perceived attractiveness found in Experiment 1 was replicated in the current experiment, suggesting a clear preference for faces with a happy expression over the angry expression. Contrary to findings from previous studies (Rule, et al., 2009; Kaisler & Leder, 2017), the perceived attractiveness of a face was increased by presenting it in the full view from the front compared to the 15° view. This benefit on attractiveness ratings was further enhanced by a happy expression. For faces with an

angry expression, however, the relatively lower attractiveness ratings did not differ across the face views.

The results from Experiment 2a suggest that face view modulates the effect of facial expression on perceived attractiveness and is thus consistent with the results of Experiment 1 and previous studies (Main, et al., 2010; Sutherland, et al., 2017). In both cases, smiling faces were rated as more attractive when the faces were facing directly at, or turning towards, the observer than when they were presented at an orientation of 15° or turning away from the observer, respectively.

No evidence that gaze shift influenced attractiveness ratings of faces was found, contrary to previous findings in (Mason et al., 2005 but only for male participants rating female faces). However, in the current experiment, gaze shift did not affect perceived attractiveness even when participant sex was taken into account.[5] Therefore, data from the current experiment suggested that perceived attractiveness was modulated by the view of the face only and not gaze direction.

One possible explanation could be that the attractiveness judgements were made based on information that was static within a trial. Previous studies have reported that a direct gaze direction increased the perceived attractiveness of faces relative to an averted gaze (e.g. Ewing, Rhodes, & Pellicano (2010). In the current experiment, both facial expression and head orientation remained constant throughout a trial and may, therefore, be perceived as a more reliable cue of attractiveness compared to a gaze shift. In the next experiment, this idea was tested by measuring attractiveness ratings to moving faces in

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[5] Further analysis of the data from Experiment 1 failed to find evidence for an interaction between gaze shift and participant sex (F (1, 34) = 2.56, p = 0.119).

which the gaze information remained stable while the orientation of the head changed within a trial.

3.5. Experiment 2b

3.5.1 Introduction

In the following experiment, face images were presented with a head turn either towards or away from the observer while the gaze direction was fixed relative to the observer. The aim of the experiment was to investigate whether facial expression integrated with either head turn or gaze direction or both, in judgements of attractiveness. Based on the results from Experiment 1, a prediction that head turn would modulate the effect of facial expression on attractiveness ratings was made. In other words, higher ratings to smiling faces were expected when the head turned towards, rather away from the observer. However, if indeed a static gaze direction acted as a more salient social cue compared to the change in head orientation, then one would expect an interaction between gaze direction and expression, as previously reported by Jones et al. (2006), that faces with a happy expression coupled with a direct gaze towards the observer were the most preferred relative to all other combinations of gaze directions and facial expressions.

3.5.2 Methods

Participants

Thirty-four volunteers (20 females; mean age = 22.2 years, *SD* = 6.72) from the student population of Trinity College Dublin, Ireland participated in this study. All were naïve to the purpose of the study, none had participated in any of the previous experiments and all

were compensated by research credits or paid €5 for their participation. All gave informed, written consent prior to the experiment.

Stimuli and apparatus

The same images of 32 faces used to construct the stimuli sets in the Experiments 1 and 2a, as well as the apparatus, were also used in the current experiment. Head turn was simulated in the same manner as described in Experiment 1, with the exception that the gaze direction remained the stable within each presentation (i.e. either direct or averted relative to the observer).

Design and procedure

The experiment was based on a three-way, within-subject design with head turn direction (away or towards the observer), static gaze direction (averted or direct relative to the observer) and facial expression (angry or happy) as factors. Each participant was presented with 128 trials, with each of the face images shown four times, once per each of the four head turn and gaze direction combinations. For each participant, a facial identity was shown with either a happy or angry facial expression and facial expression was counterbalanced across all participants. The experiment was based on the same procedures as described in Experiments 1 and 2a.

3.5.3 Results

Participants' mean attractiveness ratings for faces shown across each of the facial expressions, head turn, and gaze directions are shown in Figure 3.4. Again, the ratings

provided by female and male participants did not differ (F (1, 32) = 2.34, p = 0.136, η_p^2 = 0.068).
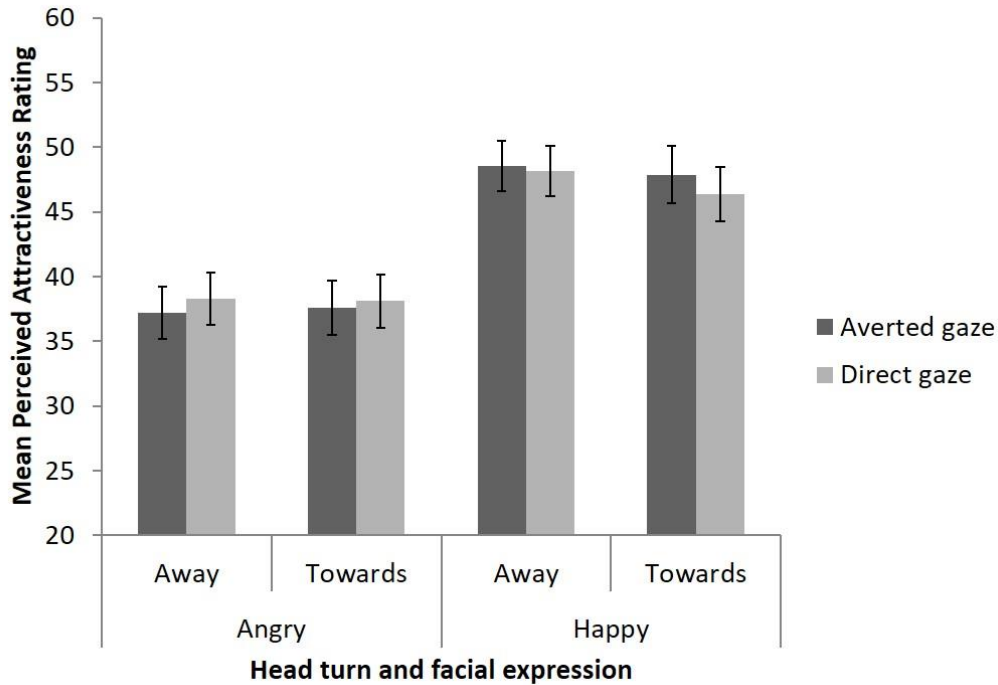
Figure 3.4 Plot showing participants' mean attractiveness ratings for faces presented with each combination of head turn, gaze direction and expression in Experiment 2b. Error bars represent ±1 standard error of the mean.

A three-way repeated-measures ANOVA was performed on the mean attractiveness ratings with the direction of head turn (away or towards the observer), gaze direction (direct or averted) and expression (angry or happy) as within-subject factors. The results of this analysis revealed a main effect of expression (F (1, 33) = 15.9, p <0.0001, η_p^2 = 0.325), with higher attractiveness ratings to faces with a happy than angry expression. The effects of head turn (F (1, 33) = 1.63, p = 0.21, η_p^2 = 0.047) and gaze direction (F (1, 33) = 0.038, p = 0.846, η_p^2 = 0.001) failed to reach statistical significance.

A significant interaction between gaze direction and expression was found (F (1, 33) = 5.67, p = 0.023). However, none of the pair-wise comparisons between averted and direct

gaze for either happy (F (1, 33) = 3.49, p = 0.071, η_p^2 = 0.096) or angry (F (1, 33) = 2.54, p = 0.12, η_p^2 = 0.071) expressions were significant following a post-hoc, simple effects analysis with Bonferroni correction.

No other two-way interactions between the independent variables reached statistical significance - head turn x expression (F (1, 33) = 2.9, p = 0.098, η_p^2 = 0.081); head turn x gaze direction (F (1, 33) = 0.972, p = 0.331, η_p^2 = 0.029); nor was there evidence for a three way interaction between head turn, gaze direction and facial expression (F (1, 33) = 0.108, p = 0.744, η_p^2 = 0.003)).

3.5.4 Discussion

An effect of facial expression on attractiveness ratings is consistent with that from Experiments 1 and 2a. In addition, as in Experiment 1, there was no evidence that head turn influenced perceived attractiveness of faces. However, the current experiment failed to replicate the interaction reported between head turn and facial expression in Experiment 1. Instead, an interaction between gaze direction and facial expression was found, although this effect was likely weak since none of the subsequent simple effects analyses reached statistical significance.

A second aim of the current experiment was to ascertain whether a stable gaze direction would render gaze information more salient compared to a gaze shift (as presented in Experiment 2a). There was no evidence to support the idea that a stable gaze direction influences attractiveness judgements during a change in head orientation. Attractiveness ratings did not differ across direct or averted gaze directions, although gaze direction may have modulated the effect of expression on perceived attractiveness. Indeed, facial expression seemed to be the main factor affecting the participants' perceived

attractiveness of the faces. A possible explanation for why gaze direction had a relatively weak effect on attractiveness judgements may be because in everyday situations, the allocation of social attention is often achieved by a gaze shift coupled with a congruent head turn. As such, it may be unusual for one to turn their head away from an observer while still fixating on them or to turn their head towards the observer whilst directing a stable gaze elsewhere in the scene (Pelisson, Prablanc, & Urquizar, 1988; Roy & Cullen, 1998). Indeed, some participants reported that the misalignment between the direction of head turns and gaze direction of the faces appeared strange. Therefore, it is worth noting that while it was possible to differentially manipulate gaze direction and head orientation in the current experiment, the ecological validity of the resulting presentation of faces may be reduced.

3.6. Experiment 3

3.6.1 Introduction

In Experiment 3, the relationship between the temporal dynamics of a shift in face view with an aligned eye- gaze (as in Experiment 1) on attractiveness judgements by changing the relative timing at which each face view was presented during a head turn. The results from Experiments 1 and 2 supported previous findings that facial attractiveness is influenced by facial expression, and that social attentional cues such as head turns (Experiment 1), the static orientation of the face (Experiment 2a) and gaze direction (Experiment 2b) modulated the effect of expression on attractiveness judgements. The interaction between facial expression and attentional cues is not surprising given that our day-to-day interactions typically rely on a combination of social cues to form a reliable percept of others' intentions and emotional states (Haxby, Hoffman, & Gobbini, 2002). Furthermore, in real life scenarios, such social cues are transient, and their temporal

properties may alter the observer's perception of their social meaning. For example, temporal differences in the duration in which an eye gaze is directed during a gaze shift can affect attractiveness judgements (Ho et al., 2018), such that a longer duration of direct than averted eye gaze is associated with higher attractiveness ratings of that face than vice versa (see also Kuzmanovic, Georgescu, Eickhoff, Shah, Bente, Fink, & Vogeley, 2009; Georgescu, Kuzmanovic, Schilbach, Tepest, Kulbida, Bente, & Vogeley, 2013). What is not clear, however, is whether such temporal effects are also found with relative differences in exposure to face views during a head turn. The direction in which a head turns may be a reliable signal of social attention when eye gaze is not perceivable, such as if the person is at a distance from the observer or if the eye region is obscured (by sunglasses or other shadings). Therefore, in this experiment, the relationship between the temporal dynamics of different face views during head turns and perceived attractiveness was explored. The eye gaze was always aligned with the orientation of the face. Specifically, the current experiment aimed to investigate whether a longer relative duration of exposure to the frontal view than 15° view of the face enhanced attractiveness ratings, as suggested by previous studies of direct eye gaze (Kuzmanovic et al., 2009; Georgescu et al., 2013).

3.6.2 Method

*Participant*s

Forty volunteers (27 female; mean age = 22.0 years, *SD* = 4.82) from the student population at Trinity College Dublin took part in this study. All were naïve to the purpose of the study (i.e. none took part in any of the previous experiments), were compensated with research credits or €5 for their participation. All gave informed, written consent prior to the experiment.

Stimuli and apparatus

The stimuli set and apparatus were the same as those described in Experiment 1. As such, eye gaze direction was aligned with the orientation of the face as the head turned towards or away from the observer.

Design and procedure

The experiment was based on a three-way, within-subject design with the direction of head turn (towards or away from the observer), facial expression (angry or happy) and relative duration of exposure to each face view as the main factors. Specifically, the exposure condition referred to the relative duration of the first face stimulus (S1) to the second face stimulus (S2) within each trial, based on the following exposure times: 300ms:1700ms or 1700ms:300ms. For example, during a head turn towards the observer, and exposure times of 300:1700ms, S1 is the 15° face view shown for 300ms followed by S2 which is the full-face view shown for 1700ms. The dependent variable was the attractiveness ratings. Each participant was presented with 128 trials in which each face was viewed four times, once under each of the four combinations of relative duration condition and direction of head turn. The same counterbalancing procedure of facial expression used in Experiment 1 was also adopted in the current experiment.

3.6.3 Results

Participants' mean attractiveness ratings for the different exposure times to each face view during head turns away or towards the observer, for each facial expression are shown in Figure 3.5. Again, participant sex was not included in the data analysis as female

and male participants did not differ significantly in the ratings they gave during the experiment (F (1, 38) = 0.59, p = 0.81).
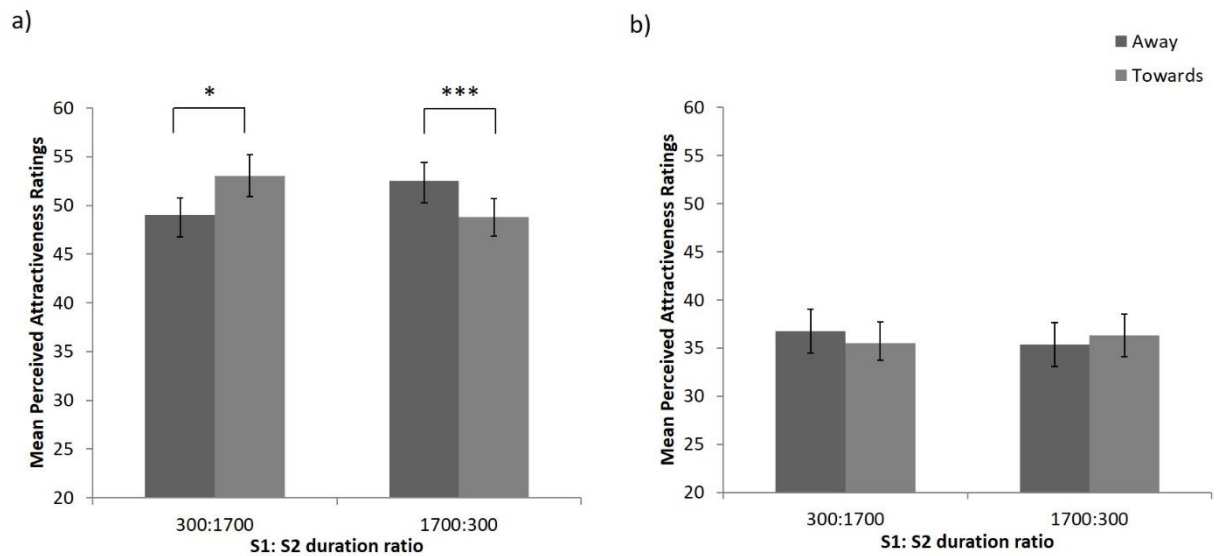
Figure 3.5 Plots depicting the interaction between head turns away or towards the observer, S1: S2 duration ratio for each of the associated face views during each head turn, and expressions on ratings of perceived attractiveness. Plot a) depicts the data for happy expressions of the faces and b) for angry expressions. Error bars represent ±1 standard error of the mean. [* $p < 0.05$; *** $p < 0.001$].

A three-way, repeated measure ANOVA was performed on the attractiveness ratings with the direction of head turn (towards or away), expression (angry or happy) and S1:S2 duration ratio (300:1700 and 1700:300) as within-subject factors. The results of the analysis revealed a significant main effect of expression (F (1, 39) = 24.8; p <0.0001, η_p^2 = 0.389), with happy rated as more attractive than an angry expression (mean difference = 14.88, SE = 2.99). No evidence for an effect of head turn (F (1, 39) = 0.003; p = 0.955) or S1:S2 duration ratio (F (1, 39) = 0.764; p = 0.387) was found. However, a significant interaction between head turn and S1:S2 duration ratio was found (F (1, 39) = 5.91; p = 0.02, η_p^2 = 0.132). The effect of facial expression did not interact with either head turn (F (1, 39) = 0.081; p = 0.777) nor S1:S2 duration ratio (F (1, 39) = 0.012; p = 0.913). A

significant three-way interaction between head turn, expression and S1:S2 duration ratio (F (1, 39) = 13.63; p = 0.001, η_p^2 = 0.259) was found (as shown in Figure 4).

Post-hoc simple effects analyses with Bonferroni correction were conducted on the 2-way interaction between head turn and exposure duration. First the effects of head turn for each exposure condition were examined. This analysis revealed that faces with a head turn away from the observer were rated as more attractive than head turns towards the observer in the 1700:300 condition only (F (1, 39) = 5.295; p = 0.027, η_p^2 = 0.12). Although there was a slight increase in ratings for head turns towards relative to those away from the observer in the 300:1700 condition, this difference failed to reach significance in the post-hoc analysis of the 2-way interaction (F (1, 39) = 3.125; p = 0.085). Second, the effects of relative exposure duration to face views during each direction of a head turn were examined. The results showed that faces with a head turn towards the observer received higher attractiveness ratings under the 300:1700 condition than the 1700:300 condition (F (1, 39) = 5.72; p = 0.022, η_p^2 = 0.128). The difference between exposure durations to different face views for a head turn away from the observer failed to reach significance (F (1, 39) = 2.56; p = 0.118). In sum, these results indicate that a longer duration of exposure to the front facing view, particularly during a head turn towards the observer, was associated with higher attractiveness ratings for the face presented.

The effect of facial expression did not interact with either head turn (F (1, 39) = 0.081; p = 0.777) nor S1:S2 duration ratio (F (1, 39) = 0.012; p = 0.913).

A significant three-way interaction between head turn, expression and S1:S2 duration ratio (F (1, 39) = 13.63; p = 0.001, η_p^2 = 0.259) was found. A post-hoc simple effects analyses on this interaction, with Bonferroni corrections, indicated that this interaction

was mainly due to the effects of head turn and exposure duration on faces with happy facial expressions (there were no effects of head turn or exposure duration on faces with angry expressions). The results of the post-hoc analyses on happy facial expressions only, showed that when the head turned towards the observer, attractiveness ratings were higher under the 300:1700 than the 1700:300ms duration condition (F (1, 39) = 11.679; $p = 0.001$, $\eta_p^2 = 0.23$). In other words, happy faces were perceived as more attractive when the head turned from an away orientation to face the observer and lingered in that facing orientation for longer. A similar effect was found with a head turn away from the observer where attractiveness ratings were higher under the 1700:300 condition, compared to the 300:1700 condition (F (1, 39) = 8.75; $p = 0.005$, $\eta_p^2 = 0.183$). In the 1700:300 condition, the head initially faces the observer and lingers in that orientation before facing away from the observer for a short time. Alternatively, the effect of head turn direction depended significantly on S1:S2 duration ratio. In the 300:1700 condition, faces with a head turn towards, rather than away from the observer were rated as more attractive (F (1, 39) = 7.1; $p = 0.011$, $\eta_p^2 = 0.154$); whereas in the 1700:300 condition, higher attractiveness ratings were given to those with a head turn away, rather than towards the observer (F (1, 39) = 15.47; $p < 0.00001$, $\eta_p^2 = 0.284$). In other words, for smiling faces, attractiveness ratings increased when the relative duration of exposure to the front facing view was longest, irrespective of whether the head turned away or towards the observer. Contrastingly for faces with an angry expression, head turn did not interact with S1:S2 duration ratio on attractiveness ratings (F (1, 39) = 2.346; $p = 0.134$).

3.6.4 Discussion

The goal of the current experiment was to investigate the role of the temporal dynamics across different face views during a head turn on the perceived attractiveness of

expressive faces. The results suggested that the temporal duration of a view of a face, and directional information of head turn combined to influence attractiveness judgements, but only when the faces were presented with a happy expression. Specifically, when a smiling face turned towards the observer, such that the full face was shown for longer, attractiveness ratings were higher than if the smiling face turned away from the observer. Furthermore, an advantage for the full-face view on attractiveness ratings was found even when the head turned away, provided the initial full-face view was shown for a long (i.e. 1700ms) than short (i.e. 300ms) duration. When the exposure times were reversed for this head turn (i.e. longer duration of the 15° than full-face view) then attractiveness ratings were lower.

The results yielded an interesting finding in that the influence of head turn and relative timing of each head orientation was modulated by facial expression. Although faces with an angry expression received lower attractiveness ratings overall, these ratings were not affected by the direction of the head turn nor the relative exposure time of the orientation of the face during the head turn. Rather, the combined effects of head turn and exposure time to each face orientation was specific to happy faces only. This finding of an advantage for happy facial expressions on attractiveness judgements is consistent with previous studies (Kuzmanovic, et al., 2009; Georgescu, et al., 2013) although it was expected that a head turn would influence attractiveness ratings for angry faces as it was found in Experiment 1. Note that in Experiment 1 the direction of the eye gaze was also aligned with the orientation of the face. This result suggests that the influences on attractiveness judgements of expressive faces may be sensitive to the changeable aspects of a face such the duration of exposure to each face view, the direction of head turns as well as the expression of the face itself.

3.7 General discussion

The current study examined the roles of head turn, gaze direction and facial expression on judgements of attractiveness using unfamiliar faces. In particular, the aim of the three experiments reported here was to assess whether these socially relevant cues affect judgements of attractiveness in a combined or independent manner (Experiments 1, 2a & 2b) and whether the temporal dynamics of the exposure of each face view during a head turn also modulates these effect of these cues (Experiment 3).

The findings confirmed the effects of these invariant facial properties on attractiveness and suggested at least some interactions between these social cues. First of all, a consistent effect of facial expression on attractiveness ratings was found in all experiments: consistent with the prediction made in this study, as well as findings from previous research (Lau, 1982; Mueser, et al., 1984; Reis, et al., 1990; Otta, et al., 1994; Otta, et al., 1996; Mehu, et al., 2008; Tracy, & Beall, 2011; Morrison, et al., 2013; Golle, et al., 2014; Ueda, et al., 2016; Ho, et al., 2018), results of the current study revealed that faces with an angry expression were rated as less attractive than those with a happy expression. Although the advantage of a happy expression on perceived attractiveness was consistent, this effect is known to be sensitive to variations in experimental paradigms and stimulus material (Mueser, et al., 1984; Morrison, et al., 2013; Ho, et al., 2018 For instance, Mueser, et al. (1984) reported that faces with a happy or neutral expression were preferred over those with a sad expression using a two-alternative-forced-choice (2AFC) task but facial expression had no effect when the task was a rating of individual face images. Similarly, Morrison, et al. (2013) argued that when a large variety of expressions are used in a study of attractiveness, this could also affect ratings compared to fewer expressions (Lau 1982; Mehu et al. 2008; Otta et al. 1994, 1996; Reis

et al. 1990). The current study used only the happy and angry facial expressions, as previous studies have reported these expressions as consistently and unambiguously rated as positive and negative, respectively, along the valence dimension (Ekman & Friesen, 1976; Neta, Davis, & Whalen, 2011). A consequence of testing only two expressions is that it is difficult to establish whether the effects of directional cues such as face view and gaze direction on attractiveness generalise to other facial expressions. In any case, given previous findings, the effect of facial expression on attractiveness ratings in the current study was not surprising.

Directional social cues such as face orientation and gaze direction alone generally did not have a strong effect on facial attractiveness. Extrapolating from the finding by Mason, et al. (2005) in which they argued for a role of dynamic social cues such as gaze shift on attractiveness, it was predicted that a head turn towards, rather than away from the observer would be rated as more attractive. However, the data from Experiments 1, 2b, and 3 showed that attractiveness ratings between the two head turn directions was modulated by other factors. An exception was found in experiment 2a in which the head did not turn during a trial and an overall advantage was found on attractiveness ratings for front facing views of faces than the 15° view.

The present finding for an advantage of the full-face view is in contrast with previous reports on the aesthetic evaluation of faces (Siéroff, 2001; Kaisler & Leder, 2017). It is possible that the processing fluency of the three-quarter view due to additional 3D information compared to the frontal or profile view (e.g. the protuberance of the nose without obscuring other facial features) gives rise to a general preference for the three-quarter view in those studies (Bruce, et al., 1987; Reber, Schwarz, & Winkielman, 2004; Kaisler & Leder, 2017). Though in the current study, the 15° head orientation might not have provided substantially more facial feature information than the frontal view,

compared to the 45° three-quarter view. Moreover, as Kaisler and Leder (2017) indicated, the three-quarter view advantage in facial attractiveness was probably due to the unlimited viewing time in their experiments and that it was sensitive to changes in the context in which the stimuli were presented. To assess the role of face view on attractiveness, contextual effects of stimulus duration were further explored in Experiment 3.

Adams and Kleck (2005) previously proposed that gaze direction and facial expression are social signals to approach or avoidance dispositions. As such, gaze directions and facial expressions that are congruent along the approach-avoidance dimension (e.g. smile and direct gaze, or sad expression and averted gaze) are processed more efficiently than when incongruent. This is referred to as the "shared signal hypothesis" (Adams & Kleck, 2005; Oosterhof, & Todorov, 2009; Rigato, Farroni, & Johnson, 2009; Benton, 2010; Milders, et al., 2011). Furthermore, Hess, Adams, and Kleck (2007) found that head orientation appeared to interact with facial expression in a similar manner, such that participants were more sensitive to the angry expression conveyed by faces directed towards them than those facing away, and a stronger feeling of repulsion was reported in response to averted faces displaying fear than direct faces. The current study also provides compelling evidence for an interaction between head view (both static orientation and dynamic head turn) and facial expression (Experiments 1, 2a, & 3) which is consistent with previous findings (Jones et al., 2006; Main, et al., 2010; Sutherland, et al., 2017). Specifically, happy faces were rated as more attractive when shown from a front face view, rather than the 15° view, or as a result of a head turn towards, rather than away from the observer. According to the 'shared signal' hypothesis proposed by Adams and Kleck, (2005), both the happy and angry expressions and the view of a face facing the observer, these cues signal approach-oriented dispositions from the perspective of the

observed face. In a similar vein, the "appraisal" hypothesis assumes that both happy and angry expressions, when shown from a front facing face orientation or when a head turn towards the observer, are behaviourally relevant to the observer, with a happy expression perceived as a cue to positive social engagement and an angry expression as a potential threat (Sander, et al., 2007; N'Diaye, et al., 2009). As such, both hypotheses predict heightened or prioritised processing of the corresponding combinations of face view and expression. Although attractiveness ratings for angry faces were significantly lower than those for happy faces, the experiments reported here did not consistently find evidence for preferred face views of difference expressions, since ratings for angry expressions they did not differ across face view and directions of head rotation. One possible explanation is that an angry facial expression may bias the perceived direction of a gaze as more towards the observer relative to a neutral expression (Ewbank, Jennings, & Calder, 2009). Moreover, in day-to-day social interactions between two persons, it is possible that anger may be more likely to be perceived as directed towards the observer, irrespective of whether the direction of the face or eyes is direct or averted. In contrast, the social reward associated with the happy expression may require cues that suggest the expression was directly relevant to the observer. Thus, the effect of facial expressions may reflect a more complicated pattern of real-life social interactions than what the 'shared signal' and 'appraisal' hypotheses propose. Moreover, the number of facial expressions tested in the current study was too limited for a conclusion to be drawn with certainty that the present findings definitively support or reject the 'shared signal' and 'appraisal' hypotheses. Future investigations may help elucidate the role of facial expressions, as encountered in everyday interactions, on attractiveness and how the influence of expression on eye gaze and face view may be affected by other contexts such as the number of persons in the social group.

In both Experiments 1 and 3, the direction of the eye gaze was aligned with the orientation of the face view. However, in Experiment 2a, the effect of gaze shift across different face views was examined. Contrary to previous findings, in which faces with direct gaze or gaze shift towards the observer were perceived as more attractive than those with averted gaze (Mason, et al., 2005; Ewing, et al., 2010; Kaisler & Leder, 2016); no evidence was found in the current study for an effect of gaze shift towards the observer for either the full or the 15° face view. As suggested based on the findings reported in Chapter 2 (Ho et al., 2018), it is possible that when eye gaze shifts are presented with other cues, that those other cues may dominate judgements of facial attractiveness. Indeed, the results from a study reported by Lassalle and Itier (2015) also provide support to this idea: they used gaze shift and expression change as a dynamic cue sequence in an attention orienting task. Maximal attention orienting was observed when a gaze shift preceded an expression change but facial expression did not modulate gaze orienting if it was presented in conjunction with or before a gaze shift. Furthermore, Ganel (2011) demonstrated that when head orientation varied between trials, the interaction between gaze and expression normally observed in a Garner interference task disappeared, implying that gaze and expression can be processed in a completely independent manner when additional information regarding head orientation was available. Taken together, the absence of interaction between expression and gaze in the current study supports the notion that integration of social cues is more flexible than obligatory.

Finally, the current study presented a novel finding that the temporal dynamics of exposure to different face views during a head turn can affect attractiveness ratings. In Experiment 3, by manipulating the timing of the exposure to the full-face or 15° view during a head turn, higher ratings of perceived attractiveness with an increase in the duration of exposure to the full-face view were found, regardless of the direction of head

turn. Again, the benefit of prolonged exposure to the front view of a face during a head turn was found for happy, but not angry facial expressions. This is consistent with previous findings in which the attractiveness or likeability of a face is enhanced by increased duration of a direct gaze which, when coupled with a happy expression, signals a prolonged social interest in the observer that is rewarding (Kuzmanovic, et al., 2009; Georgescu, et al., 2013; Ho, et al., 2018). The finding that neither face view nor gaze shifts modulate the effect of an angry expression on attractiveness, suggests that anger is associated with a potential threat regardless of direction and duration of head view and so such expressions are less likely to be preferred.

There are a few limitations of the current study. First of all, only two facial expressions were used in the experiments. Therefore, it is hard to establish whether the effects of directional cues such as head view and gaze direction on attractiveness generalise to other facial expressions such as sadness and fear too. For the same reason, the current study cannot definitively support or reject the shared signal and appraisal hypotheses. It would be interesting for future research to explore the effects of other gaze/head orientation-expression combinations which resemble real-life social interactions more comprehensively. Furthermore, the current study and the study reported in Chapter 2 have begun an exploration into the effect of temporal dynamics of non-verbal social cues on attractiveness judgements which can be advanced by introducing more systematic manipulations of the temporal properties of gaze shift, head turn and expression.

3.8 Conclusion

In summary, the current study, together with the study reported in Chapter 2 (Ho et al., 2018) represents a novel exploration into the effect of temporal dynamics of non-verbal

social cues on attractiveness judgements of faces. These studies can be further advanced by introducing more systematic manipulations of the temporal properties of gaze shift, head turn and expression, ideally in more realistic social settings than the passive observation of unfamiliar face images. In any case, the current study provides evidence that facial attractiveness appeared to be determined by the amount of social attention and positive affect directed towards the observer. The present findings also suggest that certain integration of facial expressions and directional cues might signal more nuanced social significance beyond the approach-avoidance dimension.

Chapter 4

The role of perceptual categorisation on serial dependence in judgements of attractiveness

4 The role of perceptual categorisation on serial dependence in judgements of attractiveness

4.1. Abstract

Serial dependence refers to an assimilative pull on the judgement response to a current stimulus from the response given to the preceding stimulus. This effect has been demonstrated using low-level perceptual judgments as well as higher-level judgements such as facial attractiveness. Although serial dependence is not due to a response bias, it is unclear whether the effect is limited by perceptual category organisation. To test this, serial dependence in within-category judgements of attractiveness using images of faces (male and female; Experiment 1), images of scenes (outdoor and indoor scenes of buildings; Experiment 2) and cross-category judgements (faces and scenes; Experiment 3) was measured. Evidence for serial dependence was found in all experiments involving within-category judgements, which generally weakened in subsequent trials. Interestingly, this effect was stronger to consecutive trials of same-sex than different-sex faces for attractiveness judgements in Experiment 1, but there was no difference in the effect between consecutive trials of same- and different-scene types in Experiment 2. The results of Experiment 3 confirmed that serial dependency is affected by perceptual categorisation, as the effect was weakened by consecutive trials from different, rather than similar categories. A serial contrast effect was also evident in which a stimulus was rated as less attractive when preceded by an attractive one of a different category. Collectively, these findings suggest that the temporal integration of aesthetic appraisal is confined to the context of object categories, with each requiring distinct evaluation processes, and provide insight into the categorical nature of attractiveness judgements.

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4.2. Background

One of the major challenges presented to our visual system is to maintain a stable and unified percept of the environment despite the constant fluctuations in visual inputs caused by changes in lighting, eye and head movements, occlusions, and visual noise. An efficient way to counteract these disruptions is to assume continuity in the visual environment not only spatially (Srinivasan, Laughlin, & Dubs, 1982; Field, 1987), but also temporally, by incorporating information from recent perceptual history in the computation of a current percept. The behavioural manifestation of such temporal computation is serial dependence, which has been well documented across a wide range of tasks from judgements of orientation (Fischer & Whitney, 2014; John-Saaltink, Kok, Lau, & de Lange, 2016; Fritsche, Mostert, & de Lange; 2017; Cicchini, Mikellidou, & Burr, 2017), motion direction (Alais, Leung, & Van der Burg, 2017), spatial position (Manassi, Liberman, Kosovicheva, Zhang, & Whitney, 2018) and numerosity (Cicchini, Anobile, & Burr, 2014). Furthermore, serial dependency has been demonstrated with more complex stimuli that involve global, holistic processing such as object identity (Liberman, Zhang, & Whitney, 2016), scene perception (Manassi, Liberman, Chaney, & Whitney, 2017), visual variance (Suárez-Pinilla, Seth, & Roseboom, 2018) and face perception (Liberman, Fischer, & Whitney, 2014).

A number of other phenomena have also been observed in perceptual experiments whereby the current response is affected by the processing of the preceding stimulus, such as priming, adaptation, as well as later effects that result in a response bias. Although these phenomena might be associated with serial dependence, they are distinct effects. A number of studies have been conducted in order to disentangle serial dependence from these other perceptual phenomena. For instance, adaptation due to repetitive stimulation

is typically known to bias a percept away from the adapted stimulus, resulting in the well-documented negative after-effect (Gibson & Radner, 1937; Campbell & Maffei, 1971; Knapen, Rolfs, Wexler, & Cavanagh, 2010). Several studies have provided evidence that adaptation effects can occur in conjunction serial dependence although the latter has the opposite, positive effect (Fischer & Whitney, 2014; Alais, et al., 2017; Cicchini , et al., 2017; Suárex-Pinilla, et al., 2018). Serial dependence also differs from adaptation and negative aftereffects in other ways apart from the direction of influence. For example, unlike adaptation, the strength of serial dependence can be modulated by attention and successive stimuli do not have to be presented at the same retinal location or spatial scale for serial dependence to occur suggesting that serial dependence is not due to retinotopic adaptation (Fischer & Whitney, 2014; Liberman, et al., 2014). Indeed, broad spatial tuning in serial dependence has been reported such that the strength of serial dependence was similar when the current and the preceding stimuli were presented at different, but nearby spatial locations, although the effect decreased as that distance further increased (Fischer & Whitney, 2014; Fritsche, et al., 2017). Priming, on the other hand, is generally reflected in speeded response times or improved discriminability of a target stimulus, provided the target shared similar features to a previously presented item (prime) resulting in increased sensitivity to those shared features (Tulving & Schacter, 1990; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003; Kristjánsson & Campana, 2010). In contrast, serial dependence seems to be more associated with an altered percept. Finally, some studies report positive serial dependence under the conditions in which participants were not required to produce a motor response (Fischer & Whitney, 2014; Xia, Leib, & Whitney, 2016), thus challenging the idea that the effect is underpinned by response bias.

The locus of information processing at which serial dependence operates, particularly whether or not serial dependence acts directly on perception or at later cognitive stages, remains an ongoing debate (Cicchini, & Kristjánsson, 2015; Bliss, Sun, & D'Esposito, 2017; Cicchini, et al., 2017; Fritsche, et al., 2017). On the one hand, some researchers have argued that serial dependence occurs early and is a perceptual phenomenon. For example, in their seminal study on orientation perception, Fischer and Whitney (2014) proposed the concept of a 'continuity field' as a mechanism through which the visual system utilizes information from both the recent past and the present to construct a stable percept. They demonstrated that the perceived orientation of the current stimulus was systematically attracted towards recently viewed orientations (Fischer & Whitney, 2014), contrary to a negative aftereffect commonly found in orientation discrimination tasks. Furthermore, this serial dependence effect occurred even in the absence of a motor response or recall of the preceding stimulus, suggesting that serial dependence cannot be explained by a response bias nor retained representations of previous stimuli, but an alteration in the perception of the current stimulus (Fischer & Whitney, 2014). On the other hand, it has been argued that serial dependence is post-perceptual and associated with subsequent decisional process and working memory (Fritsche, et al., 2017; Bliss, et al., 2017). In particular, Fritsche, et al. (2017) investigated serial dependence also using orientation judgement task in which participants were asked to reproduce the orientation of a stimulus presented a moment ago. They found that while the perceptual decision, in terms of orientation adjustment responses, were biased towards the orientation of the previously viewed stimulus, a change in task to a comparison of the orientation of stimulus pairs, one of which was preceded by an inducer of a particular orientation at the same location, showed that the perception of orientation was found to be biased away from the preceding stimulus. In this case, the perceptual bias exerted by the inducer can

be directly examined and the memorisation of its orientation was not necessary. Furthermore, Fritsche, et al. (2017) reported that the positive decisional bias in adjustment responses grew in magnitude as the response delay (hence the retention of previous representation) was increased, which, as the authors argued, indicated that the positive serial dependence arose as a result of a shift in working memory towards the preceding stimulus (Fritsche, et al., 2017). Both hypotheses have been supported by evidence from subsequent studies on perceptual processing (Cicchini, et al., 2017; 2018; Fornaciai, & Park, 2018; van Bergen & Jehee, 2019) and mnemonics (Bliss, et al., 2017; Czoschke, Fishcer, Beitner, Kaiser, & Bledowski, 2019). Others have argued that serial dependence may be a multi-level phenomenon which operates across the perceptual, attentional and mnemonic levels and serves a generally adaptive purpose to promote the stability of perceptual information from one moment to the next (Kiyonaga, Scimeca, Bliss, & Whitney, 2017).

Serial dependence has been reported in tasks which involve more complex stimuli and judgements. For example, in face perception, serial dependence effects has been reported for both changeable properties of a face, such as eye gaze (Alais, Kong, Palmer, & Clifford, 2018) and facial expression (Liberman, Manassi, & Whitney, 2018) as well as perception of invariant features of a face for the purpose of recognition (Liberman, et al., 2014), perception of the sex of the face (Taubert, Alais, & Burr, 2016) and facial attractiveness (Kondo, Takahashi, & Watanabe, 2012, 2013; Kramer, Jones, & Sharma, 2013; Taubert, Van der Burg, & Alais, 2016; Taubert & Alais, 2016; Xia, et al., 2016). These reports have typically found that judgments of any of these attributes of a face are biased towards those of a face previously presented in recent perceptual history. Moreover, there is some evidence to suggest that these properties of faces can have an inter-dependent effect on the magnitude of serial dependence. For instance, the effect of

serial dependence found on responses to facial expression can be modulated by facial similarity in terms of identity resemblance across successive trials of face stimuli (Liberman, et al., 2018). Furthermore, serial dependence in facial attractiveness judgements appears to be dependent on the perceptual similarity of the faces presented in the current and the preceding trials, although changes in viewpoint across the faces can disrupt the effect (Taubert & Alais, 2016). Moreover, attractiveness ratings to a face was affected by judgements to the preceding face if the two faces were of the same race but was disrupted if the faces were of different races (Kramer et al., 2013) or different sexes (Kondo, et al., 2013; Kramer, et al., 2013). However, the results reported regarding the sequential effects on judgements of attractiveness have not been consistent (Kenrick & Gutierres, 1980; Wedell, Parducci, & Geiselman, 1987; Cogan, Parker, & Zellner, 2013; Pegors, Mattar, Bryan, & Epstein, 2015). For example, both Kenrick & Gutierres (1980) and Wedell, et al. (1987) reported a repulsive effect in attractiveness judgements in which faces were judged as less attractive if preceded by relatively more attractive faces. And Cogan, et al. (2013) found that the average attractiveness ratings given to a group of moderately unattractive faces decreased further if they were preceded by some moderately more attractive faces, indicating a contrast effect in attractive judgement. However, this repulsive effect may be attributed to the long response latency used, in contrast to more recent studies on serial dependence which focused on trial by trial responses to singly presented stimuli within short inter-trial latency (Kondo et al., 2012, 2013; Kramer, et al., 2012; Taubert & Alais, 2016; Xia, et al., 2016). Pegors, et al. (2015) devised a novel paradigm whereby participants rated hair darkness and attractiveness of faces on alternating trials, in order to disentangle the response bias from the sequential effect in attractiveness judgements. Their findings showed that while the attractiveness rating given to the current face was biased towards the rating (which was a rating on hair

colour) provided in the previous trial, this attractiveness judgement was in fact biased away from the mean attractiveness of the previous face, indicating a positive response bias in rating responses and a serial contrast effect on perceived attractiveness respectively. Nonetheless, the relatively long stimulus presentation (1s to 4s, and greater contrast effect was found with longer presentation duration) in Pegors, et al.'s (2015) study compared to other studies on serial dependence (300ms in Taubert, et al., 2016; Taubert & Alais, 2016; 1s in Xia, et al., 2016) might explain the contradictory results as longer exposure may be more likely to elicit a negative perceptual aftereffect.

