



# Face perception loves a challenge: Less information sparks more attraction

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## ARTICLE INFO

### Keywords:

Face perception  
Attractiveness  
Partial information effect  
Spatial frequencies  
Contrast  
Occlusion

## ABSTRACT

Examining hedonic questions of processing fluency, objective stimulus clarity, and goodness-of-fit in face perception, across three experiments (blur, contrast, occlusion) in which subjects performed the simple, natural task of rank-ordering faces by attractiveness, we find a very consistent and powerful effect of *reduced* visual input *increasing* perceived attractiveness. As images of faces are blurred (i.e., as higher spatial frequencies are lost, mimicking at-a-distance, eccentric, or otherwise unaccommodated viewing, tested down to roughly 6 cycles across the face), reduced in contrast (linearly, down to 33% of the original image's), and even half-occluded, the viewer's impression of the faces' attractiveness, relative to non- or less-degraded faces, is greatly enhanced. In this regard, the blur manipulation exhibits a classic exponential profile, the contrast manipulation follows a simple linear trend. Given the far superior attractiveness of half-occluded faces, which have no symmetry whatsoever, we also see that it may be incorrect to claim that facial symmetry is attractive and perhaps more accurate that asymmetry may be unattractive. As tested with a total of 200 novel female faces over three experiments, we find absolutely no male/female differences in this “partial information effect” of enhanced subjective attraction, nor do we find differences across the repetition of the task through to a second block of trials in which the faces are re-encountered and no longer novel. Finally, whereas objective stimulus quality is reduced, we suggest a positive hedonic experience arises as a subjective phenomenological index of enhanced perceptual goodness-of-fit, counter-intuitively facilitated by what may be stimulus-distilling image-level manipulations.

## 1. Introduction

“The loveliest faces are to be seen by moonlight,  
when one sees half with the eye and half with the fancy.”  
- C. V. Bovee

Faces are fascinating, and the science of face perception no less so (Goldstein, 1983). Most of us enjoy an extreme expertise in face perception (Carey, 1992; Carey & Diamond, 1977; Gauthier & Tanaka, 1997; cf. Albonico, Furubacke, Barton, & Oruç, 2018; Young & Burton, 2018), both inherited and trained, and, knowingly and not, our face perception continuously fuels and drives our social and cognitive faculties and actions at the highest levels (e.g., Etcoff, 1999; Montepare, 2010; Perrett, 2010; Secord, 1958; Zebrowitz, 1997). As demonstrated and discussed throughout this special issue, our shared expertise in face processing is remarkable in its breadth and depth of functionality, its apparent effortlessness, and its robustness across a wide range of challenging and compromised visual circumstances. In this paper and series of experiments, we direct these questions of expertise, generality, fluency, and robustness toward their inextricable phenomenological

byproducts, specifically the automatic hedonic experience of the attractiveness of faces, particularly as showcased when our impressive powers of face perception are supposedly most taxed (yet perhaps optimally stimulated) by degraded, ambiguous, or incomplete visual input.

In the language of Tinbergen's (1963) levels of analysis, our methodology and theoretical approach centrally examines proximate mechanisms of visual perception – the direct and immediate interface between stimuli and behaviour – rather than speculating on consequences or preconditions of ultimate functions, for example of reproductive strategies specifically, as often the focus with facial attractiveness. Likewise, respecting Morgan's canon (1894), even in their ultimate function we care to consider first the fundamental necessities of any organism's perceptual (and memory) system functioning successfully in a complex environment, rather than explanations founded uniquely on, e.g., human mate selection or sexual interest.

Our conscious, subjective sense of a variety of perceptual and cognitive experiences, from sophisticated and robust visual face perception (detection, categorization, recognition, etc) to complex decision-making, are surprisingly and profoundly influenced by low-level (and

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often unconscious or implicit) influences arising from the interaction of the stimuli around us and the internal mechanisms and stored experiences engaged in their processing (e.g., Wilson & Nisbett, 1978). A pervasive concept arising in the literature over a number of decades suggests that much of what guides our decisions, preferences, and affective evaluations – even so far as how we fall in love or whom we elect into government – may be strongly driven by such simple factors as the familiarity of a visual or verbal stimulus, as well as the connection between this familiarity and the relative ease or “fluency” of its perceptual or conceptual processing (Allen & Jacoby, 1990; Jacoby, 1983; Jacoby & Whitehouse, 1989; Mandler, Nakamura, & Van Zandt, 1987; Reber, Schwarz, & Winkielman, 2004; Reber, Winkielman, & Schwarz, 1998; Whittlesea, 1993; Winkielman & Cacioppo, 2001; Whittlesea, Jacoby, & Girard, 1990; Winkielman, Halberstadt, Fazio, & Catty, 2006; see also Moreland & Topolinski, 2010).

Moreover, beyond the notion of this perceptual fluency arising from the prior experience of processing a given stimulus, i.e., a property of the observer, over time this concept of fluency has also become equated with the objective “clarity” of novel stimuli, i.e., a property of the stimulus, e.g., the clarity of written text or a photographic image. In fact, precisely this latter intuition or interpretation – i.e., that better photographic image quality should correspond directly with greater perceptual fluency (on first encounter) and, thus, elicit enhanced subjective preference – has explicitly motivated recent work on aesthetic preferences for natural scenes (i.e., landscapes) and their modulation by variations in image quality (Tinio & Leder, 2009). The research presented here, however, seeks to point out a fundamental concern with the special explanatory status sometimes assigned too simplistically to the objective clarity of a stimulus. Here, a series of simple experiments with images of novel faces – blurred to various degrees, lowered in contrast, or largely occluded – serve to illustrate that, despite simpler notions predicting less fluent processing, extremely un-clear and incomplete stimuli might nevertheless, through a counter-intuitively *enhanced* goodness-of-fit, so strongly activate our perceptual/cognitive processes and stored experiences as to not only appear familiar, perhaps, but to be regarded as far more attractive and pleasing as a result.

Illustrating the quick and superficial high-level judgments we construct from the visual input of facial appearance alone, election results can be predicted by whether, in 1/10th of a second, subjects feel a candidate’s face appears “competent” (Ballew & Todorov, 2007; Todorov, Mandisodza, Goren, & Hall, 2005): the first, split-second, automatic, “thought-less” visual reactions, by subjects entirely unfamiliar with the candidates – their political platforms, affiliations, qualifications – not only can predict election outcomes, they may be more predictive than subjects’ more extended, “thoughtful” deliberations. Worse, whether in an election, at a playground (Dion, 1973), in a classroom (Ambady & Rosenthal, 1993), on the dance floor (Walster, Aronson, Abrahams, & Rottman, 1966), or even on the phone (Snyder, Tanke, & Berscheid, 1977), the face-influenced evaluations and decisions we make or think we’ve made are subsequently wide open to confabulation (i.e., the unwitting lies we tell ourselves and others) as we retroactively construct plausible-sounding but false explanations for our actions (e.g., Johansson, Hall, Sikstrom, & Olsson, 2005; Wilson & Nisbett, 1978).

To gain perspective on these arguably higher-level social and cognitive processes, it’s crucial to keep in mind that, when it comes to faces, we are not merely experts in high-speed, low-resolution detection and recognition (e.g., Alonso-Prieto et al., 2015; de Heering et al., 2008; Quek, Liu-Shuang, Goffaux, & Rossion, 2018). A masked, low-pass-filtered, peripheral, 50 ms presentation is enough for a face to exert sex-specific priming effects, possibly through a subcortical route (Khalid, Finkbeiner, Konig, & Ansoorge, 2013). A 39 ms exposure to a low-pass-filtered, neutral-expression face is sufficient to obtain consistent subjective ratings of its seeming threatening (Bar, Neta, & Linz, 2006; see also Vuilleumier, Armony, Driver, & Dolan, 2003, re: fearful expressions at 200 ms and < 6 cycles/image), possibly based on the degree to

which its static structure is seen to resemble positive vs negative emotional expressions.

Moreover, not only does a 100 ms presentation provide enough input for viewers to generate consistent judgments of competence, trustworthiness, likeability, and attractiveness (Willis & Todorov, 2006), it appears to be more than enough to imbue attractive faces with the stereotypically positive social associations and personal attributions of the “beautiful is good” halo effect (Dion, Berscheid, & Walster, 1972; Locher, Unger, Sociedade, & Wahl, 1993). Attractive faces encountered for only 13 ms, below the threshold for conscious access, are not only accurately rated for attractiveness in an explicit judgment task, they serve as unconscious primes to implicitly bias responses in a subsequent cognitive task (Olson & Marshuetz, 2005; see also Gerger, Leder, Tinio, & Schacht, 2011, at 47 ms). The influence of facial appearance on affective, cognitive, and social processes and judgments – attractiveness, competence, trustworthiness, etc – seems virtually obligatory, automatic, and immediate, not requiring (and largely immune to) attention and deliberation (Hassin & Trope, 2000; Todorov & Uleman, 2003; cf. Most, Smith, Cooter, Levy, & Zald, 2007; Treisman & Gelade, 1980).

Along these lines, one powerful influence on our allegedly higher-level social and affective responses and preferences is simply whether the stimuli and options we encounter (e.g., individual people/faces) are familiar to us – that is, whether we have encountered and processed them before. (In this we might also include subsequent experiences of similarity and false familiarity – i.e., of explicitly or implicitly feeling as though we may have encountered a stimulus before, although we haven’t; e.g., Jacoby & Whitehouse, 1989; Whittlesea, 1993; see below.) This “mere exposure effect” (Zajonc, 1968; see also Bornstein, 1989, and Moreland & Topolinski, 2010), which is likely to blame even for the strong preference we have for our image in the mirror and not in photographs (Mita, Dermer, & Knight, 1977), has come to be conceived of as essentially operating through the same perceptual fluency as above. Mechanistically, the idea would be that we process previously encountered stimuli more fluently, that the processing of subsequent encounters is facilitated by this earlier exposure and fits increasingly better with accumulating stores of prior experiences (and, we would say, with our internal processing mechanisms), and, finally, that this exposure-enhanced processing fluency quite simply feels good, phenomenologically, giving rise to a pleasant subjective feeling and appraisal of the stimulus (Allen & Jacoby, 1990; Reber et al., 1998, 2004; Whittlesea et al., 1990; Winkielman & Cacioppo, 2001; Winkielman et al., 2006). Solipsistically, we attribute (or project) this positive subjective evaluation to the stimulus itself, as an objective property. For example, we might evaluate a person/face (however homely or comely) as being objectively attractive, physically and/or interpersonally, following multiple exposures (Moreland & Zajonc, 1982, and the brilliant classroom experiment by Moreland & Beach, 1992) rather than interpreting our positive hedonic response as the subjective experience or *qualia* of familiarity, indexing past exposure (cf. Jacoby, Kelley, Brown, & Jasechko, 1989).