Building on previous work described above, the goal of the current study was two-fold. Firstly, while serial dependence in facial attractiveness has been reported in a number of studies (Kondo et al., 2012,2013; Kramer, et al., 2012; Taubert & Alais, 2016; Xia, et al., 2016), it remains unclear whether such assimilative effects can be found in aesthetic evaluations in other domains. Furthermore, if the sequential items vary substantially in visual similarity but the evaluation processes and criteria can be very similar, it is unclear if serial dependency would be affected. Secondly, if serial dependence can be found in aesthetic evaluations in general, the question arises as to whether it is sensitive to changes in category memberships from trial to trial. The following three experiments were conducted to investigate serial dependence in attractiveness ratings of faces and scenes, and to measure the effect of domain and category memberships on the strength of serial assimilation.

4.3. Experiment 1

4.3.1 Introduction

Recent studies have shown that rating of attractiveness of a face was influenced by the attractiveness rating provided to a recently viewed face, an effect known as serial

dependence (Kondo, et al., 2012, 2013; Kramer, et al., 2013; Taubert & Alais, 2016; Xia, et al., 2016). However, a serial contrast effect has also been reported in ratings of attractiveness, especially during longer duration of stimulus presentation. In this case, faces were rated as less attractive when preceded by a relatively more attractive face, and vice versa (Cogan, et al., 2013; Pegors et al., 2015). The aim of the current experiment was to first establish the effect of serial dependence on judgements of facial attractiveness, using a rapid presentation paradigm similar to Taubert & Alais's study (2016). Their design suggested that a negative aftereffect could be prevented due to prolonged stimulus duration. To that end, the current experiment consisted of two parts, first, faces of the two sexes were tested for serial dependence separately such that within each block, all the trials presented faces of the same sex. Then, in the second part, both male and female faces were mixed within each block. Previously, studies have reported that a serial dependence effect on facial attractiveness decreased when consecutive stimuli differed in category memberships such as race and sex (Kondo, et al., 2013; Kramer, et al., 2013). Therefore, it was expected that the attractiveness rating in a given trial would be biased towards that in the previous trial to a greater extend when the faces presented in the two trials were of the same sex, compared to when they were different. Conversely, an assimilative bias of equal magnitude would be present regardless of the sex difference between faces in consecutive trials if it was merely due to a response bias.

4.3.2 Method

Participants

Twenty-six volunteers (18 females; mean age = 21 years, *SD* = 5.75) from the student population at Trinity College Dublin, Ireland participated in Experiments 1 and 2 of this study, which took place over four separate sessions at least 7 days apart. The two parts of

the current experiment (i.e. the same-sex blocks and the mixed-sex blocks) also took places in separate sessions. Although the two parts are preferred to Part 1 and Part 2 in this report, the order of the two parts were counterbalanced such that half of the participants completed Part 1 first and the rest completed Part 2 first. The order of experiments was also counterbalanced across sessions. All participants were naïve to the purpose of the study and were compensated with research credits for their participation. The study (and all experiments reported here) received ethical approval from the School of Psychology Research Ethics Committee at Trinity College Dublin. In accordance with this approval, all participants gave informed, written consent prior to conducting the experiment.

Stimuli and apparatus

The face stimuli used in Experiment 1 consisted of sixty photographic images of Caucasian faces (30 female, 30 male) with neutral expressions and direct gaze, obtained from the Chicago Face Database (Ma, et al., 2015). Since female faces tend to receive higher attractiveness ratings than male faces in experimental settings (Kondo, et al., 2013; Kramer, et al., 2013) and also taking into consideration the precaution suggested in Taubert & Alais (2016) to avoid skewing the results by limiting the direction of the subsequent response, faces that were not exceptionally unattractive or attractive according to the normative data provided by the Chicago database were selected. From those data, the mean attractiveness ratings (in 7-point Likert scale) associated with the selected female and male faces in this Experiment were 3.47, $SD = 0.214$ and 3.42, $SD = 0.229$, respectively.

For the purpose of this study, the images from the database were further edited to remove the hair and ear information by superimposing an oval mask onto the original image. All images were resized to 780 (width) x 1062 (height) pixels. With the participant seated at a viewing distance of 57 cm from the computer monitor, these subtended to approximately 17° by 23° in degrees of visual angle in the horizontal and vertical dimensions respectively. To minimize the potential influence of local adaption, face images were not presented from the same location in consecutive trials. As such, within any one trial, a face image appeared at one of the eight screen locations such that the centre of the image aligned with either the vertical, horizontal, or diagonal meridian. Furthermore, each image was presented 5° degrees in visual angle from the centre of the screen.

The experiment was programmed using PsychoPy (2019) and run on an Alienware AURORA R4 desktop computer with the stimuli presented on a 60cm x 34cm LCD monitor with the resolution of 2560 x 1440 pixels at 75 Hz.

Design

A within-subject, fully factorial design was adopted with serial dependence and sex of the face (female, male) as independent variables and the attractiveness ratings as the dependent variable.

For part one, each participant completed 240 trials, divided into 8 blocks of 30 trials. The order of the trials within each block was randomised. All the faces presented within the same block were of the same sex. Therefore, 4 blocks consisted of female faces only and the other 4 consisted of male faces only. The order of these blocks was counterbalanced. In other words, half of the participants started the experiment with a block of trials in

which female faces were presented, while the other participants started with a block of trials of male faces. In all subsequent blocks, the sex of the face shown was alternated. Each of the 60 face identities was rated 4 times by each participant. No single face identity was presented more than once within the same block.

For part two, the total number of trials was also 240 and the trials were also divided into 8 blocks of 30 trials. However, within each block, female faces were presented in half of the trials and male faces were presented in the other half of the trials. The order of the trials was randomised such that the face presented in any given trials could be of the same or different sexes from that in the preceding trial. The 15 female and 15 male faces that made up a block of 30 trials were selected randomly from the 60 face identities used in Part 1. Again, each of the 60 face identities was rated 4 times by each participant. No single face identity was presented more than once within the same block.

Procedure

The experiment took place in a darkened testing room in the Institute of Neuroscience, Trinity College Dublin. After giving informed written consent, participants were seated at 57 cm from the LCD monitor and given the instructions for the experiment. A single practice trial was performed to allow the participants to become familiar with the trial structure. A trial began with the presentation of a white fixation cross in the centre of a grey background, which stayed visible for 500 ms. Then, a face stimulus appeared for 300 ms. Immediately after the stimulus presentation, a sliding scale, which ranged from 0 to 100 (0 = very unattractive; 100 = very attractive), appeared at the centre of the screen and participants were asked to rate the face they just saw based on its perceived attractiveness. Participants used the mouse to control an indicator on sliding scale to give

their ratings to each presented face. They were advised to respond as quickly as possible and to utilise the whole scale. A trial was completed when participants confirmed the rating by clicking the box labelled 'Confirm rating', which appeared when the indicator on the sliding scale had been moved.

4.3.3 Results

In the data analysis of this experiment (and those of subsequent experiments), degrees of freedom were corrected using the Green-Geisser method whenever the assumption of sphericity was violated. Effect sizes were reported in terms of partial eta squared (ηp^2) for the main effects of each independent variable and their interaction(s) and Cohen's d for mean differences, respectively. The data of Part 1 of the experiment (with the same-sex blocks) were analysed separately from those of Part 2 (the mixed-sex blocks).

Part 1:

In order to quantify serial dependence, the calculation method used in Taubert & Alais (2016) was adopted. Data from the blocks of male and female face images were processed separately. First of all, for each participant, the median attractiveness ratings of male and female faces and the average attractiveness ratings for each of the 60 face images were calculated. Then, the rating response of a given trial [t] was binned into one of the two conditions depending on whether the average attractiveness rating of the face presented in the previous trial [t − 1] was higher or lower than the corresponding median rating across the block of trials (i.e. separately for male or female face categories). The difference between the average ratings of the two trial conditions (i.e. [t-1] > median and [t-1] < median) was the serial dependence, [t − 1] effect.

The mean attractiveness ratings as a function of the sex category of the face images (male or female) in are shown in Figure 4.1. A 2x2-repeated measure ANOVA was conducted with the sex category of the face (male or female) and the [t − 1] condition as the within-subject factors. The results of this analysis revealed a main effect of serial dependence (F (1, 25) = 14.6, p = 0.001, η_p^2 = 0.369). Participants rated faces as more attractive when they were preceded by a face which had a higher-than-median rather than lower-than-median attractiveness rating. The main effect of the sex category of the face did not reach statistical significance (F (1, 25) = 3.82, p = 0.062, η_p^2 = 0.133), therefore the perceived attractiveness of the female and male faces in this experiment were similar. There is no interaction between the sex of the face and serial dependence (F (1, 25) = 0.134, p = 0.717, η_p^2 = 0.005).
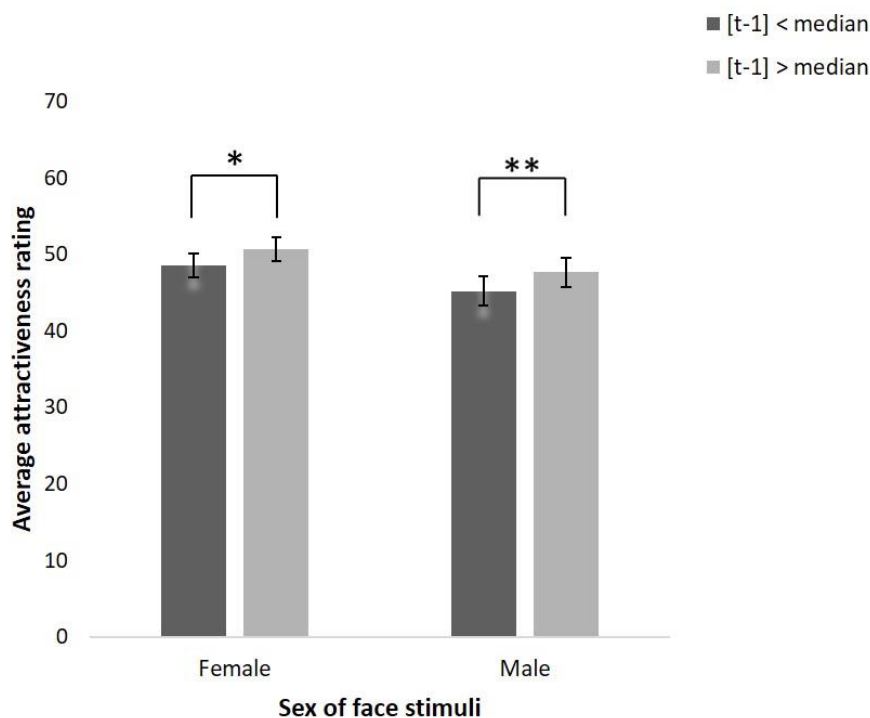
Figure 4.1 Plot showing the mean attractiveness ratings as a function of the sex category of the face images (male or female) in Experiment 1, Part 1. Error bars represent ± 1 standard error of the mean. [*p<0.05; ** p <0.01]

To determine whether the serial dependence effect sustained beyond one trial, the $[t - 2]$ and $[t - 3]$ effects were calculated using the same method above except the binning of ratings depended on whether the average attractiveness of the face presented two trials or three trials back from the face in the current trial $[t]$ was larger or smaller than the median rating correspondingly. The binned data were analysed using separate 2x2 repeated measure ANOVAs as described above, for each trial position. For both analyses, neither of the $[t - 2]$ nor $[t - 3]$ main effects of serial dependence were significant ($[t-2]$: F (1, 25) = 0.109, p = 0.744, η_p^2 = 0.004; $[t-3]$: F (1, 25) = 1.271, p = 0.27, η_p^2 = 0.048). The sex category of the face had no effect on attractiveness ratings ($[t-2]$ analysis: F (1, 25) = 3.24, p = 0.084, η_p^2 = 0.115; $[t-3]$ analysis: F (1, 25) = 3.217, p = 0.085, η_p^2 = 0.114). Finally, neither of the $[t - 2]$ nor $[t - 3]$ serial position interacted with the sex category of the face ($[t-2]$ by sex: F (1, 25) = 0.008, p = 0.929, η_p^2 < 0.0001; $[t-3]$ by sex: F (1, 25) = 0.474, p = 0.497, η_p^2 = 0.019).

Part 2:

Prior to the main analysis, the average attractiveness ratings for each face identity given by all participants were calculated and the average attractiveness ratings of male and female faces were compared. Results of paired samples t-test showed the attractiveness ratings given to male and female faces did not differ significantly (male: M = 47.4, SD = 9.03; female: M = 49.8, SD = 8.17; t (25) = 3.43, p = 0.12, Cohen's d = 0.279). As a result, for each participant, only one median rating (instead of one for female and one for male faces) was calculated. Importantly, the sex difference in faces between the current trial and the previous trial (and up to preceding three trials) rather than sex of the face (i.e. female, male) per se was included in subsequent analyses.

The [t – 1] effect:

The data were then processed in the same manner as in Part 1 where each rating was binned into the two [t-1] conditions (i.e. [t-1]>median, [t-1] <median). In order to find out whether the [t-1] serial dependence effect depended on if the faces presented in the previous trial and the current trial were of the same sex, the response ratings were further binned accordingly. The mean attractiveness ratings to each of the face categories (same, different) are shown in Figure 4.2. A 2x2-repeated measure ANOVA was conducted with the [t-1] condition and sex of the face (not female or male; but same sex of face category or different sex of face category) as the within-subject factors. Results of the analysis revealed a main effect of serial dependence [$F (1, 25) = 23.05$, $p < 0.0001$, $\eta_p^2 = 0.48$]. Faces were rated as more attractive when the preceding face had a higher-than-median, rather than lower-than-median, average attractiveness rating. The main effect of face category (same or different sex) between consecutive trials on attractiveness did not reach statistical significance ($F (1, 25) = 3.33$, $p = 0.08$, $\eta_p^2 = 0.118$). However, there was a significant interaction between t-1 serial dependence and face category ($F (1, 25) = 9.67$, $p = 0.005$, $\eta_p^2 = 0.279$) as shown in Figure 4.3. Post-hoc pairwise comparisons (with Bonferroni correction) revealed the serial dependence effect was significant only for consecutive trials where consecutive faces were of the same sex (mean difference = 5.25, $p < 0.0001$) but not when they were of different sexes (mean difference = 0.702, $p = 0.533$).
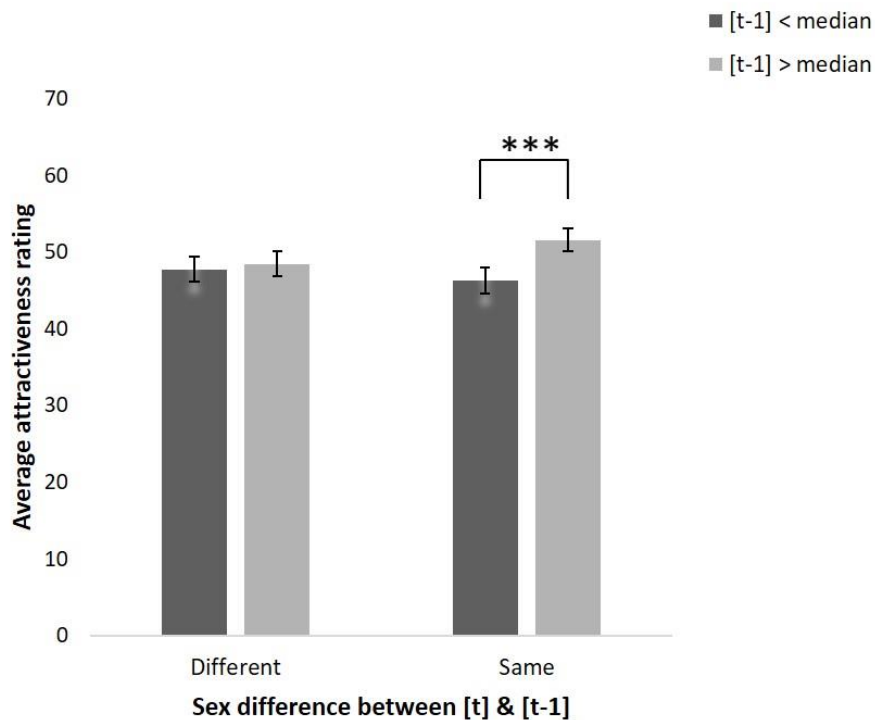
Figure 4.2 Plot showing the mean attractiveness ratings as a function of sex difference between the faces in current [t] and previous [t − 1] trials in Experiment 1, Part 2. Error bars represent ± 1 standard error of the mean. [*** p <0.001]

The [t − 2] effect:

The same analysis was repeated for the [t − 2] effect. The main effect of [t-2] serial dependence was not significant (F (1, 25) = 1.735, p = 0.2, η_p^2 = 0.065). Face category (same or different) again had no effect on attractiveness ratings (F (1, 25) = 0.505, p = 0.484, η_p^2 = 0.02). The interaction between the [t − 2] serial dependence and face category was significant (F (1, 25) = 10.69, p = 0.003, η_p^2 = 0.3). Post-hoc pairwise comparisons (with Bonferroni correction) indicated the [t − 2] effect was significant only for trials in which the sex of the face was the same as the face shown in the second previous trial [t − 2] (mean difference = 2.72, p = 0.03) but not when the sex of the face differed between these trials (mean difference = -1.49, p = 0.064).

The effect of [t – 1] on the [t – 2] serial dependence:

The [t-2] trials in which the sex of the face did not change, and in which a significant serial dependence effect was found (average number of trials = 112, *SD* = 10.7), included two variants of trial sequence. One was that the intermediatory trial [t-1] included a face image that was of different sex from that shown in the current [t] trial and the [t – 2] trials. The second version was that the sex of the face remained the same in all three consecutive trials, t-2, t-1 and t[6]. The results of a paired-samples t-test showed that the magnitude of the [t – 2] effect did not differ between the two trial sequences (mean difference = 0.356, *t* (25) = 0.337, *p* = 0.739, Cohen's *d* = 0.0672).

The [t – 3] effect:

The [t – 3] serial dependence was also calculated and analysed. The main effect of [t – 3] serial dependence did not reach statistical significance (*F* (1, 25) = 0.037, *p* = 0.848, η_p^2 = 0.001) and neither did the effect of the face category between the current and the [t – 3] trials (*F* (1, 25) = 0.002, *p* = 0.967, η_p^2 < 0.0001). However, there was an interaction between [t – 3] serial dependence and face category (*F* (1, 25) = 8.564, *p* = 0.007, η_p^2 = 0.255). Post-hoc pairwise comparisons (with Bonferroni correction) showed that the [t – 3] serial dependence effect was significant when the sex of the face presented in the current trial was the same as that presented in the [t – 3] trial (mean difference = 1.899, *p* = 0.012). Conversely, when the sex of the faces differed between the current and [t – 3] trials, the serial dependence effect was also significant but in the opposite direction

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[6] The average number of trials following the two sequences 'same-different-same' and 'same-same-same' were 59.4 (*SD* = 10.2) and 52.7 (*SD* = 7.16) respectively.

(mean difference = -2.06, $p = 0.028$), hence a contrast, rather than assimilative effect was observed.

The effect of [t – 1] on the [t – 3] effects:

The results of two paired-samples t-test showed the sex difference between [t] and [t – 1] had no significant effect on the magnitudes of the [t – 3] serial dependence (mean difference = 1.32, $t(25) = 1.14$, $p = 0.264$, Cohen's $d = 0.291$) and serial contrast effects (mean difference = 2.18, $t(25) = 1.14$, $p = 0.084$, Cohen's $d = 0.39$) respectively.

The strength of serial dependence beyond [t – 1]

Finally, the magnitudes of the [t – 1], [t – 2] and [t – 3] effects found in the respective trials in which the faces shown were from the same sex category (i.e. where the faces in [t] were sex-matched with those in [t-1] for the [t-1] effect, [t] faces matched those in [t-2] for the [t-2] effect, and [t] faces matched those in [t-3] for the [t-3] effect) were compared, three paired-samples t-tests were performed (Figure 4.3). The results showed that the [t – 1] effect was significantly larger than either the [t – 2] (mean difference = 2.53, $t(25) = 3.28$, $p = 0.003$, Cohen's $d = 0.619$) or [t – 3] effects (mean difference = 3.35, $t(25) = 4.60$, $p < 0.0001$, Cohen's $d = 0.888$). The magnitudes of the [t – 2] and [t – 3] effects did not differ significantly (mean difference = 0.825, $t(25) = 0.913$, $p = 0.37$, Cohen's $d = 0.211$).
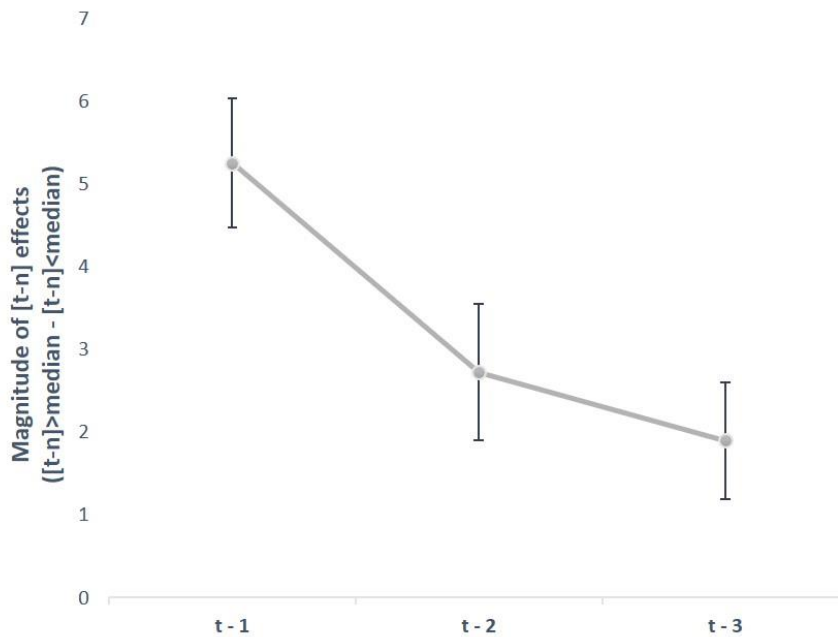
Figure 4.3 Plot showing the magnitudes of the serial dependence effect across [t – n] for trials in which the same category of the sex of the face was presented in Experiment 1b.

4.3.4 Discussion

The findings from Experiment 1 were consistent with those of previous studies (Kondo, et al., 2012, 2013; Kramer, et al., 2013; Taubert & Alais, 2016; Xia, et al., 2016) in which the perceived attractiveness of the current face stimulus was biased towards the attractiveness of the face viewed in the previous trial. This effect was found to be prominent for both female and male faces. The sex category of faces did not have an effect on overall attractiveness ratings, which is not surprising given that the selected face stimuli were matched according to pre-test ratings of attractiveness available on the Chicago face database. In contrast to the [t-1] effect, the [t – 2] and [t – 3] effects did not reach statistical significance in the current experiment, suggesting that the influence on attractiveness ratings by previous trials was transient and by immediately preceding trial only. This finding is somewhat in contrast with previous studies on serial dependence

which found that the response given to a stimulus in the current trial was affected by stimuli viewed up to 12 seconds prior to the present stimulus (Taubert & Alais, 2016; Taubert & Alais, 2016; Liberman, et al., 2018; Suárez-Pinilla, et al., 2018). In other words, depending on the stimulus duration and participants' reaction time, the response score provided in any given trial could be affected by a stimulus presented a number of trials back. Moreover, the presence of a [t – 2] (and [t – 3], etc.) effect would suggest a serial dependence effect which cannot be explained by either motor or cognitive response bias (Taubert & Alais, 2016). The average reaction time of the participants in the current experiment was 2.47 seconds (SD = 1.18 s), which was well within the time range whereby a [t – 2] serial dependence was possible. It is not clear why our results suggest a limited effect of serial dependency on attractiveness judgements of faces, given that others have reported longer-lasting effects. Indeed, the results to the within-category judgements of faces fail to rule out a distinction between the effects of serial dependence or of a response bias.

A [t – 1] effect was found also in Part 2 of the experiment in which the trials consisted of a mix of female and male faces. The attractiveness ratings provided during a given trial were biased towards those provided in the previous trial. However, this effect was significant only in trials where the current face stimulus and the preceding face stimulus belonged to the same category of the sex of the face. This result is consistent with, and replicates, previous findings (Kondo, et al., 2013; Kramer, et al., 2013) which showed that the serial dependence effect was weakened if the faces presented in consecutive trials differed in sex. Furthermore, significant, but weaker [t – 2] and [t – 3] serial dependence effects were also found, but only in trials where the sex of faces in [t] was the same as that in [t – 2] and [t – 3] respectively.

It is not clear why the serial dependency effect was more robust to trial position when the sex of the face was unchanged but presented in a mixed block of trials, than when presented in a block of trials in which the sex category of the faces was unchanged. One possibility is that the differences in results are due to a shorter average reaction time of participants to the mixed blocks of trials ($M = 1.97$, $SD = 0.59$) compared to those for the within-category blocks of trials[7], which may have allowed for serial dependence to be observable beyond [t – 1]. It was also apparent that the serial effect was not unidirectional, as there was a significant [t – 3] contrast effect in trials where the sex of the face differed from that three trials back. This weakening of serial dependence and the emergence of contrast effects from faces presented further in trial history has been previously reported by Suárez-Pinilla, et al. (2018). According to their findings, both serial dependence and serial contrast could be induced by the same stimuli within difference time frames, with dependence driven by more recent exposures and a longer-lasting contrast effect manifesting as the assimilative bias is reduced with time.

Consistent with previous studies, (Kramer et al., 2013; Taubert & Alais, 2016; Taubert et al., 2016), the effects observed in Experiment 1 suggest that serial dependence operated at a perceptual level and cannot be explained by a response bias. However, findings of the current experiment did not differentiate between a serial dependence effect due to visual similarities among faces from within the same sex category or higher-level category membership which might affect the underlying criteria through which attractiveness of female and male faces was respectively judged. The remaining experiments aimed to disentangle the two by investigating serial dependence in aesthetic judgements of scenes of built environments.

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[7] Results of paired-samples t-test on the average reaction times observed in Experiments 1a and 1b: t (25) = 0.499, p = 0.021, Cohen's d = 0.536.

4.4. Experiment 2

4.4.1 Introduction

Having established serial dependence in facial attractiveness, the aim of the current experiment was twofold. The first objective was to test for serial dependence in aesthetic judgements of architectural spaces. Unlike faces, which possesses relatively similar visual properties (e.g. the configuration of eyes, nose, and mouth, the general appearance of human skin, etc.) despite differences in identities, architectural spaces are less regular both globally (e.g. configuration, arrangement of objects) and locally (e.g. presence of different objects and materials). If the serial dependence effects observed in Experiment 1 were only determined by the similarities between stimuli in terms of visual properties, a weaker, if not absent, serial dependence would be predicted in the aesthetic ratings of built environments which varied substantially. On the other hand, if serial dependence also operated beyond the perceptual level, serial dependence should manifest in the aesthetic evaluation of different architectural spaces too. Secondly, this experiment also aimed to investigate whether serial dependence in aesthetic judgements of built environments was sensitive to the change of scene category (indoor, outdoor). Findings from Experiment 1 demonstrated that a change in the sex of faces between consecutive trials substantially weakened serial dependence. Based on this result, it was predicted that a change in scene category might also disrupt serial dependence.

4.4.2 Method

Participants

Participants who took part in Experiments 1 participated in the current experiment (n = 26).

Stimulus and apparatus

The stimuli of the current study consisted of sixty colour photographs of built environments. Thirty of these were images of interior living spaces (e.g. bedroom, living room, kitchen) and were obtained from the stimulus set used in Vartanian, et al. (2013) with the approval from the corresponding author. In their original stimuli set, the images were categorised according to the curvilinearity of contours (curvilinear, rectilinear). For the current study, 15 images from each category were randomly selected. The other thirty photographs were images of building exteriors obtained from the Internet using Google Image[TM] . Precaution was taken during the selection of these images so that the picture qualities were comparable with those of the indoor images and that the images did not depict people and other irrelevant objects such as vehicles. These images were then cropped so that the building of interest in each of them occupied between 60% and 70% of the total image area[8]. Finally, all images, while having their aspect ratios locked, were resized to the range of image size between 550 x 800 pixels and 650 x 800 pixels. The apparatus used in the current experiment was identical to that used in previous experiments.

Design and procedure

The design in the current study is similar to that of Experiment 1. It was a within-subject, fully factorial design with serial dependence and scene type (indoor, outdoor) as

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[8] This area percentage was calculated using an online area calculator SketchAndCalc[TM] (Dobbs, 2011).

independent variables and the attractiveness ratings as the dependent variable. For the purpose of the current experiment, this experiment, just like Experiment 1, consisted of two parts: Part 1 in which within the same block only one scene type was presented and Part 2 in which a mix of scene types were presented within the same block. The order of the two parts was counterbalanced across participants.

For Part 1, each participant completed 8 blocks of 30 trials. Within the same block, all the images presented were of the same scene type and the trials were randomised. The order of the blocks was counterbalanced. In other words, half of the participants started the experiment with an indoor block while the rest started with an outdoor block and all subsequent blocks alternated between scene types. Each of the 60 images was rated 4 times by each participant. The experimental procedure was the same as described in Experiment 1. One exception was that the images in the current study were presented in the centre of the screen rather than appearing at different locations.

For Part 2, the arrangement of including a mix of scene types was as described in Experiment 1 such that each participant completed 8 blocks of 30 trials within which there were images of both indoor and outdoor scenes.

4.4.3 Results

Part 1:

The [t – 1] effect:

The data were prepared as in Experiment 1a. For each participant, a median rating was calculated for each of the scene types respectively and the response ratings were binned into the two [t – 1] conditions by comparing the average rating of the stimulus in the

preceding trial with the corresponding median value and an average was then calculated for each of the resulting bins. Figure 4.4 shows the mean attractiveness ratings as a function of scene category. A 2x2 repeated measures ANOVA was performed with $[t-1]$ serial dependence ($[t-1]$ < median, $[t-1]$ > median) and scene type (indoor, outdoor) as within-subject factors (Figure 4.5). The results revealed a significant main effect of $[t-1]$ serial dependence ($F(1, 25) = 14.9$, $p = 0.001$, $\eta_p^2 = 0.373$). Scene type had no effect on attractiveness ratings ($F(1, 25) = 0.013$, $p = 0.91$, $\eta_p^2 = 0.013$) and did not interact with serial dependence ($F(1, 25) = 1.02$, $p = 0.322$, $\eta_p^2 = 0.039$).

Figure 4.4 Plot showing the mean attractiveness ratings as a function of scene category in Experiment 2, Part 1. Error bars represent ± 1 standard error of the mean. [*p<0.05; *** p <0.001]

The $[t-n]$ effects:

The data were re-binned, and the same analysis described above was repeated to test for the $[t-2]$ and $[t-3]$ effects respectively. Results showed an absence of the $[t-2]$ effect

(F (1, 25) = 0.505, p = 0.484, η_p^2 = 0.02). However, a significant [t − 3] contrast effect was found (F (1, 25) = 8.41, p = 0.008, η_p^2 = 0.252). Participants gave a lower rating to the built environment presented in a given trial [t] when the average attractiveness of the stimulus in the [t − 3] trial was higher than the median rating. In both analyses, scene type had no effect on attractiveness ratings ([t-2] analysis: $F(1, 25)$ = 0.124, p = 0.728, η_p^2 = 0.005; [t-3] analysis: $F(1, 25)$ = 0.167, p = 0.686, η_p^2 = 0.007) nor did it interact with the [t − 2] ($F(1, 25)$ = 0.956, p = 0.338, η_p^2 = 0.037) and the [t − 3] conditions ($F(1, 25)$ = 4.17, p = 0.052, η_p^2 = 0.143).

Part 2:

A preliminary analysis was first conducted to investigate the effect of scene type on attractiveness ratings. Results of a paired-sample t-test showed that attractiveness ratings did not differ between outdoor (M = 59.3, SD = 11.2) and indoor (M = 59.3, SD = 9.29) scenes (t (25) = 0.572, p = 0.573, Cohen's d = 0.0999). Therefore, scene type was not included as a factor in addition to the difference in scene type between consecutive trials (i.e. same, different, which was the subject of interest in the current experiment) in the subsequent analyses. One median rating (instead of two, one for each scene type) was calculated on all 60 images for each participant for the purpose of calculating the serial dependence effects.

The [t − 1] effect:

The data were prepared as described in previous experiments. In order to investigate whether serial dependence in aesthetic judgements of built environments is affected by a change in scene type, the ratings in each [t − 1] conditions (i.e. [t − 1] < median and [t − 1] > median) were further binned into two groups, one in which the stimulus of the current

trial [t] was the of the same scene type as the preceding trial [t − 1] or the other when the two were different. Figure 4.5 shows the mean attractiveness rating as a function of scene category difference between the current trial [t] and [t − 1] A 2x2 repeated measures ANOVA was then performed with the [t − 1] serial dependence and scene type change as within-subject factors (Figure 4.6). A main effect of [t − 1] serial dependence was revealed (F (1, 25) = 29.2, $p < 0.0001$, $\eta_p^2 = 0.538$). The exterior of a building or an indoor architectural space was rated as more attractive when the average rating of the stimulus presented in the preceding was higher than the median score. The change in scene type had no effect on the ratings (F (1, 25) = 0.017, $p = 0.896$, $\eta_p^2 = 0.001$) nor did it interact with serial dependence (F (1, 25) = 0.122, $p = 0.73$, $\eta_p^2 = 0.005$). In other words, the magnitude of the [t − 1] effect was not affected by a change in scene type.

Figure 4.5 Plot showing the mean attractiveness rating as a function of scene category difference between the current trial [t] and [t − 1] in Experiment 2, Part 2. Error bars represent ± 1 standard error of the mean. [*p<0.05; ** p <0.01]

The [t – n] effects:

Further analyses using the same method described previously, namely a 2x2 repeated measures ANOVA, revealed a significant [t – 2] serial dependence (F (1, 25) = 5.18, p = 0.032, η_p^2 = 0.172). This effect was not affected by a change in scene type between the current and the [t – 2] trials as the interaction between serial dependence and scene type change was not significant (F (1, 25) = 0.468, p = 0.5, η_p^2 = 0.018). The main effect of scene type change also did not reach statistical significance (F (1, 25) = 0.053, p = 0.82, η_p^2 = 0.002).

Results of a separate analysis showed non-significant main effects of [t – 3] serial dependence (F (1, 25) = 0.051, p = 0.823, η_p^2 = 0.002) and scene type change between the current and the [t – 3] trials (F (1, 25) = 0.004, p = 0.952, η_p^2 < 0.0001). No interaction was found between these two factors either (F (1, 25) = 2.43, p = 0.132, η_p^2 = 0.089).

The strength of serial dependence beyond [t – 1]

The average magnitudes of the [t – 1] and [t – 2] effects were 3.04 (SD = 5.29) and 1.64 (SD = 6.48) respectively (Figure 4.6). However, the results of a paired-samples t-test indicated that this difference was not statistically significant (t (51) = 1.18, p = 0.244, Cohen's d = 0.237).

Figure 4.6 Plot showing the magnitudes of the serial dependence effect across [t – n] in Experiment 2b. Note that the [t -3] effect was not significant in this experiment.

4.4.4 Discussion

Consistent with the results of previous experiments in this study, a robust [t – 1] serial dependence was found in aesthetic judgments of both indoor architectural spaces and outdoor building exteriors. The stimuli used in the current study were irregular in terms of their visual properties. For instance, the outdoor images depicted buildings of different window sizes, heights and colours and the indoor images showed a variety of architectural spaces of different functions (e.g. kitchen, living room). As such, it is unlikely that the serial dependence observed in this experiment was merely due to a low-level perceptual pull towards the preceding scene. This reaffirmed the evidence that serial dependence operated not only at the level of processing of simple features (Fischer & Whitney, 2014; Alais, Leung, & Van der Burg, 2017; Manassi, et al., 2018) , but also at higher levels of perception such as face identity (Liberman, et al., 2018) and scene gist (Manassi, et al., 2017).

Contrary to the prediction based on results of Experiment 1, the magnitude of serial dependence was unaffected by whether the consecutive scenes belonged to the same or different scene categories (i.e. indoor or outdoor). This serial dependence extended beyond [t – 1] as a significant [t – 2] effect was found. One possible explanation to the absence of scene category effect on serial dependence in this experiment could be that although indoor and outdoor scenes possessed different visual and semantic properties (Oliva & Schyns, 2000; Torralba & Oliva, 2003), the mechanisms underlying the aesthetic evaluation of these scenes might not require access to the cognitive, categorical processing. It is possible that the serial dependence in the aesthetic evaluations of scenes found here reflected an assimilation of aesthetic judgements formed at a level of 'gist perception' before further analysis of scene category (Mullin, Hayn-Leichsenring, Redies, & Wagemans, 2018).

4.5. Experiment 3

4.5.1 Introduction

In Experiment 1, serial dependence in facial attractiveness ratings were sensitive to changes in category membership (i.e. sex of the face) across trials, suggesting that serial dependence operates beyond the lowest-level processing of facial features in face perception (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2002). On the other hand, serial dependence in attractiveness ratings of scenes of built environments remained robust regardless of changes in scene category (indoor or outdoor) between trials (Experiment 2), which suggests an early assimilation of aesthetic responses. This final experiment was conducted in order to reconcile these findings and to further extend the investigation into the perceptual limits of the serial dependency effect within and across categories. To that end, participants were required to provide ratings of their

aesthetic judgements of a mix of faces and scenes. Since the cross-category effect of interest here was between faces and scenes (not between subcategories of sex and scene type), only female faces and indoor scenes were used. A prediction based on the results of Experiment 1 was that serial dependence would occur only if the stimuli in the current and preceding trials belonged to the same stimulus category. Conversely, an early assimilation of aesthetic responses would result in a serial dependence effect regardless of stimulus category.

4.5.2 Method

Participants

Fifteen participants (11 females; mean age = 28.3 years, *SD* = 7.47) from the student and staff population at Trinity College Dublin, Ireland participated in the current experiment. All were naïve to the purpose of the study and did not take part in the previous experiments reported here. They all gave informed, written consent prior to conducting the experiment.

Stimulus and apparatus

The stimuli set of this experiment consisted of the 30 images of female faces only taken from Experiment 1, and 30 images of indoor scenes used in Experiment 2. The apparatus used in this experiment was the same as that used in previous experiments.

Design and procedure

The design of the current experiment was similar to that in Experiments 1 and 2. The experiment consisted of 4 blocks of 60 trials each. Within each block a mix of face and scene images were presented. Trials were presented in a randomised order across

participants. The procedure and trial structure were the same as described in previous experiments except here all images were presented in the centre of the screen. The participants were instructed to rate how attractive the face or the scene presented was.

4.5.3 Results

Prior to the main analysis, the average attractiveness ratings to the face and scene images were calculated for each participant. The results of a paired-sample t-test showed that there was no significant difference in ratings provided to the faces ($M = 50.5$, $SD = 10.4$) and scenes ($M = 52.4$, $SD = 11.0$) (t (14) $= 0.392$, $p = 0.701$, Cohen's $d = 0.179$). Therefore, for the purpose of further analyses, only the change in stimulus category (same, different) but not the stimulus category per se (face, scene) was included as a factor. A single median rating was calculated for all 60 images (scenes and faces) for each participant for the purpose of calculating the serial dependence effects.

The [t – 1] effect

Similar to the data binning process described in Experiments 1 and 2, the data were first binned according to a given trial [t], based on whether the average rating of the stimulus in the preceding trial [t – 1] was smaller or larger than the median rating, and then further binned according to whether the stimulus category in [t] was the same or different to that in [t – 1]. The data were then analysed using a 2x2 repeated measures ANOVA with the [t – 1] condition ([t-1] < median, [t-1] > median) and the change in stimulus category (same, different) as within-subject factors.

The mean ratings to each of the category changes as a function of serial position is shown in Figure 4.7. The results revealed a significant main effect of category change (F (1, 14) = 9.05, p = 0.009, η_p^2 = 0.393). Participants rated a stimulus (regardless of whether it was a face or a scene) as more attractive if it belonged to the same category as the stimulus presented in the preceding trial compared different categories. The main effect of [t − 1] serial dependence was not significant (F (1, 14) = 2.02, p = 0.177, η_p^2 = 0.126). However, there was a significant interaction between serial dependence and category change F (1, 14) = 18.6, p = 0.001, η_p^2 = 0.571), as shown in Figure 4.7. Post-hoc pairwise comparisons (with Bonferroni correction) were conducted and the results indicated that there was a serial dependence effect when the stimuli presented in trials [t] and [t − 1] were from the same category (mean difference = 10.7, p < 0.0001). Contrarily, a serial contrast effect was found when there was a change in category between consecutive trials (mean difference = -7.93, p = 0.005).
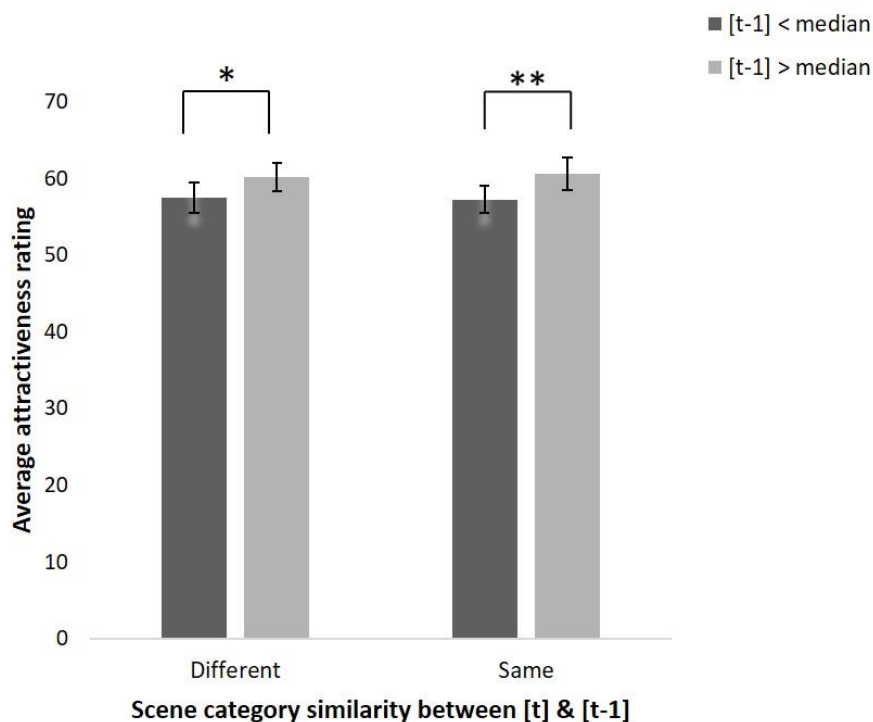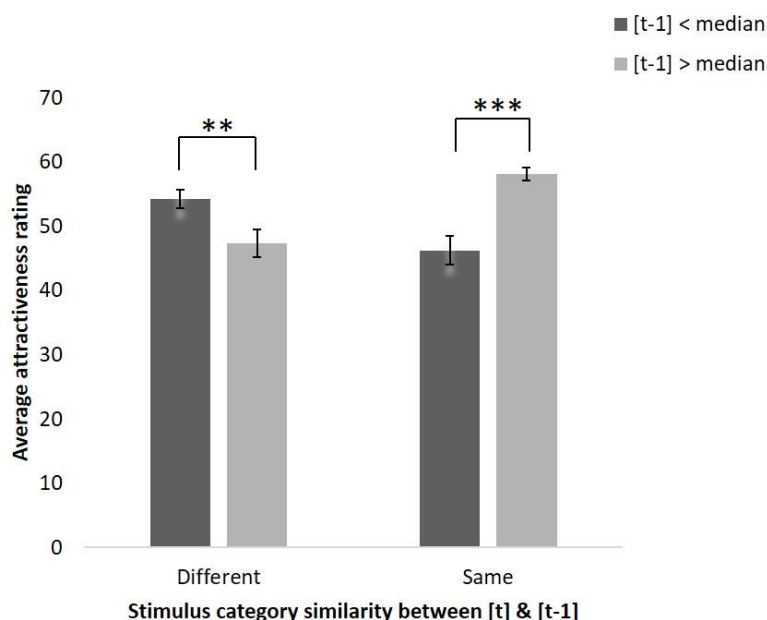

Figure 4.7 Plot showing the mean attractiveness ratings as a function of stimulus category difference between the current trial [t] and [t − 1] in Experiment 3. Error bars represent ± 1 standard error of the mean. [** p <0.01; *** p < 0.001]

The [t - n] effects

Further analyses using the same method described in previous experiments showed no evidence for an effect of the serial dependence ([t-2]: $F(1, 14) = 1.22$, $p = 0.289$, $\eta_p^2 = 0.08$; [t-3]: $F(1, 14) = 1.46$, $p = 0.247$, $\eta_p^2 = 0.094$) nor the change in stimulus category ([t-2]: $F(1, 14) = 1.54$, $p = 0.235$, $\eta_p^2 = 0.099$; [t-3]: $F(1, 14) = 0.392$, $p = 0.542$, $\eta_p^2 = 0.027$) beyond [t – 1]. However, there was a significant interaction between the [t – 2] effect and category change ($F (1, 14) = 10.7$, $p = 0.006$, $\eta_p^2 = 0.432$). Post-hoc pairwise comparisons (with Bonferroni correction) showed a significant [t – 2] serial dependence effect when the stimuli presented in the current trial [t] and [t – 2] trials were from the same category (mean difference $= 7.68$, $p = 0.01$), but not when stimulus category differed between [t] and [t – 2] (mean difference $= -2.81$, $p = 0.344$).

The interaction between the [t – 3] effect and category change was not significant ($F (1, 14) = 0.648$, $p = 0.434$, $\eta_p^2 = 0.044$).

The effect of [t – 1] on the [t – 2] effect

The result of a paired-samples t-test showed that the magnitude of the [t – 2] serial dependence effect was unaffected by the category of the stimulus in the immediately preceding trial [t – 1] (mean difference $= 1.63$, $t (14) = 1.002$, $p = 0.333$).

The strength of serial dependence beyond [t – 1]

Figure 4.8 illustrates the diminishing of serial dependence across preceding trials [t – 1] to [t – 3]. The average magnitude of the [t – 1] effect was significantly higher than the [t – 2] effect (mean difference $= 4.14$, $t (14) = 2.73$, $p = 0.016$; Cohen's $d = 0.438$).
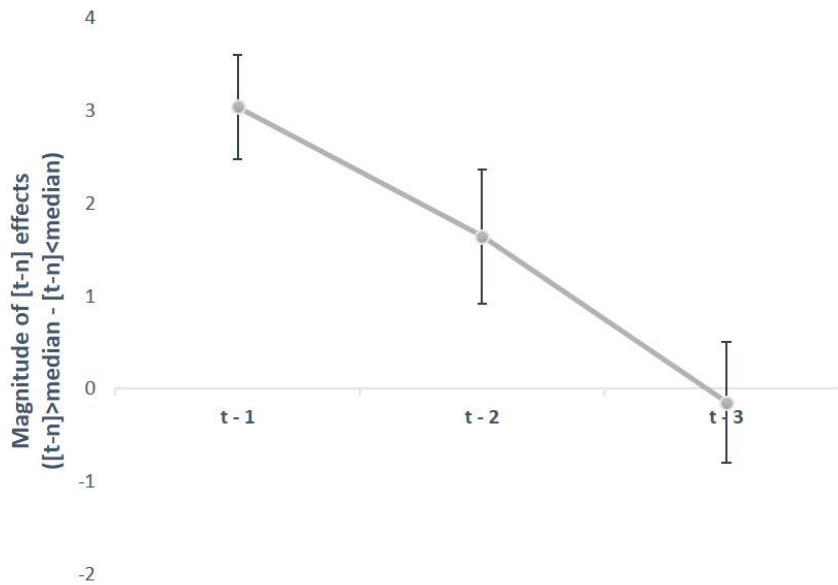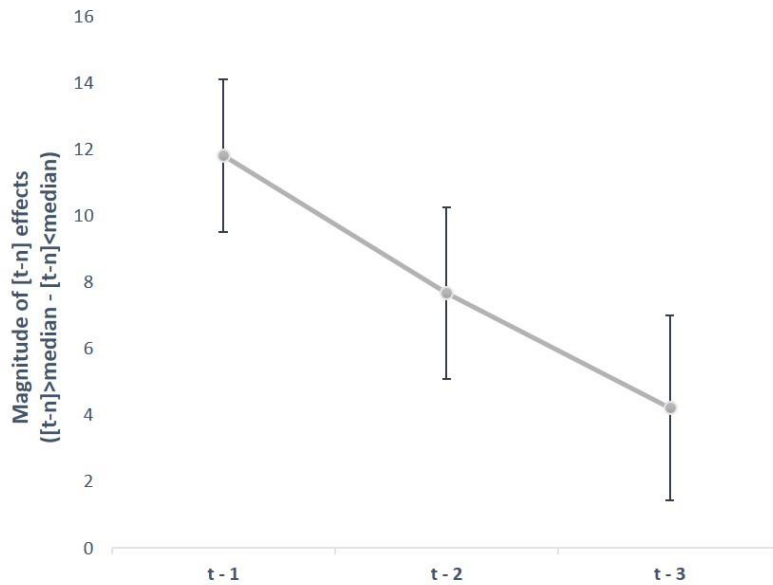
Figure 4.8 Plot showing the magnitudes of the serial dependence effect across [t – n] in Experiment 3. Note that the [t – 3] serial dependence did not reach statistical significance.

4.5.4 Discussion

In contrast to the results of the previous experiments, an overall serial dependence effect in attractiveness ratings was not found in this experiment. Instead, the serial effects were highly dependent on whether the stimulus category differed between the current and the preceding trials. In the case where stimuli presented in consecutive trials belonged to the same category (i.e. both faces, or both scenes), there was a significant serial dependence effect, which weakened although remained significant two trials back (i.e. [t – 2]). This finding is consistent with the results of Experiment 1 but not Experiment 2 (in which a category change did not affect serial dependence). Moreover, these results suggest that the serial dependence is unlikely to be due to an assimilation of aesthetic responses formed before the perceptual processes necessary for the categorisation of visual stimuli. On the other hand, when there was a change in stimulus category, a contrast effect was

found. A scene was rated as less attractive than it would otherwise be when preceded by a face that was rated as highly attractive (compared to the median rating) and likewise for faces preceded by a scene rated as attractive. Conversely, a scene received a higher attractiveness rating when preceded by a relatively unattractive face and likewise for faces preceded by a less attractive scene. However, this contrast effect was not observed beyond [t − 1]. Interestingly, the average attractiveness ratings of stimuli (both faces and scenes) preceded by an image from a different category was lower than when the stimulus category remained the same in successive trials. This might reflect a decrease in overall aesthetic appeal due to a disruption of perceptual fluency which was also evident from an increase in reaction time in those trials[9] (Reber, Schwarz, & Winkielman, 2004).

4.6. General discussion

Serial dependence in visual perception has been well documented (Fischer & Whitney, 2014; Liberman, et al., 2014; Cicchini, et al., 2017; Manassi, et al., 2017; 2018; Suarez-Pinilla, et al., 2018). However, a relatively underexplored issue was whether aesthetic evaluations were also susceptible to the effect of serial dependence. The current study aimed to build on previous work of serial dependence in facial attractiveness (Kondo et al., 2012, 2013; Kramer, et al., 2012; Taubert & Alais, 2016; Xia, et al., 2016) and extend the investigation to examine the locus of processing of serial dependence relative to the aesthetic evaluation of visual stimuli of other domains, namely scenes of outdoor and indoor architectural spaces.

The first main finding was that generally serial dependence was robust during sequential aesthetic evaluations of similar items. In all experiments, except Experiment 3, the [t −

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[9]Mean difference = 215ms, $t(14) = 4.04$, $p = 0.001$, Cohen's $d = 0.232$

1] effect was found to be significant and positive. For both faces and scenes, attractiveness ratings provided to the present trial were pulled towards the attractiveness of the stimulus presented in the previous trial. This effect generalised from recently viewed stimuli up to stimuli which were viewed two trials ago (Experiments 2 & 3) and even, in some cases (Experiments 1), 3 trials back. These serial effects on perceptual performance are characteristic of serial dependence and are considered distinct from a response bias (Fischer & Whitney, 2014; Taubert & Alais, 2016; Alais, et al., 2017; Suárez, et al., 2018).

However, not all previous studies on serial dependence have reported such a persistent perceptual assimilation across multiple trials (Kondo, et al., 2012, 2013; Xia, et al., 2016). For instance, Xia, et al. (2016) found that attractiveness ratings to faces was affected by the attractiveness of the face presently in the immediately preceding trial only; but they were successful in obtaining serial dependence in the absence of a motor response (Experiment 2 of their study). On the other hand, serial dependence tends to sustain over multiple trials in studies where the duration of stimulus exposure is shorter (Taubert & Alais, 2016). Multiple studies have reported a time frame between 5 to 12 seconds in which recently viewed stimuli could have an effect on the judgement of the current stimulus (Liberman, et la., 2014; Xia, et al., 2016; Suárez, et al., 2018). The stimulus duration of 300 ms used in the present experiments was comparable to that in those previous reports. However, the effect of stimulus duration on serial dependence was outside the scope of the current study. Nonetheless, there did seem to be an association between the average time taken to respond (hence the number of trials completed within a set amount of time, since a response instantaneously triggered the start of a new trial) and the strength of serial dependence over multiple trials such that the [t – 2] and [t – 3] effects were found in experiments with shorter average reaction times. On the other hand,

the results of the current study could in fact be an indication of the effect of serial dependence on reaction time, consistent with the notion that serial dependence serves as an optimisation strategy to speed up responses by integrating incoming signals with accumulated evidence in recent perceptual history (Cicchini, et al., 2018).

Secondly, the strength of serial dependence was modulated by not just the visual similarity between successive stimuli, nor the perceptual category to which the stimuli belonged but also the context in which distinct evaluation processes are involved. For example, for the within-category faces presented In Experiment 1, the attractiveness ratings were affected by the attractiveness of the face viewed in the preceding trial. While similar results were obtained across sex categories in Experiment 1, the effects were found only in trials where the sex of the face did not change between consecutive trials. The change in sex between successive trials attenuated the effect of serial dependence, which may be a result of differences in facial features between male and female faces. This explanation, however, was unsatisfactory, since it cannot account for the results of Experiments 2, in which the images of scenes arguably varied a lot more in terms of their visual features and yet a compelling effect of serial dependence was found. A more probable explanation is that the evaluation processes of facial attractiveness for female and male faces are differentiated after the sex of the face has been identified during the perceptual process. Indeed, it has repeatedly been shown that sexual dimorphism enhances perceived attractiveness (Perrett, Lee, Penton-Voak, Rowland, Yoshikawa, Burt, Henzl, Castles, & Akamatsu, 1998). It follows that there may be a prototypical reference for attractive faces of each sex with which a new face would need to be compared against, which is possible only after assigning the face to the corresponding sex category. A recent event related potential (ERP) study by Carbon, Faerber, Augustin, Mitterer, and Hutzler (2018) demonstrated that the onset of an analysis of the sex of a

face preceded that of facial attractiveness. The results of the current study concur with the conclusion made by Carbon, et al. (2018) that sex category information from a face is available and likely taken into account during the earliest stage of attractiveness processing. In short, the attractiveness rating provided to the previous face of the opposite sex is not integrated into the present judgement because a distinct evaluation process is involved.

While serial dependence was found in aesthetic judgements for scenes of built environments, the change of scene category did not have an effect on the magnitude of serial dependence (Experiment 2) in contrast to the result found with images of faces. The literature on scene perception suggests that complex visual information can be extracted even upon brief exposure to an image of a scene (Thorpe, Fize, & Marlot, 1996; Fei-Fei, Iyer, Koch, & Perona, 2007; Oppermann, Hassler, Jescheniak, & Gruber, 2012; Harel, Groen, Kravitz, Deouell, & Baker, 2016). This is commonly referred to as the perception of 'scene gist', in which the global spatial information necessary for scene category is extracted around 150 ms after stimulus onset (Thorpe, et al., 1996; Harel, et al., 2016). In other words, the presentation duration of 300 ms in the current study was sufficient for the scene categorisation to take place. The presence of serial dependence in attractiveness ratings of scenes from different categories implies the aesthetic evaluation precedes scene categorisation. This conclusion is supported by the result that automatic and reliable aesthetic evaluations that correlated highly with those made during prolonged viewing can be elicited at the 'gist' level within 50ms of stimulus onset (Mullin, Hayn-Leichsenring, Redies, & Wagemans, 2017). Furthermore, Mullin, et al. (2017) reported similar aesthetic evaluations of outdoor urban (which resembled the outdoor images of the current study) and indoor scenes (Experiment 3 in their study). Therefore, it is likely that the aesthetic evaluation process of these two categories of architectural spaces is

similar, and the aesthetic judgements are readily assimilated across successive trials regardless of scene category membership. One caveat of the current study is that the effect of motor inertia was not totally ruled out, even though the indicator with which the participant used to make their rating appeared at a random location on the rating scale at the start of each trial (hence reducing some motor response bias). Future studies could improve by introducing some variations in which a motor response is recorded, for instance, by changing the physical orientation of the rating scale (horizontal, vertical) or alternating between asking the participant to enter a numeric score and using the rating scale.

Thirdly, a serial contrast effect in which the attractiveness ratings were biased away from the attractiveness of preceding trials was found under two circumstances in the current experiments. The first type of serial contrast appeared to have a delayed onset such that the rating of the current face (Experiment 1b) or architectural space (Experiment 2a) was under the influence of the stimulus three trials back (i.e. $[t - 3]$), and this effect was independent of the category membership of the immediately preceding stimulus (i.e. $[t - 1]$). A more prominent and immediate serial contrast effect was observed in Experiment 3 – the aesthetic judgement of the current stimulus (face or an indoor scene) is biased away from the attractiveness of the preceding stimulus from a different category. These two seemingly distinct types of serial contrast effects might not have arisen through different mechanisms. Instead, whether or not the resulting effect was a bias away or towards the attractiveness of recently viewed stimuli might have depended on the relative strengths of the counteracting serial dependence and contrast effects operating in different time scales but jointly influence judgement in any given trial, which in turn were affected by other factors such as category membership. This explanation is supported by findings from previous studies on serial dependence which suggest the existence of both positive

and negative serial dependence effects (Parker, Bascom, Rabinovitz, & Zellner, 2008; Cogan, et al., 2013; Alais, et al., 2017; Suárez, et al., 2018; Huang, et al., 2018; Pegors, et al., 2015). For instance, Suárez-Pinilla, et al. (2018) reported a similar trend of serial dependence in visual variance perception tracing up to ten trials back. They demonstrated a fast-acting serial bias towards the most recent perceptual history, which lasted over two trials but to a gradually lesser extent and simultaneously a persistent repulsive bias, which was akin to a negative aftereffect and emerged only when the serial attractive bias diminished (Suárez-Pinilla, et al., 2018). The contrast effect observed in Experiment 3 could be the result of a failed assimilation of aesthetic judgement due to a drastic change in stimulus category involving very different evaluation criteria, thus leading to a much earlier emergence of contrast effect. However, this contrast effect contradicted the findings in a study by Pegor, et al. (2015), who argued that the positive, assimilative component found in their interleaving hair colour and attractiveness judgement tasks was a bias induced by the numeric rating response and that the perception of aesthetic appeal or hair colour of a given face was biased away from the corresponding attribute of the preceding face. Critically, a change of stimulus category coupled with a change of task (i.e. preceding the target face whose attractiveness was to be judged with a trial of temperature judgement of a depicted scene), according to their results, eliminated any serial effect altogether (Pegors, et al., 2015). While they concluded that the attractiveness of the preceding scene (which was implicit, as participants were not required to judge, nor proved to be aware of, the aesthetic appeal of the scene) had no effect on the attractiveness judgement of the current face, the absence of any serial effect might have reflected an independent evaluation of each face as a result of task switching.

4.7 Conclusion

To sum up, the findings of the current study did not directly inform on the issue whether serial dependence in aesthetic judgments was fundamentally a perceptual phenomenon in which the resultant perception of the current stimulus is altered by the preceding stimuli, or a post-perceptual bias whereby the working memory of the current stimulus is shifted as a result of recent representations. Nonetheless, the results of the current study provide new evidence that aesthetic judgements are influenced by the attractiveness of recently viewed stimuli in the category domain of scenes. Furthermore, the present findings shed light on the level of perceptual processing required for aesthetic evaluations to be elicited relative to serial dependence effects to emerge.

Chapter 5

The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study

5 The role of individual differences on perceived beauty and intimacy in residential architecture – a large-scale study

5.1. Abstract

Recent findings from empirical studies and neuroaesthetics have established the role of simple visual properties in images of architecture in associated aesthetic evaluations and approach-avoidance decisions. There is, however, increasing evidence that individual differences modulate the effects of these properties, and studies involving small sample sizes may contribute to inconsistencies in results. The current study included a sample size of more than two thousand participants, including expert architects, architect students and non-experts, to investigate the inter-dependent relationships between visual features in scenes of indoor and outdoor architectural buildings and personality traits on ratings of aesthetic appeal and perceived intimacy. Results showed that the aesthetic ratings of indoor living spaces were most affected by space openness, while ratings of intimacy could not be predicted by the visual features nor personality factors considered in the study. Curvature and window-to-wall ratio were the main predictors of the aesthetic judgements of building exteriors, where non-experts and architecture students, but not experts, preferred curvilinear over rectilinear contours. Ratings of 'agreeableness' were associated with an aesthetic preference for buildings with low window-to-wall ratios while ratings of 'openness' were associated with a preference for relatively big windows. The perceived intimacy of these buildings, however, depended mainly on the level of extroversion, as well as visual features such as the height of the building, and some modulation by curvature and window-to-wall ratio. Lastly, curvature enhanced the perceived intimacy of buildings in non-experts only. Collectively, the results shed light on the complex relationship between aesthetic and affective judgements of the built

environment and call for a closer collaboration between the disciplines of science and architecture in the study of aesthetics.

5.2. Background

The Ancient Roman architect Marcus Vitruvius asserted in his De architectura (Vitruvius & Morgan, 1960), the most respected treatise on architecture to survive from antiquity, that good architecture must exhibit the three virtues of *firmitas* (strength), *utilitas* (functionality), and *venustas* (beauty). Some of the qualities which Vitruvius considered to be instrumental to appreciation of beauty in architecture, such as proportion and symmetry, are still considered crucial criteria in modern design practice (Kruft, 1994; Lefas, 2000; Mitra & Pauly, 2008; Gangwar, 2017). While historically the discussion on aesthetics had predominantly been philosophical and theoretical in the discipline of architecture, empirical research of architectural aesthetics has progressed from limited and isolated studies in architecture and environmental psychology (with the work by architects such as Arthur Stamps III since the early 1990s being more comprehensive; Stamps, 1989, 1991, 1997a, 1997, 1999, 2000, 2010, 2013) to experimental psychology and neuroscience more recently (Vartanian, Navarrete, Chatterjee, Fich, Leder, Modroño, Nadal, Rostrup, & Skov, 2013, 2015, 2017; Vecchiato, Tieri, Jelic, De Matteis, Maglione, & Babiloni, 2015; Coburn, Vartanian, & Chatterjee, 2017; Thömmes & Hübner, 2018; Ruta, Mastandrea, Penacchio, Lamaddalena, & Bove, 2018). The aim of all recent studies was to identify the influences of basic visual properties in architecture such as contour, ceiling height, and space openness, as well as their interactions with individual differences, on aesthetic preferences for built environments.

5. The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study

The effects of smooth and curved contours on judgements of aesthetic pleasure and evaluations have been well documented, dating from the earliest work in empirical aesthetics which demonstrated preferences for simple curved lines over straight angular ones (Stratton, 1902; Valentine, 1913) to the studies a century later which established the universal preferences for curvature in perceivers across different age groups (Quinn, Brown, & Streppa, 1997; Jadva, Hines, & Golombok, 2010), cultures (Gómez-Puerto, Rosselló, Corradi, Acedo-Carmona, Munar, & Nadal, 2018), and even in non-human primates (Munar, Gómez-Puerto, Call, & Nadal, 2015). Furthermore, these preferences extend to different tasks (Palumbo, Ruta, & Bertamini, 2015; Palumbo & Bertamini, 2016a) with stimuli from a wide range of categories such as simple geometric or abstract shapes (Silvia & Barona, 2009; Cotter, Silvia, Bertamini, Palumbo, & Vartanian, 2017) and everyday objects (Bar & Neta, 2006) such as product packaging (Westerman, Gardner, Sutherland, White, Jordan, Watts, & Wells, 2012), cars (Leder & Carbon, 2005), and in interior design and architecture (Vartarian, et al., 2013, 2017; Thömmes & Hübner, 2018; Ruta, et al., 2018). Since curvature is so universally preferred, it has been considered a potential "aesthetic primitive" (Munar, Gómez-Puerto, López-Navarro, & Nadal, 2014). Furthermore, it appears that the preference for curvature is compelling in its own right and does not depend on an aversion to angularity and sharp corners (Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016). However, the origin of the curvature effect remains debatable with evidence supporting both an evolutionary explanation (i.e. the developmental, cross-cultural and cross-species studies mentioned above) and a learning explanation that preference for curvature is acquired through repeated exposure, both perceptual and cultural (Gómez-Puerto, Munar, & Nadal 2016). Despite the robustness and universality of the curvature effect, preferences for curvature have been shown to be modulated by individual differences in personality and expertise.

Specifically, experts in art, as well as individuals who are more open to experience showed a greater preference for, and higher aesthetic sensitivity to, curvature in abstract shapes (Silvia & Barona, 2009; Cotter, et al., 2017). While the effect of curvature was found in both aesthetic judgements and approach-avoidance decisions regarding architectural spaces, the effect was manifested differently in experts (architects and designers) and non-experts (Vartarian, et al., 2017). Experts were shown to be less susceptible to the curvature effect when making approach-avoidance decisions regarding an architectural space (i.e. to enter or not), indicating that the aesthetic appeal of curvature can be disentangled from the positive emotions and pleasure associated with curvature (Vartarian, et al., 2017). Moreover, aesthetic judgements of architecture are highly variable across individuals, compared to other domains such as faces and natural landscapes (Vessel, Stahl, Maurer, Denker, & Starr, 2014; Vessel, Maurer, Denker, & Starr, 2018). It is possible that these variations are due to the differences in personality and level of expertise in architecture and interior design.

In the neuroimaging study reported by Vartarian et al. (2013), the effects of ceiling height and space openness were controlled for in order to investigate the effect of contours on aesthetic judgements and approach-avoidance decisions to architectural spaces. They found a significant aesthetic preference for curvilinear spaces which was associated with increased activation in the anterior cingulate cortex, an area associated with rewards and affect when participants viewed curvilinear architectural spaces. In a subsequent study Vartarian, et al. (2015) reported that high ceilings enhanced the aesthetic appeal of architectural spaces but had no effect on approach-avoidance decisions. In contrast, space openness influenced both aesthetic preferences and the willingness to enter such that open spaces were considered more beautiful than enclosed spaces and enclosed spaces elicited a desire to exit (Vartarian, et al., 2015). These behavioural findings were complemented

by neuroimaging data whereby rooms with high ceilings activated cortical regions involved in visuospatial exploration and attention in the dorsal stream while enclosed spaces were associated with increased activation in the anterior midcingulate cortex (aMCC) (which is an area with direct projections from the amygdala), suggesting an emotional response that accompanied avoidance tendencies (Vartarian, et al., 2015). These studies are important breakthroughs in the empirical studies of aesthetics in architecture and marked the beginning of neuroaesthetics in architecture on which future research could build. However, there remains a number of unanswered questions from the Vartarian, et al. studies (2013, 2015). For example, they did not include all three properties (i.e. curvature, ceiling height, and space openness) as factors simultaneously in the same experiment. Therefore, it is unclear how these factors interact on the perceived beauty and approach-avoidance decisions when viewing architectural spaces, whether one factor exerts a greater effect than others or if all contribute to aesthetic value and influence approach-avoidance tendencies independently.

The aim of the current study, which built on previous work by Vartarian, et al. (2013, 2015, 2017), was to investigate the interactions between the visual features tested in their work (i.e. curvature, ceiling height, and space openness) and the modulation of these stimulus effects by individual differences such as personality and expertise. Furthermore, the contributory factors to judgements of architectural aesthetics was also extended to building exteriors.

Another important consideration in architectural design is intimacy, which can be interpreted as a sense of privacy, cosiness, and comfort (Pallasmaa, 1992; Namazian & Mehdipour, 2013). For instance, the architect Christopher Alexander (1977), proposed the concept of 'intimacy gradient' in buildings. Accordingly, he proposed that individual

rooms should be arranged in the order of increasing privacy requirements from the entrance (the most public space where guests and strangers can have access to) to deep within the dwelling, which is exclusive to the occupants (e.g. the bedroom). A building with disrupted intimacy gradient is considered by Alexander as badly designed. It is unclear how intimacy relates to approach-avoidance decisions since the factors underlying the perception of intimacy in built environment has not been explored from an empirical perspective. It is possible that a perception of a building as lacking in intimacy, be it caused by visual features or personal factors, would lead to an increase in avoidance tendencies and decisions. The current study examined the effects of building features and tested for any interactions between building properties, personality and level of expertise on perceived intimacy of architectural spaces.

To extend previous empirical investigations of aesthetic judgements of building exteriors, a number of visual properties were focused on in the present study. Curvature was included as one of the candidate visual features to be investigated and, based on results of all the studies reviewed above, it was predicted that the presence of curvilinear contours would enhance the aesthetic appeal and possibly perceived intimacy of a building exterior due to the positive pleasure elicited by curvature which might lead to a feeling of comfort (Dazkir & Read, 2012).

Current architectural trends suggest that buildings with big windows are preferred over those with small windows. In practice, window-to-wall ratio refers to the relative area of windows to the surface area of a building. It is often used by architects as a parameter in architectural design and its effects on a number of building qualities such as energy efficiency (Yiwen & Yi, 2006; Goia, 2016), daylighting (Mangkuto, Rohmah, & Asri, 2016), and thermal comfort (Hassan, Guirguis, Shaalan, & El-Shazly, 2007) have been

tested extensively. So, while the aesthetic considerations of window-to-wall ratio might be discretionary to the architects' or the clients' preference, an optimal window-to-wall ratio is often obtained by maximising functionality. Furthermore, larger windows allow more natural light into a building and so window-to-wall ratio may be related to the perceived openness of an architectural structure, if not a direct measure of openness. Since open space has been found to be more aesthetically pleasing than enclosed space (Vartarian, et al., 2015), it was predicted that for building exteriors, high, compared to low, window-to-wall ratio would be rated as more beautiful. On the other hand, large windows might decrease a sense of privacy and therefore reduce perceived intimacy.

The last visual property tested in the present study of aesthetic judgements of building exteriors was building height. There is no evidence to suggest a universal preference for tall, low, or medium-height buildings. However, the effects of curvature and window-to-wall ratio on perceived beauty and intimacy of building exteriors might be modulated by building height. Moreover, participants in our study might be more familiar with medium and low height buildings that are more abundant in Ireland, thus perceive them as more beautiful as a result of the mere exposure effect; although it is possible that tall buildings might be preferred based on their novelty (Martindale, Moore, & West, 1988). Furthermore, residential buildings with different building heights imply different living conditions. For example, high-rise apartment buildings might be associated with a compact living style in a city while a house is more likely to be associated with suburban or country living, and each building type may have different social implications such as privacy and closeness with the community. These might lead to differences in aesthetic preferences or perceived intimacy for building height.

The effects of personality on aesthetics evaluations have been reported in a variety of tasks involving different stimuli. Some examples included preferences of simple geometrical shapes and patterns (Cotter, et al., 2017; Friedenberg, 2019), different styles of artwork (Mohan, & Mohan, 1965; Roubertoux, Carlier, & Chaguiboff, 1971; Furnham & Walker, 2001; Chamorro-Premuzic & Furnham, 2004; Chamorro-Premuzic, Reimers, Hsu, & Ahmetoglu, 2011; Cleridou & Furnham, 2014; Myszkowski, Storme, Zenasni, & Lubart, 2014), as well as in architecture (Ibrahim, Abu-Obeid, & Al-Simadi, 2002; Cook & Furnham, 2012; Cleridou & Furnham, 2014; Banaei, Ahmadi, Gramann, & Hatami, 2019). Despite the variations in the methodologies in terms of the use of different personality assessments, stimuli, and tasks, some consistencies were observed. For example, openness to experience, and to a lesser degree extroversion, appeared to be a consistent candidate in predicting positive aesthetic experiences, stimulation seeking and enjoyments of unconventional arts (e.g. pop and abstract arts), whereas agreeableness and conscientiousness were somewhat associated with more conservative attitudes in arts (Furnham & Walker, 2001; McManus & Furnham, 2006). Based on these findings, it was expected that the aesthetic evaluation of the built environments in this study might also be modulated, at least to a certain extent, by personality traits of the participants. Openness to experience in particular might exert a bigger effect on aesthetic judgements compared to other traits.

5.3. The study of aesthetic and intimacy judgements of buildings

5.3.1 Introduction

The aesthetic evaluation of architecture appears to exhibit large variability across individuals' responses compared to other domains such as faces and natural landscapes in which a stronger 'shared taste' has been observed (Vessel, et al., 2014; 2018). Yet many visual features that are considered beautiful universally (e.g. curvilinear contour, symmetry) are incorporated in built environments, indicating that some consensus on what is beautiful in architecture might exist. The objective of the current study was twofold. The first aim was to measure the extent to which aesthetic appreciation in architecture can be accounted for by low-level visual features or individual differences in personality and level of expertise in architecture. Secondly, since architecture differs from other more typical subjects of aesthetic appreciation (e.g. a painting) in that architecture serves the obvious functional purpose of providing refuge, it is possible that aesthetic preferences in architecture may reflect a purely hedonic appeal or overlap with the positive affects elicited by a desirable environment that is safe, comfortable and functional. If the latter was true, then factors affecting the aesthetic value of a built environment should also affect its perceived intimacy, an attribute associated with privacy, cosiness and comfort. To address these questions, a large-scale representative sample of participants were recruited from visitors to an exhibition entitled "Intimacy" hosted by the Science Gallery, Trinity College Dublin (https://dublin.sciencegallery.com/intimacy/).

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5.3.2 Method

Participants

A total of 2,081 participants volunteered to take part in the current study. The age range of the participants was 18 to 65 years (1003 females, mean age = 35.6 years, *SD* = 10.4). All were naïve to the purpose of the study and participation was voluntary with no compensation. Participants were asked about their expertise in architecture by specifying whether they were "qualified architects", "students in architecture", or "neither of the above" (i.e. non-experts). Fifty-nine participants identified themselves as qualified architects (20 females, mean age = 40.8 years, *SD* = 7.27) and 35 as students in architecture (17 females, mean age = 24.1 years, *SD* = 4.26). The study received ethical approval from the School of Psychology Research Ethics Committee at Trinity College. In accordance with this approval, all participants gave informed consent prior to the experiment.

Stimuli and apparatus

The stimuli of the current study consisted of eighty colour images of built environments. Forty of these were images of interior living spaces (e.g. bedroom, living room, kitchen) and were obtained from the stimulus set used by Vartanian, et al. (2013) with the approval of the corresponding author. Among these forty images, half depicted rectilinear spaces while the other half depicted curvilinear spaces. Within each contour group, half of the spaces had low ceilings and the other half had high ceilings. Furthermore, within each group of contour-ceiling combinations, half depicted an open space, and the other an enclosed space. This resulted in eight groups of contour-ceiling-openness combinations with five unique examples of images in each group. The categorisation of images according to contour (curvilinear, rectilinear), ceiling height (high, low) and space

openness (open space, enclosed space) was adopted from Vartanian, et al. (2013). The other forty images depicted the exteriors of residential buildings obtained from the internet using Google Image^{TM}. The images were selected based on a number of criteria which included image size and resolution, such that these were comparable in dimension to the indoor images. The images were also matched on style of the buildings depicted (only modern buildings without any elaborate ornaments), the absence or minimum presence of images of people and irrelevant objects (e.g. wire, trees) which have been shown to influence the overall aesthetics of the streetscape (Stamps, 1997) and, more importantly, the presence of visual features such as contour (curvilinear, rectilinear), window-to-wall ratio (low: windows constituted less than 30% of the total visible surface area of the building; high: windows constituted more than 50% of the total visible surface area of the building), and building height (short: three-storey or below, medium: four-to-nine-storey, tall: ten-storey or above), which were of main interest in the current study. Five undergraduate students in Trinity College Dublin who were naïve to the purpose of the current study were invited to judge the selected images of buildings and reached interrater consensus regarding their categorisation based on the above features. As a result, the final stimulus set of images of building exteriors consisted of 4 combinations of contour and window-to-wall ratios, and within each, there were 3 short buildings, 4 medium buildings and 3 tall buildings (Figure 5.1). All images, had a constant aspect ratio, were resized to the range of image size between 550 x 800 pixels and 650 x 800 pixels.
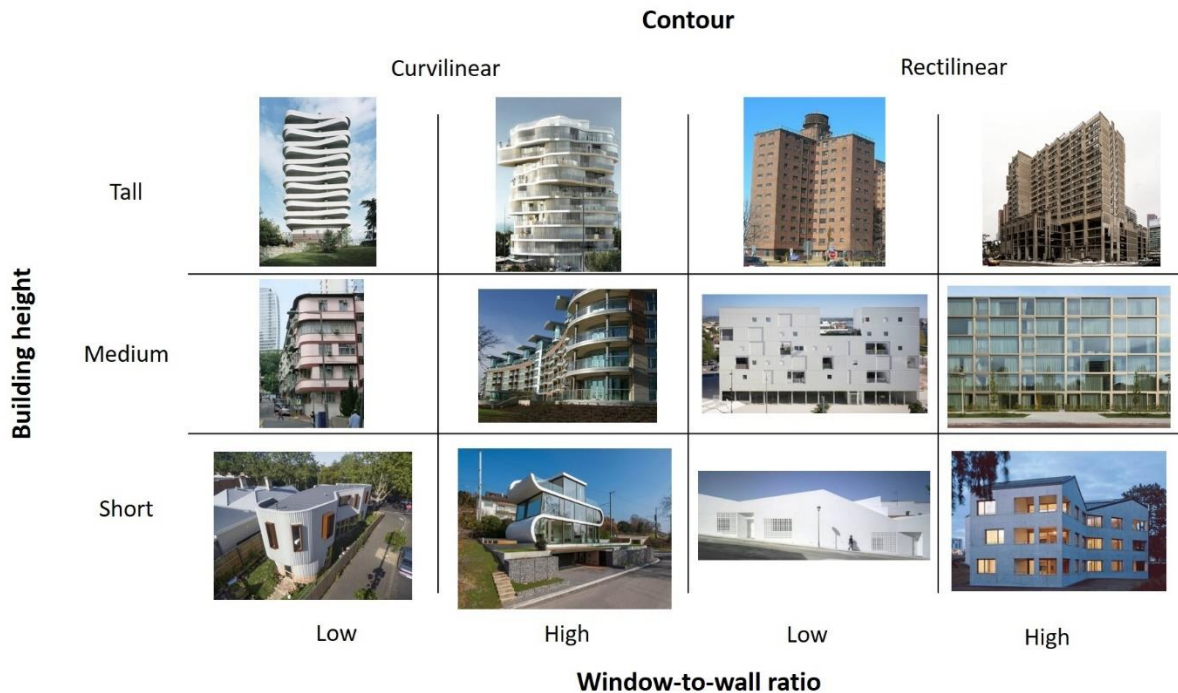
Figure 5.1 Examples of images (Public domain photographs) of building exteriors used as stimuli. Curvilinear buildings contain mainly curvilinear contours while rectilinear buildings contain mainly rectilinear edges.

Personality measurements were also taken across five dimensions, namely openness to experience, conscientiousness, extraversion, agreeableness, and negative emotionality using the 15-item extra-short form of the Big Five Inventory–2 (BFI-2-XS) (Soto & John, 2017). The short version was used instead of the 60-item long form (BFI-2) in order to keep the length of the study to a maximum of 15 minutes as required for a public exhibition. Each item consisted of a statement which participants read and were asked to respond using a rating scale from 1 (disagree strongly) to 5 (agree strongly).

The experiment was programmed using PsychoPy (Peirce, 2007) and run on a Dell Inspiron 3470 desktop computer. The stimuli were presented on a 34cm x 27.5cm HP LCD monitor with a resolution of 1280 x 800 at 60 Hz.

5. The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study

Design

A mixed-model design was adopted with a number of the within-subject and between-subject predictors, as well as random factors within participants and stimuli. The properties of the built environments which every participant viewed were within-subject predictors and included contour (curvilinear, rectilinear), ceiling height (low, high) and space openness (close, open) for indoor architectural spaces; and contour (curvilinear, rectilinear), building height (short, medium, tall) and window-to-wall ratio (low, high) for building exteriors. The between-subject predictors were the five dimensions of personality measures and expertise in architecture. The dependent variables were the perceived intimacy and beauty ratings provided by the participants to each of the images of built environments. There were four versions of the study whereby the stimuli were images of either all indoor architectural spaces or all building exteriors and the task was either to rate the intimacy or the beauty of the architecture. Each participant took part in only one of the versions and was presented with 40 trials.

Procedure

The experiment took place in the Science Gallery, Trinity College Dublin in which the experimental setup was one of the exhibits (Figure. 5.2). A brief description of the study was provided on a wall panel positioned next to the setup, which gave the participants an introduction to the study as well as an operational definition of 'intimacy' and part of it read,

"When referring to an environment, the word 'intimacy' is often defined as "a cosy and private or relaxed atmosphere". A sense of intimacy can arise not only when we enter

environments that we are familiar with, like our own homes, but also places that are

unfamiliar, public, or even outdoors…"

Each participant was positioned within the testing booth and stood in front of a computer monitor. The description of the study again appeared as the 'Start' screen of the experiment. The four versions of the study were presented in rotation throughout the whole period of the exhibition with each version presented for a maximum of 32 days. Prior to the experiment, participants provided basic demographic information (e.g. age range, gender, level of knowledge in architecture), completed the BFI-2-XS questionnaire (Soto & John, 2017) and were instructed on the ratings task. A single practice trial was performed in order for the participants to familiarise themselves with the trial structure. Each trial started with a white fixation cross presented in the centre of the screen for 500ms, followed by a 30ms interval. Then, in the centre of the screen, an image of a building or an indoor architectural space appeared and remained on the screen until the end of the trial, which was marked by a response cue for the participant to provide a beauty or an intimacy rating of the built environment being viewed. The participant responded by adjusting the location of a marker on a sliding scale which ranged from 0 to 100, with 0 representing not beautiful, or not intimate at all and 100 presenting very beautiful, very intimate. The participant was encouraged to utilize the whole scale. The experiment took approximately ten minutes for each participant to complete.

Figure 5.2 The experimental set up of the current study within the Intimacy exhibition at the Science Gallery Dublin.