This mere exposure effect does not require explicit, conscious learning and recognition following the past encounters (Kunst-Wilson & Zajonc, 1980; Mandler et al., 1987; Wilson, 1979); in fact, it may be even stronger when the prior exposure goes unnoticed and explicit learning/recognition does not take place (Bornstein, 1989; Bornstein & D’Agostino, 1992). This has led to Zajonc’s distinction between “thinking” and “feeling”, and his asserting the primacy of the latter (Zajonc, 1980, 1984). It might also be noted that alongside its robustness and generality, unsurprisingly the mere exposure effect is modulated by a variety of factors such as exposure duration, number of repetitions, stimulus type/complexity, delay prior to ratings, etc (Bornstein, 1989). (Likewise, as some may rightly note, in the special case of very negative affective stimuli, repeated exposures and more fluent processing may produce a more negative subjective experience than less fluent processing, i.e., a kind of sensitization, exaggerating a predominantly negative stimulus’ valence. In fact, this might be

predicted by the recognition mechanism suggested by Bar (2003) and Kveraga, Boshyan, and Bar (2007), discussed below in experiment 1, e.g., a negative-affective response to a coarse-grained figure that resembles a snake.) Critically, as prefaced above, following a great deal of work connecting prior exposure, familiarity, ease of processing, and affect (e.g., Jacoby, 1983; Reber et al., 2004; Whittlesea et al., 1990), the concept of fluency has migrated somewhat from the inside out, and over time these ideas have become linked, almost as a matter of fact, to the objective quality and clarity of the stimuli in question (e.g., Tinio & Leder, 2009). As such, objectively clearer and unambiguous novel images, text, etc are then expected to be processed more fluidly, to elicit a sense of familiarity – perhaps along with a mistaken sense of having been encountered before – and to be found pleasant, attractive, and preferable.

However, a major problem has gone unnoticed in the assumed equation of stimulus clarity and processing fluency, on into the presumed chain from objective clarity and completeness to subjective preference and liking, and this becomes apparent once we start to consider how the perceptual system and higher-level mechanisms process incoming stimuli and relate them to stored instances, internal templates, or (more contentiously or metaphorically) “representations” of previously encountered objects, people, scenes, words, etc (e.g., Jones & Mewhort, 2007; O’Toole, Abdi, Deffenbacher, & Valentin, 1995; Tarr & Pinker, 1989; cf. Kolers, 1976). In this vein, the various manipulations and effects exploited and observed in the three face experiments in this paper can be conceptually approached from a fairly basic perspective.

Viewing Fig. 1.1, for instance, you should have no trouble reading “ABCD” and “1234” despite their being partially obscured and presumably occluded by three large, irregular shapes. More than enough familiar visual information remains in the stimulus to trigger your very well-trained internal templates for uppercase English letters and Arabic numerals, automatically filling-in the gaps or interruptions; alternatively, perhaps it’s not that any real “filling-in” or “completion” takes place, literally, only that our perceptual and inferential machinery effectively compensates for such gross disruptions and absences in the input when providing us with a coherent, rich, and complete-seeming subjective percept and mental interpretation (Cohen, Dennett, & Kanwisher, 2016; Dennett, 1991, 1992). Never mind that the gray blobs were, in fact, placed over “ABGD” and “12B4”; if “seeing” “ABCD” and “1234” could even be called a “mistake” here, it occurs for an excellent reason. Quite apart from the still-visible structural properties of objects themselves suggesting their full un-occluded appearance (e.g., Sekuler, 1994), we have a vast store of explicit and implicit experience or “knowledge” of the world – built-in perceptual guides concerning the structure and regularities of the physical world and the probabilities of the occurrence and sequencing of certain scenes, sounds, etc, along with the most likely explanations for how these are generated (and, ultimately, our best behavioural responses to them). These help connect our always noisy and incomplete sensations to sensible and stable percepts.

Likewise, as an illustration of “perceptual filling-in” *not* in response to occlusion, taking a closer look at the cartoon hand – meant to symbolically direct the reader’s attention (Posner, 1980) to the blotchy alphanumeric display and perhaps momentarily draw attention away



Fig. 1.1. Simple schematic depicting bottom-up and top-down perceptual interactions, with elements of occlusion, “perceptual filling-in”, and contextual effects reminiscent of Bregman (1981) – and even a hint of a watercolour/neon-spreading illusion (Broerse et al., 1999; Pinna et al., 2001) within the cartoon hand (see text).

from itself – you may see its interior as being tinted, throughout, a very light grey. This inner region is only outlined in grey, however, and at least the subjective experience is that the visual system appears to fill in the rest of the space like a watercolor brush (Broerse, Vladusich, & O’Shea, 1999; Pinna, Brelstaff, & Spillmann, 2001).

With this in mind, it becomes easier to see how the perceptions, evaluations, and interpretations we continuously experience are guided and constrained by the strength of our internal stores and the processes that operate on them (e.g., the visual appearance of objects, such as a person at a distance; more abstract concepts and beliefs, such as trustworthiness and competence; or spurious but compelling associations between the two, such as those automatically connecting a person’s superficial appearance with his/her presumed personal, intellectual, even moral traits; e.g., Montepare, 2010; Secord, 1958; Zebrowitz, 1997). All of this can of course be intentionally manipulated to pleasing and mutually-acknowledged effect in art (e.g., the provocative use of construed and ambiguous occlusions in the work of Magritte; Halper, 1999), and in our experimental manipulations here we specifically explore these influences on our face perception in naturalistic viewing situations.

In this manner we can see how the literature may have slowly gone past important distinctions between the objective “clarity” of a stimulus and the “fluency” of its processing within the viewer – or, more accurately, the stimulus’ goodness-of-fit with the visual system’s internal stores and mechanisms (or, we could say, its accumulated experiences combined with its innate machinery). A deeper look at the object recognition field suggests it is ultimately this goodness-of-fit (e.g., Bar, 2003; Ullman, 1995) – what one might metaphorically call a “resonance” between input stimuli and the closest matching states of the perceptual/cognitive system – that should best predict the subjective familiarity, positive evaluation, and preference for the input stimulus; moreover, this may be quite independent of whether the stimulus was objectively “clear” (e.g., high-resolution photograph, non-obstructed text, etc). That is, in previous examinations (not specifically centred on face perception) certain objectively clearer stimuli may indeed have had their effect on inducing familiarity, positive responses, etc, but perhaps only as a special case of the type of stimuli that may have maximally matched and stimulated internal perceptual mechanisms.

A concrete example illustrates this point nicely and carries us to our first experiment: blurring an image, by definition, makes it less clear, and so, from the weight of past theory and research, one might predict that blurrier images will be harder and slower to process, less “fluent”, and thus – crucially – less pleasant, evaluated more negatively, and dispreferred. Does this agree, however, with our typical real-world experiences or, better yet, with careful observations we can make in a controlled setting – and not simply for images in general but particularly for the very common, very biologically- and socially-compelling case of faces? One clue, from the temporal domain, suggests we may be wise to question universally equating processing fluency and hedonic preference with the clarity (or the overspecification and disambiguation) of the stimulus: novel faces are judged to be *more* attractive (and likable, trustworthy, and competent) when visible for *less* time (100 ms vs 500 ms; Willis & Todorov, 2006).

The three experiments in this paper aim to answer precisely this central question – starting, in fact, with the very question of image blur and facial attractiveness. From the outset we acknowledge and appreciate the decades of experimental and theoretical work on the facial-morphological parameters that influence the perception of facial attractiveness (e.g., variables such as the “usual suspects” of symmetry, sexual dimorphism, “averageness”/prototypicality, etc; Grammer & Thornhill, 1994; Langlois & Roggman, 1990; Perrett et al., 1998) as well as on the influence of surface/skin properties (e.g., Fink, Grammer, & Mads, 2006; Jones, Little, Burt, & Perrett, 2004); apparent age as well as interwoven neonatal vs mature features (Cunningham, 1986; Korthase and Trenholme, 1982, 1983); cues to height and adiposity (Coetzee, Perrett, & Stephen, 2009; Re & Perrett, 2012); and, beyond

attractiveness, facial cues of apparent health (e.g., Foo, Simmons, & Rhodes, 2017; Rhodes et al., 2001, 2007) and even of personality traits and clinical states (e.g., Jones, Kramer, & Ward, 2012; Little, Burt, & Perrett, 2006; Scott, Kramer, Jones, & Ward, 2013). Together with similar examinations of other physical attributes (e.g., waist-to-hip ratio; Singh, 1993), the study of objective face-level metrics of attractiveness has contributed enormously to the development of a thriving literature in evolutionary psychology concerned with evolved mate-selection strategies and the corresponding “honest signals” of mate quality on which they operate, spanning questions of differential parental investment, fecundity and nobility, “good genes” in general, parasite resistance, immunohistocompatibility, hormone signaling, and much more (e.g., Barber, 1995; Buss, 1989; Buss & Schmitt, 1993; Feinberg, 2008; Fink & Penton-Voak, 2002; Gangestad & Scheyd, 2005; Johnston, Hagel, Franklin, Fink, & Grammer, 2001; Kenrick, Li, & Butner, 2003; Little, 2014b; Roberts et al., 2005; Roney & Simmons, 2008; Scheib, Gangestad, & Thornhill, 1999; Symons, 1979, 1995; Thornhill & Gangestad, 1993, 1999; Trivers, 1972), even with some work reporting mixed results in relating facial appearance and attractiveness to actual measures of health and mate quality (e.g., Foo et al., 2017; Kalick, Zebrowitz, Langlois, & Johnson, 1998).

Nevertheless, we do question whether something crucial may have been missed by these appropriately face-level metrics, something based not in the objective distal structure of the faces themselves, as does indeed vary across attractive and unattractive faces and may serve as evolved signals, but rather, perhaps, at an entirely different – more general, fundamental – level affecting our visual/perceptual system and thereby our hedonic responses, evaluations, and subsequent behaviour. If so, such a level of action and influence, if properly isolated and manipulated, could be exploited to generate vastly different experiences of the facial attractiveness of (i.e., subjective attraction to) any given face, without any alterations to that face per se, or even its true familiarity to the viewer. In fact, we may also find, strangely and uniquely in this pursuit, a very unexpected point of intersection in the age-old question of whether beauty (facial or otherwise) is something objectively “out in the world”, quantifiable in measures of the object/stimulus, or “in the eye of the beholder”, quantifiable as characteristics of the subject/viewer – i.e., entirely of the evaluator’s perceptual machinery, experiences, and perhaps resonance with newly encountered stimuli. As a matter of fact, we may find that even this distinction, given the intimate convolution of the two alternatives, may not only describe a false dichotomy but also overlook an intervening source of influence.