5.3.3 Data analysis approach

Data from 324 participants (all non-experts) were not included in the analyses after screening for missing trials, which indicated the participants did not complete the study. As a result, the main analyses included four sets of data (one for each version of the study) from 1757 participants: 388 participants (11 architects, 5 architecture students) rated the beauty of the indoor spaces; 587 participants (23 architects, 11 architecture students) rated the beauty of the building exteriors; 343 participants (14 architects, 8 architecture students) rated the intimacy of indoor spaces; and, 439 participants (11 architects, 11 architecture students) rated the intimacy of building exteriors. These four sets of data were analysed independently.

In order to analyse the effects of building features, personality traits, and expertise in architecture on perceived beauty and intimacy of built environments, the linear mixed-model (LMM) approach was employed. Unlike repeated-measures ANOVA, LMM can simultaneously account for random variability at both the participant and stimulus levels

without data aggregation to obtain group averages, hence reduce Type 1 error (Baayen, Davidson, & Bates, 2008; Judd, Westfall, & Kenny, 2012). The LMMs were fit by maximum likelihood in R with the *lmer* program in the *lm4* library (Bates, Mächler, Bolker, & Walker, 2015) and the *lmerTest* library (Kuznetsova, Brockhoff, & Christensen, 2016) was used for testing of statistical significance such that the *p* values were estimated for the *t* tests based on the Satterthwaite's method to approximate degrees of freedom. In the models for the two sets of rating responses (aesthetic and intimacy) involving indoor architectural spaces, the fixed effects included three categorical stimulus predictors, namely, contour, ceiling height and space openness. The reference levels were 'curvilinear' for contour, 'high' for ceiling height, and 'close' for space openness. For the other two sets of ratings to building exteriors, the stimulus-related fixed effects were also categorical and included contour, building height and window-to-wall ratio. The reference levels were 'curvilinear' for contour, 'medium' for building height, and 'high' for window-to-wall ratio. Additionally, the five personality trait dimension scores (i.e. openness to experience, conscientiousness, extroversion, agreeableness, and negative emotionality) were centred, standardised and included as continuous fixed effects. Since the number of observations in the three levels of expertise in architecture (i.e. architects, architecture students and non-experts) was not predetermined and therefore imbalanced (there were far more non-experts than architects and architecture students), expertise was included as a categorical fixed effect only if it improved the overall model fit. The reference level for expertise is 'expert'. The random factors were participant ID and stimulus ID. The recommendation by Barr, Levy, Scheepers, & Tily (2013) that the random effects structure should be maximal, was followed such that random intercepts within stimuli and the random intercepts and slopes for the stimulus features within participants were included in the models unless non-convergence was encountered.

5. The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study

The number of variables in the current study was relatively large compared to previous studies on empirical aesthetics of architecture (Vartanian, et al., 2013, 2015, 2017). Therefore, cautious construction of the fixed effects structure was required to optimise the LMM to avoid overfitting and loss of statistical power. To this end, eight models were built for each data set in sequence of increasing model complexity and model selection was carried out by comparing the Akaike Information Criterion (AIC), whereby lower AIC values indicate increased relative goodness of fit. The models are described as follows with the corresponding *lmer* model specifications in R, where F presents the three stimulus features, and P represents the five personality measurements.

    i.   *The random intercepts model included only the random intercepts of participants and stimuli.*

        Model specification:

M_i ← lmer (rating ~ 1 + (1 | participant ID) + (1 | stimulus ID))   (1)

    ii.   *The random intercepts and slopes models included only the random intercepts and random slopes for participants and random intercepts for stimuli. This model was then compared with M_i. The better model between the two was designated as the null model.*

        Model specification:

M_{ii} ← lmer (rating ~ 1 + (1 + F_1 + F_2 + F_3 | participant ID) + (1 | stimulus ID))   (2)

    iii.   *The stimulus main effects model included only the fixed effects of stimulus features, as well as the random intercepts (and random slopes, depending on the null model selected) for participants and stimuli. For brevity, the combination of random intercepts and random slopes is referred to as random effects in the model specifications from hereon.*

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Model specification:

$$M_{iii} \leftarrow lmer\ (rating \sim 1 + F_1 + F_2 + F_3 + random\ effects) \qquad (3)$$

iv.   *The full main effects model included all fixed effects except expertise (five personality measurements and three stimulus features), and the random effects. This model was then compared with M_{iii} and the better between the two was used to base the subsequent models on.*

Model specification:

$$M_{iv} \leftarrow lmer\ (rating \sim 1 + F_1 + F_2 + F_3 + P_1 + P_2 + P_3 + P_4 + P_5 + random\ effects) \qquad (4)$$

v.   *The stimulus feature interactions model was built by adding 3 two-way stimulus feature interactions terms (e.g. contour x space openness, building height x window-to-wall ratio) onto model iii or model iv. The lmer function automatically computes the main effects of factors in any interaction terms. Therefore, the individual main effects were not specified in the model if the factor was included in the interaction terms.*

Model specification:

$$M_v \leftarrow lmer\ (rating \sim 1 + F_1\ x\ F_2 + F_2\ x\ F_3 + F_1\ x\ F_3 + random\ effects) \qquad (5)$$

Or

$$M_v \leftarrow lmer\ (rating \sim 1 + P_1 + P_2 + P_3 + P_4 + P_5 + F_1\ x\ F_2 + F_2\ x\ F_3 + F_1\ x\ F_3 + random\ effects) \qquad (6)$$

vi.   *The personality-feature interactions model included all the two-way interaction terms between the stimulus features and personality measurements (e.g. contour x openness to experience, window-to-wall ratio x negative emotionality) as fixed effects in addition to the random effects.*

5. The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study

Model specification:

$M_{vi} \leftarrow$ lmer (rating ~ $1 + F_1 \times P_1 + F_1 \times P_2 + F_1 \times P_3 + F_1 \times P_4 + F_1 \times P_5$

$+ F_2 \times P_1 + F2 \times P_2 + F_2 \times P_3 + F_2 \times P_4 + F_2 \times P_5$

$+ F_3 \times P_1 + F_3 \times P_2 + F_3 \times P_3 + F_3 \times P_4 + F_3 \times P_5 +$ random effects)   (7)

vii.   The extended interactions model was built by combining M_v and M_{vi} so that both the interactions between stimulus features and those between personality measurements and stimulus features were included in the model.

Model specification:

$M_{vii} \leftarrow$ lmer (rating ~ $1 + F_1 \times F_2 + F_2 \times F_3 + F_1 \times F_3$

$+ F_1 \times P_1 + F_1 \times P_2 + F_1 \times P_3 + F_1 \times P_4 + F_1 \times P_5$
$+ F_2 \times P_1 + F2 \times P_2 + F_2 \times P_3 + F_2 \times P_4 + F_2 \times P_5$
$+ F_3 \times P_1 + F_3 \times P_2 + F_3 \times P_3 + F_3 \times P_4 + F_3 \times P_5 +$ random effects)   (8)

viii.   The expertise model was built by adding expertise and the two-way interaction terms between expertise and individual features (e.g. expertise x contour) as fixed effects to the best model among $M_{iii \ to \ vii}$. in terms of AIC values.

Model specification:

$M_{viii} \leftarrow$ lmer (rating ~ $1 + F_1 \times$ Expertise $+ F_2 \times$ Expertise $+ F_1 \times$ Expertise

$+$ fixed effects specified in (3), (4), (5), (6), (7), or (8) $+$ random effects)   (9)

5.3.4 Results

The variance inflation factors (VIF) were estimated for all models to detect potential multicollinearity. The maximum VIF value obtained was 3, which was way below the critical value of 10 (Hair, Black, Babin, & Anderson, 2010).

Effects of contour, ceiling height, space openness, personality, and expertise on perceived beauty of indoor architectural spaces (n = 388)

The data were best described by M_{iii} (the stimulus main effects model), which performed significantly better than the null (random intercepts and random slopes only) model (χ^2 (3) = 14.2, p = 0.00264). Table 5.1 shows the goodness of fit statistics of the models built.

Table 5.1 Models built to predict beauty ratings of indoor architectural spaces

LMM	df	AIC	Δdf	χ^2	p
Null (M_{ii})	13	137837	-	-	-
Stimulus main effects (M_{iii})	**16**	**137829**	**3**	**14.2**	**0.00264**[**]
Full main effects (M_{iv})	21	137832	8	20.9	0.00744[**]
Stimulus feature interactions (M_{v})	19	137834	6	15.6	0.0162[*]
Personality-feature interactions (M_{vi})	36	137848	23	35.4	0.0477[*]
Extended interactions (M_{vii})	39	137852	26	36.7	0.0788
Expertise (M_{viii})	24	137841	11	18.6	0.0686

Note: Chi-squared statistics reflects the difference between the null and a given model (** $p < 0.01$; * $p < 0.05$). Model in bold is the best model with the lowest AIC value.

The chosen model revealed a significant main effect of perceived space openness (β = 10.6, SE = 3.18, t (40.5) = 3.33, p = 0.00184). Open spaces were rated significantly more beautiful than enclosed spaces (Figure 5.3). Although architectural spaces with low ceilings were rated as less beautiful than those with high ceilings the effect of ceiling height failed to reach significance (β = -6.24, SE = 3.18, t (40.3) = -1.96, p = 0.0565). The main effect of contour also did not reach statistical significance (β = -4.58, SE = 3.17, t (40.3) = -1.44, p = 0.157). Table 5.2 provides a summary of the model estimates.

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Table 5.2 Estimates of fixed effects from the linear mixed effects model predicting beauty ratings of indoor architectural spaces as a function of space openness, ceiling height, and contour

Fixed effects	β	SE	df	t	p
(Intercept)	51.6	3.23	43.1	16.0	<0.001[***]
Space openness: open	10.6	3.18	40.5	3.33	0.00184[**]
Reference level: enclosed					
Ceiling height: low	-6.24	3.18	40.3	-1.96	0.0565
Reference level: high					
Contour: rectilinear	-4.58	3.17	40.06	-1.44	0.157
Reference level: curvilinear					

Note: *** $p < 0.001$; ** $p < 0.01$.
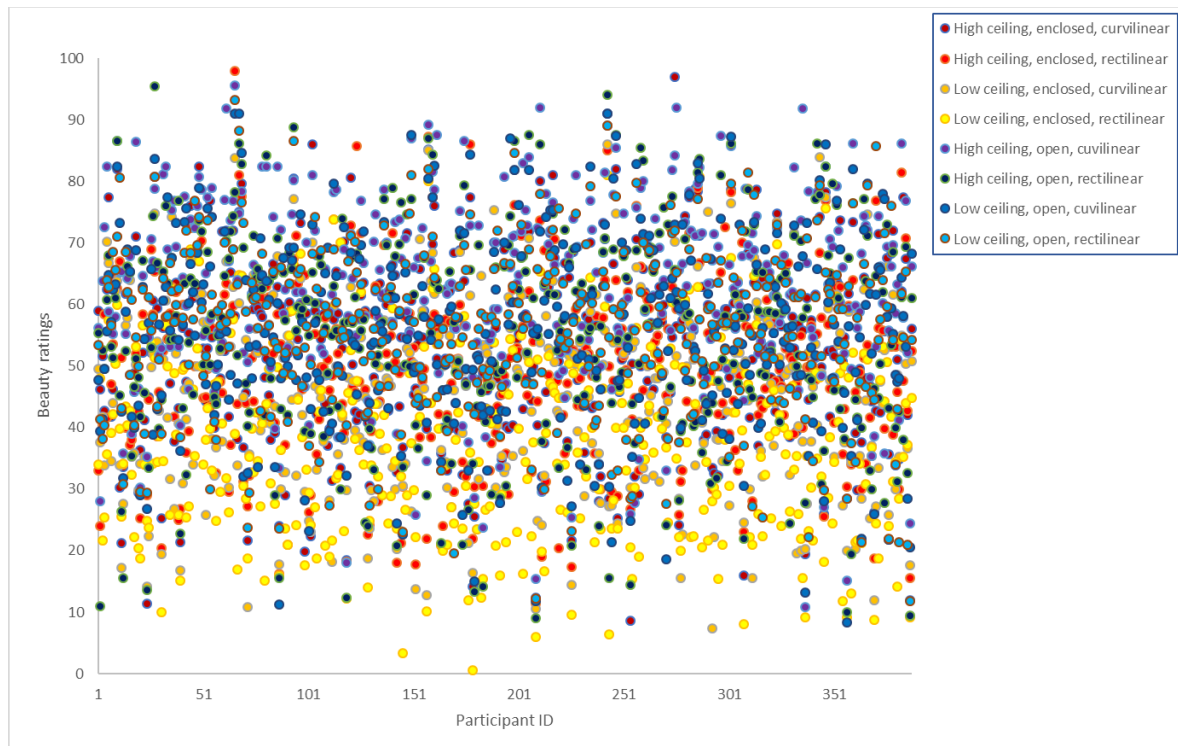
Figure 5.3 Plot showing the average beauty ratings of indoor architectural spaces of each combination of ceiling height, space openness, and contour by all participants. Each data point represents of average rating of a particular combination by one participant.

Including personality measurements, expertise, and interaction terms to the model did not

improve the model fit (Table 5.1). Therefore, it was concluded that beauty ratings of

indoor architectural spaces were, out of all the factors considered, only affected by perceived openness of the space but not affected by personality and expertise, nor did these factors interact with the stimulus features.

Effects of contour, ceiling height, space openness, personality, and expertise on perceived intimacy of indoor architectural spaces (n = 343)

None of the models built yielded better predictions on intimacy ratings than the null model (Table 5.3). This indicates that perceived intimacy ratings were unaffected by the ceiling height, contour, space openness, nor any personality measurements and expertise in architecture.

Table 5.3 Models built to predict intimacy ratings of indoor architectural spaces

LMM	df	AIC	Δdf	χ^2	p
Null (M$_i$)	**4**	**124422**	**-**	**-**	-
Stimulus main effects (M$_{iii}$)	7	124425	3	2.40	0.494
Full main effects (M$_{iv}$)	12	124427	8	10.5	0.229
Stimulus feature interactions (M$_v$)	10	124429	6	4.88	0.559
Personality-feature interactions (M$_{vi}$)	27	124429	23	38.5	0.0226[*]
Extended interactions (M$_{vii}$)	*Model failed to converge*				
Expertise (M$_{viii}$)	15	124436	11	8.20	0.695

Note: Chi-squared statistics reflects the difference between the null and a given model
* $p < 0.05$). Model in bold is the best model with the lowest AIC value.

Effects of contour, building height, window-to-wall ratio, personality, and expertise on perceived beauty of building exteriors (n = 587)

The data were best described by M$_{viii}$ (the expertise model), which performed significantly better than the null (random intercepts only) model (χ^2 (39) = 96.8, $p <$ 0.001). It included all main effects of stimulus features, personality measurements, expertise levels, as well as the personality-feature interactions and expertise-feature

interactions. Table 5.4 shows the goodness of fit statistics of models built and Table 5.5

provides a summary of the model estimates.

Table 5.4 Models built to predict beauty ratings of building exteriors

LMM	df	AIC	Δdf	χ^2	p
Null (M_i)	4	208835	-	-	-
Stimulus main effects (M_{iii})	8	208826	4	16.3	0.00261**
Full main effects (M_{iv})	13	208830	5	6.49	0.261
Stimulus feature interactions (M_v)	13	208828	9	24.2	0.004***
Personality-feature interactions (M_{vi})	33	208822	29	71.0	<0.001***
Extended interactions (M_{vii})	38	208824	34	78.8	<0.001***
Expertise (M_{viii})	**43**	**208816**	**39**	**96.8**	**<0.001*****

Note: Chi-squared statistics reflects the difference between the null and a given model (** $p < 0.01$, *** $p < 0.001$). Model in bold is the best model with the lowest AIC value.

Curvilinear buildings were rated as more beautiful than rectilinear buildings, but the

chosen model revealed that effect of contour on beauty ratings of building exteriors failed

to reach significance (β = -8.58, SE = 4.42, t (109) = -1.94, p = 0.0548). The effect of

contour was modulated by level of expertise in architecture as reflected by a significant

interaction between the two (Expertise: non-experts by Contour: rectilinear, β = -3.67, SE

= 1.34, t (22850) = -2.75, p = 0.006; Expertise: student by Contour: rectilinear, β = -7.49,

SE = 2.3, t (22850) = -3.26, p = 0.001). Post hoc multiple comparisons were performed

to test for the differences in beauty ratings given to curvilinear and rectilinear buildings

by participants of different level of expertise in architecture using the *lsmeans* function

within the *lsmeans* library, which estimated degrees of freedom using the Satterthwaite's

method and p values were adjusted using the Tukey method. The results showed that

experts gave marginally higher beauty ratings to curvilinear buildings than rectilinear

ones (mean difference = 10.6, SE = 3.67, t (52) = 2.89, p = 0.06). Significantly higher

ratings were given to curvilinear buildings than rectilinear building by both non-experts

(mean difference = 14.3, SE = 3.44, t (40) = 4.15, p = 0.002) and architecture students

(mean difference = 18.1, SE = 3.92, t (67) = 4.62, p < 0.0001) (Figure 5.4).

5. The role of individual differences on perceived beauty and intimacy from images of residential architecture – a large scale study
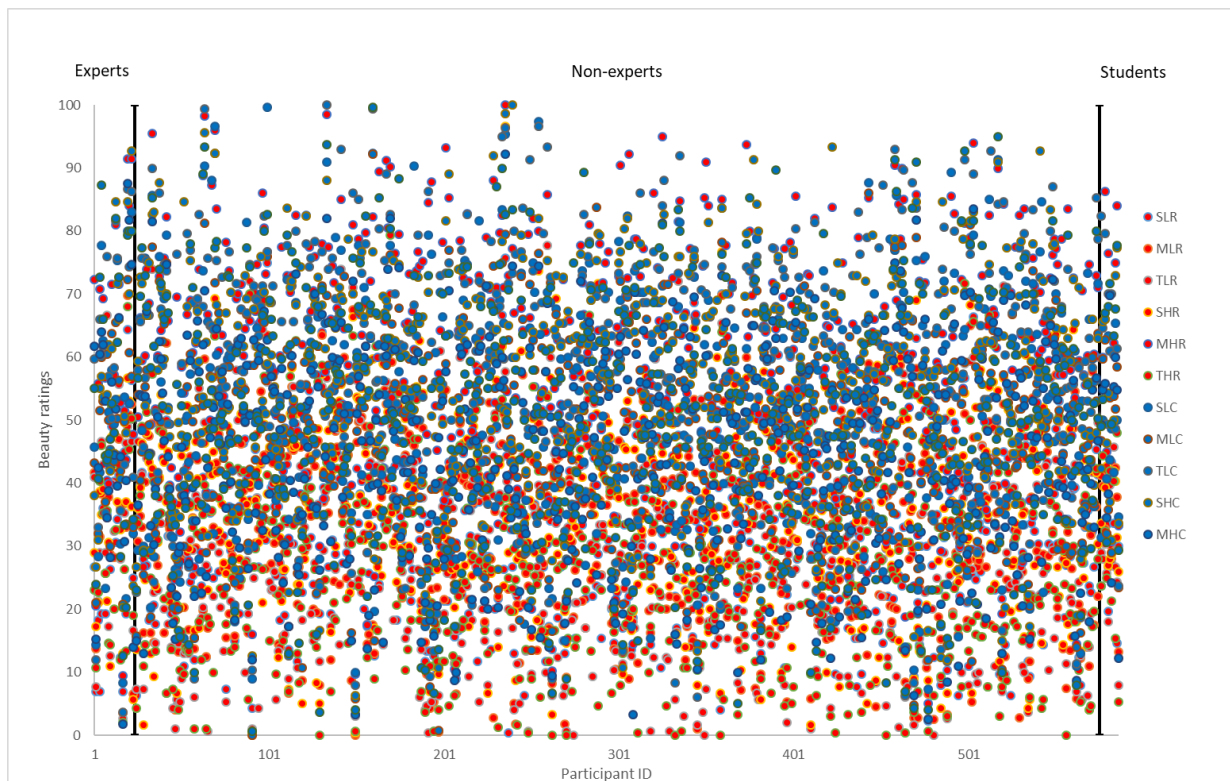
Figure 5.4 Plot showing the average beauty ratings of building exteriors of each combination of building height (S: short, M: medium, T: tall), window-to-wall ratio (L: low, H: high), and contour (R: rectilinear, in red, C: curvilinear, in blue) by all participants. Each data point represents of average rating of a particular combination by one participant. Participants with participant ID 1-23 were experts (practising architects or interior designers), 24 to 576 were non-experts, and 577 to 587 were students in architecture or interior design.

The main effect of window-to-wall ratio on beauty ratings did not reach statistical significance (β = -6.76, SE = 4.42, t (109) = -1.53, p = 0.129). However, there were significant interactions between window-to-wall ratio and the measurements of two of the personality dimensions – extraversion (β = -0.232, SE = 0.112, t (22850) = -2.07, p = 0.039) and agreeableness (β = -0.233, SE = 0.116, t (22850) = 2.01, p = 0.045).

Participants who scored higher in the extraversion dimension gave lower beauty ratings to buildings with low window-to-wall ratios, but participants' agreeableness scores increased with beauty ratings for buildings with low window-to-wall ratios.

The main effect of building height also failed to reach significance (Building height: short, β = -7.7, SE = 5.33, t (109) = -1.44, p = 0.152; Building height: tall, β = -4.63, SE

= 5.33, t (109) = -0.868, p = 0.387). There was a significant interaction between expertise level and building height on beauty ratings (Building height: short x Expertise: non-expert, β = 4.4, SE = 1.62, t (22850) = 2.72, p = 0.006). However, results of the post hoc Tukey multiple comparison were non-significant. None of the other main effects nor interactions reached statistical significance (Table 5.5)

Table 5.5 Estimates of fixed effects from the linear mixed effects model predicting beauty ratings of building exteriors as a function of window-to-wall ratio, building height, contour, personality, and expertise in architecture

Fixed effects	β	SE	df	t	p
(Intercept)	57.7	7.40	46.2	7.80	<0.001***
Window-to-wall ratio: low	-6.76	4.42	109	-1.53	0.129
Reference level: high					
Building height: short	-7.70	5.33	109	-1.44	0.152
Reference level: medium					
Building height: tall	-4.63	5.33	109	-0.868	0.387
Reference level: medium					
Contour: rectilinear	-8.58	4.42	109	-1.94	0.0548
Reference level: curvilinear					
Openness to Experience	0.366	0.276	837	1.33	0.184
Conscientiousness	-0.150	0.258	837	-0.579	0.563
Extroversion	0.284	0.259	837	1.10	0.273
Agreeableness	-0.415	0.269	837	-1.54	0.123
Negative emotionality	-0.350	0.213	837	-1.65	0.100
Window-to-wall ratio: low x Openness to Experience	0.140	0.119	22850	1.18	0.239
Window-to-wall ratio: low x Conscientiousness	-0.017	0.112	22850	-0.155	0.877
Window-to-wall ratio: low x Extroversion	-0.232	0.112	22850	-2.07	0.039*
Window-to-wall ratio: low x Agreeableness	0.233	0.116	22850	2.01	0.045*
Window-to-wall ratio: low x Negative emotionality	0.034	0.092	22850	0.374	0.709
Building height: short x Openness to Experience	-0.233	0.144	22850	-1.62	0.105
Building height: short x Conscientiousness	0.177	0.135	22850	1.31	0.190
Building height: short x Extroversion	-0.023	0.135	22850	-0.172	0.863
Building height: short x Agreeableness	0.186	0.140	22850	1.32	0.186
Building height: short x Negative emotionality	0.072	0.111	22850	0.648	0.517
Building height: tall x Openness to Experience	0.142	0.144	22850	0.990	0.322

Table 5.5 Continued.

Fixed effects	β	SE	df	t	p
Building height: tall x Extroversion	0.194	0.135	22850	1.43	0.152
Building height: tall x Agreeableness	-0.254	0.140	22850	-1.81	0.071
Building height: tall x Negative emotionality	0.147	0.111	22850	1.33	0.185
Contour: rectilinear x Openness to Experience	-0.001	0.119	22850	-0.008	0.993
Contour: rectilinear x Conscientiousness	-0.171	0.112	22850	-1.53	0.127
Contour: rectilinear x Extroversion	-0.191	0.112	22850	-1.70	0.089
Contour: rectilinear x Agreeableness	0.091	0.116	22850	0.787	0.431
Contour: rectilinear x Negative emotionality	0.057	0.092	22850	0.621	0.535
Expertise: Non-expert *Reference level: Expert*	-0.316	3.09	837	-0.102	0.919
Expertise: Student *Reference level: Expert*	4.27	5.32	837	0.803	0.422
Expertise: Non-expert x Window-to-wall ratio: low	-0.081	1.34	22850	-0.061	0.951
Expertise: Non-expert x Building height: short	4.40	1.62	22850	2.72	0.006**
Expertise: Non-expert x Building height: tall	-0.216	1.62	22850	-0.134	0.894
Expertise: Non-expert x contour: rectilinear	-3.67	1.34	22850	-2.75	0.006**
Expertise: Student x Window-to-wall ratio: low	-2.00	2.30	22850	-0.872	0.383
Expertise: Student x Building height: short	1.32	2.78	22850	0.475	0.635
Expertise: Student x Building height: tall	1.31	2.78	22850	0.470	0.638
Expertise: Student x contour: rectilinear	-7.49	2.30	22850	-3.26	0.0011**

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Effects of personality, contour, building height and window-to-wall ratio on perceived intimacy of building exteriors (n = 439)

The best-fitting model was the expertise model (χ^2 (44) = 121, $p < 0.0001$). It included all main effects of stimulus features, personality measurements, expertise level, as well as the stimulus feature interactions, personality-feature interactions and expertise-feature interactions. Table 5.6 shows the goodness of fit statistics of models built and Table 5.7 provides a summary of the model estimates.

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Table 5.6 Models built to predict intimacy ratings of building exteriors

LMM	df	AIC	Δdf	χ^2	p
Null (M$_i$)	4	155856	-	-	-
Stimulus main effects (M$_{iii}$)	8	155846	4	18.1	0.00117**
Full main effects (M$_{iv}$)	13	155849	9	24.8	0.00323**
Stimulus feature interactions (M$_v$)	13	155842	9	32.5	0.0001***
Personality-feature interactions (M$_{vi}$)	33	155832	29	82.5	<0.0001***
Extended interactions (M$_{vii}$)	38	155827	34	96.9	<0.0001***
Expertise (M$_{viii}$)	**48**	**155823**	**44**	**121**	**<0.0001***

Note: Chi-squared statistics reflects the difference between the null and a given model (*** $p < 0.001$; ** $p < 0.01$). Model in bold is the best model with the lowest AIC value.

According to the chosen model, a significant main effect of building height on intimacy ratings was found (Building height: tall, β = -8.92, SE = 4.34, t (74) = -2.06, p = 0.043). The results of a post hoc Tukey multiple comparison revealed that the intimacy ratings for tall buildings were significantly lower than those for building of medium height (mean difference = 8.56, SE = 2.37, t (59.4) = 3.61, p = 0.0018) and short buildings (mean difference = 11.85, SE = 2.53, t (59.4) = 4.68, p = 0.0001). There was no difference in intimacy ratings between short and medium-height buildings (mean difference = 3.29, SE = 2.37, t (59.4) = 1.389, p = 0.353).

The effect of building height was modulated by window-to-wall ratio (Building height: tall x Window-to-wall ratio: low, β = 11.6, SE = 4.29, t (39.9) = 2.72, p = 0.01). The results of a post hoc Tukey multiple comparison test confirmed that for buildings with high window-to-wall ratios only, tall buildings were rated as less intimate than both medium-height (mean difference = 14.4, SE = 3.2, t(49.2) = 4.5, p = 0.0006) and short buildings (mean difference = 14.04, SE = 3.42, t(49.2) = 4.11, p = 0.002). However, the effect of building height was non-significant among buildings with low window-to-wall ratios.

Contour was also found to interact with building height on intimacy ratings (Building height: tall x Contour: rectilinear, β = -12.04, SE = 4.29, t (39.9) = -2.81, p = 0.008).

Results of the post hoc analysis showed that the effect of building height was significant only for rectilinear, but not curvilinear buildings such that tall buildings with rectilinear contours were rated as less intimate than those of short (mean difference = 17.7, *SE* = 3.42, *t* (49.2) = 5.18, *p* = 0.0001) or medium heights (mean difference = 14.6, *SE* = 3.2, *t* (49.2) = 4.56, *p* = 0.0005). Additionally, an effect of contour was observed in tall buildings but not shorter buildings. Tall curvilinear buildings were rated as more intimate than their rectilinear counterparts (mean difference = 13.6, *SE* = 3.35, *t* (45.3) = 4.05, *p* = 0.0026).

There was a significant interaction between the openness-to-experience personality dimension and building heights (Building height: tall x Openness to experience, *β* = -1.43, *SE* = 0.362, *t* (17080) = -3.94, *p* <0.0001), indicating that participants who scored higher in the openness-to-experience dimension gave lower intimacy ratings to tall buildings.

The main effect of window-to-wall ratio on intimacy ratings did not reach statistical significance (*β* = -3.36, *SE* = 3.8, *t* (68.47) = -0.882, *p* = 0.381). However, the interaction between the openness- to-experience personality dimension and window-to-wall ratio was significant (*β* = 0.961, *SE* = 0.3, *t* (17080) = 3.21, *p* = 0.001), indicating that openness- to-experience score increased with intimacy ratings for buildings with low window-to-wall ratios compared to those with high window-to-wall ratios. Expertise level in architecture also modulated the effect of window-to-wall ratio (Window-to-wall ratio: low x Expertise: non-expert, *β* = -4.05, *SE* = 1.9, *t* (17080) = -2.13, *p* = 0.033; Window-to-wall ratio: low x Expertise: student, *β* = -6.97, *SE* = 2.66, *t* (17080) = -2.62, *p* =0.009). Both non-experts and architecture students gave lower intimacy ratings to buildings with low window-to-wall ratio compared to experts. However, the results of a post doc analysis showed that none of these differences were significant.

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The main effect of contour was not significant ($\beta = 0.63$, $SE = 3.8$, $t(68.5) = 0.166$, $p = 0.869$), although the effect of contour depended on expertise level (Contour: rectilinear x Expertise: non-expert, $\beta = -4.77$, $SE = 1.9$, $t(17080) = -2.51$, $p = 0.012$). Results of the post hoc analysis showed that only non-experts, but not architecture students nor architects, rated curvilinear buildings as significantly more intimate compared to rectilinear buildings (mean difference = 7.6, $SE = 1.79$, $t(40) = 4.24$, $p = 0.0017$) (Figure 5.5).
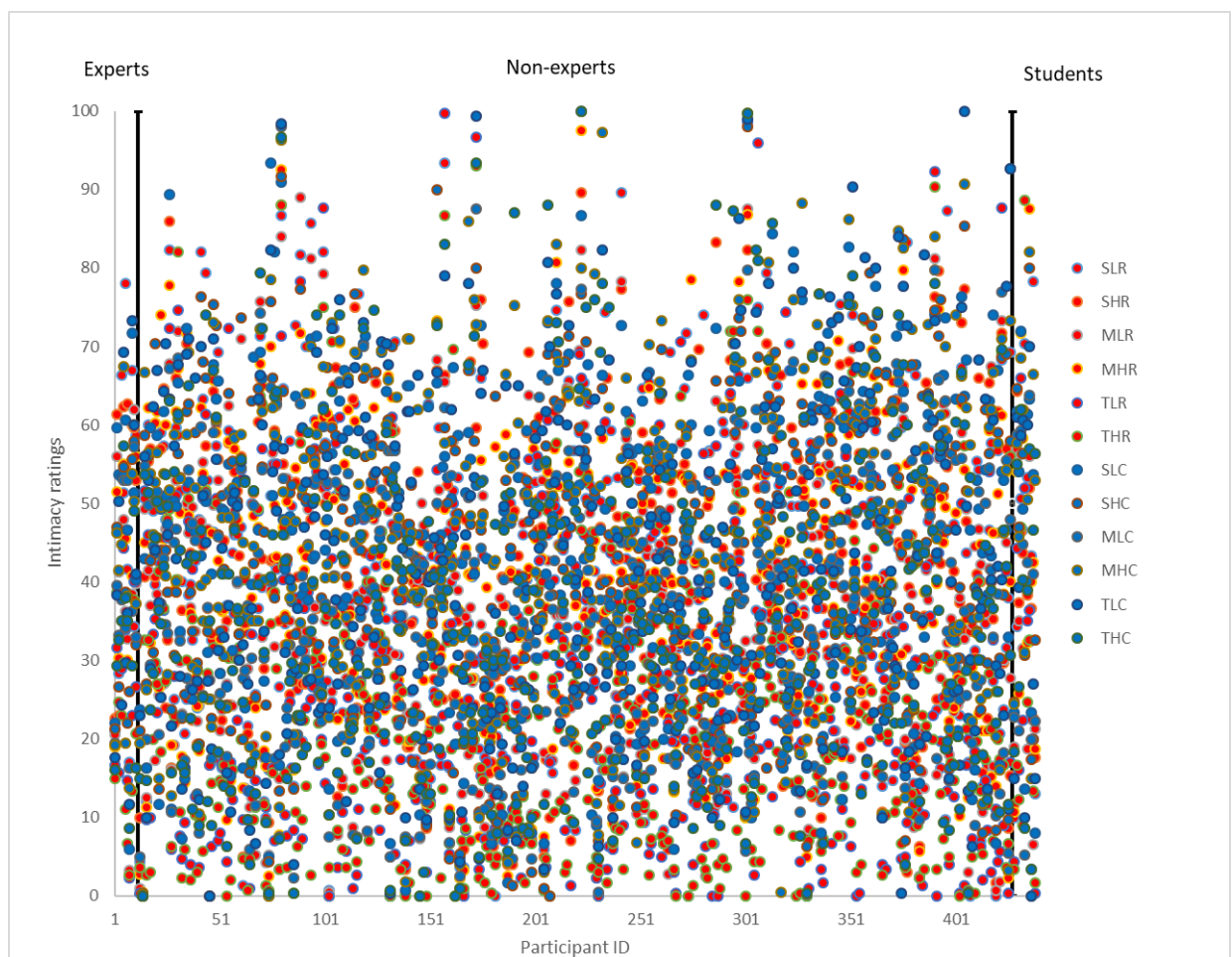
Figure 5.5 Plot showing the average intimacy ratings of building exteriors of each combination of building height (S: short, M: medium, T: tall), window-to-wall ratio (L: low, H: high), and contour (R: rectilinear, in red, C: curvilinear, in blue) by all participants. Each data point represents of average rating of a particular combination by one participant. Participants with participant ID 1-11 were experts (practising architects or interior designers), 12 to 428 were non-experts, and 429 to 439 were students in architecture or interior design.

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An interaction between the agreeableness personality dimension and contour was found (β = -0.723, SE = 0.303, t (17080) = -2.39, p = 0.017), indicating that as participants' scores in the agreeableness dimension increased, the intimacy ratings they gave to rectilinear buildings decreased.

Finally, there was a main effect of the extraversion personality dimension (β = 1.7, SE = 0.785, t (581) = 2.17, p = 0.03). Participants who scored highly in the extraversion dimension gave higher intimacy ratings overall.

Table 5.7 Estimates of fixed effects from the linear mixed effects model predicting intimacy ratings of building exteriors as a function window-to-wall ratio, building height, contour, personality, and expertise in architecture

Fixed effects	β	SE	df	t	p
(Intercept)	40.4	5.48	434.60	7.37	<0.001***
Window-to-wall ratio: low *Reference level: high*	-3.36	3.80	68.47	-0.882	0.381
Building height: short *Reference level: medium*	2.76	4.34	73.99	0.637	0.526
Building height: tall *Reference level: medium*	-8.92	4.34	73.99	-2.06	0.043*
Contour: rectilinear *Reference level: curvilinear*	0.630	3.80	68.47	0.166	0.869
Window-to-wall ratio: low x Building Height: short	7.26	4.29	39.85	1.69	0.098
Window-to-wall ratio: low x Building Height: tall	11.6	4.29	39.85	2.72	0.010**
Contour: rectilinear x Building Height: short	-0.346	4.29	39.85	-0.081	0.936
Contour: rectilinear x Building Height: tall	-12.04	4.29	39.85	-2.81	0.008**
Window-to-wall ratio: low x Contour: rectilinear	1.35	3.55	39.85	0.379	0.707
Openness to Experience	-0.771	0.774	581	-1.00	0.319
Conscientiousness	-1.14	0.814	581	-1.40	0.162
Extroversion	1.70	0.785	581	2.17	0.030*
Agreeableness	0.249	0.781	581	0.319	0.750
Negative emotionality	-0.239	0.814	581	-0.294	0.769
Window-to-wall ratio: low x Openness to Experience	0.961	0.300	17080	3.21	0.001**

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Table 5.7 Continued

Fixed effects	β	SE	df	t	p
Window-to-wall ratio: low x Agreeableness	0.274	0.303	17080	0.905	0.365
Window-to-wall ratio: low x Negative emotionality	0.334	0.315	17080	1.06	0.289
Building height: short x Openness to Experience	0.448	0.362	17080	1.24	0.216
Building height: short x Conscientiousness	0.243	0.381	17080	0.638	0.523
Building height: short x Extroversion	-0.096	0.367	17080	-0.261	0.794
Building height: short x Agreeableness	-0.227	0.366	17080	-0.621	0.535
Building height: tall x Openness to Experience	-1.43	0.362	17080	-3.94	<0.001***
Building height: tall x Conscientiousness	-0.451	0.381	17080	-1.18	0.237
Building height: tall x Extroversion	0.426	0.367	17080	1.16	0.246
Building height: tall x Agreeableness	0.166	0.366	17080	0.453	0.651
Building height: tall x Negative emotionality	0.179	0.381	17080	0.470	0.638
Contour: rectilinear x Openness to Experience	0.534	0.300	17080	1.78	0.075
Contour: rectilinear x Conscientiousness	-0.109	0.315	17080	-0.344	0.731
Contour: rectilinear x Extroversion	-0.254	0.304	17080	-0.835	0.404
Contour: rectilinear x Agreeableness	-0.723	0.303	17080	-2.39	0.017*
Contour: rectilinear x Negative emotionality	0.068	0.315	17080	0.214	0.830
Expertise: Non-expert *Reference level: Expert*	3.28	4.90	581	0.669	0.504
Expertise: Student *Reference level: Expert*	7.54	6.87	581	1.10	0.273
Expertise: Non-expert x Window-to-wall ratio: low	-4.05	1.90	17080	-2.13	0.033*
Expertise: Non-expert x Building height: short	-3.30	2.30	17080	-1.44	0.151
Expertise: Non-expert x Building height: tall	3.08	2.30	17080	1.34	0.179
Expertise: Non-expert x contour: rectilinear	-4.77	1.90	17080	-2.51	0.012*
Expertise: Student x Window-to-wall ratio: low	-6.97	2.66	17080	-2.62	0.009**
Expertise: Student x Building height: short	-5.49	3.21	17080	-1.71	0.088
Expertise: Student x Building height: tall	-1.41	3.21	17080	-0.438	0.662
Expertise: Student x contour: rectilinear	-3.72	2.66	17080	-1.40	0.162

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

5.4 Discussion

The aims of the current study were to investigate the factors underlying aesthetic evaluation of built environments and to disentangle judgements of perceived intimacy from aesthetic, hedonic appreciation. The results of the current study suggested that both the visual properties of built environments and individual differences among participants in their expertise and personality dimensions affected judgements of architecture beauty and perceived intimacy, and that some of these factors did so in an integrated manner, depending on the type of built environment shown.

5.4.1 The effect of visual properties on beauty judgements of built environments

For indoor architectural spaces, contrary to what was predicted based on previous studies (Bar & Neta, 2006; Vartarian, et al., 2013; Munar ,et al., 2015; Palumbo, et al., 2015), perceived curvature did not increase beauty ratings. Instead, of all the factors considered in the current study, space openness was the only feature that affected the perceived beauty of indoor living spaces. Spaces with high ceilings were rated as marginally more beautiful than those with low ceilings although this difference failed to meet statistical significance. Additionally, these factors independently influenced beauty judgments in that there was no evidence of an interaction. Therefore, even though a high ceiling might 'compensate' for an enclosed space in creating a sense of openness, and an open space might make up for a low ceiling (Stamps, 2010), these combinations might not necessarily enhance beauty evaluation. Nevertheless, these findings were somewhat consistent with those reported by Vartarian et al. (2015), in which participants were more likely to judge architectural spaces as beautiful if they had high, rather than low ceilings, and were open, rather than enclosed. On the other hand, Vartarian, et al., (2013) reported an aesthetic preference for curvilinear spaces as well as an increased activation in a brain

region associated with rewards and affect. However, in their study ceiling height and space openness were controlled to measure the independent effect of curvature on architectural beauty. More recently, they replicated their finding for an enhancing effect of curvature on aesthetic judgements of architectural interiors, but only among experts (architects and designers) and with a limited number of images: only four images from the original stimulus set were used for beauty judgments without controlling for ceiling height and space openness (Vartarian, et al., 2017). Therefore, the inclusion of all three architectural space properties as factors in the current study might lead to the domination of space openness over curvature as a global and more salient feature (Franz, von der Heyde, & Bülthoff, 2005). The emotional valence associated with space openness might also precede that associated with curvature (Leder, Tinio, & Bar, 2011). Furthermore, the stimuli used in the current study consisted of only a subset of images from the stimuli set used by Vartarian, et al. (2013, 2015, and 2017). Specifically, all the architectural spaces presented in the current study were interiors of residential homes, excluding a wide range of other scene categories in the original image set that included offices, libraries and other public spaces. Therefore, comparing the results of the current study to those reported by Vartarian, et al.'s (2013, 2015, and 2017), aesthetic evaluation process of indoor living spaces appeared to be distinct from aesthetic evaluations of spaces from other functional categories. Space openness might affect beauty judgements of living spaces more than public spaces, and curvature might be a less crucial feature in determining aesthetic judgements in living spaces (but see the following section on the effect of expertise), compared to public spaces. Future research could address the possibility that the function of an architectural space modulates the effects of visual properties on beauty judgements.