## 2. Experiment 1: Image Blur / Spatial Frequencies / Effective Resolution

### 2.1. Introduction

In earlier work (Fatke et al., under revision; Sadr, Fatke, Massay, & Sinha, 2002), we established that the ability to reliably evaluate (i.e., ordinally rank or numerically rate) the relative attractiveness of faces is very well-preserved even when all the stimuli are extremely blurry – in fact, blurred to the point at which one’s ability to recognize identity (of well-known celebrities, at least) begins to overwhelmingly fail. (The latter appears to occur at roughly 4–6 cycles across the width of the face for grayscale images; Ginsburg, 1978; Sinha, 2002; Yip & Sinha, 2002.) This was a paradigm simulating common real-world visual circumstances, such as seeing faces from a great distance, in one’s peripheral vision, or at any distance not matching one’s current focal length/accommodation.

This discovery also spoke to the finding that newborns and young infants, despite their very poor vision (Banks & Salpatek, 1978; Dobson & Teller, 1978; Hansen & Fulton, 1993; Norcia, Tyler, & Hamer, 1990; Peterzell & Teller, 1996; Teller, 1997), show adult-like preferences for attractive faces (Damon, Mottier, Meary, & Pascalis, 2017; Langlois et al., 1987; Samuels & Ewy, 1985; Slater et al., 1998, 2000a, 2000b),

just as they appear to be able to discriminate between adult faces using incredibly low spatial frequencies (de Heering et al., 2008). In fact, as a crucial theoretical point, we suggest adult face perception and evaluation retains this central reliance on low spatial frequencies, as observed in infancy – i.e., that the privileged value and use of low spatial frequencies is preserved across development and remains fundamental to face processing and associated feelings of attraction, familiarity, etc, however much as adults we confabulate detail- and featural-based accounts of our perceptions and preferences.

Nevertheless, starting perhaps from the first author’s own subjective experiences in preparing and inspecting the stimuli for our earlier studies, and especially from past subjects’ comments regarding the (illusory) familiarity of the blurriest faces encountered, it became clear that it might be a very different and even more pressing question to examine the relative attractiveness of more- versus less-blurry faces within mixed sets of stimuli.

### 2.2. Methods

#### 2.2.1. Participants

Thirty subjects (11 men, 19 women; mean age = 21.4 years,  $SD = 2.8$ ) participated in this study. As with all three experiments, all subjects were undergraduate students from the University of Lethbridge and received nominal course credit for their participation. All procedures were in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and approved by the university’s Human Subject Research Committee. The subjects were naive to the purpose of the study, other than its concerning ratings of facial attractiveness, and had not previously encountered any of the stimulus faces. Informed consent was obtained following the subjects’ being given in writing a detailed description of the experimental task, stimuli, duration, potential risks and benefits, etc, and subjects were free to withdraw at any time and still receive the participation credit. A university-wide electronic recruitment/scheduling system was used which supplied no identifying information to the experimenter, and other than the subjects’ sex, age, and visual acuity (i.e., confirming, as required in the recruitment description, that they had normal or corrected-to-normal vision, the latter requiring their prescribed glasses or contact lenses to be worn for the session; subjects not meeting this criteria were not admitted into the study) no identifying information was collected from the subjects, not even in the usual pleasantries of greeting the subject on arrival nor in debriefing and the denouement.

Two subjects completed only one block of trials, simply as a result of performing the task slowly; while included in Fig. 2.2, their block 1 data could not be included in the ANOVA analyses requiring balanced design across both blocks (see Results, below; Section 2.3). An additional two subjects (i.e., not counted in the above 30) were excluded altogether: one who had, despite the recruitment criteria, arrived without appropriate corrective eyewear (nor followed other initial instructions), and one who arrived intoxicated – a condition known, at a minimum, to influence judgments of attractiveness (e.g., Jones, Jones, Thomas, & Piper, 2003).

#### 2.2.2. Stimuli

The source images for this experiment were 100 grayscale front-facing forward-gazing female face photographs taken from the FERET database (Phillips, Wechsler, Huang, & Rauss, 1998, 2000). Notably, a very important consideration underlies use of a female-only stimulus set – which pertains equally throughout this paper, for experiments 2 and 3: male and female subjects tend to agree quite closely in their attractiveness judgments of female faces (e.g., Iliffe, 1960; Korthase & Trenholme, 1982). Much greater variability is seen in attractiveness ratings (and in the influence of relevant stimulus dimensions underlying them, e.g., symmetry and sexual dimorphism) of male faces than female faces, particularly as a function of variables influencing female subjects, such as the subjects’ personality traits, current relationship status,



Fig. 2.1. Sample set of five randomly arrayed and variably-blurred female face images as might be presented to a subject for ordinal ranking of attractiveness in one of the 20 trials per block in experiment 1. From left to right, the blur levels for this set are: 12, 60, 6, 18, and 36 cycles/face-width.

menstrual phase, short- versus long-term motives, and even self-perceived attractiveness (e.g., Little, Burt, Penton-Voak, & Perrett, 2001; Little, Jones, Penton-Voak, Burt, & Perrett, 2002; Penton-Voak et al., 1999; Welling, DeBruine, Little, & Jones, 2009). Not only do such variables fall well outside our interests here, they would only contribute noise to our goal of identifying consistent effects characterizing the face-perceptual processes of human observers universally, male and female.

These 100 images provide us with a baseline set of faces naturally varying in attractiveness, and it is important to note that, as a starting point, their wide range of baseline attractiveness derives entirely from the natural variation of the faces across virtually all previously-studied objective metrics of facial attractiveness – or at least those visible in a two-dimensional grayscale image. Very intentionally, then, and without our having artificially manipulated them along these lines, these faces provide a wide, natural range of variation in sexual dimorphism, symmetry, “averageness”, and many other dimensions such as cues to height, apparent age, adiposity, health, etc (see above and below) and even some modest variation from neutral to positive expressions, also known to contribute to attractiveness (e.g., Lau, 1982; Hildebrandt, 1983; Thornton, 1943; Reis et al., 1990). In fact, experiment 3 extends the scope of our stimuli with an additional 100 faces as well.

Not only does this approach and stimulus set provide a good dynamic range of baseline attractiveness judgments as a basis for comparison with the effects of the experimental manipulations, we can be confident that the image-level manipulation of blur (as well as of contrast and occlusion in the second and third experiments) is operating effectively on all manner of natural sources of face-level attractiveness signals, as would be encountered in real-world viewing conditions. Moreover, the strict randomization and counterbalancing (see below) ensure that, across the subjects and over the full data set, each individual face from this set is assigned to and contributes equally to each of the manipulated levels of the independent variable; that is, the contribution of any given face “x” to the data set is equivalent across all five blur levels. This means that we succeed in collapsing across all pre-existing variations in these other face-level dimensions (which give the non-manipulated faces the starting range of natural variation in attractiveness), so that only the image-level manipulation (here, five levels of blur; later, contrast and occlusion) remains to systematically drive (and thus explain) the observed experimental effects on attractiveness judgments, the dependent variable.

Using a custom script in the MathWorks MATLAB programming environment, each face was manually cropped from side to side, excluding the ears, and from top to bottom, from hairline to full extent of chin. Following this, the faces were rotated slightly, as necessary, so that the pupils would be perfectly level horizontally. One may note that the bicubic interpolation used in this rotation step itself introduces a very slight level of blur; however, this minimal smoothing artifact is by far smaller than even the first step of blur (from 60 cycles/face to 36 cycles/face) among the experimental conditions. Following this cropping and rotation, across the entire set of 100 faces the mean

luminance, image-wide contrast, and overall histograms were normalized according to the pre-processing routines described previously for our RISE experiments and subsequent SHINE toolbox (Sadr & Sinha, 2001, 2004; Willenbockel et al., 2010).

The size of images varied from roughly 3.5 to 4.5 degrees of visual angle, horizontally, at the intended viewing distance of ~50 to ~60 cm (i.e., roughly arm’s reach of the computer screen). It’s important to note that although the selected set of 100 images were of roughly the same size, these base images were not resized to be of the exact same dimensions (or even just to be of the exact same width, without altering their aspect ratio), fundamentally because, however this might have been performed, such a resizing operation would, by definition, confer a variable level of blur/smoothing based on each image’s original resolution and the variable amount of stretching/contraction to a new, normalized size. That is, to allow for the source images to serve as a non-blur baseline at their natural, original resolution, with their full complement of higher spatial frequencies intact, there was, necessarily, some variability permitted in their raw pixel sizes within this 3.5–4.5 degree range.

In MATLAB, these baseline images comprising the “60” cycles/face baseline level (i.e., in their original, unfiltered form – which, as stated above, did vary somewhat in horizontal pixel size and thus their precise baseline resolution) were manipulated into four additional blur levels for the independent variable, all together comprising the original/maximum high-spatial frequency content of roughly 60 cycles across the width of the face (original images; least blurry) down to 36, 18, 12, and 6 cycles/face (most blurry), using the standard image processing technique of Gaussian filtering/blur in the Fourier domain. A sample set of five stimuli appears in Fig. 2.1. These blur levels were chosen to span and well-sample a range of spatial frequencies/effective-resolutions from the original resolution/sharpness to as high a blur level as possible while still staying within the range in which subjects can perform highly reliable attractiveness judgments consistent with high-resolution rankings and ratings (true down to just under 3 cycles eye-to-eye; Fatke et al., under revision; Sadr et al., 2002).

Stimulus images were presented on a DELL Ultrascan p991 CRT monitor with matte-black bezel, gamma-corrected using the standard operating system utility in Microsoft Windows 7. As with all the experiments in this study, the stimuli were pre-processed, manipulated, and presented (and the subjects’ responses recorded) using MATLAB. The data collection was conducted in a dimly lit laboratory room lined with and sub-divided by matte black, light-absorbing fabric.

### 2.2.3. Procedure

The experimental session was organized into two blocks, with 20 trials per block, and a random selection of five stimulus faces presented in a horizontal array in each trial. The subject’s task was to use the computer’s mouse/pointer to rearrange each set of five faces, sorting the faces to indicate, left to right, the subject’s ordinal ranking of the most to the least attractive, followed by pressing a key to advance to the next trial of five. Note that the outcome of this procedure was a simple

ordinal ranking, a technique which for a number of years we have consistently found to be much more natural, quick, and reliable than Likert-style numerical ratings; for such a task, the latter would be prone to criterion drifts, scaling and anchoring effects, clustering, hedging, etc. No time limit was imposed, with most subjects completing each block in roughly 8–12 min at their own pace.

The assignment of each of 100 faces to the five blur levels was randomized and counterbalanced based on a subject number generated for each participant. Also randomized were the assignment of each face to the 20 to-be-ranked sets of five faces (and, thus, the matter of with which other four faces each face would be compared), the ordering of these trials within the block, and each face's initial/random left-to-right placement within each set of five. The only constraint imposed on the random assignment of faces to trials was that in each trial of five faces, each of the five possible levels of blur be represented once, avoiding the occurrence of trials/sets in which many or all of the five faces might be of the same level of blur, such trials contributing only noise to the intended test of whether attractiveness differences exist across levels of blur. Finally, in progressing from the first block to the second, all of these randomization and counterbalancing steps were performed anew, as would occur for an entirely new subject starting the first block.