The data from the current study also suggest that visual properties such as curvature have different effects on the aesthetic judgements of the exterior of residential buildings. Most

of the participants rated buildings with curvilinear contours as more beautiful, consistent with the findings of previous studies which investigated the effect of curvature on the aesthetic preferences of building façades (Thömmes & Hübner, 2018; Ruta, et al., 2018). The reason why an effect of curvature effect was specific to building exteriors, but not indoor spaces might be that curvature was a more salient visual feature in the images of building exteriors compared to the indoor images used in the current study. Physical measurements of the extent of curvature presented across categories might help elucidate this finding.

Contrary to the architectural trend that big windows are beautiful, buildings with high window-to-wall ratios were not rated as more beautiful compared to those with low window-to-wall ratios. Although, as discussed in the next session, the effect of window-to-wall ratio was modulated by two personality dimensions. There are a number of other possible explanations as to why high window-to-wall ratio was not considered beautiful universally. First of all, preferences for big windows may indeed be based on aesthetic judgement but these may be susceptible to other modulating factors (e.g. the proportion of the windows, spatial arrangement of the windows, window design and material) which were not measured in the current study. Again, feature salience might also explain the lack of window-to-wall ratio effect (but the presence of a relatively more compelling effect of curvature) for building exteriors and on the contrary, a robust effect of space openness (but an absence of curvature effect) for indoor spaces. Another possibility is that what is aesthetically pleasing is not the big windows per se, but the consequences of having big windows, such as the improved natural lighting, perceived openness (which was found to be a factor enhancing beauty for indoor spaces in the current study), or the panoramic view, which can only be appreciated from inside the building.

Building height was not a contributing factor of architectural beauty, nor did it interact with curvature and window-to-wall ratio. In other words, these factors affect aesthetic judgements of dwellings of different heights similarly. This finding might appear trivial, however, it raises the question of whether it means the aesthetic evaluation of very different types of architecture (e.g. a bungalow in a rural village and a 60-storey apartment building in a city) depends on the same set of visual properties. The results of other studies suggest this conjecture is unsatisfactory and unlikely. For instance, Stamps (1991) found that for high rise buildings, participants across all demographics consistently preferred "complex modern" buildings, over "old brick" or "plain" ones. On the contrary, another study showed that the relationship between the complexity of house façades and aesthetic preferences in single-family houses followed the classic Berlyne's (1971) inverted U-shaped curve, whereby overly complex and plain façades were the least preferred (Akalin, Yildirim, Wilson, & Kilicoglu, 2008). Therefore, the lack of interaction between the visual properties considered here on beauty judgements of built environment highlights the need to consider more visual properties, other cultural, social, personal and historical dimensions, in order to comprehensively represent the complexity in architectural design. In a later section, this limitation of the current study is further discussed.

5.4.2 The effects of personality traits on beauty judgements of built environments

Previous studies have reported the effects of personality on aesthetics evaluations in simple geometrical shapes and patterns (Cotter, et al., 2017; Friedenberg, 2019), artwork (Mohan, & Mohan, 1965; Roubertoux, et al., 1971; Furnham & Walker, 2001; Chamorro-Premuzic & Furnham, 2004; Chamorro-Premuzic, et al., 2011; Cleridou & Furnham,

2014; Myszkowski, et al., 2014), and architecture (Ibrahim, et al., 2002; Cook & Furnham, 2012; Cleridou & Furnham, 2014; Banaei, et al., 2019). It was predicted that the variations observed in aesthetic ratings of residential architecture might also be explained by individual differences in some personality measurements. However, the results suggest that the aesthetic judgements of indoor architectural spaces were not sensitive to individual differences in personality traits, and the effects of space openness and ceiling height were consistent across participants, irrespective of personality type. It is possible that the big-five traits modulate the effects of other architectural properties (such as complexity and novelty) not included in the current study. On the other hand, the personality dimensions of extroversion and agreeableness, but not openness to experience, modulated the effect of window-to-wall ratio on the beauty judgements of building exteriors. Specifically, extroverts gave higher beauty ratings to buildings with high window-to-wall ratios but those who scored high in the agreeableness dimension preferred buildings with low window-to-wall ratios. It is possible that buildings with relatively big windows appear more modern and unconventional which is more appealing to extroverts. On the other hand, people who are more agreeable preferred a more conventional style of buildings, which usually have relatively smaller windows. In other words, preferences in building styles and novelty may be better accounted for by the big five traits (Cook & Furnham, 2012; Cleridou & Furnham, 2014).

Contrary to Cotter, et al.'s (2017) and Banaei, et al.'s (2019) findings, preferences for curvature were not associated with personality traits for either indoor or outdoor architecture. Though it is worth noting that in Cotter et al.'s (2017) study, the modulation by the openness-to-experience trait on the curvature effect was found in aesthetic judgements of novel, irregular polygons only but not familiar shapes (Cotter, et al., 2017). The architecture presented in the current study might not have appeared as sufficiently

novel and therefore its aesthetic evaluation did not tap into the individual differences in novelty and stimulation seeking traits. On the other hand, the difference between the present findings and those in Banaei et al.'s (2019) study could be due to the lower saliency of the curvilinear features in the current study compared to theirs, in which participants were presented with an immersive built environment with very prominent contour features in 3D using virtual reality.

In sum, the present data support the idea that that relationship between personality traits and aesthetic preferences in architecture may depend on context, with a relatively greater role of trait expression in judgements of building exteriors than indoor living spaces (Ibrahim, et al., 2002).

5.4.3 The effects of expertise on beauty judgements of built environments

As mentioned earlier, Vartarian, et al. (2017) found that experts in architecture were more likely to judge curvilinear spaces as beautiful and rectilinear ones as not beautiful compared to non-experts. However, in the current study, the expertise effect on the preference for curvature (and, as discussed, the curvature advantage itself) was absent for indoor living spaces, and for building exteriors, a different pattern of expertise effect was found. Experts showed only a marginal aesthetic preference for curvilinear buildings while architecture students and non-experts rated rectilinear buildings as much less beautiful than curvilinear ones, with architecture students giving higher beauty ratings to curvilinear buildings than non-experts. This suggests that the effect of expertise on preferences for curvature might not be proportional to the level of expertise (or the amount of industry experience) in the discipline, since we might expect that qualified architects should have more experience than architecture students, who in turn are more

experienced than non-experts. However, the levels of expertise were defined differently in the current study compared to Vartarian, et al.'s (2017). In their study, the expert group consisted of both practising and soon-to-be qualified architects and designers, while in the current study, they were categorised into two different groups (i.e. experts, students). The present data showed that the preference for curvature was sensitive to this differentiation. Vartarian, et al. (2017) proposed that the expertise effect on preference for curvature could be explained by either a learned sensitivity to curvature or an increased negative association with rectilinear spaces due to the professional training received by experts. While these explanations make much sense, neither offer a complete explanation for the complex expert effects found in the current study. The lack of preference for curvature in the current study might reflect a more complex evaluation process in architects, compared to non-experts. Architects might consider many other factors, other than curvature, in determining the aesthetic value of a building which were not included in the study, nor were they salient to non-experts. In practice, in formal design reviews conducted by those who had professional training in architecture or urban planning, almost every building feature in addition to seemingly more holistic characteristics (which tend to be quite vague and hard to operationally define, e.g. harmony, 'in good proportion') are included as evaluation criteria (Stamps, 1997a; 2000). On the one hand, it cannot be assumed that the full set of criteria were used by the experts in the current study, since only single images of the building exteriors were shown and in the context of a public exhibition in a gallery, the evaluation was a lot more casual. On the other hand, it is likely that the experts adopted more professional standards to evaluate these images compared to non-experts or even architecture students. Experts might also be more critical and conservative in evaluating the aesthetic value of buildings (Leder, Gerger, Brieber, & Schwarz, 2014) and less inclined to be impressed by individual

features. The modulation of expert effects by stimulus category has previously been reported. For instance, Silvia and Barona (2009) and Cotter, et al. (2017) both found that the enhanced preference for curvature in experts was found only for abstract, irregular shapes. Furthermore, Leder and Carbon (2005) reported that while experts did have a stronger preference for curvature in car interiors compared to novices (Experiment 1), this effect could be confounded by the innovativeness of design, which when included, the interaction between preference for curvature and level of expertise vanished and a trend that low innovativeness was more appealing to experts than non-experts was observed (Experiment 2). Note also that the 'experts' in the study by Leder and Carbon (2005) were 'museum experts', not experts in car interior design who would perhaps have profession-specific design insights, just like the architects in the current study did with built environments. On the other hand, preferences for curvature in non-experts might reflect a more universal preference that exists as a result of perceptual fluency (Reber, Schwarz, & Winkielman, 2004), the positive affect elicited by curved contours (Dazkir, & Read, 2012; Gómez-Puerto, et al., 2016), or even an acquired taste through mere exposure. For instance, many products in our everyday life, from shampoo bottles to cars, are designed to have curved contours.

5.4.4 The effects of visual properties on perceived intimacy of built environments

Besides aesthetic appeal, perceived intimacy in living spaces and residential building exteriors was also investigated. Generally, intimacy is used to describe the close relationship between people, but when used in built environment, it refers to "a cosy, private or a relaxed atmosphere" (Intimacy, 2019). It was therefore predicted that the underlying factors of perceived beauty and intimacy of architectural spaces might be

somewhat overlapping. In particular, the nature of aesthetic preference for curvature has been considered from an appraisal-related perspective whereby curvilinearity elicits positive and pleasant emotions (Dazkir, & Read, 2012; Gómez-Puerto, et al., 2016). Consequently, it was predicted that curvature might also increase perceived intimacy. Surprisingly, none of the architectural features (i.e. contour, ceiling height and space openness) influenced intimacy ratings of living spaces in this study. Although, indoor living spaces were rated as more intimate compared to building exteriors[10], suggesting that the interpretation of intimacy was consistent across participants with the guidance they received regarding the meaning of intimacy (see Method section). In contrast, the effects of visual properties on perceived intimacy of building exteriors were large. First, tall buildings were rated as the least intimate compared to buildings of short and medium heights. There are two possible explanations to this finding that are not mutually exclusive: tall residential buildings are often apartment buildings which are usually more common in densely populated urban areas and have been found to be associated with a living condition in which social relations are more impersonal, less social or cooperative and the fear of crime is greater (Gifford, 2007; but see Mouratidis, 2018 for the positive effects of compact urban living on subjective social well-being). The perceived intimacy of tall buildings was low possibly as a result of this negative association with a less satisfactory living style. Secondly, because the study was conducted in Dublin, Ireland, where high-rise apartment buildings are relatively rare and most of the population live in houses or apartment buildings of short to medium heights, participants might have found the short and medium buildings they viewed during the study more familiar (although none of the depicted building was located in Ireland) and this greater visual familiarity might have led to greater perceived intimacy. Interestingly, while window-to-wall ratio

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[10] Mean difference = 9.81, *SE* = 0.297, t (29238) = 33.01, *p* < 0.0001, Cohen's *d* = 0.377.

and contour affected the beauty judgements of building exteriors independently, these factors alone had no effect on intimacy ratings. This contradicts the predictions that 1) relative window size might be associated with perceived privacy such that high window-to-wall ratios might weaken the sense of privacy thus, intimacy; and 2) since curvilinearity elicits pleasant emotions (Dazkir, & Read, 2012; Gómez-Puerto, et al., 2016), curvilinear buildings might be rated as more intimate. Instead, window-to-wall ratio and contour modulated the effect of building height on intimacy judgements. For buildings with high window-to-wall ratios and those with rectilinear contours, intimacy ratings are negatively associated with building height. However, building height had no effect on perceived intimacy for buildings with low window-to-wall ratios and those with curvilinear contours. It is intriguing that the effect of building height was found only for buildings predicted to be less intimate (those with relatively big windows and rectilinear contours). Furthermore, a curvature effect was significant only in tall buildings such that curvilinearity was rated as more intimate than rectilinearity. In sum, it appears that the perceived intimacy of building exteriors is influenced by a combination of building characteristics, rather than individual features. The nature of these complex interactions remains to be investigated in future research.

5.4.5 The effects of personality traits on perceived intimacy of built environments

Intimacy may be considered as a personal or subjective feeling. As such, it was predicted that the perceived intimacy of living spaces was affected not only by their visual properties but also by individual differences such as the personality traits and expertise of the participants. Contrary to this prediction, personality traits had no effect on perceived intimacy of indoor living spaces. The data suggest that none of the parameters considered in the current study had any effects on how intimate a living space was

perceived. It is, therefore, appropriate to speculate that the intimacy of indoor environment depends on other factors yet to be explored, such as the presence of other people. For building exteriors, however, more individual differences were found. First of all, extroverts gave higher intimacy ratings in general, which could be attributed to their predisposition to experience positive affects (Costa & McCrae, 1980; Larsen & Ketelaar, 1989, 1991). As discussed, there was no evidence from the present results that openness to experience had an effect on the aesthetic judgement of buildings. Yet openness to experience was found to modulate the effects of window-to-wall ratio and building height. The score in this personality trait was positively associated with the intimacy ratings of buildings with low, compared to high, window-to-wall ratios; and negatively associated with those of tall, compared to medium and short, buildings. In other words, the intimacy judgements by those who were more open to experience aligned with the predictions made regarding the influences of window-to-wall ratio and building height. Perhaps these individuals were more predisposed to imagine, in an embodied manner, the living conditions in the unfamiliar buildings depicted during the study (Woo, Chernyshenko, Longley, Zhang, Chiu, & Stark, 2014). Participants who scored higher in the agreeableness dimension rated rectilinear buildings a lot less intimate than those who were less agreeable. Agreeableness is associated with conventionalism and conservatism in aesthetics (Chamorro-Premuzic, Reimers, Hsu, & Ahmetoglu, 2009), therefore this trait could be reflected in an enhanced preference for curvature, which is a relatively universal aesthetic feature (Bar and Neta, 2006). This finding is consistent with a recent study by Banaei, et al. (2019) in which they found agreeableness increased with pleasure associated with curved slopes and surfaces in the VR environment. However, agreeable participants did not rate curvilinear buildings more beautiful, which indicates the preference for curvature in those who are more agreeable is not rooted in aesthetic

features per se. Agreeable individuals are also more inclined to seek social harmony (Barlett & Anderson, 2012). Rectilinear contours might be perceived as more threatening (although this idea remains debateable: Palumbo, et al., 2015; Gómez-Puerto, et al., 2016; Bertamini, et al., 2016) by these individuals who tend to avoid conflicts. It is unclear whether this predisposition can be extended to evaluation of intimacy in architecture too.

5.4.6 The effects of expertise on perceived intimacy of built environments

Compared to beauty, intimacy is a less familiar dimension used in Psychology than architecture to describe the built environment. It is more often referred to the close relationship between people. However, in practice, architects consider intimacy as one of the crucial elements when designing living spaces (Pallasmaa, 1992; Namazian & Mehdipour, 2013). The concept of an 'intimacy gradient', proposed by architect Christopher Alexander (1977), for example, shapes the interior structures in dwellings by taking into considerations the functions of living spaces and the required amount of privacy. An "uncomfortable" building can be resulted from a violation of the intimacy gradient. As such, it was predicted that architects exhibited higher sensitivity to the intimacy of architectural spaces. However, this was not reflected in the data of the current study. At least, there was no evidence to suggest that architects and architecture students judge the intimacy of indoor architectural spaces differently from non-experts. For building exteriors, on the other hand, both the effects of window-to-wall ratio and contour on perceived intimacy were modulated by expertise in architecture. The interaction between window-to-wall ratio and expertise indicated a possible trend that both architecture students and non-experts rated buildings with low window-to-wall ratio as less intimate compared to experts. However, since the post-hoc analyses did not show

any significant results, it remains unclear whether and how people with different levels of expertise in architecture consider relative window size as a contributing factor to building intimacy.

In Vartanian et al.'s (2017) study, when participants were asked to make an approach-avoidance decision (i.e. enter or exit), non-experts were more likely to opt to enter curvilinear, rather than rectilinear spaces while such effect of curvilinearity was not observed in experts. The current study replicated this pattern of expertise-curvature interaction on perceived intimacy. Specifically, only non-experts rated curvilinear buildings more intimate than rectilinear ones. This suggests that they are more prone to the implicit (possibly affective) influences of curvilinearity compared to architects and architecture students who have likely been trained on the concept of intimacy discussed above.

5.4.7 Limitation of current study and future research

The current study provided new evidence for an interaction on aesthetic judgements between visual features in architectural scenes and individual differences in personality and level of expertise in architecture, revealing the complex nature of aesthetic appreciation for built environments. However, many unanswered questions remain to be addressed through further research in the empirical aesthetics of architecture. First of all, the complexity of architectural design has by no means been fully explored in the psychology of aesthetics. One of the challenges remains bringing together the two very different categories of disciplines – architecture and design on the one hand, in which reducing the aesthetic qualities of architecture to simple physical properties is generally disapproved of (Nasar, 1994); and experimental psychology and neuroscience on the

other, where the empirical nature of testing makes it difficult to replicate such complex experiences in both the design and evaluation processes of architecture in a highly controlled laboratory environment. For instance, many visual features were uncontrolled in the present study in order to preserve as much ecological validity of the stimuli as possible, while focusing the investigation on only a few simple visual properties. The effects of these visual properties might also have confounded with other factors that were not considered in the current investigation. For example, the effect of curvature on aesthetics judgements might be modulated by the participants' personal tastes in building styles and preference for novelty. Buildings with curvilinear contours might be perceived as more innovative, or luxurious, which might in turn appeal to both people who prefer more modern designs, and those who prefer designs that reflect opulence. In other words, the social meaning leading to aesthetic preferences in architecture might differ among individuals. Images of buildings were presented in colour and without controlling for complexity and symmetry, nor removing the immediately surrounding objects and landscapes, which might influence the aesthetic judgement of the image overall (Stamps, 1997). Although, an eye tracking study subsequently conducted (see Chapter 6) showed that when asked to evaluate the aesthetic appeal of a building, participants fixated more than 90% on the building itself, suggesting that other unrelated peripheral features were ignored. Furthermore, architects of residential buildings very often do not design one house in isolation but take into consideration how 'harmonic' or aesthetically pleasing it would be when placed within the landscape, neighbourhood and in close vicinity to other structures. Future research could investigate the effects of streetscape, greenery, and other peripheral features on the aesthetic evaluation of building exteriors. Architects also use a vocabulary during the design process which does not necessarily have an equivalent psychological construct or manipulable stimulus variable. In order to bridge the gap

between the two disciplines, it is necessary to identify the common variables. The current study showed for example, that the concept of intimacy in architecture somewhat resembled the approach-avoidance tendency in the language of experimental psychology, which can be tested empirically. However, it is clear that none of the variables considered in the current study had a strong influence on the perceived intimacy of indoor living spaces. Future research is required to explore the concept of architectural intimacy more systematically.

5.5 Conclusion

Taken together, the results of the current study provide new evidence on the interactions between simple visual properties and individual differences on the aesthetic judgements, as well as the perception of intimacy of indoor living spaces and building exteriors, a common concept in the discipline of architecture which appeared to be at least to some degree associated with the well-studied affective dimension in psychology. The present results sheds light on the complexity of such judgements in architecture which warrants future research through close collaboration between scientists and experts from the architecture and design disciplines.

Chapter 6

Eye movements and aesthetic judgements of architecture – an exploratory study

6   Eye movements and aesthetic judgements of architecture – an exploration study

6.1. Abstract

Is beauty in the eye movements of the beholder? The aesthetic evaluation of a scene requires the observer to first engage in the visual scanning of the target, a process which can in turn be affected by bottom-up characteristics of the image, such as its complexity, the saliency of objects within the scene or even simpler visual features such as contours, top-down processing related to contexts, motivation and interests, as well as individual differences. As a result, the fixation-saccade patterns provide rich information regarding the spatial relocation of attention, as well as a detailed description of the time lapse, reflecting the alternation between general survey and focused attention during aesthetic evaluation. The purpose of the eye-tracking study reported in this chapter was to investigate the relationship between the visual features and perceived attractiveness of building exteriors, and the gaze patterns during the aesthetic evaluations of those buildings. The behavioural data showed a clear preference for curvature in building exteriors over rectilinearity, consistent with the evidence from numerous previous reports. However, contrary to previous studies of eye movements during aesthetic evaluation, the results of the current study did not show an increase of fixations and fixation duration with the aesthetic appeal of buildings. A trend of modulation of eye movements by building height was observed but the effect failed to reach statistical significance. It was also found that when asked to evaluate the aesthetic appeal of a building, participants dedicated a close to 100% of total dwell time within the area of interest, which was the target building to be evaluated. Visual inspection of the aggregated fixation heat maps revealed some interesting patterns of visual scanning

among buildings of different feature categories despite the absence of statistical significance.

6.2. Background

When asked to evaluate the aesthetic appeal of a building, it is inevitable for the observer to first engage in a visual exploration at the target in question. Given the immediacy of eye movements to attentional allocation, gaze patterns during the aesthetic evaluation of buildings can be informative to the underlying perceptual and aesthetic processing that lead to an aesthetic judgement. Does what catch the eye determine subsequent aesthetic evaluations of the building? Or do people simply look longer at buildings that they find aesthetically pleasing, regardless of local features of architecture?

Visual exploration relies on a repetitive alternation between relatively stable gaze positions and shifts of gaze achieved by eye movements to bring different parts of the visual field onto the fovea, a small region of the retina with the highest acuity for further processing. This pattern of fixations and saccades not only is a direct reflection of spatial attentional allocation which can be a result of bottom-up stimulus saliency (Remington, 1980; Shepherd, Findlay, & Hockey, 1986; Sheliga, Riggio, & Rizzolatti, 1994; Tanaka & Shimojo, 2001; Rolfs, Jonikaitis, Deubel, & Cavanagh, 2011); but also, inferences regarding the top-down control of eye movements during visual tasks varying in task demands and goals can be made by studying the corresponding scan paths (Underwood, Foulsham, van Loon, Humphreys, & Bloyce, 2006). Therefore, eye movements are the interface at which perception meets cognition, and vision meets action (Richardson, Dale, & Spivey, 2007). Eye movement analyses remain a versatile tool in both basic psychological research, including areas such as attention (Remington, 1980; Shepherd, et al., 1986; Sheliga, et al., 1994; Hoffman & Subramaniam, 1995; Tanaka & Shimojo,

2001; Rolfs, et al., 2011), reading (Henderson & Ferreira, 1990), problem solving (Knoblich, Öllinger, & Spivey, 2005), face perception (Stacey, Walker, & Underwood, 2005), scene perception (Rayner & Pollatsek, 1992; Underwood, et al., 2006); as well as in applied disciplines such as clinical psychology (Mogg, Millar, & Bradley, 2000; Kellough, Beevers, Ellis, & Wells, 2008), marketing (Pieters & Wedel, 2017), product design (Carbon, Hutzler, & Minge, 2006; Clement, 2007), user experience (Bergstrom & Schall, 2014), urban landscape design (Lucio, Mohamadian, Ruiz, Banayas, & Bernaldez, 1996), and so on.

Although the observations regarding eye movements can be dated all the way back to Aristotle's descriptions of possible and impossible movements of the two eyes (Wade & Tatler, 2005, 2011), it was George Stratton (1902, 1906), Guy Buswell (1935), and Alfred Yarbus (1967) who are among the most recognised pioneers of eye movement research (Wade & Tatler, 2005, 2011), and their works are particularly relevant to the inquiry of the current study, which is the relationship between eye movements and aesthetics. Stratton (1902; 1906) was first to empirically study the relationship between gaze patterns and perception of line forms. He reported, using photographic recordings of the eye, that contrary to the intuition whereby smooth contours elicited smooth gaze pursuit, the eye movements during the viewing of smooth curves were jerky, irregular, and paused (fixating) abruptly at locations that did not correspond to the exact form of the line being observed. This discrepancy between the rather pleasurable aesthetic experience (which Stratton considered an illusion) arose when viewing smooth curves and symmetrical forms and the corresponding eye movements and fixations had in fact led him to dismiss the use of eye tracking to study aesthetic experience:

"The sources of our enjoyment of symmetry, therefore, are not to be discovered in the form of the eye's behaviour. A figure which has for us a satisfying balance may be brought to the mind by most unbalanced ocular motions." (Stratton, 1906, p, 95).

A few decades later, Buswell published a book entitled *How People Look At Pictures: A Study of the Psychology of Perception in Art* (Buswell, 1935) which documented the large-scale eye movements research he conducted on 200 participants whose gaze patterns were recorded as they viewed multiple complex pictures, instead of simple patterns and geometrical shapes. Buswell (1935) conducted systematic analyses on the data, focusing on a wide range of possible effects on fixations (e.g. the changes in fixation duration during the initial versus the latter period of viewing, the temporal and spatial distributions of fixations on the picture, influence of task instructions on fixation patterns) and conducted extensive comparisons in the patterns of fixations of observers in multiple viewings of the same pictures, and of those who were from different cultures, age groups, and had different level of artistic expertise. Critically, he was particularly interested in the effects of picture characteristics on patterns of fixations. While, unlike Stratton (1906), Buswell did find eye movements corresponding with contours in pictures, he came to the same conclusion as Stratton that there was little evidence to suggest variations in eye movements were associated with aesthetic experience and advocated for a cognitive approach to account for vision (Wade & Tatler, 2011).

One other crucial finding by Buswell's (1935) was that the locations selected for fixations during viewing was influenced by the task instructions given to the participants prior to the viewing. This was later confirmed by Yarbus (1967), who famously conducted this experiment in which he presented his participant with the same painting for seven times, and each time before the viewing, he asked his participant a different question. He found that the locations of fixations during the viewing of the same picture by the same

participant can drastically change depending on the question being asked beforehand, which suggested that top-down influences can override any bottom-up stimulus driven influences on gaze behaviour. Taken together, the classic work of Stratton (1902; 1906), and particularly Buswell (1935) and Yarbus (1967) had opened up a promising field of eye movements research through their rigorously empirical approach of eye movement recordings and the use of complex pictures as stimuli, which provided a closer to everyday experience scenario in the study of gaze behaviour. Despite the reservation to infer complex aesthetic experiences based on gaze patterns (Buswell, 1935) and the emphasis of these early studies on the top-down influences on gaze, later studies while recognising the high-level modulation of gaze by cognitive processes (Henderson & Hollingworth, 1999) have established that the eye movements during the viewing of an image were not as random as Buswell (1935) had suggested, but in fact regions that received higher densities of fixations were those that reflected the perceiver's interest in information of relevance (Mackworth & Morandi, 1967; Antes, 1974; Rizzolatti, Riggio, Dascola, & Ulmiltá, 1987). Furthermore, subsequent research in attention and scene perception has highlighted the stimulus-driven, bottom-up influences of low-level image properties on spatial attention (e.g. luminance contrast, orientation, colour). The notion of a saliency map was introduced by Koch and colleagues who proposed an influential computational model in which selective processing of complex scenes was guided by low-level features based on their saliency (Itti, Koch, & Niebur, 1998; Itti & Koch, 2000, 2000a). This model was supported to different extents by evidence from eye movement studies, with some reporting a strong correlation between saliency of stimulus features and locations of fixations (Reinagel & Zador, 1999; Parkhurst, Law, & Niebur, 2002) while some reported a weak link between the two (Mannan, Ruddock, & Wooding, 1997). Tatler, Baddeley, and Gilchrist (2005) proposed an alternative framework in which

observers' initial fixation patterns can be predicted by a stimulus driven, saliency-based computation but over time different top-down strategies were used to guide saccades depending on task demands (Tatler, Baddeley, & Vincent, 2006; Tatler & Vincent, 2009). Many studies that followed have used eye tracking as alternative or complementary method to verbal reports in order to study preferences and aesthetic processing. Unlike subjective reports, eye tracking provides a means to scrutinise the evaluation process as it happens. Among a wide range of eye movement measurements, the first fixation and duration of fixation are often considered indicators of visual preferences, whereby regions of interest attract attention for further aesthetic evaluation (Shimojo, Simion, Shimojo, & Scheier, 2003; Sütterlin, Brunner, & Opwis, 2008; Quian Quiroga, & Pedreira, 2011; Holmes & Zanker, 2012; Burriss, Marcinkowska, & Lyons, 2014). The preferential gaze paradigm is routinely used to infer preferences in infants (Griffey & Little, 2014), as well as clinical populations such as autism spectrum disorder (Pierce, Marinero, Hazin, McKenna, Barnes, & Malige, 2016). However, some argued that first and longer fixations do not always reflect liking but could be associated with an interest towards novel (but not necessary aesthetically appealing) stimuli to maximise the rate of information acquisition (Amir, Biederman, & Hayworth, 2011). Therefore, caution is needed when inferring preferences from eye movement patterns.

In summary, the studies reviewed above suggest the eye movement patterns can be influenced by both stimulus-driven, bottom-up visual features and some top-down task-related cognitive control mechanisms, which in turn could reflect visual preferences and aesthetic processing.

6.3. An eye tracking study on the aesthetic evaluation of architectural beauty

6.3.1. Introduction

In Chapter 5, it was found that simple visual properties such as curvature (Vartanian, Navarrete, Chatterjee, Fich, Leder, Modroño, Nadal, Rostrup, & Skov, 2013, 2015, 2017; Vecchiato, Tieri, Jelic, De Matteis, Maglione, & Babiloni, 2015; Coburn, Vartanian, & Chatterjee, 2017; Thömmes & Hübner, 2018; Ruta, Mastandrea, Penacchio, Lamaddalena, & Bove, 2018) and relative window size influenced aesthetic evaluations of building exteriors and the effects of these features were in turn modulated by top-down influences such as individual differences among the perceivers in some personality dimensions, as well as their levels of expertise in architecture. The objectives of this exploratory eye tracking experiment were to determine whether differences in building features influenced gaze behaviour and whether there was an association between the gaze pattern and the perceived attractiveness of the buildings. If gaze behaviour reflected aesthetic preferences in images of architecture, then the predictions were that curvilinearity, which was found to influence beauty judgements of building exteriors in Chapter 5 would also be associated with longer averaged fixation duration and a high number of fixations during viewing; and that attractiveness ratings would be associated with measurements of gaze patterns too. For the purpose of this study, other eye movements other than fixations and saccades, such as smooth pursuit, vergence, blinks, and microsaccades were not considered in this experiment.

6.3.2 Method

Participants

Twelve volunteers (8 females; mean age = 27 years, *SD* = 4.94) from the student population at Trinity College Dublin, Ireland participated in the current study. All had normal vision without the need to wear corrective glasses. All were naïve to the purpose of the study and were compensated with research credits for their participation. This study received ethical approval from the School of Psychology Research Ethics Committee at Trinity College Dublin. In accordance with this approval, all participants gave informed, written consent prior to conducting the experiment.

Stimuli and apparatus

The stimuli of this experiment consisted of the same forty photographic images of residential building exteriors used in Chapter 5 which included 12 short buildings (three-storey or below), 12 tall buildings (ten-storey or above), and 16 buildings of medium heights (four-to-nine-storey). In each building height category, there were four combinations of window-to-wall ratio (low, high) and contour (rectilinear, curvilinear). The sizes of stimuli ranged from 550 x 800 pixels to 650 x 800 pixels (or approximately 12° x 17.4° to 14.1° x 17.4° in visual angle). An area of interest was predefined for each image to be the building itself, excluding the background and surrounding objects. Participants' gaze behaviour during the experiment were recorded using a desktop mounted, video-based eye tracker (EyeLink 1000 Plus, SR Research, Mississauga, ON, Canada) with a spatial resolution of 0.01° of visual angle, at a sampling rate of 1000 Hz. The eye tracker operated by emitting infra-red light through the illuminator and capturing images of the eye with its camera sensor. In each eye image, the corneal reflection and

the position of the centre of pupil were identified. While the location of corneal reflection remained relatively stable when the participant's head was immobilised, the location of pupil centre on the camera sensor changed with eye movements. By monitoring any changes in the pupil-corneal reflection relationships, the eye movements reflecting gaze behaviour can be computed while adjusting for minor shifts in head position. Saccades and fixations were identified using the default parser configuration of EyeLink 1000 Plus in which a shift in eye position larger than 0.1° of visual angle with a minimum velocity of 30° of visual angle per second or a minimum acceleration of $8000°s^{-2}$, maintained for at least 4 ms was identified as a saccade. Any data points which did not meet these criteria were identified as fixations.

The experiment was programmed using the SR Research Experiment Builder (SR Research, Mississauga, ON, Canada) and run at the display computer connected to the host computer which controlled the eye tracker. Stimuli were presented on a 60cm x 34cm LCD monitor with a resolution of 2560 x 1440 pixels LCD monitor at 75 Hz.

Design

The current experiment adopted a within-subject design with three stimulus factors which were the features of the building exteriors presented, namely, building height, window-to-wall ratio, and contour. The dependent variables were the attractiveness ratings given to each depicted building and eye movement measurements during the viewing of the images, which included the total number of fixations and saccades, average duration of fixation (in milliseconds) and the average saccade amplitude (in degrees of visual angle); all within the area of interest. Each participant was presented with 40 images of building exteriors and each was viewed once only.

Procedure

The experiment took place in a darkened testing room in the Institute of Neuroscience, Trinity College Dublin. After giving informed written consent, participants were seated at 57 cm from the LCD monitor and given the instructions for the experiment. The participants' heads were immobilised using a chin and forehead rest. Viewing of the images were binocular but only the eye movements of the dominant eye were recorded. The dominant eye of each participant was determined by first asking the participant to make a triangular aperture with his or her hands and to fixate with both eyes on a target located about 5 metres away through the aperture, then he or she was instructed to close one eye at a time while still maintaining the location of the aperture and looking at the target with the other eye. The dominant eye was the one which saw the target remained within, rather than shifted outside, the aperture when viewing the target monocularly. Just prior to the start of the experiment, an automatic nine-point calibration of the eye tracker, followed by validation, was conducted to ensure accurate tracking. A trial began with a 10-pixel white fixation cross in the centre of the screen which lasted for 500 ms, followed by a 30 ms blank. A stimulus image then appeared on the screen for seven seconds during which the eye movements of the participants were recorded. The end of a trial was marked by a response cue which appeared after the stimulus image disappeared at the centre of the screen, asking participants to rate the attractiveness of the building they just viewed, on a scale from 1 (very unattractive) to 7 (very attractive). Participants were given a break after every ten trials and the same calibration and validation procedure mentioned above was repeated before the experiment resumed. The whole experiment took approximately thirty minutes to complete.

6.3.3 Approach of data analysis

The sample size of the current study was relatively small due to its exploratory nature. The linear mixed model (LMM) was therefore used to analyse the results of this experiment to avoid data aggregation and to minimize the loss of statistical power, as well as to account for the random variabilities in participants and images (Baayen, Davidson, & Bates, 2008; Judd, Westfall, & Kenny, 2012). The LMMs were fit by maximum likelihood in R with the *lmer* program in the *lm4* library (Bates, Mächler, Bolker, & Walker, 2015) and the *lmerTest* library (Kuznetsova, Brockhoff, & Christensen, 2016) was used for testing of statistical significance such that the *p* values were estimated for the *t* tests based on the Satterthwaite's method to approximate degrees of freedom. The random factors in the analyses of both the behavioural data and eye movement data were participant ID and stimulus ID such that a random-intercepts null model was fit by including only the random intercepts of participants and stimuli for each analysis. The specification of the null models in *R* is:

M_{null} ← lmer (dependent variable ~ 1 + (1 | participant ID) + (1 | stimulus ID))

 Model evaluation was carried out by first comparing a proposed model with the null model using the *anova* function in R. In the case where multiple proposed models performed significantly better than the null model, the one with the best goodness-of-fit based on the Akaike Information Criterion (AIC) values was selected (i.e. the lowest AIC value). The random slopes were included only if they improved overall model fit.

6.3.4 Results of behavioural data analysis

Table 6.1 shows the average attractiveness ratings of building exteriors in all building feature categories across all participants. In order to analyse the effects of building features on the perceived attractiveness of building exterior, three linear mixed models were built, with building height, window-to-wall ratio, and contour as fixed effects and their reference levels were 'short', 'low', and 'rectilinear' respectively. The models are described as follows with the corresponding *lmer* model specifications in R.

The first LMM included only the main effects of building features:

$M_i \leftarrow$ lmer (Attractive rating ~ 1 + building height + window-to-wall-ratio + contour
+ (1 | participant ID) + (1 | stimulus ID))

The second model included the two-way interactions between building features (the main effects of any building features in the two-way interaction terms were automatically included by the *lmer* function):

$M_{ii} \leftarrow$ lmer (Attractive rating ~ 1 + building height* window-to-wall-ratio + window-to-wall-ratio* contour + contour* building height + (1 | participant ID) + (1 | stimulus ID))

Lastly, the third model included the three-way interaction among building features:

$M_{iii} \leftarrow$ lmer (Attractive rating ~ 1 + building height* window-to-wall-ratio* contour
+ (1 | participant ID) + (1 | stimulus ID))

Table 6.2 shows the goodness-of-fit statistics of these three models compared to the null model. The data were best described by M_i (the stimulus main effects model), which performed significantly better than the null model ($\chi^2 (4) = 13.6$, $p = 0.00854$) and including interaction terms did not improve the model fit significantly (two-way interactions: $\chi^2 (5) = 10.4$, $p = 0.0643$, three-way interaction: $\chi^2 (7) = 10.4$, $p = 0.165$).

Table 6.1 The mean attractiveness ratings of building exteriors with each combination of building height, window-to-wall ratio and contour across all participants.

Building height	Window-to-wall ratio	Contour	Mean attractiveness rating	SD
Short	Low	Rectilinear	3.50	1.65
		Curvilinear	4.19	1.54
	High	Rectilinear	3.81	1.72
		Curvilinear	4.78	1.46
Medium	Low	Rectilinear	3.85	1.43
		Curvilinear	4.06	1.55
	High	Rectilinear	4.30	1.27
		Curvilinear	4.81	1.57
Tall	Low	Rectilinear	3.06	1.37
		Curvilinear	4.97	1.34
	High	Rectilinear	2.58	1.48
		Curvilinear	4.61	1.52

Table 6.2 Linear mixed models built to predict attractiveness ratings of building exteriors

LMM	df	AIC	Δdf	χ^2	p
Random-intercepts only (M_{null})	4	1716	-	-	-
Stimulus main effects (M_i)	**8**	**1711**	**4**	**13.6**	**0.00854****
Stimulus 2-way-interactions (M_{ii})	13	1712	9	24.1	0.00922**
Stimulus 3-way-interactions (M_{iii})	15	1714	11	24.085	0.0124*

Note: Chi-squared statistics reflects the difference between the null and a given model (** $p < 0.01$, *$p < 0.05$). Model in bold is the best model with the lowest AIC value.

The chosen model revealed a significant main effect of contour ($\beta = 0.987$, $SE = 0.269$, $t(39.9) = 3.67$, $p = 0.0007$). Buildings with curvilinear contours were rated as significantly more attractive compared to rectilinear buildings. Neither the main effects of building height (medium compared to short: $\beta = 0.187$, $SE = 0.325$, $t(39.9) = 0.576$, $p = 0.568$; tall compared to short: $\beta = 10.6$, $SE = 3.18$, $t(40.5) = 3.33$, $p = 0.00184$) nor window-to-wall ratio ($\beta = -0.264$, $SE = 0.347$, $t(39.9) = -0.761$, $p = 0.451$) reached statistical significance.

6.3.5 Results of eye movement data analysis

The raw eye tracking data were processed using the EyeLink Data Viewer in order to generate the reports on the fixations and saccades in all the trials completed by each participant, with the interest period of each trial set as the entire 7s during the viewing of the stimulus image. Subsequently, for each trial, four eye movement variables were obtained, namely, the total number of fixations, the total number of saccades, the average fixation duration (in millisecond), and the average saccade amplitude (in degree of visual angle), all within the areas of interest, which were predefined as the buildings depicted. (See Table 6.3). A total of 480 trials were completed by all the participants but one trial was removed from the following analyses due to a loss of pupil information by the eye tracker during the trial. Across all participants and trials, the average percentage of dwell time within the areas of interest was 97.3% ($SD = 8.4\%$).

Table 6.3 Descriptive statistics of eye movement variables across 12 participants across all trials

Eye movement variable	Value averaged across all participants and trials	*SD*
Number of fixations	24.6	5.05
Average fixation duration	252 ms	66.3 ms
Number of saccades	23.8	5.108
Average saccade amplitude	4.44°of visual angle	1.18°

The relationship between building features and eye movements

Using the same methods of model building and selection as the behavioural data, each eye movement variable was modelled respectively as a function of building features in order to investigate the effects of building features on viewing behaviour. As a result, for each eye movement variable, a null model with random intercepts of participants and

stimuli only, as well as a number of candidate models which included either individual (or all) main effects of building features only, two-way interactions of building features, or three-way interaction of building features were built, and they are specified as the following:

Null model (M_{null}):
M_{null} ← lmer (eye movement variable ~ 1 + (1 | participant ID) + (1 | stimulus ID))

Contour effect model ($M_{contour}$):
$M_{contour}$ ← lmer (eye movement variable ~ 1 + contour + (1 | participant ID) + (1 | stimulus ID))

Window-to-wall effect model (M_{w2w}):
M_{w2w} ← lmer (eye movement variable ~ 1 + window-to-wall ratio + (1 | participant ID) + (1 | stimulus ID))

Building height effect model (M_{bh}):
M_{bh} ← lmer (eye movement variable ~ 1 + building height + (1 | participant ID) + (1 | stimulus ID))

Main effects (of all three building features) model (M_{main}):
M_{main} ← lmer (eye movement variable ~ 1 + contour + window-to-wall ratio + building height + (1 | participant ID) + (1 | stimulus ID))

Two-way interactions model (M_{2inter}):
M_{2inter} ← lmer (eye movement variable ~ 1 + contour*window-to-wall ratio + window-to-wall ratio*building height + contour*building height + (1 | participant ID) + (1 | stimulus ID))

Three-way interaction model (M_{3inter}):
M_{3inter} ← lmer (eye movement variable ~ 1 + contour*window-to-wall ratio*building height + (1 | participant ID) + (1 | stimulus ID))

i.   The effects of building features on the number of fixations at the building

Table 6.4 shows the goodness of fit statistics of all the candidate models compared with the null model. The building height effect model had the best goodness of fit ($\chi^2 (2) = 6.01$, $p = 0.0496$, AIC = 694.3). However, the effect of building height on the number of

fixations according to the chosen model did not reach statistical significance (medium compared to short: $\beta = 0.097$, $SE = 0.0787$, t (39.1) = 1.23, $p = 0.225$; tall compared to short: $\beta = 0.0971$, $SE = 0.0841$, t (39.03) = -1.23, $p = 0.227$). Figure 6.1 shows three examples of fixation heat maps (based on fixation count) of buildings averaged across 12 participants, one from each building height category.

Table 6.4 Linear mixed models built to predict number of fixations as a function of building features

Dependent variable	LMM	df	AIC	Δdf	χ^2	p
	M_{null}	4	696.3	-	-	-
	$M_{contour}$	5	697.8	1	0.503	0.478
	M_{w2w}	5	697.8	1	0.537	0.464
Number of fixations	**M_{bh}**	**6**	**694.3**	**2**	**6.01**	**0.0496***
	M_{main}	8	697.1	4	7.24	0.124
	M_{2inter}	13	700.5	9	13.8	0.13
	M_{3inter}	15	698.5	11	19.8	0.0481*

Note: Chi-squared statistics reflects the difference between the null and a given model (*$p < 0.05$). Model in bold is the best model with the lowest AIC value.
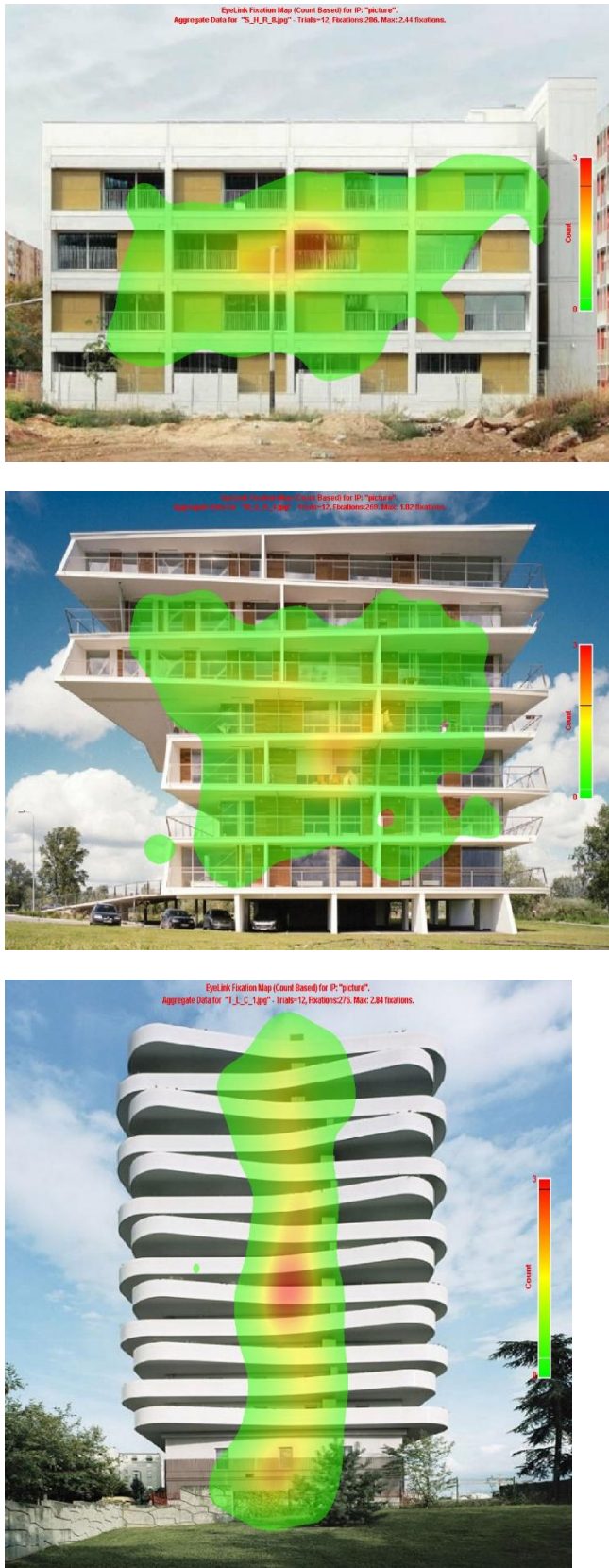
Figure 6.1 Fixation heat maps (based on fixation count, averaged across 12 participants) of three buildings with different building heights (top: short; middle: medium; bottom: tall). The colour gradient from green to red represents a fixation count from 0 to 3.

ii. The effects of building features on the average fixation duration at the building

Table 6.5 shows the goodness of fit statistics of all the candidate models compared with the null model. The building height effect model had the best goodness of fit (χ^2 (2) = 7.92, p = 0.0191, AIC = 850.7). However, the effect of building height on the average fixation duration according to the chosen model did not reach statistical significance (medium compared to short: β = -0.137, SE = 0.0748, t (39.1) = -1.84, p = 0.074; tall compared to short: β = 0.0786, SE = 0.0799, t (39.01) = 0.984, p = 0.331). Figure 6.2 shows three examples of fixation heat maps (based on duration) of buildings averaged across 12 participants, one from each building height category.

Table 6.5 Linear mixed models built to predict the average fixation duration as a function of building features

Dependent variable	LMM	df	AIC	Δdf	χ^2	p
	M_{null}	4	854.7	-	-	-
	$M_{contour}$	5	856.3	1	0.328	0.567
	M_{w2w}	5	856.2	1	0.452	0.502
Average fixation duration	**M_{bh}**	**6**	**850.7**	**2**	**7.92**	**0.0191***
	M_{main}	8	853.8	4	8.89	0.0639
	M_{2inter}	13	858.2	9	14.4	0.108
	M_{3inter}	15	856	11	20.6	0.0375*

Note: Chi-squared statistics reflects the difference between the null and a given model (*p < 0.05). Model in bold is the best model with the lowest AIC value.
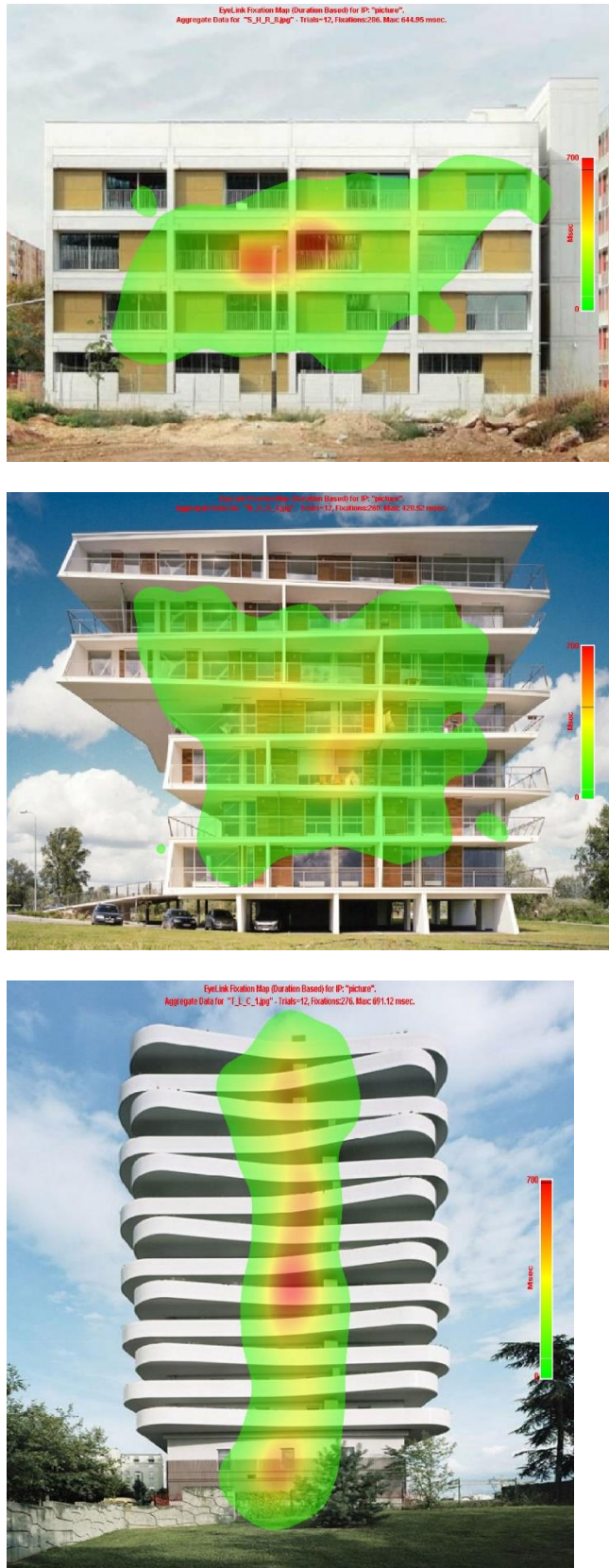
Figure 6.2 Fixation heat maps (based on duration in ms, averaged across 12 participants) of three buildings with different building heights (top: short; middle: medium; bottom: tall). The colour gradient from green to red represents a duration from 0 to 700ms.

iii. The effects of building features on the number of saccades within the building

Table 6.6 shows the goodness of fit statistics of all the candidate models compared with the null model. None of the proposed models was significantly better than the null model in terms of goodness-of-fit. Therefore, the number of saccades in any given trial had no relationship with the building height, window-to-wall ratio, nor contour of the building viewed.

Table 6.6 Linear mixed models built to predict the number of saccades as a function of building features

Dependent variable	LMM	df	AIC	Δdf	χ^2	p
	M$_{null}$	**4**	**704.8**	**-**	**-**	**-**
	M$_{contour}$	Model failed to converge				
Number of saccades	M$_{w2w}$	5	706.3	1	0.531	0.466
	M$_{bh}$	6	703.2	2	5.61	0.0605
	M$_{main}$	8	706.2	4	6.6	0.158
	M$_{2inter}$	13	710.4	9	12.3	0.192
	M$_{3inter}$	15	708.9	11	17.9	0.0848

Note: Chi-squared statistics reflects the difference between the null and a given model. Model in bold is the best model with the lowest AIC value.

iv. The effects of building features on the average saccade amplitude within the building

Table 6.7 shows the goodness of fit statistics of all the candidate models compared with the null model. The building height effect model had the best goodness of fit (χ^2 (2) = 6.56, $p = 0.0377$, AIC = 1067.7). The model revealed a significant main effect of building height on the average saccade amplitude (medium compared to short: $\beta = 0.324$, $SE = 0.121$, t (39.1) = 2.67, $p = 0.0109$; tall compared to short: $\beta = 0.177$, $SE = 0.13$, t (39.1) = 1.36, $p = 0.181$). Post hoc multiple comparison with the Tukey method was performed to test for the differences in the average saccade amplitudes when participants viewed buildings of different heights, using the *glht* function within the *multcomp* library. The results showed that the average saccade amplitude was significantly larger when participants viewed medium-height buildings, compared to short buildings ($z = 2.67$, SE

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= 0.121, p = 0.0207). However, the average saccade amplitudes did not differ between trials with tall and short buildings (z = 1.36, SE = 0.13, p = 0.361), nor between tall and medium-height buildings (z = -1.22, SE = 0.121, p = 0.443). Figure 6.3 shows three examples of aggregated saccade maps of buildings, one from each building height category.

Table 6.7 Linear mixed models built to predict the average saccade amplitude as a function of building features

Dependent variable	LMM	df	AIC	Δdf	χ^2	p
	M_{null}	4	1070.2	-	-	-
	$M_{contour}$	5	1071.7	1	0.554	0.457
	M_{w2w}	5	1072.2	1	0.0094	0.923
Average saccade amplitude	**M_{bh}**	**6**	**1067.7**	**2**	**6.558**	**0.0377***
	M_{main}	8	1071	4	7.22	0.125
	M_{2inter}	13	1076.9	9	11.3	0.256
	M_{3inter}	15	1143.2	11	11.6	0.392

Note: Chi-squared statistics reflects the difference between the null and a given model (*p < 0.05). Model in bold is the best model with the lowest AIC value.

Figure 6.3 Aggregated saccade maps (of all 12 participants) of three buildings with different building heights (top: short; middle: medium; bottom: tall). Each yellow line represents one saccade. The numbers marked the spatial starting points of the saccades and values represent its temporal location within the saccade sequence.

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The relationship between eye movements and attractiveness ratings of the buildings

Each eye movement variable was modelled as a function of attractiveness ratings given to the buildings, and a corresponding null model with random intercepts only was used to test for the effect of ratings. The null and hypothetical models were specified as the following:

Null model (M_{null}):
M_{null} ← lmer (eye movement variable ~ 1 + (1 | participant ID) + (1 | stimulus ID))

Attractiveness effect model ($M_{contour}$):
M_{attr} ← lmer (eye movement variable ~ 1 + rating + (1 | participant ID) + (1 | stimulus ID))

Table 6.8 shows the goodness of fit statistics of all the hypothetical models compared with their respective null models. None of the hypothetical models performed significantly better than the corresponding null models in modelling the eye movement variables. Therefore, the effect of attractiveness ratings given to the buildings on any of the eye movement measurements did not reach statistical significance.

Table 6.8 Linear mixed models built to predict viewing behaviour as a function of building attractiveness ratings

Dependent variable	LMM	df	AIC	Δdf	χ^2	p
Number of fixations	M_{null}	4	696.3	-	-	-
	M_{attr}	5	695.3	1	2.97	0.0848
Average fixation duration	M_{null}	4	854.7	-	-	-
	M_{attr}	5	855.4	1	1.26	0.262
Number of saccades	M_{null}	4	704.8	-	-	-
	M_{attr}	5	704.1	1	2.64	0.104
Average saccade amplitude	M_{null}	4	1070.2	-	-	-
	M_{attr}	5	1071	1	1.203	0.273

6.4 Discussion

In Chapter 5, the findings that the aesthetic judgements of building exteriors varied as a function of some simple visual features such as curvature and window-to-wall ratio, with some modulations of individual differences in personality and level of expertise in architecture, were reported. The objective of the current study was to explore the relationship between the visual features of building exteriors, their perceived attractiveness and the perceivers' viewing behaviour during the aesthetic evaluation. To that end, participants' eye movements were recorded as they viewed images of residential building exteriors and gave a rating of attractiveness to each of the buildings they were presented with.

Contrary to the predictions made based on previous eye movement studies on aesthetic perception in which aesthetic preferences or perceived attractiveness were generally associated with more and longer fixations (Shimojo, et al., 2003; Sütterlin, e al., 2008; Quian Quiroga, & Pedreira, 2011; Holmes & Zanker, 2012; Burriss, et al., 2014), the current study found no evidence of a relationship between gaze behaviour and attractiveness judgements of building exteriors. Specifically, the number of fixations and the average fixation duration within the area of interest, which was designated as the building to be evaluated, did not increase with its attractiveness ratings. Furthermore, although curvature enhanced the attractiveness ratings of the buildings, consistent with findings from previous studies (Vartanian, et al., 2013, 2015, 2017; Vecchiato, et al., 2015; Thömmes & Hübner, 2018; Ruta, et al., 2018), the gaze patterns during the viewing of curvilinear buildings were not significantly different from those when rectilinear buildings were viewed. Rather, a weak modulation of building height on the number and average duration of fixations and the average saccade amplitude during the viewing was found. However, the direction of modulation regarding building height could not be

determined due to the insignificant results in most of the post-hoc analyses. Participants' average saccade amplitudes were larger when viewing buildings of medium heights compared to short buildings, but no other differences were found in other gaze measurements between buildings of different heights. The finding that participants made larger saccades when viewing tall buildings is intriguing since the images in the current study were cropped and resized such that the final image sizes were comparable and the buildings occupied the similar areas of the images (hence were of similar retinal image sizes), despite having different 'depicted heights'. Previous studies have shown that the amplitudes of voluntary saccades increased not only with the physical size of the stimulus (von Wartburg, Wurtz, Pflugshaupt, Nyffeler, Lüthi, & Müri, 2007) but also the illusive size when viewing a visual illusion such as the Müller-Lyer illusion (McCarley, Kramer, & DiGirolamo, 2003). Therefore, it is possible that the taller buildings were perceived to be taller thus elicited saccades of larger amplitudes, compared to the shorter buildings even though their physical image sizes were similar. Further investigations, for instance, by systematically varying both the building heights and scaling factors, are needed in order to test this hypothesis.

A visual inspection on the fixation heat maps of the buildings showed that participants tended to fixate in the centre of the image, consistent with previous reports (Mannan, et al., 1997; Tatler, 2007) and also revealed that there seemed to be more and longer fixations when participants viewed taller buildings, but the confirmation of this effect will require further investigations. Nevertheless, building height did not have an effect on attractiveness ratings (consistent with the results reported in Chapter 5). In other words, any differences in gaze when viewing buildings of different heights cannot be explained by the differences in the aesthetic appeals of these buildings. The results of the current study suggested a dissociation between beauty judgements and gaze behaviour

during the evaluation process, which appeared to be modulated by different visual properties of the buildings. Curvature enhanced attractiveness judgements but might not necessarily be a salient feature that capture spatial attention during viewing – participants did not appear to fixate on the curved contours more so than the rectilinear contours (as shown in the gaze measurements and visual inspection of fixation heat maps). Physically measuring the saliency of curvature in the images of architecture can address this issue in future studies. Building height, on the other hand, modulated the average amplitude of saccade during viewing, but did not have an effect on the aesthetic appeal of buildings.

Due to the exploratory nature of the current study and the consideration of maintaining ecological validity of the stimuli, there was minimal control of low-level visual properties of the images. Therefore, it is unclear whether the results can be explained in terms of a saliency-based account of gaze patterns. Furthermore, the current study did not set out to investigate the time course of gaze behaviour during the aesthetic evaluation of buildings. It is possible that gaze behaviour during certain period within the evaluation process is more informative than others. For example, Locher, Krupinski, Mello-Thoms & Nodine (2008) reported that within the first 100ms during the viewing of a painting, a holistic 'gist' of the pictorial composition was obtained, followed by more detailed evaluative processes in which local areas of interests were securitised. Future studies are required to investigate the relationship between visual properties of architecture and fixation patterns over time which might better reflect the different stages of aesthetic evaluation.

6.5 Conclusion

The patterns of visual exploration during the aesthetic evaluation of building exteriors was studied. The preliminary results indicated that contrary to a commonly reported (yet debatable) relationship between aesthetic preferences and fixation duration, the gaze patterns appeared to have little association with the attractiveness ratings or the visual features of the buildings which contributed to those aesthetic judgements. Further investigations into the changes of gaze patterns over time during the viewing as well as a more systematic manipulation of low-level properties of stimuli will shed light on the underlying processes leading to the aesthetic experience of architecture.

Chapter 7

The pursuit of beauty continues – general discussion and future research

7 The pursuit of beauty continues – general discussion and future research

7.1. Abstract

This thesis has documented a series of experiments on the aesthetic processing of two ubiquitous stimuli in our visual word – human faces and built environments. In this chapter, the findings in the preceding chapters were summarised and discussed in terms of the research questions set out to be addressed in this PhD project, the theoretical implications in the wider context of the experimental aesthetics, as well as the practical implications that could inform design practice. Finally, there is a discussion on the limitations and outstanding questions in this project which invite further investigations and research.

7.2. Summary of findings

The experiments reported in Chapter 2 investigated the effects of gaze shifts and facial expressions on perceived attractiveness. Participants were asked to rate the perceived attractiveness of female faces conveying either a neutral or a happy expression, which were presented with a gaze shift away to towards the participant. In all experiments, effects of facial expression were found, with higher attractiveness ratings given to faces that conveyed a positive, rather than a negative expression, irrespective of the direction of gaze-shifts. However, the effect of the expression intensity among happy faces on attractiveness ratings was less forthcoming. It was predicted that the perceived attractiveness of a face would increase with the intensity of happiness it conveyed. This was shown not to be the case in the experiments reported here. In Experiments 1a and 1b, a slight smile (which was a morph between the neutral expression and a close-mouthed smile) was rated as more attractive than both the close-mouthed smile and the neutral expression. However, that same slight-smile expression was rated as less attractive than the neutral expression in Experiment 3. In Experiment 2, a clear preference to the open-mouthed smile over the angry expression was found, but this open-mouthed-smile expression was rated as not more or less attractive than the neutral expression in both Experiments 2 and 3. These inconsistencies of the effect of smile intensity across experiments were attributed to the contextual effect whereby different combinations of expressions were presented in each experiment. With regards to the effect of gaze shift on perceived attractiveness, in Experiment 1a, faces with gaze shifts away from the observer were preferred. However, when the dynamics of the gaze shift was disrupted, by adding an intermediate delay of 500ms (Experiment 1b), the effect of direction of gaze shift vanished. Furthermore, by manipulating the relative duration of each gaze direction during a gaze shift (Experiment 3), it was found that faces with a longer duration of direct

gaze were perceived to be more attractive, particularly in the initial exposure to a face, were found. This study provided new evidence regarding the complex effects of facial expression on perceived attractiveness and the role of social attention reflected by gaze shifts as well as its dynamics on attractiveness judgements.

In Chapter 3, the effect of another changeable facial property, namely, face view (both in its static form and during head turn towards or away from the observer), on perceived attractiveness was investigated, in conjunction with the effects of facial expressions and gaze directions and gaze shifts. In all experiments, happy faces were consistently rated as more attractive than angry faces. A head turn towards the observer, whereby a full-face view was shown, was associated with relatively higher attractiveness ratings when gaze direction was aligned with face view (Experiment 1). However, preference for full-face views of happy faces was not affected by gaze shifts towards or away from the observer (Experiment 2a) and disappeared altogether when the gaze direction remained static while the head turned (Experiment 2b). In Experiment 3, the relative duration of each face view (front-facing or averted at 15°) during a head turn away or towards the observer was manipulated. There was a benefit on attractiveness ratings for happy faces shown for longer duration from the front view; regardless of the direction of head turn. These findings support previous studies indicating a preference for positive expressions on attractiveness judgements, which is further enhanced by the front views of faces, whether presented during a head turn or shown statically. In sum, the findings reported in Chapters 2 and 3 imply a complex interaction between cues of social attention, indicated by the view of the face shown, and reward on attractiveness judgements of unfamiliar faces.

The aim of the experiments reported in Chapter 4 was to investigate a robust effect commonly found in rating experiments and in perception in general, known as serial

dependence. The effects of serial dependence in within-category judgements of attractiveness using images of faces (male and female; Experiment 1), images of scenes (outdoor and indoor scenes of buildings; Experiment 2) and cross-category judgements (faces and scenes; Experiment 3) were measured. Serial dependence was found in all experiments that involved a single category of stimuli and generally weakened in subsequent trials. The effect was more compelling in consecutive trials where by the faces presented in the current and the preceding trials were of the same sex. Serial dependence was not observed when the faces presented in the consecutive trials were of different sexes. For attractiveness judgements of scenes, however, the strength of serial dependence did not differ between same- and different-scene-type trials. A serial contrast effect was also evident, whereby a stimulus was rated as less attractive when preceded by an attractive one of a different category. Collectively, these findings indicated the temporal integration of aesthetic appraisal does not simply depend on visual similarities between stimuli but is confined within the context of perceptual categories which might require distinct evaluation processes.

The large-scale study reported in Chapter 5 aimed to investigate the inter-dependent relationships between visual features in scenes of indoor and outdoor architectural buildings and personality traits and level of expertise in architecture on ratings of aesthetic appeal and perceived intimacy. Results showed that only space openness, but not curvature nor ceiling height, was a major predictor of the aesthetic appeal when indoor living spaces were evaluated. There was also no evidence of any personality or expertise effects. Furthermore, the ratings of intimacy could not be predicted by the visual features nor personality factors considered in the study. On the other hand, the aesthetic judgements of building exteriors depended on curvature and window-to-wall ratio, but not building height; where non-experts and architecture students, but not experts,

preferred curvilinear over rectilinear contours. Ratings of 'agreeableness' were associated with an aesthetic preference for buildings with low window-to-wall ratios while ratings of 'openness' were associated with a preference for relatively big windows. The perceived intimacy of these buildings, however, depended mainly on the level of extroversion, as well as visual features such as the height of the building, and some modulation by curvature and window-to-wall ratio. Lastly, curvature enhanced the perceived intimacy of buildings in non-experts only. Collectively, the results shed light on the complex relationship between aesthetic and affective judgements of the built environment.

The purpose of the eye-tracking study reported in Chapter 6 was to investigate whether the visual features studied in Chapter 5 and the perceived attractiveness of building exteriors had any relationships with the gaze patterns during the aesthetic evaluations of these buildings. The behavioural data showed a clear preference for curvature in building exteriors over rectilinearity, consistent with the evidence from numerous previous reports but the eye movement data showed no relationship between the aesthetic appeal of buildings and the number of fixations, nor fixation duration. There is a weak indication that building height might modulate eye movements, but the effect failed to reach statistical significance.

7.3. Implications of findings

The chapters of this thesis can be broadly divided into three topics which resolve around the main theme of visual aesthetic processing. The first topic concerns the transient facial features that modulate the perception of facial attractiveness (Chapters 2 and 3), the second topic is the relationship between the processes of perceptual categorisation, serial

dependence and aesthetic evaluation (Chapter 4), and the third topic relates to the influences of stimulus-related visual features and individual differences among perceivers on the aesthetic evaluation of built environments (Chapter 5 & 6).

7.3.1 Changeable facial features and facial attractiveness

Faces are unique stimuli. They possess a huge amount of information which our visual system is highly sensitive to, for the right reason, since the abilities to rapidly detect and discriminate facial expressions, gaze directions and face views are crucial in determining the emotional states, as well as the attentional allocation of the people we are interacting with, in the order to respond accordingly (Argyle, & Cook, 1976; Ekman, 1982; Langton, Watt, & Bruce, 2000; Wilson, Wilkinson, Lin, & Castillo, 2000; Adolphs, 2002). Not only does the ability to extract these social signals from faces emerge very early in life (Farroni, Csibra, Simion, & Johnson, 2002; 2007), it is often accompanied by some rather universal preferences which persist to influence facial attractiveness judgements in adulthood. While the effects of unchangeable properties such as symmetry (Perrett, Burt, Penton-Voak, Lee, Rowland, & Edwards, 1999; Scheib, Gangestad, & Thornhill, 1999), averageness (Grammer & Thornhill, 1994; Rhodes and Tremewan, 1996; Rhodes, Sumich, & Byatt, 1999; Rubenstein, Langlois, & Roggman, 2002), and sexual dimorphism (Perrett, Lee, Penton-Voak, Rowland, Yoshikawa, Burt, & Akamatsu, 1998; Rhodes, Hickford, & Jeffrey, 2000; Rhodes, 2006) on facial attractiveness have been well studied, the effects of transient, changeable features, particularly the interactions between them, on facial attractiveness have been less forthcoming and this had motivated the research reported in Chapters 2 and 3 of this thesis. A wealth of evidence from previous studies have pointed to the robust effects of facial expressions on perceived attractiveness (Lau, 1982; Mueser, Grau, Sussman, & Rosen, 1984; Reis, Wilson, Monestere, Bernstein,

Clark, Seidl, & Radoane, 1990; Otta, Lira, Delevati, Cesar, & Pires, 1994; Otta, Abrosio, & Hoshino, 1996; Mehu, Little, & Dunbar, 2008; Tracy, & Beall, 2011; Morrison, Morris, & Bard, 2013; Golle, Mast, & Lobmaier, 2014; Ueda, Kuraguchi, & Ashida, 2016). While the findings reported in this thesis concur with previous studies that facial attractiveness ratings were indeed affected by facial expressions in all the experiments reported in Chapters 2 and 3, and that the expression of anger was consistently rated as unattractive relatively to neutral or happy expressions, the effects of emotional intensity of happy expressions on perceived attractiveness were not as predicted. In Chapter 2, one of the main predictions regarding the effects of facial expression was that attractiveness ratings of a face would increase with its intensity of the smile it conveyed. In other words, the 'bigger' the smile, the more attractive it is rated. Such linear and simplistic relationship was not observed in the results. Instead, the perceived attractiveness of a neutral expression and a particular smile (slight, close-mouthed, open-mouthed) appeared to depend on what other facial expressions were also present in the same testing session. For example, in Chapter 2, a neutral expression was rated as less attractive than a morphed expression between neutral and closed-mouthed smile in Experiment 1, but the neutral expression was subsequently rated as more attractive than that same slight-smile expression in Experiment 3. The difference in the expressions presented in these two experiments was that in Experiment 3, the close-mouthed smile used in Experiment 1 was replaced with an open-mouthed smile. Even more surprisingly, the open-mouthed smile, which was the most intense smile used in the experiments reported here, did not receive the highest attractiveness ratings compared to all other expressions. While the open-mouthed smile was rated as more attractive than the angry expression (Experiment 2 in Chapter 2, and all the experiments in Chapter 3), it was rated as more or less equally attractive as the neutral expression (Experiments 2, 3, Chapter 2). Besides attributing

these results to contextual effect, the assumption underlying the prediction that the perceived attractiveness of faces would increase with the intensity of happy expression was challenged. First of all, even though it was possible to adjust the intensity of the smile in the face stimuli (i.e. from neutral to slight smile, to a close-mouthed full smile, and then an open-mouthed big smile), the positive affect associated with these resultant expressions might not have been proportional to the manipulations. Different forms of smile were known to convey different social meanings (Ekman, & Friesen, 1982; Ambadar, Cohn, & Reed, 2009). Taken together, the findings reported in this thesis regarding the effects of facial expression on perceived attractiveness implied that judgements of valence associated with facial expressions are susceptible to a large extent the effects of context in which the expressions were presented, which can lead to an ambiguity in the social meaning perceived by the observer.

Eye gaze and face view were the other two features of interest in the investigation of facial attractiveness in this thesis and their effects were examined in conjunction with facial expressions in a series of experiments reported in Chapters 2 and 3. Both eye gaze and head orientation can serve as directional cues to the attention allocation. In the context of social interaction, direct gaze and front-facing view signal social attention directed at the perceiver. Previous studies have reported a positive effect of these social cues on perceived attractiveness (Mason, Tatkow, and Macrae, 2005; Ewing, Rhodes, & Pellicano, 2010). Few studies have examined the interactions between these directional signals on facial attractiveness (Jones, DeBruine, Little, Conway, & Feinberg, 2006; Main, DeBruine, Little, & Jones, 2010; Sutherland, Young and Rhodes, 2017) and these studies have only investigated these social cues in their static form. Explanations have been given from the shared-signal and appraisal accounts to interpret the findings in these studies whereby direct gaze (Jones, et al., 2006) or full front face view (Main, et al., 2010;

Sutherland, Young and Rhodes, 2017), when coupled with happy expressions increased perceived attractiveness. According to the shared-signal hypothesis, social signals such as gaze direction and facial expressions can be categorised along the approach-avoidance dimension such that some signals indicate an approach tendency from the expressor (e.g. direct gaze, happy and angry expressions) while others indicate a disposition to avoid (e.g. head turn away, sad expression) and signals that aligned in the approach-avoidance dimension enhance the effects of one another (Adams & Kleck, 2005). Therefore, the shared-signal hypothesis predicted that happy faces with a gaze shift, or head turn towards, rather than away from the participants would be rated as more attractive; while angry faces with a gaze shift towards, rather than away from the participants would be rated as less attractive. Results contrary to this prediction were found. First of all, the effects of facial expressions were found to be independent of those of gaze shifts (Chapter 2). Secondly, while there was an interaction between expression and head turn as well as face view (Chapter 3), the effects of these two directional signals were only significant in happy, but not angry faces. Taken together, the conclusions drawn from the findings reported in this thesis regarding changeable facial features and attractiveness are, first, the interactions between these social signals, only happened under certain conditions, especially not when the saliency of one is higher than the other and second, because these features are transient and social in nature, examining their effects on attractiveness requires, at the very least, presentation of stimuli in their dynamic form as well as an effort to maximise the ecological validity of these stimuli.

7.3.2 Perception categorisation, serial dependence, and aesthetic evaluation

In the last section, the contextual effects were discussed as a potential confounding factor that overrode the effects of facial expression on facial attractiveness. However, in order

to gain more understanding in the contributing factors of aesthetic evaluations, it is necessary to consider the artefacts in the measurement of these evaluations. Chapter 4 was dedicated to the investigation of serial dependence and the effect of perceptual categorisation on serial dependence was specifically examined.

Serial dependence is a well-studied phenomenon in perception whereby the current judgement is biased towards those in recent perceptual history (Fischer & Whitney, 2014; John-Saaltink, Kok, Lau, & de Lange, 2016; Fritsche, Mostert, & de Lange; 2017; Cicchini, Mikellidou, & Burr, 2017; Alais, Leung, & Van der Burg, 2017; Manassi, Liberman, Kosovicheva, Zhang, & Whitney, 2018; Cicchini, Anobile, & Burr, 2014). The function which serial dependence serves in maintaining the stability and continuity of percept has been proposed and tested using computational approaches, which indicated that indeed serial dependence is an efficient mechanism through which the visual system maintain stability of vision despite constant fluctuation of signal strength, lighting, visual noise, etc. (Cicchini et al., 2017). It is also a compelling example of how the judgment response given to a stimulus in any given trial during a perceptual experiment might not reflect entirely the effect of the intended experimental manipulations. Given that experiments in aesthetics routinely involve the production of evaluative responses by the participants in rather quick succession[11], serial dependence is indeed a relevant concern in experimental aesthetics. Furthermore, it has been shown that serial dependence is distinct from response biases. Therefore, the precautions taken to minimise response biases (such as presenting stimuli at different location, using implicit measurements without the need for participants to make a motor response) might not be equally effective in dealing with serial dependence during aesthetic rating or preference tasks. Indeed,

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[11]In the experiment reported in Chapter 5, the average reaction time of participants was approximately 3s, even though the stimuli were presented under a free viewing condition.

previously, studies have demonstrated that facial attractiveness judgements are also susceptible to the effects of serial dependence (Kondo, Takahashi, & Watanabe, 2012, 2013; Kramer, Jones, & Sharma, 2013; Taubert, Van der Burg, & Alais, 2016; Taubert & Alais, 2016; Xia, et al., 2016; Chang, Kim, & Cho, 2017; Huang, He, Ma, Ren, Zhao, & Zeng, 2018) but it was unclear whether serial dependence can also be found in the aesthetic judgements of visually more diverse stimuli such as scenes of built environments since the studies mentioned above used stimuli that were more homogenous. For example, the strength of serial dependence in facial expression judgements (Liberman, et al., 2018) was modulated by similarity in face identity between successive stimuli.

The results of the experiments documented in Chapter 4 showed that serial dependence was a robust effect that affected judgements of facial attractiveness and was attenuated when successive faces were of different sexes, consistent with previous findings (Kondo, et al., 2013; Kramer, et al., 2013). Serial dependence also strongly affected the attractiveness judgements of scenes of architectural spaces, which has not been reported before. This new finding suggested that the strength of serial dependence rely, only to a small, if any, extent, on the visual similarities between the stimuli presented in close temporal proximity, since the scenes presented in the experiment varied quite vastly in terms of basic visual properties (e.g. colour and complexity), Furthermore, unlike in judgements of facial attractiveness, where a change in sex category between faces presented in successive trial reduced serial dependence, a change in scene category during judgements of scene attractiveness from one trial to the next did not affect the magnitude of serial dependence.

These results were discussed in terms of the locus of processing of serial dependence relative to the levels of processing at which perceptual categorisations take place

temporally. The assumption was that if a certain categorisation process occurs before the assimilation of attractiveness judgements across trials could take place, then serial dependence will be weakened, if not totally eliminated in trials where there is a change in the category in question. On the other hand, if the attractiveness judgement process precedes a categorisation process, then a change in category will not affect the strength of serial dependence, since the assimilation of aesthetic responses will have already been completed before the categorisation. This assumption might sound counterintuitive to our experience of aesthetic appreciation at first glance because it suggests a possibility that an aesthetic judgement can be made to a stimulus even before the perceiver knows what it is. However, the results from the experiments reported here, with the support of previous findings regarding the temporal properties of face and scene perceptions, suggest that this is likely the case. In an EEG study by Carbon, Faerber, Augustin, Mitterer, and Hutzler (2018), it was shown that gender categorisation occurred before attractiveness judgement, meaning gender-specific criteria were likely used in the attractiveness evaluation process and before the assimilation of attractiveness judgements takes place. Indeed, serial dependence ceased to occur when there was a change of sex category between successive trials (Experiment 1, Chapter 4). On the other hand, a change in scene type (e.g. indoor to outdoor) did not reduce serial dependence (Experiment 2, Chapter 4). This is also consistent with the prediction based on levels of processing as well as previous findings regarding 'gist' beauty – whereby aesthetic evaluations can be made as early as during the 'gist' perception level (as early as 50s upon exposure), prior to further semantic categorisation of scene types (Mullin, Hayn-Leichsenring, Redies, & Wagemans, 2017).

Another important piece of finding during the investigation of serial dependence was that there appeared to be a serial contrast effect, which is akin to a negative after-effect,

operating in parallel to but opposing serial dependence, and emerged prominently as the assimilation of aesthetic judgements gradually diminished across trials (Experiment 3. Chapter 4). This reversal of serial effects has been reported in a visual variance judgment experiment by Suárex-Pinilla, Seth, & Roseboom (2018). Note that in their study, there was not a category change comparable to Experiment 3 in Chapter 4. In fact, the stimuli used in their study was quite homogenous. The drastic change in perceptual category (i.e. faces and scenes) might have substantially enhanced the contrast effect observed in Chapter 4 as a result of a failed assimilation of aesthetic responses across trials of different category.

Taken together, the experiments reported in Chapter 4 provided new evidence regarding the nature of serial dependence whereby the assimilation of aesthetic judgements across trials is likely not dependent on the similarities in visual properties nor perceptual categories between the current stimulus and those in recent perceptual history per se, but the locus of processing at which the perceptual categorisation in question takes place relative to the elicitation of aesthetic response.

7.3.3 Factors affecting the aesthetic evaluation of built environment

Chapters 5 and 6 of this thesis were dedicated to the investigation of architectural beauty. Compared to facial attractiveness where robust universality of preferences can be found, the individual differences in the aesthetic preferences for architecture are arguably much larger (Vessel, Stahl, Maurer, Denker, & Starr, 2014; Vessel, Maurer, Denker, & Starr, 2018). The built environments also differ from other domains of aesthetic interest in that architecture serves a fundamental function of providing safety and refuge. Therefore, the aesthetic judgements for a building or indoor scene of architectural space might reflect a

mix of aesthetic and functional preferences, together with other personal factors that affect hedonic experiences in general (such as personality and level of expertise). On the other hand, some characteristics that are considered aesthetically pleasing universally such as curvature (Bar & Neta, 2006; Gómez-Puerto, Rosselló, Corradi, Acedo-Carmona, Munar, & Nadal, 2018) and symmetry (Little, Apicella, & Marlowe, 2007; Makin, Pecchinenda, & Bertamini, 2012; Bode, Helmy, & Bertamini, 2017) have been found to influence aesthetic preferences in architecture too (Vartanian, Navarrete, Chatterjee, Fich, Leder, Modroño, Nadal, Rostrup, & Skov, 2013, 2015, 2017; Vecchiato, Tieri, Jelic, De Matteis, Maglione, & Babiloni, 2015; Coburn, Vartanian, & Chatterjee, 2017; Thömmes & Hübner, 2018; Ruta, Mastandrea, Penacchio, Lamaddalena, & Bove, 2018), notwithstanding the fact that these features also affect other dimensions of pleasantness (e.g. approach-avoidance decisions) that are distinct from aesthetics (Vartanian, et al., 2013; 2017; Munar, Gómez-Puerto, & Gomila, 2014) and the preferences for these features are in turn modulated by individual differences (Cotter, Silvia, Bertamini, Palumbo, & Vartanian, 2017; Leder, Tinio, Brieber, Kröner, Jacobsen, & Rosenberg, 2019).

To collectively consider the inter-relationship between visual features, personality and expertise in aesthetic preferences and the perception of intimacy in the built environment, a large-scale study with more than 2000 participants was conducted. The findings suggested that the aesthetic judgements of indoor and outdoor architectural spaces depended on rather different sets of building characteristics.