### 2.3. Results

The results demonstrated a very clear and pronounced effect of increased blur producing an increase in perceived attractiveness. This was true all the way to the greatest level of blur, which, as stated above, begins to approach the maximum level of blur subjects can withstand while still producing reliable attractiveness judgments.

The data were examined using a 5 blur-level (within-)  $\times$  2 block (within-)  $\times$  2 sex (between-subject) repeated measures analysis of variance in R. As should be clear from the plotted data (see Fig. 2.2 for all subjects' block 1 data), there was a very strong, significant effect of blur:  $F(4,104) = 26.25$ ,  $MSE = 25.09$ ,  $p = 4.68 \times 10^{-15}$ , generalized  $\eta^2 = 0.375$  (Bakeman, 2005), for the two blocks combined; adjusted for sphericity (Mauchly's test:  $W = 0.520$ ,  $p = 0.069$ ), with a Greenhouse-Geisser correction (epsilon = 0.728) this gives  $F(2.91,75.7) = 26.25$ ,  $MSE = 25.09$ ,  $p = 1.46 \times 10^{-11}$ .

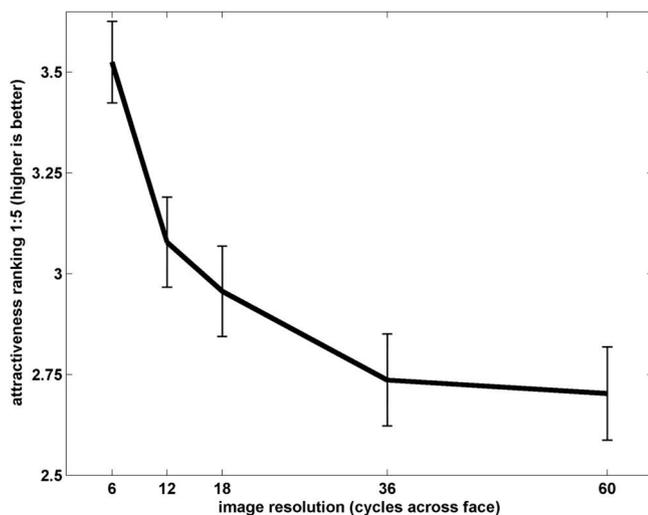


Fig. 2.2. Data from all 30 subjects' first block of trials in the blur experiment, revealing a very strong and significant effect of reduced image resolution (increased blur) producing a pronounced increase in perceived attractiveness;  $F(2.91,75.7) = 26.25$ ,  $MSE = 25.09$ ,  $p = 1.46 \times 10^{-11}$ , generalized  $\eta^2 = 0.375$ , for the two blocks combined. As with all data figures in this paper, all error bars are 95% confidence intervals about the mean, calculated using MATLAB's fitdist and paramci functions with respect to the estimate of the mean at each level.

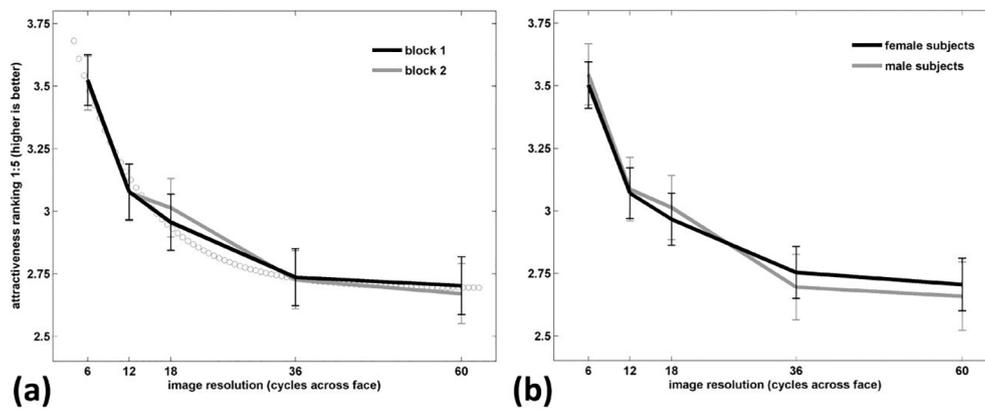
As expected, there were no effects (nor interaction effects) of block number (i.e., repetition) nor of subjects' sex (see Fig. 2.3(a) and (b) respectively). As discussed below, the data exhibited not only a monotonic progression but a very characteristic exponential profile.

### 2.4. Discussion

In considering theoretical questions of the perceptual/neural mechanisms underlying this striking effect, one immediate consideration harkens back to Bar's contention (Bar, Kassam et al., 2006; Bar, 2003; Kveraga et al., 2007) that, relative to fine-grained images, lower-frequency stimuli might be privileged in some sense and pass more rapidly through the visual system on to higher-level centres, not to mention dedicated subcortical pathways (e.g., Khalid et al., 2013; Vuilleumier et al., 2003). The main implication of this view of perceptual processing, echoed in many respects by others who have emphasized the important and early role of low spatial frequencies in face perception (e.g., Goffaux & Rossion, 2006; Goffaux et al., 2010; Quek et al., 2018; Rossion, 2014; cf. Sergent, 1986), asserts itself in our current context of subjective hedonic evaluation very nicely in offering a coarse-grained fluency-via-fit model of preferential processing and positive-affective response, particularly considering the ubiquity of reward signals throughout the brain (Vickery, Chun, & Lee, 2011).