For indoor spaces, the main determinant was space openness while curvilinearity and to some degree window-to-wall ratio (modulated by personality) contributed to aesthetic judgements for building exteriors. The lack of a curvature preference for indoor spaces contradicted the findings by Vartanian, et al. (2013; 2017) but the differences in findings

could possibly be explained by the differences in the stimulus sets, choice of independent variables to be included in the analyses, as well as sample sizes. Nonetheless, this sensitivity to experimental manipulations suggest that any effects of visual properties on aesthetic judgements of architecture would likely exhibit huge variabilities across both participants within and across studies. This is consistent with the finding that aesthetic preferences in architecture indeed show more individual differences (Vessel, et al., 2014, 2018). For the eye movement recordings, no evidence was found to suggest an inter-dependent relationship between eye movements, visual properties and aesthetic judgements. In fact, the viewing behaviour during aesthetic judgements of building exteriors was somewhat modulated by building height, which had no effect on aesthetic ratings, and curvature, which enhanced ratings did not affect eye movements. There were no significant differences in the number and duration of fixations across different trials and generally participants engaged in visual exploration on the whole building, with slightly more fixations around the centre of the screen. The implications of these findings were that: 1) the aesthetic judgments made to these building exteriors were likely based on a more global percept of the depicted building, and 2) the individual features that enhanced ratings might not necessarily be more salient and attract fixations.

Manipulating individual visual features embedded in architectural spaces as 'independent variables' to measure the aesthetic judgements can also cause relatively unreliable results compared to measuring the effects of isolated visual features in simpler contexts or scenes. This amounts to what Makin (2017) referred to as a 'gestalt nightmare' whereby measuring only the effects of individual features presented in a global context consisting of others uncontrolled-for and unmeasured variables can lead to wrong conclusions regarding these features, which when presented in isolation, might not produce the same results. In the current findings, none of the factors included in the intimacy rating task for

indoor architectural spaces was found to have any effects on intimacy ratings. It is unclear whether those factors individually would have had an effect on perceived intimacy if not embedded with other factors. The same dilemma also existed in investigating the effects of individual differences on aesthetic judgements. Taken together, the large-scale study reported here provide new evidence on the complex inter-dependence relationship between visual properties and personal factors on aesthetic judgements in architecture and any attempts to account for aesthetic preferences in architecture in an overly reductive psychophysical manner are likely to be unfruitful.

7.4 Theoretical implications

In various chapters throughout the thesis, some results have been discussed in terms of the effect of perceptual fluency on aesthetic preferences. In the experiments reported in Chapter 2, the happy expressions were not consistently rated as more attractive than the neutral faces as predicted. However, when the open-mouthed smile was presented under less ambiguous conditions, in which only an unambiguously negative (i.e. angry) expression was present in the same testing session, it was rated as more attractive (Chapter 3). While the clarity of facial expressions might have facilitated the recognition of the corresponding emotions and hence affected the valence of faces, there was little evidence to suggest that it was the perceptual fluency arisen upon unambiguous expression recognition that led to higher attractiveness ratings. It is more likely that the social meaning associated with positive facial expression that enhanced the perceived attractiveness of smiling faces.

A switch in perceptual categories (e.g. from faces to scenes) during an attractiveness judgement task decreased attractiveness ratings, possibly as a result of task switching

whereby 'fluency' was disrupted (Chapter 4); and architectural spaces with curved contours might be rated as more attractive due to the perceptual fluency associated with curvature (Chapter 5). However, perceptual fluency was not measured during any of the experiments conducted in this research project.

Furthermore, in terms of facial attractiveness, the perceptual fluency account of aesthetic preferences has been used to explain the averageness advantage in which faces with configuration mathematically closer the population average in the corresponding gender are considered more attractive (Potter, Corneille, Ruys, & Rhodes, 2007; Trujillo, Jankowitsch, & Langlois, 2014). However, the factors of interest in the current project were changeable, rather than invariant properties of faces. Nevertheless, the perceptual fluency hypothesis would make some predictions regarding the results of the experiments reported here. For example, direct gaze has been shown to attract visuospatial attention (Senju & Hasegawa, 2005), the enhanced attention to a face might increase perceptual fluency during the processing of the face and in turn enhance attractiveness. This prediction was not supported by the data presented in this thesis. The effects of gaze shift on facial attractiveness have not been consistent and appeared to be modulated by the relative duration of direct gaze with front-facing head orientation (Experiment 3, Chapter 2) and masked by the effects of other more salient social signals such as expression and head turn. Therefore, the results presented here showed no evidence that direct gaze enhanced visuospatial attention and perceptual fluency is unlikely to be the modulating factor affecting attractiveness ratings of faces.

In a similar vein, the perceptual fluency hypothesis would also predict some visual properties in the built environment such as curvature would increase perceptual fluency and so enhance aesthetic judgements. This was not apparent. There was also no evidence from the eye tracking study that any particular visual features considered had appeared

more salient that they had attracted substantially more attention which led to an enhanced perceptual fluency.

On the other hand, findings reported in all the experiments here generally are consistent with the predictions made by models which strive to take into accounts both bottom-up, stimulus related and top-down, observer-related influences. For example, the model proposed by Leder, et al., (2004) predicted that for architecture, various aspects of the stimuli (e.g. building features) as well as the observer (e.g. expertise) would affect the aesthetic judgement on any given building or architectural space. According to the model, after a pre-classification of the stimulus into a specific context (i.e. the study in the Science Gallery reported in Chapter 5, in which participants were informed about their task to evaluate images of architecture aesthetically), the visual properties of architectural spaces considered in the experiments (i.e. curvilinearity, building/ ceiling heights, window-to-wall ratio, and space openness) were processed through "perceptual analyses", the first stage of processing. Then depending on the perceiver's experience and knowledge, the familiarity and prototypicality of the architectural space in question were determined through "implicit memory integration" (Leder, et al., 2004). This is also the stage at which the differences between non-experts and experts emerged, but it is during the next stage, "explicit classification", when the expertise and knowledge of architects/ interior designers and students in these disciplines lead to more detailed analyses in regard to the style, historical context, and intended meaning of the architecture, which might be relatively trivial, if not absent, in non-experts. This could be the reason why in the study reported in Chapter 5, experts' aesthetic evaluation of building exteriors depended less on simple visual properties such as curvilinearity compared to non-experts. The final two stages of aesthetic processing occur in parallel, one concerns the "cognitive mastering and evaluation", in which the aesthetic merit of

the building is assessed and the other involves the "affective and emotional processing",

in which aesthetic emotion is a by-product of aesthetic processing and can be influenced

by the outputs of each perceptual or cognitive stage. This model assumes a hierarchical

structure of processing in which perception precedes cognition. Even though top-down

influences such as expertise, social and cultural experiences come into play during the

stages of "implicit memory integration", "explicit classification" and "cognitive

mastering and evaluation", they relied on the outputs of a bottom-up perceptual process.

It remains unclear whether these factors in turn influence perceptual analyses, for

instance, through enhanced attention to visual features that are more relevant to the

participants depending on their expertise, social and cultural backgrounds. Moreover, the

findings from the facial attractiveness experiments cannot be explained by this

information processing model proposed by Leder, et al (2004) for two reasons. Firstly,

the aim of the model was to account for the aesthetic experiences with artwork. As such,

"explicit classification" and "cognitive mastering and evaluation" are not applicable to

human faces. Secondly, the social aspects of facial attractiveness evaluation also cannot

be captured by the model. Specifically, the three changeable features of faces investigated

(Chapters 2 and 3), namely facial expression, eye gaze direction and head orientation,

were communicative cues which convey social meanings that can be perceived as

positive or negative, self-relevant or irrelevant. Therefore, the enhanced attractiveness

ratings under certain conditions, for instance, when a smiling face turned towards the

participant, was likely due to the positive valence associated with such pleasant social

engagement or the past experience of similar encounter.

The model of aesthetic experience proposed by Redies (2015) is more appropriate in

accounting for the processes involved during aesthetic evaluation of stimuli from

different areas and domains. However, as an all-encompassing theoretical framework, it

serves more as a descriptive, rather than a predictive model, without making any particular predictions regarding the magnitudes of effects, nor any interactions between factors. Even though this model was also proposed to explain mainly the aesthetic experiences of viewing artworks, Redies (2015) explicitly considered a number of extensions to a wider range of aesthetic scenarios including encounter of everyday visual stimuli not regarded as art, such as faces and residential architecture. The central idea of the model is that there exists two largely independent modes of aesthetic processing which runs in parallel. The first one involves the "beauty-responsive mechanism", which is activated when a visual stimulus possesses an intrinsic beautiful "form" and its properties are processed through sensory coding and perceptual analyses. This process is fast, stimulus-driven (bottom-up), biological, and universal. Accordingly, certain features associated with facial attractiveness activate the beauty-responsive mechanism and therefore general preferences in faces for these features are observed across individuals and cultures. Social cues which enhance perceived facial attractiveness such as happy expressions and direct gaze are known to activate the reward neural circuit, which is also automatic and largely universal (Kampe, et al., 2001; O'Doherty, et al., 2003). It is unclear, however, how the beauty-responsive mechanism proposed in Redies's (2015) model is associated with the reward circuit despite the similarity. On the other hand, simple visual properties such as space openness and curvature in architecture are processed through the beauty-responsive mechanism accordingly to the model but the findings reported in Chapter 5 did not suggest universal preferences for these features. Instead, big individual differences were observed and the effects of visual properties of architectural spaces on aesthetic evaluations were modulated by level of expertise and personality traits of the participants. This can be explained by the second mode of processing, which is top-down and cognitive. The cognitive encoding of stimulus

depends mainly on contextual information (e.g. the circumstances under which the observer was to aesthetically evaluate a given object) and the subsequent cognitive processing is highly variable among individuals, depending on their expertise, familiarity with the target, social and cultural backgrounds. Personality traits, although not mentioned in the model, is more likely to exert an effect on this cognitive processing pathway, rather than the sensory-perceptual process. As a result, an aesthetic experience is generally dependent on the outputs of both channels of processing described above. Yet, there are cases where one channel (sensory-perceptual or cognitive) is predominant in determining the final outcome of aesthetic experience. For example, art experts who understand the historical context and intended meanings by the artist, can aesthetically appreciate a piece of modern artwork which does not possess a perceptually "beautiful" form. In this case, the output of the cognitive channel dominates the resultant aesthetic experience. The findings reported in this thesis support this possibility.

7.5 Limitations, outstanding questions, and future research

7.5.1 The choice of stimuli

The limitations of each experiment have been discussed through the chapters. For example, the use of FaceGen faces in Chapters 2 and 3 allowed for the fine control of expression, gaze direction and face view, as well as other factors that were not of interest to the current study. However, concerns have been raised regarding the ecological validity of such stimuli. Specifically, these CG images of faces appeared unnatural to most participants, especially when the hair information was also removed. This was reflected in the overall lower attractiveness ratings in these faces compared to those in other experiments where photos of real faces were used (Chapter 4), as well as the

subjective reports of participants that they found these faces unpleasant to look at in general.

During the planning of the experiments on architectural aesthetics, it became apparent that the choices of stimuli appropriate for testing at the level of control typically applied in psychological research were limited. For faces, there are existing image databases with highly standardised photographs of faces, such as the Chicago Face Database (Ma, et al., 2015), and at least 95 more, available for researchers to use. However, to the author's best knowledge, this is not the case for images of architecture. Instead, among the limited number of databases of scene images available, none of them contained images of the reached the level of standardisation comparable to the face images. As a result, the selection of images from the public domain became a challenging task in which a large number of criteria had to be applied to minimise the effects of potential confounding factors. A compilation of architectural images suitable for psychological research is now underway as a result of this project.

7.5.2 The use of ratings in the investigation of aesthetic judgements

The experiments reported in this thesis all revolved around the main theme of aesthetic evaluations. Specifically, in each experiment, the research question to be addressed had been to investigate the effects of a set of factors on the aesthetic judgements, in the form of ratings to any given face or building depicted in an image presented on the screen, on a scale between zero and a hundred, which represented respectively the very unattractive and the very attractive. As a result, the aesthetic preferences of participants can be quantified and compared. Indeed, aesthetic preferences do appear to fall along a continuum of like vs. dislike decisions, with the possibility of being neutral. Rating tasks also allow for a larger number of unique stimuli to be presented, compared to other tasks

such as the 2AFC task in which each stimulus has to be presented multiple times in order for it to be paired with different stimuli. Therefore, in situations where the testing time needs to be limited (e.g. collecting data in a gallery or from children), the rating task is a more efficient method to obtain aesthetic judgements to a large number of unique stimuli within a relatively short time. However, the use of ratings in aesthetic research has its disadvantages. First of all, ratings were given without a reference frame in the beginning of the testing session and therefore the criterion might not be consistent throughout the experiment. Furthermore, the reference frame developed might be only specific to the particular set of stimuli presented in the same block. There is also a possibility that participants develop a certain tendency in their response, the most common of which is the tendency to give intermediate, neutral responses. Last but not least, a single numerical rating as a measurement of aesthetic evaluation is likely not able to capture the richness of aesthetic experience elicited by faces conveying socially self-relevant cues and architectural spaces which can arouse a range of subjective and affective responses, which in turn affect the resultant aesthetic judgements. These can be measured through additional physiological and neurological techniques such as skin conductance recording, eye tracking with pupillometry, EEG and fMRI. Behaviourally, including more rating scales of other dimensions (e.g. likeability, arousal, pleasantness, and interest) or adopting implicit associated tests (IAT) will serve to better understanding the multidimensionality of aesthetic experiences.

7.5.3 Outstanding questions and future research

In the investigation of the effects of changeable facial features on attractiveness, one of the objectives was to examine these social cues in their dynamic forms, which are how they are perceived in real-life scenarios. While the results reported in Chapters 2 and 3

indicated indeed the temporal dynamics of gaze shift and head turn modulated the effects of both on facial attractiveness, the findings were preliminary as only three relative duration ratios were tested (i.e. 1700s:300s, 1000s:1000s and 300:1700s). The temporal manipulation was not systematic enough to capture all the possible dynamics of these social cues. Furthermore, the eye gaze, expression, and head turn, conveyed by the faces used in the experiments did not fully represent how these social signals are displayed in real scenarios of social interaction. In essence, the participants were not engaging in a scenario of social interaction when evaluating these faces trial by trial. Further investigations will be required to simulate a closer-to-real-life scenario in the experimental set up. Ideally real models instead of images of faces would greatly enhance the ecological validity of the experiment.

The experiments conducted on serial dependence have generated informative findings regarding the locus of serial dependence relative to the evaluative processes of stimuli from different categories. EEG would provide a promising avenue for further verification of these results (e.g. using an ERP paradigm and comparing the N200 and LRP effects during a go/no-go task similar to the paradigm in Carbon, et al., 2018). Further experiments can also be conducted to test the sensitivity of serial dependence to more different perceptual category combinations.

There are plenty of outstanding questions arose from the experiments conducted on the aesthetic judgements in architecture reported in Chapters 5. The main limitation of these studies is the use of non-standardised photographs, while ecological validity was somewhat maintained by not altering the images, it is hard to confirm whether the effects found in these experiments were specific to these images only. Furthermore, even though the sample size of the study reported in Chapter 5 was relatively large, the number of stimuli was few, with 5 examples in each of the building feature combination. Future

research is required to investigate these effects more extensively using more well-controlled stimuli, as well as with more examples in each condition. While the use of linear mixed models as a method of data analysis was able to account for random variability in both participants and stimuli without having to average the ratings, the analyses were limited to the predetermined factors defined by categorising the stimulus images into groups according to only a few simple visual features, ignoring many other properties which can potentially modulate preferences. As such, additional analyses using techniques such as cluster analysis will provide an avenue to reveal the effects of architectural characteristics (e.g. style, colour) that were not tested on aesthetic preferences. Subsequently, relating these effects to the individual differences among participants in their age, gender, level of expertise in architecture and interior design, as well as personality traits, inferences can be made regarding the concept of "taste", which was not addressed in this thesis.

The eye-tracking study reported in Chapter 6 was exploratory in nature. While the findings were somewhat intriguing, they are by no mean confirmable unless a follow up is conducted with more participants. It is also possible to utilize the technology of Virtual Reality combined with eye-tracking in order to create an immersive view of architecture spaces.

Finally, some effort had been made during the participant recruitment process to reduce sample homogeneity in terms of age, sex, social and educational backgrounds (e.g. large scale study in Chapter 5). However, the participants who took part in the experiments reported throughout this thesis were recruited mainly in Ireland, and the USA (online experiments in Chapter 2). It remains to be investigated that whether the findings reported can be generalised across other cultures. Although it is well documented that agreement between individuals and across cultures is high in regard to facial features associated with

attractiveness (e.g. youth, averageness, symmetry) (Langlois, Kalakanis, Rubenstein, Larson, Hallam, & Smoot, 2000; Little, 2014), some cultural differences in facial attractiveness judgements have been reported. These differences might have originated through social learning (Little, Jones, DeBruine, & Caldwell, 2011) or even prevalence of illnesses in different regions which leads to distinctive preferences in health-associated facial features (DeBruine, Hones, Crawford, Welling, & Little, 2010, Little, 2014). Future studies could explore whether the effects of social attentional and emotional cues (e.g. eye gaze and head orientation) on facial attractiveness vary across cultures. Likewise, the study on aesthetic evaluation of architecture should be extended to other populations to ascertain the influence of cultural context on architectural appreciation.

8 Concluding comments

Despite the fact that the numerous research questions this thesis set out to address all concerned the factors that contribute to the evaluation processes of facial attractiveness and architectural aesthetics, the purpose of this thesis was never to formulate beauty in these domains. Instead, the motivation behind this research project came from the author's eagerness to better understand aesthetic evaluations as a universal human experience from an empirical perspective, as well as the ambition to engage in the dialogue between the disciplines of humanities and experimental psychology, which has already begun and continue to grow in recent years. By examining the physical, personal, and social aspects in the aesthetic judgements of faces and buildings, two of the most ubiquitous stimuli in our visual world, the new evidence generated as a result was promisingly abundant and firmly reiterated that aesthetic judgements are neither subjective nor objective in their entirety but are products of the interaction between the beheld and the beholder.

References

Adams Jr, R. B., & Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychological science, 14*(6), 644-647.

Adams Jr, R. B., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion, 5*(1), 3.

Adams Jr, R. B., Franklin Jr, R. G., Rule, N. O., Freeman, J. B., Kveraga, K., Hadjikhani, N., Yoshikawa, S., & Ambady, N. (2009). Culture, gaze and the neural processing of fear expressions. *Social cognitive and affective neuroscience*, *5*(2-3), 340- 348.

Adams Jr, R. B., Franklin Jr, R. G., Kveraga, K., Ambady, N., Kleck, R. E., Whalen, P. J., Hadjikhani, N., & Nelson, A. J. (2011). Amygdala responses to averted vs direct gaze fear vary as a function of presentation speed. *Social Cognitive and Affective Neuroscience, 7*(5), 568-577.

Adams Jr, R. B., Franklin Jr, R. G., Nelson, A. J., Gordon, H. L., Kleck, R. E., Whalen, P. J., & Ambady, N. (2011). Differentially tuned responses to restricted versus prolonged awareness of threat: A preliminary fMRI investigation. *Brain and Cognition, 77*(1), 113-119.

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current opinion in neurobiology*, *12*(2), 169-177.

Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'Connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, *32*(3), 537- 551.

Alais, D., Leung, J., & Van der Burg, E. (2017). Linear summation of repulsive and attractive serial dependencies: Orientation and motion dependencies sum in motion perception. *Journal of Neuroscience*, *37*(16), 4381-4390.

Alexander, C. (1977). *A pattern language: towns, buildings, construction*. Oxford university press.

Ambadar, Z., Cohn, J. F., & Reed, L. I. (2009). All smiles are not created equal: Morphology and timing of smiles perceived as amused, polite, and embarrassed/nervous. *Journal of nonverbal behavior*, *33*(1), 17-34.

Ambady, N., & Rosenthal, R. (1993). Half a minute: Predicting teacher evaluations from thin slices of nonverbal behavior and physical attractiveness. *Journal of personality and social psychology*, *64*(3), 431.

Amir, O., Biederman, I., & Hayworth, K. J. (2011). The neural basis for shape preferences. *Vision research*, *51*(20), 2198-2206.

Anstis, S., Mayhew, J., & Morley, T. (1969). The perception of where a face or television 'portrait' is looking. *The American Journal of Psychology, 82*(4), 474-489. doi: 10.2307/1420441

Antes, J. R. (1974). The time course of picture viewing. *Journal of experimental psychology*, *103*(1), 62.

Argyle, M., & Cook, M. (1976). *Gaze and mutual gaze.* Cambridge, England: Cambridge University Press.

Alais, D., Leung, J., & Van der Burg, E. (2017). Linear summation of repulsive and attractive serial dependencies: Orientation and motion dependencies sum in motion perception. *Journal of Neuroscience*, *37*(16), 4381-4390.

Alais, D., Kong, G., Palmer, C., & Clifford, C. (2018). Eye gaze direction shows a positive serial dependency. *Journal of vision*, *18*(4), 11-11.

Alter, A. L., & Oppenheimer, D. M. (2009). Uniting the tribes of fluency to form a metacognitive nation. *Personality and social psychology review*.

Arnheim, R. (1974). *Entropy and art: An essay on disorder and order*. University of California Press.

Armstrong, T., & Detweiler-Bedell, B. (2008). Beauty as an emotion: The exhilarating prospect of mastering a challenging world. *Review of general psychology, 12*(4), 305.

Atkinson, A. P., & Adolphs, R. (2011). The neuropsychology of face perception: beyond simple dissociations and functional selectivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1571), 1726-1738.
Balas, B., & Pacella, J. (2017). Trustworthiness perception is disrupted in artificial faces. *Computers in Human Behavior*, *77*, 240-248.

Balas, B., Tupa, L., & Pacella, J. (2018). Measuring Social Variables in Real and Artificial Faces. *Computers in Human Behavior*.

Balsdon, T., & Clifford, C. W. (2017). A bias-minimising measure of the influence of head orientation on perceived gaze direction. *Scientific reports, 7*, 41685.

Balsdon, T., & Clifford, C. W. (2018). Task dependent effects of head orientation on perceived gaze direction. *Frontiers in psychology*, *9*, 2491.

Banaei, M., Ahmadi, A., Gramann, K., & Hatami, J. (2019). Emotional evaluation of architectural interior forms based on personality differences using virtual reality. *Frontiers of Architectural Research*.

Bar, M., & Neta, M. (2006). Humans prefer curved visual objects. *Psychological science*, *17*(8), 645-648.

Barlett, C. P., & Anderson, C. A. (2012). Direct and indirect relations between the Big 5 personality traits and aggressive and violent behavior. *Personality and Individual Differences*, *52*(8), 870-875.

Belke, B., Leder, H., & Carbon, C. C. (2015). When challenging art gets liked: Evidences for a dual preference formation process for fluent and non-fluent portraits. Plos One, 10(8), e0131796. doi:10.1371/journal.pone.0131796

Benton, C. P. (2010). Rapid reactions to direct and averted facial expressions of fear and anger. *Visual Cognition, 18*(9), 1298-1319.

Bereczkei, T., & Mesko, N. (2007). Hair length, facial attractiveness, personality attribution: A multiple fitness model of hairdressing. *Review of psychology*, *13*(1), 35-42.

Bergstrom, J. R., & Schall, A. (Eds.). (2014). *Eye tracking in user experience design*. Elsevier.
Berlyne, D. E. (1960). Conflict, arousal, and curiosity.

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception & Psychophysics*, *8*(5), 279-286.

Berlyne, D. E. (1971). *Aesthetics and psychobiology* (Vol. 336): JSTOR.

Berlyne, D. E. (1974). *Studies in the new experimental aesthetics: Steps toward an objective psychology of aesthetic appreciation*. Hemisphere.

Bernstein, M., & Yovel, G. (2015). Two neural pathways of face processing: A critical evaluation of current models. *Neuroscience & Biobehavioral Reviews*, *55*, 536-546.

Bertamini, M., Palumbo, L., Gheorghes, T. N., & Galatsidas, M. (2016). Do observers like curvature or do they dislike angularity?. *British Journal of Psychology*, *107*(1), 154-178.

Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive psychology*, *14*(2), 143-177.

Bindemann, M., Mike Burton, A., & Langton, S. R. (2008). How do eye gaze and facial expression interact?. Visual Cognition, 16(6), 708-733.

Bird, G. D., Lauwereyns, J., & Crawford, M. T. (2012). The role of eye movements in decision making and the prospect of exposure effects. *Vision Research*, *60*, 16-21.

Bliss, D. P., Sun, J. J., & D'Esposito, M. (2017). Serial dependence is absent at the time of perception but increases in visual working memory. *Scientific Reports*, *7*(1), 14739.

Bode, C., Helmy, M., & Bertamini, M. (2017). A cross-cultural comparison for preference for symmetry: comparing British and Egyptians non- experts. *Psihologija*, *50*(3), 383-402.

Bornstein, R. F., & D'Agostino, P. R. (1994). The attribution and discounting of perceptual fluency: Preliminary tests of a perceptual fluency/attributional model of the mere exposure effect. *Social Cognition*, *12*(2), 103-128.

Bruce, V., Valentine, T., & Baddeley, A. (1987). The basis of the 3/4 view advantage in face recognition. *Applied cognitive psychology*, *1*(2), 109-120.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British journal of psychology*, *77*(3), 305-327.

Bublatzky, F., Pittig, A., Schupp, H. T., & Alpers, G. W. (2017). Face-to-face: Perceived personal relevance amplifies face processing. *Social cognitive and affective neuroscience, 12*(5), 811-822.

Burriss, R. P., Marcinkowska, U. M., & Lyons, M. T. (2014). Gaze properties of women judging the attractiveness of masculine and feminine male faces. *Evolutionary Psychology*, *12*(1), 147470491401200102.

Buswell, G. T. (1935). How people look at pictures: a study of the psychology and perception in art.

Calbi, M., Heimann, K., Barratt, D., Siri, F., Umiltà, M. A., & Gallese, V. (2017). How Context Influences Our Perception of Emotional Faces: A Behavioral Study on the Kuleshov Effect. *Frontiers in psychology, 8*, 1684.

Camerlink, I., Coulange, E., Farish, M., Baxter, E. M., & Turner, S. P. (2018). Facial expression as a potential measure of both intent and emotion. *Scientific reports, 8*(1), 17602.

Calder, A. J., Young, A. W., Perrett, D. I., Etcoff, N. L., & Rowland, D. (1996). Categorical perception of morphed facial expressions. *Visual Cognition*, *3*(2), 81-118.

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human perception and performance*, *26*(2), 527.

Calder, A. J., Jenkins, R., Cassel, A., & Clifford, C. W. (2008). Visual representation of eye gaze is coded by a nonopponent multichannel system. *Journal of Experimental Psychology: General*, *137*(2), 244.

Campbell, F. W., & Maffei, L. (1971). The tilt after-effect: a fresh look. *Vision Research*, *11*(8), 833-840.

Campbell, R. (1996). Dissociating face processing skills: Decisions about lip read speech, expression, and identity. *The Quarterly Journal of Experimental Psychology: Section A*, *49*(2), 295-314.

Carbon, C. C., Hutzler, F., & Minge, M. (2006). Innovativeness in design investigated by eye movements and pupillometry. *Psychology Science*, *48*(2), 173.

Carbon, C. C., Faerber, S. J., Augustin, M. D., Mitterer, B., & Hutzler, F. (2018). First gender, then attractiveness: Indications of gender-specific attractiveness processing via ERP onsets. *Neuroscience letters*, *686*, 186-192.

Carlin, J. D., & Calder, A. J. (2013). The neural basis of eye gaze processing. *Current opinion in neurobiology*, *23*(3), 450-455.

Carver, C. S., & Harmon-Jones, E. (2009). Anger is an approach-related affect: evidence and implications. *Psychological bulletin, 135(2)*, 183.

Cash, T. F. (1999). The psychosocial consequences of androgenetic alopecia: a review of the research literature. *The British journal of dermatology, 141(3)*, 398-405.

Chamorro·Premuzic, T., Reimers, S., Hsu, A., & Ahmetoglu, G. (2009). Who art thou? Personality predictors of artistic preferences in a large UK sample: The importance of openness. *British Journal of Psychology*, *100*(3), 501-516.

Chatterjee, A. (2010). Neuroaesthetics: A coming of age story. Journal of Cognitive Neuroscience, 23(1), 53–62. doi:10.1162/jocn.2010.21457

Chatterjee, A. (2015). The aesthetic brain: How we evolved to desire beauty and enjoy art (reprint edition). Oxford, England: Oxford University Press.

Chenier, T., & Winkielman, P. (2009). The origins of aesthetic pleasure: processing fluency and affect in judgment, body, and the brain. *Neuroaesthetics*, 275-289.

Cicchini, G. M., Anobile, G., & Burr, D. C. (2014). Compressive mapping of number to space reflects dynamic encoding mechanisms, not static logarithmic transform. *Proceedings of the National Academy of Sciences*, *111*(21), 7867-7872.

Cicchini, G. M., & Kristjánsson, Á. (2015). Guest editorial: On the possibility of a unifying framework for serial dependencies. i. *Perception*, *6*(6).

Cicchini, G. M., Mikellidou, K., & Burr, D. (2017). Serial dependencies act directly on perception. *Journal of Vision*, *17*(14), 6-6.

Clement, J. (2007). Visual influence on in-store buying decisions: an eye-track experiment on the visual influence of packaging design. *Journal of marketing management*, *23*(9-10), 917-928.

Cline, M. (1967). The Perception of Where a Person Is Looking. *The American Journal of Psychology, 80*(1), 41-50. doi: 10.2307/1420539

Coburn, A., Vartanian, O., & Chatterjee, A. (2017). Buildings, beauty, and the brain: A neuroscience of architectural experience. *Journal of Cognitive Neuroscience*, *29*(9), 1521-1531.

Cogan, E., Parker, S., & Zellner, D. A. (2013). Beauty beyond compare: Effects of context extremity and categorization on hedonic contrast. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(1), 16.

Conway, C. A., Jones, B. C., DeBruine, L. M., & Little, A. C. (2008). Evidence for adaptive design in human gaze preference. *Proceedings of the Royal Society of London B: Biological Sciences*, *275*(1630), 63-69.

Cooper, R. M., Law, A. S., & Langton, S. R. (2013). Looking back at the stare-in-the-crowd effect: Staring eyes do not capture attention in visual search. *Journal of vision*, *13*(6), 10-10.

Costa, P. T., & McCrae, R. R. (1980). Influence of extraversion and neuroticism on subjective well-being: happy and unhappy people. *Journal of personality and social psychology*, *38*(4), 668.

Cotter, K. N., Silvia, P. J., Bertamini, M., Palumbo, L., & Vartanian, O. (2017). Curve appeal: exploring individual differences in preference for curved versus angular objects. *i-Perception*, *8*(2), 2041669517693023

Crookes, K., Ewing, L., Gildenhuys, J. D., Kloth, N., Hayward, W. G., Oxner, M., Pond, S., & Rhodes, G. (2015). How well do computer-generated faces tap face expertise?. *PloS one*, *10*(11), e0141353.

Cupchik, G. C. (2007). A critical reflection on Arnheim's Gestalt theory of aesthetics. *Psychology of Aesthetics, Creativity, and the Arts, 1*(1), 16.

Czoschke, S., Fischer, C., Beitner, J., Kaiser, J., & Bledowski, C. (2019). Two types of serial dependence in visual working memory. *British Journal of Psychology*, *110*(2), 256-267.

Davenport, J. L., & Potter, M. C. (2004). Scene consistency in object and background perception. *Psychological Science*, *15*(8), 559-564.

Dazkir, S. S., & Read, M. A. (2012). Furniture forms and their influence on our emotional responses toward interior environments. *Environment and Behavior, 44,* 722–734. http://dx.doi.org/10.1177/0013916511402063

DeBruine, L. M., Jones, B. C., Crawford, J. R., Welling, L. L., & Little, A. C. (2010). The health of a nation predicts their mate preferences: cross-cultural variation in women's preferences for masculinized male faces. *Proceedings of the Royal Society B: Biological Sciences, 277*(1692), 2405-2410.

De Lucio, J. V., Mohamadian, M., Ruiz, J. P., Banayas, J., & Bernaldez, F. G. (1996). Visual landscape exploration as revealed by eye movement tracking. *Landscape and urban planning*, *34*(2), 135-142.

Dosen, A. S., & Ostwald, M. J. (2013). Methodological characteristics of research testing prospect–refuge theory: a comparative analysis. *Architectural Science Review*, *56*(3), 232-241.

Einav, S., & Hood, B. M. (2006). Children's use of the temporal dimension of gaze for inferring preference. *Developmental psychology*, *42*(1), 142.

Ekman, P., & Friesen, W. V. (1976). Measuring facial movement. *Environmental psychology and nonverbal behavior*, *1*(1), 56-75.

Ekman, P., & Friesen, W. V. (1982). Felt, false, and miserable smiles*. Journal of nonverbal behavior, 6*(4), 238-252.

Ekman, P., Friesen, W.V., O'Sullivan, M., Chan, A., Diacoyanni-Tarlatzis, I., Heider, K., Krause, R., Lecompte, W.A., Pitcairn, T., Ricci-Bitti, P.E., Scherer, K.R., Tomita, M. and Tzavaras, A. (1987). Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of Personality and Social Psychology*, 53, 712–717.

Engell, A. D., & Haxby, J. V. (2007). Facial expression and gaze-direction in human superior temporal sulcus. *Neuropsychologia, 45*(14), 3234-3241.

Etcoff, N. L. (1984). Selective attention to facial identity and facial emotion. *Neuropsychologia*, *22*(3), 281-295.

Ethofer, T., Gschwind, M., & Vuilleumier, P. (2011). Processing social aspects of human gaze: a combined fMRI-DTI study. *Neuroimage*, *55*(1), 411-419.

Ewbank, M. P., Jennings, C., & Calder, A. J. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *Journal of Vision*, *9*(12), 16-16.

Ewing, L., Rhodes, G., & Pellicano, E. (2010). Have you got the look? Gaze direction affects judgements of facial attractiveness. *Visual Cognition*, *18*(3), 321-330.

Eysenck, H. J. (1941). A critical and experimental study of colour preferences. *The American Journal of Psychology, 54*(3), 385-394.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National academy of sciences, 99*(14), 9602-9605.

Farroni, T., Menon, E., Rigato, S., & Johnson, M. H. (2007a). The perception of facial expressions in newborns. *European Journal of Developmental Psychology*, *4*(1), 2 -13.

Farroni, T., Massaccesi, S., Menon, E., & Johnson, M. H. (2007). Direct gaze modulates face recognition in young infants. *Cognition*, *102*(3), 396-404.

Favelle, S., & Palmisano, S. (2018). View specific generalisation effects in face recognition: Front and yaw comparison views are better than pitch. *PloS one, 13*(12), e0209927.

Fei-Fei, L., Iyer, A., Koch, C., & Perona, P. (2007). What do we perceive in a glance of a real-world scene?. *Journal of vision*, *7*(1), 10-10.

Fischer, J., & Whitney, D. (2014). Serial dependence in visual perception. *Nature neuroscience*, *17*(5), 738.

Fornaciai, M., & Park, J. (2018). Attractive serial dependence in the absence of an explicit task. *Psychological science*, *29*(3), 437-446.

Fritsche, M., Mostert, P., & de Lange, F. P. (2017). Opposite effects of recent history on perception and decision. *Current Biology*, *27*(4), 590-595.

Foster, C. A., Witcher, B. S., Campbell, W. K., & Green, J. D. (1998). Arousal and attraction: Evidence for automatic and controlled processes. *Journal of Personality and Social Psychology*, *74*(1), 86.

Friedenberg, J. (2019). Beauty in the eye of the beholder: Individual differences in preference for randomized visual patterns. *Experimental psychology*.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: visual attention, social cognition, and individual differences. *Psychological bulletin*, *133*(4), 694.

Furnham, A., & Walker, J. (2001). The influence of personality traits, previous experience of art, and demographic variables on artistic preference. *Personality and Individual Differences*, *31*(6), 997-1017.

Gamer, M., & Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *Journal of Experimental Psychology: Human Perception and Performance, 33*(3), 705.

Ganel, T., Goshen-Gottstein, Y., & Goodale, M. A. (2005). Interactions between the processing of gaze direction and facial expression. *Vision research*, *45*(9), 1191- 1200.

Ganel, T. (2011). Revisiting the relationship between the processing of gaze direction and the processing of facial expression. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(1), 48.

Gangwar, G. (2017). Principles and Applications of Geometric Proportions in Architectural Design. *J. Civ. Eng. Environ. Technol*, *4*(3), 171-176.

George, N., Driver, J., & Dolan, R. J. (2001). Seen gaze-direction modulates fusiform activity and its coupling with other brain areas during face processing. *Neuroimage*, *13*(6), 1102-1112.

Georgescu, A. L., Kuzmanovic, B., Schilbach, L., Tepest, R., Kulbida, R., Bente, G., & Vogeley, K. (2013). Neural correlates of "social gaze" processing in high-functioning autism under systematic variation of gaze duration. *NeuroImage: Clinical*, *3*, 340-351.

Gibson, J. J., & Radner, M. (1937). Adaptation, after-effect and contrast in the Perception of tilted lines. I. Quantitative studies. *Journal of experimental psychology*, *20*(5), 453.

Gibson, J. J., & Pick, A. D. (1963). Perception of another person's looking behavior. *The American Journal of Psychology*, *76*(3), 386-394.

Goia, F. (2016). Search for the optimal window-to-wall ratio in office buildings in different European climates and the implications on total energy saving potential. *Solar Energy*, *132*, 467-492.

Golden, L. (1975) Plato's Concept of Mimesis. *British Journal of Aesthetics, 15,* 118– 131.

Golle, J., Mast, F. W., & Lobmaier, J. S. (2014). Something to smile about: The interrelationship between attractiveness and emotional expression. *Cognition & Emotion, 28*(2), 298-310.

Gómez-Puerto, G., Munar, E., & Nadal, M. (2016). Preference for curvature: A historical and conceptual framework. *Frontiers in human neuroscience*, *9*, 712.

Gómez-Puerto, G., Rosselló, J., Corradi, G., Acedo-Carmona, C., Munar, E., & Nadal, M. (2018). Preference for curved contours across cultures. *Psychology of Aesthetics, Creativity, and the Arts*, *12*(4), 432.

Graham, R., & LaBar, K. S. (2007). Garner interference reveals dependencies between emotional expression and gaze in face perception. *Emotion*, *7*(2), 296.

Graham, R., & LaBar, K. S. (2012). Neurocognitive mechanisms of gaze-expression interactions in face processing and social attention. *Neuropsychologia*, *50*(5), 553-566.

Griffey, J. A., & Little, A. C. (2014). Infant's visual preferences for facial traits associated with adult attractiveness judgements: Data from eye-tracking. Infant Behavior and Development, 37(3), 268-275.

Grossmann, T., Johnson, M. H., Farroni, T., & Csibra, G. (2007). Social perception in the infant brain: gamma oscillatory activity in response to eye gaze. *Social cognitive and affective neuroscience*.

Hair Jr, J. F., Black, J. W., Babin, B. J., & Anderson, E. R. (2010). Multivariate Data Analysis (Seventh Ed., pp.1–758). Edinburgh: Pearson Education Limited.

Hall, J. A., Andrzejewski, S. A., Murphy, N. A., Mast, M. S., & Feinstein, B. A. (2008). Accuracy of judging others' traits and states: Comparing mean levels across tests. *Journal of Research in Personality*, *42*(6), 1476-1489.

Harel, A., Groen, I. I., Kravitz, D. J., Deouell, L. Y., & Baker, C. I. (2016). The temporal dynamics of scene processing: A multifaceted EEG investigation. *Eneuro*, *3*(5).

Harmon-Jones, E., & Sigelman, J. (2001). State anger and prefrontal brain activity: evidence that insult-related relative left-prefrontal activation is associated with experienced anger and aggression. *Journal of personality and social psychology*, *80*(5), 797.

Harmon-Jones, E., Lueck, L., Fearn, M., & Harmon-Jones, C. (2006). The effect of personal relevance and approach-related action expectation on relative left frontal cortical activity. *Psychological Science*, *17*(5), 434-440.

Hassan, M. A., Guirguis, N. M., Shaalan, M. R., & El-Shazly, K. M. (2007). Investigation of effects of window combinations on ventilation characteristics for thermal comfort in buildings. *Desalination*, *209*(1-3), 251-260.

Hayn-Leichsenring, G. U., & Chatterjee, A. (2019). Colliding Terminological Systems— Immanuel Kant and Contemporary Empirical Aesthetics. *Empirical Studies of the Arts*, *37*(2), 197-219.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, *51*(1), 59-67.

Hekkert, P., Snelders, D., & Van Wieringen, P. C. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British journal of Psychology*, *94*(1), 111-124.

Henderson, J. M., & Ferreira, F. (1990). Effects of foveal processing difficulty on the perceptual span in reading: implications for attention and eye movement control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(3), 417.

Henderson, J. M., & Hollingworth, A. (1999). High-level scene perception. *Annual review of psychology*, *50*(1), 243-271.

Hess, U., Adams, R. B., & Kleck, R. E. (2007). Looking at you or looking elsewhere: The influence of head orientation on the signal value of emotional facial expressions. *Motivation and Emotion*, *31*(2), 137-144.

Hesslinger, V. M., Carbon, C. C., & Hecht, H. (2017). The Sense of Being Watched Is Modulated by Arousal and Duration of the Perceptual Episode. *i-Perception, 8*(6), 2041669517742179.

Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., & Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach–avoidance motivational brain systems. *Neuropsychologia*, *46*(9), 2423-2430.

Ho, P. K., Woods, A., & Newell, F. N. (2018). Temporal shifts in eye gaze and facial expressions independently contribute to the perceived attractiveness of unfamiliar faces. *Visual Cognition, 26*(10), 831-852.

Hoffman, J. E., & Subramaniam, B. (1995). The role of visual attention in saccadic eye movements. *Perception & psychophysics*, *57*(6), 787-795.

Holmes, T., & Zanker, J. M. (2012). Using an oculomotor signature as an indicator of aesthetic preference. *i-Perception*, *3*(7), 426-439.

Huang, Y., Pan, X., Mo, Y., & Ma, Q. (2016). Brain potentials indicate the effect of other observers' emotions on perceptions of facial attractiveness. *Neuroscience letters*, *617*, 277-282.

Intimacy. (2019). In *Oxford Online Dictionary*. Retrieved from https://en.oxforddictionaries.com/definition/intimacy

Itti, L., & Koch, C. (2000). A saliency-based search mechanism for overt and covert shifts of visual attention. *Vision research*, *40*(10-12), 1489-1506.

Itti, L., & Koch, C. (2001a). Computational modelling of visual attention. *Nature reviews neuroscience*, *2*(3), 194.

Jadva, V., Hines, M., & Golombok, S. (2010). Infants' preferences for toys, colors, and shapes: Sex differences and similarities. *Archives of sexual behavior*, *39*(6), 1261-1273.

John-Saaltink, E. S., Kok, P., Lau, H. C., & De Lange, F. P. (2016). Serial dependence in perceptual decisions is reflected in activity patterns in primary visual cortex. *Journal of Neuroscience*, *36*(23), 6186-6192.

Jones, B. C., DeBruine, L. M., Little, A. C., Conway, C. A., & Feinberg, D. R. (2006). Integrating gaze direction and expression in preferences for attractive faces. *Psychological Science*, *17*(7), 588-591.

Jones, P.B., Canniffe, E. (2007) *Modern Architecture Through Case Studies* 1945–1990 (Architectural Press, Oxford)

Kaisler, R. E., & Leder, H. (2016). Trusting the looks of others: Gaze effects of faces in social settings. *Perception, 45*(8), 875-892.

Kaisler, R. E., & Leder, H. (2017). Combined effects of gaze and orientation of faces on person judgments in social Situations. *Frontiers in psychology, 8*, 259.

Kampe, K. K., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Psychology: Reward value of attractiveness and gaze. *Nature*, *413*(6856), 589.

Kant, I. (1922). *Kritik der Urteilskraft* [Critique of the Power of Judgment]. Leipzig, Germany: F. Meiner.

Kaufmann, J. M., & Schweinberger, S. R. (2004). Expression influences the recognition of familiar faces. *Perception*, *33*(4), 399-408.

Kellough, J. L., Beevers, C. G., Ellis, A. J., & Wells, T. T. (2008). Time course of selective attention in clinically depressed young adults: An eye tracking study. *Behaviour research and therapy*, *46*(11), 1238-1243.

Kenrick, D. T., & Gutierres, S. E. (1980). Contrast effects and judgments of physical attractiveness: When beauty becomes a social problem. *Journal of Personality and Social Psychology*, *38*(1), 131.

Kiyonaga, A., Scimeca, J. M., Bliss, D. P., & Whitney, D. (2017). Serial dependence across perception, attention, and memory. *Trends in Cognitive Sciences*, *21*(7), 493- 497.

Kleinke, C. L. (1986). Gaze and eye contact: a research review. *Psychological bulletin*, *100*(1), 78.

Kluttz, N. L., Mayes, B. R., West, R. W., & Kerby, D. S. (2009). The effect of head turn on the perception of gaze. *Vision Research, 49*(15), 1979-1993.

Knapen, T., Rolfs, M., Wexler, M., & Cavanagh, P. (2009). The reference frame of the tilt aftereffect. *Journal of Vision*, *10*(1), 8-8.

Knoblich, G., Öllinger, M., & Spivey, M. J. (2005). Tracking the eyes to obtain insight into insight problem solving. *Cognitive processes in eye guidance*, 355-75.

Kondo, A., Takahashi, K., & Watanabe, K. (2012). Sequential effects in face-attractiveness judgment. *Perception*, *41*(1), 43-49.

Kondo, A., Takahashi, K., & Watanabe, K. (2013). Influence of gender membership on sequential decisions of face attractiveness. *Attention, Perception, & Psychophysics, 75*(7), 1347-1352.

Kramer, R. S., Jones, A. L., & Sharma, D. (2013). Sequential effects in judgements of attractiveness: the influences of face race and sex. *PLoS One, 8*(12), e82226.

Kristjánsson, Á., & Campana, G. (2010). Where perception meets memory: A review of repetition priming in visual search tasks. *Attention, Perception, & Psychophysics*, *72*(1), 5-18.

Kruft, H. W. (1994). *History of architectural theory*. Princeton Architectural Press. Kuzmanovic, B., Georgescu, A. L., Eickhoff, S. B., Shah, N. J., Bente, G., Fink, G. R., & Vogeley, K. (2009). Duration matters: dissociating neural correlates of detection and evaluation of social gaze. *Neuroimage*, *46*(4), 1154-1163.

Landwehr, J. R., Labroo, A. A., & Herrmann, A. (2011). Gut liking for the ordinary: Incorporating design fluency improves automobile sales forecasts.*Marketing Science*, *30*(3), 416-429.

Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological science*, *1*(2), 115-121.

Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., & Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychological bulletin, 126*(3), 390.

Langton, S. R., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition, 6*(5), 541-567.

Langton, S. R. (2000). The mutual influence of gaze and head orientation in the analysis of social attention direction. *The Quarterly Journal of Experimental Psychology: Section A, 53*(3), 825-845.

Langton, S. R., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in cognitive sciences*, *4*(2), 50-59.

Langton, S. R. H., Honeyman, H., & Tessler, E. (2004). The influence of head contour and nose angle on the perception of eye-gaze direction. *Perception and Psychophysics, 66*, 752–771.

Larsen, R. J., & Ketelaar, T. (1989). Extraversion, neuroticism and susceptibility to positive and negative mood induction procedures. *Personality and individual Differences*, *10*(12), 1221-1228.

Larsen, R. J., & Ketelaar, T. (1991). Personality and susceptibility to positive and negative emotional states. *Journal of personality and social psychology*, *61*(1), 132.

Lassalle, A., & Itier, R. J. (2015). Emotional modulation of attention orienting by gaze varies with dynamic cue sequence. *Visual cognition*, *23*(6), 720-735.

Lau, S. (1982). The effect of smiling on person perception. *The Journal of Social Psychology*, *117*(1), 63-67.

Lawson, R. (2015). I just love the attention: implicit preference for direct eye contact. *Visual Cognition*, *23*(4), 450-4

Leder, H., & Nadal, M. (2014). Ten years of a model of aesthetic appreciation and aesthetic judgments: The aesthetic episode–Developments and challenges in empirical aesthetics. *British Journal of Psychology*, *105*(4), 443-464.

Leder, H., Tinio, P. P., Brieber, D., Kröner, T., Jacobsen, T., & Rosenberg, R. (2019). Symmetry Is Not a Universal Law of Beauty. *Empirical Studies of the Arts*, *37*(1), 104- 114.

Lefas, P. (2000). On the fundamental terms of Vitruvius's architectural theory. *Bulletin of the Institute of Classical Studies*, 179-197.

Li, J., Oksama, L., & Hyönä, J. (2016). How facial attractiveness affects sustained attention. *Scandinavian journal of psychology, 57*(5), 383-392.

Liberman, A., Fischer, J., & Whitney, D. (2014). Serial dependence in the perception of faces. *Current Biology*, *24*(21), 2569-2574.

Liberman, A., Zhang, K., & Whitney, D. (2016). Serial dependence promotes object stability during occlusion. *Journal of vision*, *16*(15), 16-16.

Liberman, A., Manassi, M., & Whitney, D. (2018). Serial dependence promotes the stability of perceived emotional expression depending on face similarity. *Attention, Perception, & Psychophysics*, *80*(6), 1461-1473.

Little, A. C., Apicella, C. L., & Marlowe, F. W. (2007). Preferences for symmetry in human faces in two cultures: data from the UK and the Hadza, an isolated group of hunter-gatherers. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1629), 3113-3117.

Little, A. C., Jones, B. C., DeBruine, L. M., & Caldwell, C. A. (2011). Social learning and Human mate preferences: a potential mechanism for generating and maintaining between-population diversity in attraction. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1563), 366-375.

Little, A. C. (2014). Facial attractiveness. *Wiley Interdisciplinary Reviews: Cognitive Science*, *5*(6), 621-634.

Locher, P., Krupinski, E. A., Mello-Thoms, C., & Nodine, C. F. (2008). Visual interest in pictorial art during an aesthetic experience. *Spatial vision*, *21*(1-2),55-78.

Ma, Correll, & Wittenbrink (2015). The Chicago Face Database: A free stimulus set of faces and norming data. *Behavior Research Methods, 47,* 1122-1135.

Ma, F., Xu, F., & Luo, X. (2015). Children's and adults' judgments of facial trustworthiness: the relationship to facial attractiveness. *Perceptual and Motor Skills*, *121*(1), 179-198.

Mackworth, N. H., & Morandi, A. J. (1967). The gaze selects informative details within pictures. *Perception & psychophysics*, *2*(11), 547-552.

Macrae, C. N., Hood, B. M., Milne, A. B., Rowe, A. C., & Mason, M. F. (2002). Are you looking at me? Eye gaze and person perception. *Psychological Science*, *13*(5), 460-464.

MacDorman, K. F., Green, R. D., Ho, C. C., & Koch, C. T. (2009). Too real for comfort? Uncanny responses to computer generated faces. *Computers in human behavior*, *25*(3), 695-710.

Main, J. C., DeBruine, L. M., Little, A. C., & Jones, B. C. (2010). Interactions among the effects of head orientation, emotional expression, and physical attractiveness on face preferences. *Perception*, *39*(1), 62-71.

Makin, A. D. J., Pecchinenda, A., & Bertamini, M. (2012). Implicit affective evaluation of visual symmetry. *Emotion*, *12*(5), 1021.

Manassi, M., Liberman, A., Chaney, W., & Whitney, D. (2017). The perceived stability of scenes: serial dependence in ensemble representations. *Scientific Reports*, *7*(1), 1971.

Manassi, M., Liberman, A., Kosovicheva, A., Zhang, K., & Whitney, D. (2018). Serial dependence in position occurs at the time of perception. *Psychonomic bulletin & review*, *25*(6), 2245-2253.

Mannan, S. K., Ruddock, K. H., & Wooding, D. S. (1997). Fixation patterns made during brief examination of two-dimensional images. *Perception*, *26*(8), 1059-1072.

Mangkuto, R. A., Rohmah, M., & Asri, A. D. (2016). Design optimisation for window size, orientation, and wall reflectance with regard to various daylight metrics and lighting energy demand: A case study of buildings in the tropics. *Applied energy*, *164*, 211-219.

Marr, D. (1982). Vison.

Martindale, C., Moore, K., & West, A. (1988). Relationship of preference judgments to typicality, novelty, and mere exposure. *Empirical Studies of the Arts*, *6*(1), 79-96.

Martindale, C. (2007). Recent trends in the psychological study of aesthetics, creativity, and the arts. *Empirical studies of the arts, 25*(2), 121-141.

Martindale, C., Moore, K., & Borkum, J. (1990). Aesthetic preference: Anomalous findings for Berlyne's psychobiological theory. *The American Journal of Psychology*, 53-80.

Maruyama, K., & Endo, M. (1983). The effect of face orientation upon apparent direction of gaze. *Tohoku Psychologica Folia, 42*, 126–138.

Maruyama, K., Endo, M., & Sakurai, K. (1985). An experimental consideration on ''Mona Lisa gaze effect''. *Tohoku Psychologica Folia, 44*(1–4), 109–121.

Masame, K. (1990). Perception of where a person is looking: Overestimation and underestimation of gaze direction. *Tohoku Psychologica Folia, 49*, 33–41.

Mason, M., Hood, B., & Macrae, C. N. (2004). Look into my eyes: Gaze direction and person memory. *Memory*, *12*(5), 637-643.

Mason, M. F., Tatkow, E. P., & Macrae, C. N. (2005). The look of love gaze shifts and person perception. *Psychological Science*, *16*(3), 236-239.

Mastandrea, S., Bartoli, G., & Carrus, G. (2011). The automatic aesthetic evaluation of different art and architectural styles. *Psychology of Aesthetics, Creativity, and the Arts, 5*(2), 126.

Mehu, M., Little, A. C., & Dunbar, R. I. (2008). Sex differences in the effect of smiling on social judgments: An evolutionary approach. *Journal of Social, Evolutionary, and Cultural Psychology*, *2*(3), 103.

McCarley, J. S., Kramer, A. F., & DiGirolamo, G. J. (2003). Differential effects of the Müller-Lyer illusion on reflexive and voluntary saccades. *Journal of Vision*, *3*(11), 9-9.

Milders, M., Hietanen, J. K., Leppänen, J. M., & Braun, M. (2011). Detection of emotional faces is modulated by the direction of eye gaze. *Emotion*, *11*(6), 1456.

Mitra, N. J., & Pauly, M. (2008). Symmetry for architectural design. *Advances in Architectural Geometry*, 13-16.

Mohan, J., & Mohan, V. (1965). Personality and variability in aesthetic evaluation. *Psychological Studies*.

Mogg, K., Millar, N., & Bradley, B. P. (2000). Biases in eye movements to threatening facial expressions in generalized anxiety disorder and depressive disorder. *Journal of abnormal psychology*, *109*(4), 695.

Moors, P., Verfaillie, K., Daems, T., Pomianowska, I., & Germeys, F. (2016). The Effect of Head Orientation on Perceived Gaze Direction: Revisiting Gibson and Pick (1963) and Cline (1967). *Frontiers in psychology, 7*, 1191. doi:10.3389/fpsyg.2016.01191

Morrison, E. R., Morris, P. H., & Bard, K. A. (2013). The stability of facial attractiveness: Is it what you've got or what you do with it?. *Journal of Nonverbal Behavior*, *37*(2), 59-67.

Mullin, C., Hayn-Leichsenring, G., Redies, C., & Wagemans, J. (2017). The gist of beauty: An investigation of aesthetic perception in rapidly presented images. *Electronic Imaging*, *2017*(14), 248-256.

Munar, E., Gómez-Puerto, G., & Gomila, A. (2014). 1 The Evolutionary Roots of Aesthetics: An Approach-Avoidance Look at Curvature Preference. In *Embodied aesthetics* (pp. 3-17). Brill.

Munar, E., Gómez-Puerto, G., López-Navarro, E., & Nadal, M. (2014). Visual preference for curvature as a potential aesthetic primitive. In *Proceedings of the Twenty-Third Biennial Congress of the International Association of Empirical Aesthetics, ed A. Kotzbelt (New York, NY)* (pp. 316-319).

Munar, E., Gómez-Puerto, G., Call, J., & Nadal, M. (2015). Common visual preference for curved contours in humans and great apes. *PloS one*, *10*(11), e0141106.

Mueser, K. T., Grau, B. W., Sussman, S., & Rosen, A. J. (1984). You're only as pretty as you feel: facial expression as a determinant of physical attractiveness. *Journal of Personality and Social Psychology*, *46*(2), 469.

Myszkowski, N., Storme, M., Zenasni, F., & Lubart, T. (2014). Is visual aesthetic sensitivity independent from intelligence, personality and creativity?. *Personality and Individual Differences*, *59*, 16-20.

Namazian, A., & Mehdipour, A. (2013). Psychological demands of the built environment, privacy, personal space and territory in architecture. *International Journal of Psychology and Behavioral Sciences*, *3*(4), 109-113.

Neta, M., Davis, F. C., & Whalen, P. J. (2011). Valence resolution of ambiguous facial expressions using an emotional oddball task. *Emotion (Washington, D.C.), 11*(6), 1425– 1433. doi: 10.1037/a0022993

Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. *Trends in cognitive sciences*, *13*(3), 135-143.

O'Doherty, J., Winston, J., Critchley, H., Perrett, D., Burt, D. M., & Dolan, R. J. (2003). Beauty in a smile: the role of medial orbitofrontal cortex in facial attractiveness. *Neuropsychologia*, *41*(2), 147-155.

Oliva, A., & Schyns, P. G. (2000). Diagnostic colors mediate scene recognition. *Cognitive psychology*, *41*(2), 176-210.

Oppermann, F., Hassler, U., Jescheniak, J. D., & Gruber, T. (2012). The rapid extraction of gist— early neural correlates of high-level visual processing. *Journal of Cognitive Neuroscience*, *24*(2), 521-529.

Oosterhof, N. N., & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(32), 11087– 11092. http://doi.org/10.1073/pnas.0805664105

Oosterhof, N. N., & Todorov, A. (2009). Shared perceptual basis of emotional expressions and trustworthiness impressions from faces. *Emotion, 9*(1), 128.

Otsuka, Y., Mareschal, I., Calder, A. J., & Clifford, C. W. (2014). Dual-route model of the effect of head orientation on perceived gaze direction. *Journal of Experimental Psychology: Human perception and performance, 40*(4), 1425.

Otsuka, Y., Mareschal, I., & Clifford, C. W. (2016). Testing the dual-route model of perceived gaze direction: linear combination of eye and head cues. *Journal of vision, 16*(8), 8-8.

Otta, E., Lira, B. B. P., Delevati, N. M., Cesar, O. P., & Pires, C. S. G. (1994). The effect of smiling and of head tilting on person perception. *The Journal of psychology*, *128*(3), 323-331.

Otta, E., Abrosio, F. F. E., & Hoshino, R. L. (1996). Reading a smiling face: Messages conveyed by various forms of smiling. *Perceptual and motor skills*, *82*(3_suppl), 1111-1121.

O'Toole, A. J., Roark, D. A., & Abdi, H. (2002). Recognizing moving faces: A psychological and neural synthesis. *Trends in cognitive sciences*, *6*(6), 261-266.

Palanica, A., & Itier, R. J. (2012). Attention capture by direct gaze is robust to context and task demands. *Journal of Nonverbal Behavior*, *36*(2), 123-134.

Pallasmaa, J. (1994). Identity, intimacy and domicile. *Finish Archit. Rev*, *1*, 16.

Palumbo, L., Ruta, N., & Bertamini, M. (2015). Comparing angular and curved shapes in terms of implicit associations and approach/avoidance responses. *PloS one*, *10*(10), e0140043.

Palumbo, L., & Bertamini, M. (2016a). The curvature effect: A comparison between preference tasks. *Empirical Studies of the Arts*, *34*(1), 35-52.

Palumbo, L., & Bertamini, M. (2016). Preference for curvature: immediate or mediated response?. *Empirical Studies of the Arts*, *34*, 35-52.

Parker, S., Bascom, J., Rabinovitz, B., & Zellner, D. (2008). Positive and negative hedonic contrast with musical stimuli. *Psychology of aesthetics, creativity, and the arts*, *2*(3), 171.

Pavlović, M., & Marković, S. (2012). Automatic processes in aesthetic judgment: Insights from the implicit association test. *Psihologija*, *45*(4), 377-393.

Pappas, N. (2017). Plato's Aesthetics. *The Stanford Encyclopedia of Philosophy*, Edward N. Zalta (ed.), URL =<https://plato.stanford.edu/archives/ fall2017/entries/plato-aesthetics/>.

Parkhurst, D., Law, K., & Niebur, E. (2002). Modeling the role of salience in the allocation of overt visual attention. *Vision research*, *42*(1), 107-123.

Patterson, M. L. (1982). A sequential functional model of nonverbal exchange. *Psychological review*, *89*(3), 231.

Pegors, T. K., Mattar, M. G., Bryan, P. B., & Epstein, R. A. (2015). Simultaneous perceptual and response biases on sequential face attractiveness judgments. *Journal of Experimental Psychology: General*, *144*(3), 664.

Peirce, J. W. (2007). PsychoPy—psychophysics software in Python. *Journal of neuroscience methods*, *162*(1), 8-13.

Pelisson, D., Prablanc, C., & Urquizar, C. (1988). Vestibuloocular reflex inhibition and gaze saccade control characteristics during eye-head orientation in humans. *Journal of Neurophysiology*, *59*(3), 997-1013.

Perrett, D. I., Lee, K. J., Penton-Voak, I., Rowland, D., Yoshikawa, S., Burt, D. M., Henzi, S. P., Castles, D. L., & Akamatsu, S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature*, *394*(6696), 884.

Perrett, D. I., Burt, D. M., Penton-Voak, I. S., Lee, K. J., Rowland, D. A., & Edwards, R. (1999). Symmetry and human facial attractiveness. *Evolution and human behavior*, *20*(5), 295-307.

Peskin, M., & Newell, F. N. (2004). Familiarity breeds attraction: Effects of exposure on the attractiveness of typical and distinctive faces. *Perception*, *33*(2), 147-157.

Pierce, K., Marinero, S., Hazin, R., McKenna, B., Barnes, C. C., & Malige, A. (2016). Eye tracking reveals abnormal visual preference for geometric images as an early biomarker of an autism spectrum disorder subtype associated with increased symptom severity. *Biological psychiatry*, *79*(8), 657-666.

Pieters, R., & Wedel, M. (2017). A review of eye-tracking research in marketing. In *Review of marketing research* (pp. 143-167). Routledge.

Phillips, F., Norman, J. F., & Beers, A. M. (2011). Fechner's aesthetics revisited. In *Fechner's Legacy in Psychology* (pp. 183-191). BRILL.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of experimental psychology: human learning and memory*, *2*(5), 509.

Potter, T., Corneille, O., Ruys, K. I., & Rhodes, G. (2007). "Just another pretty face": A multidimensional scaling approach to face attractiveness and variability. *Psychonomic Bulletin & Review*, *14*(2), 368-372.

Potter, T., & Corneille, O. (2008). Locating attractiveness in the face space: Faces are more attractive when closer to their group prototype. *Psychonomic Bulletin & Review*, *15*(3), 615-622.

Quinn, P. C., Brown, C. R., & Streppa, M. L. (1997). Perceptual organization of complex visual configurations by young infants. *Infant Behavior and Development*, *20*(1), 35-46.

Quian Quiroga, R., & Pedreira, C. (2011). How do we see art: an eye-tracker study. *Frontiers in human neuroscience*, *5*, 98.

Rayner, K., & Pollatsek, A. (1992). Eye movements and scene perception. *Canadian Journal of Psychology/Revue canadienne de psychologie*, *46*(3), 342.

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological science*, *9*(1), 45-48.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience?. *Personality and social psychology review, 8*(4), 364-382.

Reber, R. (2012). Processing fluency, aesthetic pleasure, and culturally shared taste. *Aesthetic science: Connecting minds, brains, and experience*, 223-249.

Reinagel, P., & Zador, A. M. (1999). Natural scene statistics at the centre of gaze. *Network: Computation in Neural Systems*, *10*(4), 341-350.

Reis, H. T., Wilson, I. M., Monestere, C., Bernstein, S., Clark, K., Seidl, E., ... & Radoane, K. (1990). What is smiling is beautiful and good. *European Journal of Social Psychology*, *20*(3), 259-267.

Remington, R. W. (1980). Attention and saccadic eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, *6*(4), 726.

Rhodes, G., & Tremewan, T. (1996). Averageness, exaggeration, and facial attractiveness. *Psychological science*, *7*(2), 105-110.

Rhodes, G., Hickford, C., & Jeffery, L. (2000). Sex-typicality and attractiveness: Are supermale and superfemale faces super-attractive?. *British journal of psychology*, *91*(1), 125-140.

Ricciardelli, P., & Driver, J. (2008). Effects of head orientation on gaze perception: how positive congruency effects can be reversed. *The Quarterly journal of experimental psychology*, *61*(3), 491-504.

Ricciardelli, P., Lugli, L., Pellicano, A., Iani, C., & Nicoletti, R. (2016). Interactive effects between gaze direction and facial expression on attentional resources deployment: the task instruction and context matter. *Scientific reports*, *6*, 21706.

Richardson, D. C., Dale, R., & Spivey, M. J. (2007). Eye movements in language and cognition. *Methods in cognitive linguistics*, *18*, 323-344.

Rigato, S., Farroni, T., & Johnson, M. H. (2009). The shared signal hypothesis and neural responses to expressions and gaze in infants and adults. *Social Cognitive and Affective Neuroscience, 5*(1), 88-97.

Rizzolatti, G., Riggio, L., Dascola, I., & Umiltá, C. (1987). Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. *Neuropsychologia*, *25*(1), 31-40.

Roy, J. E., & Cullen, K. E. (1998). A neural correlate for vestibulo-ocular reflex suppression during voluntary eye–head gaze shifts. *Nature neuroscience*, *1*(5), 404.

Rubenstein, A. J., Langlois, J. H., & Roggman, L. A. (2002). What makes a face attractive and why: The role of averageness in defining facial beauty. In G. Rhodes & L. A. Zebrowitz (Eds.), *Advances in visual cognition, Vol. 1. Facial attrativeness: Evolutionary, cognitive, and social perspectives* (pp. 1-33). Westport, CT, US: Ablex Publishing.

Rule, N. O., Ambady, N., & Adams Jr, R. B. (2009). Personality in perspective: Judgmental consistency across orientations of the face. *Perception*, *38*(11), 1688-1699.

Ruta, N., Mastandrea, S., Penacchio, O., Lamaddalena, S., & Bove, G. (2018). A comparison between preference judgments of curvature and sharpness in architectural façades. *Architectural Science Review*, *62*(2), 171-181.

Rolfs, M., Jonikaitis, D., Deubel, H., & Cavanagh, P. (2011). Predictive remapping of attention across eye movements. Nature neuroscience, 14(2), 252.

Said, C. P., & Todorov, A. (2011). A statistical model of facial attractiveness. *Psychological Science*, *22*(9), 1183-1190.

Saegusa, C., Intoy, J., & Shimojo, S. (2015). Visual attractiveness is leaky: the asymmetrical relationship between face and hair. *Frontiers in psychology*, *6*, 377.

Sander, D., Grandjean, D., Kaiser, S., Wehrle, T., & Scherer, K. R. (2007). Interaction effects of perceived gaze direction and dynamic facial expression: Evidence for appraisal theories of emotion. *European Journal of Cognitive Psychology, 19*(3), 470- 480.

Sato, W., Kochiyama, T., Uono, S., & Yoshikawa, S. (2010). Amygdala integrates emotional expression and gaze direction in response to dynamic facial expressions. *NeuroImage, 50*(4), 1658-1665.

Scheib, J. E., Gangestad, S. W., & Thornhill, R. (1999). Facial attractiveness, symmetry and cues of good genes. *Proceedings of the Royal Society of London B: Biological Sciences*, *266*(1431), 1913-1917.

Schuller, A. M., & Rossion, B. (2001). Spatial attention triggered by eye gaze increases and speeds up early visual activity. *Neuroreport*, *12*(11), 2381-2386.

Schweinberger, S. R., & Soukup, G. R. (1998). Asymmetric relationships among perceptions of facial identity, emotion, and facial speech. *Journal of Experimental Psychology: Human perception and performance*, *24*(6), 1748.

Senior, C. (2003). Beauty in the brain of the beholder. *Neuron*, *38*(4), 525-528.

Senju, A., & Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Visual cognition*, *12*(1), 127-144.

Senju, A., Hasegawa, T., & Tojo, Y. (2005). Does perceived direct gaze boost detection in adults and children with and without autism? The stare-in-the-crowd effect revisited. *Visual Cognition*, *12*(8), 1474-1496.

Seyama, J. I., & Nagayama, R. (2005). The effect of torso direction on the judgement of eye direction. *Visual Cognition*, *12*(1), 103-116.

Sheliga, B. M., Riggio, L., & Rizzolatti, G. (1994). Orienting of attention and eye movements. *Experimental Brain Research*, *98*(3), 507-522.

Shepherd, M., Findlay, J. M., & Hockey, R. J. (1986). The relationship between eye movements and spatial attention. *The Quarterly Journal of Experimental Psychology*, *38*(3), 475-491.

Shimojo, S., Simion, C., Shimojo, E., & Scheier, C. (2003). Gaze bias both reflects and influences preference. *Nature neuroscience*, *6*(12), 1317.

Siéroff, E. (2001). Feature processing and superiority of three-quarter views in face recognition. *Brain and Cognition, 46*(1-2), 272-276.

Silvia, P. J., & Brown, E. M. (2007). Anger, disgust, and the negative aesthetic emotions: Expanding an appraisal model of aesthetic experience. *Psychology of Aesthetics, Creativity, and the Arts*, *1*(2), 100.

Silvia, P. J., & Barona, C. M. (2009). Do people prefer curved objects? Angularity, expertise, and aesthetic preference. *Empirical studies of the arts*, *27*(1), 25-42.

Silvia, P. J. (2012). Human emotions and aesthetic experience. *See Shimamura & Palmer, 2012*, 250-275.

Smith, A. D., Hood, B. M., & Hector, K. (2006). Eye remember you two: Gaze direction modulates face recognition in a developmental study. *Developmental science*, *9*(5), 465-472.

Soto, C. J., & John, O. P. (2017). Short and extra-short forms of the Big Five Inventory–2: The BFI-2-S and BFI-2-XS. *Journal of Research in Personality, 68*, 69- 81.

SR Research Experiment Builder 2.1.512 [Computer software]. (2018). Mississauga, Ontario, Canada: SR Research Ltd.

Stacey, P. C., Walker, S., & Underwood, J. D. (2005). Face processing and familiarity: Evidence from eye·movement data. *British Journal of Psychology*, *96*(4), 407-422.

Stamps, A. E. (1989). Are environmental aesthetics worth studying?. *Journal of architectural and planning research. 6*, 244-355.

Stamps III, A. E., & Nasar, J. L. (1997a). Design review and public preferences: effects of geographical location, public consensus, sensation seeking, and architectural styles. *Journal of Environmental Psychology*, *17*(1), 11-32.

Stamps, A. E. (1997). Some streets of San Francisco: preference effects of trees, cars, wires, and buildings. *Environment and Planning B: planning and design*, *24*(1), 81-93.

Stamps, A. E. (1999). Physical determinants of preferences for residential facades. *Environment and Behavior*, *31*(6), 723-751.

Stamps, A. E. (2013). *Psychology and the aesthetics of the built environment*. Springer Science & Business Media.

Stratton, G. M. (1902). Eye-movement and the Aesthetics of visual form. *Philosophische Studien*, *20*, 336-359.

Stratton, G. M. (1906). Symmetry, linear illusions, and the movements of the eye. *Psychological Review*, *13*(2), 82.

Suárez-Pinilla, M., Seth, A. K., & Roseboom, W. (2018). Serial dependence in the perception of visual variance. *Journal of vision*, *18*(7), 4-4.

Sui, J., & Liu, C. H. (2009). Can beauty be ignored? Effects of facial attractiveness on covert attention. *Psychonomic Bulletin & Review, 16*(2), 276-281.

Sutherland, C. A., Young, A. W., & Rhodes, G. (2017). Facial first impressions from another angle: How social judgements are influenced by changeable and invariant facial properties. *British Journal of Psychology*, *108*(2), 397-415.

Sütterlin, B., Brunner, T. A., & Opwis, K. (2008). Eye-tracking the cancellation and focus model for preference judgments. *Journal of Experimental Social Psychology*, *44*(3), 904-911.

Sweeny, T. D., & Whitney, D. (2017). The center of attention: Metamers, sensitivity, and bias in the emergent perception of gaze. *Vision research, 131*, 67-74.

Symons, L. A., Lee, K., Cedrone, C. C., & Nishimura, M. (2004). What are you looking at? Acuity for triadic eye gaze. The Journal of general psychology, 131(4), 451.

Tanaka, Y., & Shimojo, S. (2001). Temporal and spatial characteristics of attention to facilitate manual and eye-movement responses. *Perception*, *30*(3), 283-302.

Tatler, B. W., Baddeley, R. J., & Gilchrist, I. D. (2005). Visual correlates of fixation selection: Effects of scale and time. *Vision research*, *45*(5), 643-659.

Tatler, B. W., Baddeley, R. J., & Vincent, B. T. (2006). The long and the short of it: Spatial statistics at fixation vary with saccade amplitude and task. *Vision research*, *46*(12), 1857-1862.

Tatler, B. W. (2007). The central fixation bias in scene viewing: Selecting an optimal viewing position independently of motor biases and image feature distributions. *Journal of vision*, *7*(14), 4-4.

Tatler, B. W., & Vincent, B. T. (2009). The prominence of behavioural biases in eye guidance. *Visual Cognition*, *17*(6-7), 1029-1054.

Taubert, J., Van der Burg, E., & Alais, D. (2016). Love at second sight: Sequential dependence of facial attractiveness in an on-line dating paradigm. *Scientific reports*, *6*, 22740.

Taubert, J., Alais, D., & Burr, D. (2016). Different coding strategies for the perception of stable and changeable facial attributes. *Scientific reports*, *6*, 32239.

Thömmes, K., & Hübner, R. (2018). Instagram likes for architectural photos can be predicted by quantitative balance measures and curvature. *Frontiers in psychology*, *9*, 1050.

Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature*, *381*(6582), 520.

Todorović, D. (2006). Geometrical basis of perception of gaze direction. *Vision research, 46*(21), 3549-3562.

Todorović, D. (2009). The effect of face eccentricity on the perception of gaze direction. *Perception, 38*(1), 109-132.

Torralba, A., & Oliva, A. (2003). Statistics of natural image categories. *Network: computation in neural systems*, *14*(3), 391-412.

Tracy, J. L., & Beall, A. T. (2011). Happy guys finish last: the impact of emotion expressions on sexual attraction. *Emotion*, *11*(6), 1379.

Trujillo, L. T., Jankowitsch, J. M., & Langlois, J. H. (2014). Beauty is in the ease of the beholding: A neurophysiological test of the averageness theory of facial attractiveness. *Cognitive, Affective, & Behavioral Neuroscience*, *14*(3), 1061-1076.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, *247*(4940), 301-306.

Ueda, R., Kuraguchi, K., & Ashida, H. (2016). Asymmetric Effect of Expression Intensity on Evaluations of Facial Attractiveness. *SAGE Open*, *6*(4), 2158244016677569.

Underwood, G., Foulsham, T., van Loon, E., Humphreys, L., & Bloyce, J. (2006). Eye movements during scene inspection: A test of the saliency map hypothesis. *European Journal of Cognitive Psychology*, *18*(03), 321-342.

Valentine, C. W. (1913). The beauty of form. In *An introduction to experimental psychology of beauty* (pp. 38-53). London : T.C. & E.C. Jack ; New York : Dodge.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. The Quarterly Journal of Experimental Psychology, 43(2), 161-204.

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin & Review*, *11*(3), 482-487.

van Bergen, R. S., & Jehee, J. F. (2019). Probabilistic representation in human visual cortex reflects uncertainty in serial decisions. *bioRxiv*, 671958.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proceedings of the National Academy of Sciences*, *110*(Supplement 2), 10446-10453.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2015). Architectural design and the brain: effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of environmental psychology*, *41*, 10-18.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., Rostrup, N., Skov, M., Corradi, G., & Nadal, M. (2017). Preference for Curvilinear Contour in Interior Architectural Spaces: Evidence From Experts and Nonexperts. *Psychology of Aesthetics, Creativity, and the Arts*. Advance online publication. http://dx.doi.org/10.1037/aca0000150

Vecchiato, G., Tieri, G., Jelic, A., De Matteis, F., Maglione, A. G., & Babiloni, F. (2015). Electroencephalographic correlates of sensorimotor integration and embodiment during the appreciation of virtual architectural environments. *Frontiers inpsychology*, *6*, 1944.

Vessel, E. A., Stahl, J., Maurer, N., Denker, A., & Starr, G. G. (2014, February). Personalized visual aesthetics. In *Human Vision and Electronic Imaging XIX* (Vol. 9014, p. 90140S). International Society for Optics and Photonics.

Vessel, E. A., Maurer, N., Denker, A. H., & Starr, G. G. (2018). Stronger shared taste for natural aesthetic domains than for artifacts of human culture. *Cognition*, *179*, 121- 131.

Vitruvius, P., & Morgan, M. H. (1960). *Vitruvius: The ten books on architecture*. New York: Dover Publications.

von Grünau, M., & Anston, C. (1995). The detection of gaze direction: A stare-in-the-crowd effect. *Perception*, *24*(11), 1297-1313.

von Wartburg, R., Wurtz, P., Pflugshaupt, T., Nyffeler, T., Lüthi, M., & Müri, R. M. (2007). Size matters: Saccades during scene perception. *Perception*, *36*(3), 355-365.

Vorberg, D., Mattler, U., Heinecke, A., Schmidt, T., & Schwarzbach, J. (2003). Different time courses for visual perception and action priming. *Proceedings of the National Academy of Sciences*, *100*(10), 6275-6280.

Vuilleumier, P., George, N., Lister, V., Armony, J., & Driver, J. (2005). Effects of perceived mutual gaze and gender on face processing and recognition memory. *Visual Cognition*, *12*(1), 85-101.

Wade, N., & Tatler, B. W. (2005). *The moving tablet of the eye: The origins of modern eye movement research*. Oxford University Press, USA.

Wade, N. J., & Tatler, B. W. (2011). Origins and applications of eye movement research. *Oxford handbook on eye movements*, 17-46.

Wedell, D. H., Parducci, A., & Geiselman, R. E. (1987). A formal analysis of ratings of physical attractiveness: Successive contrast and simultaneous assimilation. *Journal of Experimental Social Psychology*, *23*(3), 230-249.

Westerman, S. J., Gardner, P. H., Sutherland, E. J., White, T., Jordan, K., Watts, D., & Wells, S. (2012). Product design: Preference for rounded versus angular design elements. *Psychology & Marketing*, *29*(8), 595-605.

Wilkowski, B. M., & Meier, B. P. (2010). Bring it on: angry facial expressions potentiate approach-motivated motor behavior. *Journal of personality and social psychology, 98*(2), 201.

Willis, J., & Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. *Psychological science*, *17*(7), 592-598.

Wilson, H. R., Wilkinson, F., Lin, L. M., & Castillo, M. (2000). Perception of head orientation. *Vision research*, *40*(5), 459-472.

Wollaston, W. H. (1824). Xiii. on the apparent direction of eyes in a portrait. *Philosophical Transactions of the Royal Society of London*, (114), 247-256.

Woo, S. E., Chernyshenko, O. S., Longley, A., Zhang, Z. X., Chiu, C. Y., & Stark, S. E. (2014). Openness to experience: Its lower level structure, measurement, and cross- cultural equivalence. *Journal of personality assessment*, *96*(1), 29-45.

Woods, A. T., Velasco, C., Levitan, C. A., Wan, X., & Spence, C. (2015). Conducting perception research over the internet: a tutorial review. PeerJ, 3, e1058.

Xia, Y., Leib, A. Y., & Whitney, D. (2016). Serial dependence in the perception of attractiveness. *Journal of vision*, *16*(15), 28-28.

Yamashita, W., Kanazawa, S., & Yamaguchi, M. K. (2012). The effect of gaze direction on three-dimensional face recognition in infants. *Vision research*, *68*, 14-18.

Yang, T. T., Menon, V., Eliez, S., Blasey, C., White, C. D., Reid, A. J., ... & Reiss, A. L. (2002). Amygdalar activation associated with positive and negative facial expressions. Neuroreport, 13(14), 1737-1741.

Young, A. W., Rowland, D., Calder, A. J., Etcoff, N. L., Seth, A., & Perrett, D. I. (1997). Facial expression megamix: Tests of dimensional and category accounts of emotion recognition. Cognition, 63(3), 271-313.

Young, A. W., & Bruce, V. (2011). Understanding person perception. *British journal of psychology*, *102*(4), 959-974.

Yarbus, A. L. (1967). Eye movements during perception of complex objects. In *Eye movements and vision* (pp. 171-211). Springer, Boston, MA.

Yiwen, J., & Yi, J. (2006). Influence of window–wall ratio on annual energy consumption for heating and air conditioning in residential buildings. *Heating, Ventilating and Air Conditioning*, *36*(6), 1-5.

Young, A. W., Newcombe, F., Haan, E. H. D., Small, M., & Hay, D. C. (1993). Face perception after brain injury: Selective impairments affecting identity and expression. *Brain*, *116*(4), 941-959.

F.A.O. Pik Ki Ho
Approval ID: SPREC122012-1

School of Psychology Research Ethics Committee

23rd March 2016

Dear Pik Ki,

The School of Psychology Research Ethics Committee recognises you as a named investigator on the project entitled "Socializing agents – social interaction experiments" which received ethical approval in February 2013.

Please note that you will be required to submit a completed **Project Annual Report Form** on each anniversary of this approval, until such time as the research is complete and the thesis is submitted. The form is available for download from the Ethics section of the School website.

Adverse events associated with the conduct of this research must be reported immediately to the Chair of the Ethics Committee.

Yours sincerely,

Richard Carson
Chair,
School of Psychology Research Ethics Committee

F.A.O. Pik Ki Ho
Approval ID: SPREC092018-16

School of Psychology Research Ethics Committee

30th November 2018

Dear Pik Ki,

The School of Psychology Research Ethics Committee has reviewed your application entitled "The psychology of visual aesthetics – insights from architecture: an eye tracking study and a community-based study in the Science Gallery" and I am pleased to inform you that it was approved.

Please note that you will be required to submit a completed **Project Annual Report Form** on each anniversary of this approval, until such time as an **End of Project Report Form is submitted** upon completion of the research. Copies of both forms are available for download from the Ethics section of the School website.

Adverse events associated with the conduct of this research must be reported immediately to the Chair of the Ethics Committee.

Yours sincerely,

Richad Carson
Chair,
School of Psychology Research Ethics Committee