Indeed, by itself, such a framework (e.g., Bar, 2003; Goffaux et al., 2010) might not necessarily demand a processing stage in which missing higher spatial frequencies are "filled in" at all (cf. Dennett, 1991, 1992), only a privileging of low-spatial-frequency stimuli, resulting here in a positive subjective qualia tied to the latter's streamlined processing and high-level fit. Quite separately, of course, it could also be asserted, as we note elsewhere in this paper, that the missing higher spatial frequencies (i.e., detailed facial features) could be in some respect filled in, at least in some implicit or effective sense, and that the results of this experiment reveal the strong bias of the visual system to do so with a clear tendency to produce a more attractive result than a neutral or less attractive one – that is, that such a perceptual completion would be supported by some amalgam of one's existing stored experiences and/or native templates (particularly those best fitting the lower frequencies in the stimulus; see Section 5, General Discussion), which would by its very nature confer great advantages in terms of subsequent or simultaneous goodness-of-fit-based hedonic evaluation. The internal templates would nicely match the "input", the latter having been largely composed of an internal-template-driven perceptual completion. That said, as above it's important to note that all throughout these discussions our intent is to accept the use of "filling-in" and "completion" in a loose, figurative, place-holder sense, and not as a competitor to the alternative notion of "finding out" (Dennett, 1991, 1992), where missing input need not at all be completed, extrapolated, interpolated, etc in order for perceptual and cognitive operations to proceed with their processing as usual; nor would a filling-in necessarily have to occur for us to have the *subjective* experience of seeing far more than we actually do (Cohen et al., 2016). Moreover, it's certainly not the case that, as in the neon-spreading and watercolour illusions, viewers actually perceive/hallucinate "filled-in" high-frequency details in the blurry face photographs (although, see Harmon & Julesz, 1973, and Shahangian & Oruc, 2014, for some interesting considerations on this as well).

Also worth noting is that while it's a common intuition that a little blur may serve to remove blemishes, wrinkles, etc, thus producing a modest increase in perceived attractiveness (e.g., consider the classic technique of spreading Vaseline™ on a camera lens when filming cinema stars, as one can see in almost any close-up of a female actor in the original Star Trek television series), this cannot explain the above results. The effect continues to grow well past this level of blur (i.e., well past the point of having removed slight imperfections and smoothed the skin, etc), beginning to approaching the point where the



**Fig. 2.3.** In the blur effect on attractiveness, there were no differences between the first block and second block of trials (a), nor between male and female subjects' responses (b). Moreover, within the examined range, the subjects' responses closely resemble an exponential curve (open circles in (a); see discussion). Error bars are 95% confidence intervals about the mean.

images are nearly smoothed to the level at which (known) faces can become unrecognizable. (Recognizability of low-passed faces seems to fall precipitously between 6 and 4 cycles/face (Ginsburg, 1978; Sinha, 2002; Yip & Sinha, 2002; perhaps slightly lower than originally suggested from block-quantized stimuli; Harmon, 1973; Harmon & Julesz, 1973), though there is good evidence now that such thresholds may well vary with retinal image size (Gao & Maurer, 2011; Ojanpaa & Nasanen, 2003; Oruç & Barton, 2010b; Shahangian & Oruç, 2014; Yang, Shafai, & Oruç, 2014); see also below. Naturally, different tasks operate on different information (cf. Sergent, 1986; Ruiz-Soler & Beltran, 2006), and spatial-frequency thresholds for face detection (e.g., Torralba & Sinha, 2001) are even lower, of course, possibly down to  $\sim 0.5$  cycles/degree (Quek et al., 2018) – which, oddly, approximates spatial frequencies sufficient for newborn infants' apparent recognition of adult faces (de Heering et al., 2008).)

In fact, partly in relation to this phenomenon and to this approach more generally, we are interested to follow-up this study using the RISE image manipulation technique (Sadr & Sinha, 2001, 2004) in place of Gaussian blur, the former parametrically altering image structure using a special form of Fourier phase scrambling while simultaneously preserving, if desired, the spatial frequencies (and contrast, luminance, etc) of the source image. Indeed, this might well be done while systematically examining in tandem the influence of variable stimulus size and/or viewing distance (e.g., Oruç & Barton, 2010b; Yang et al., 2014). These could be very valuable experimental directions in further characterizing the underlying mechanisms of this specifically blur-mediated “partial information effect”.

Along similar lines, some might speculate that the underlying mechanism of this blur-based increase in attractiveness might be mediated by an averageness/prototypicality effect (Galton, 1883; Langlois & Roggman, 1990; Symons, 1979). This certainly might be a reasonable initial intuition but unfortunately is not quite consistent with the pattern of the results, nor with relevant data from our companion studies and related literature. The idea that the blurry faces could be so degraded as to have begun to converge to one or more largely undifferentiated (and thus unrecognizable) average or prototype face(s), and that this “averageness” drives the observed increase in attractiveness, seems ultimately untenable due to three major problems. First, such a mechanism would be expected to apply only to faces below  $\sim 6$  cycles/face (i.e., perhaps the 4–6 cycles/face range or lower, as mentioned just above; Ginsburg, 1978; Sinha, 2002; Yip & Sinha, 2002), and thus would not explain the substantial attractiveness increases already seen at 12 and 18 cycles/face, nor even the sharp incline from 12 to 6 cycles/face itself, given that such an effect would not come into play until somewhat below 6 cycles/face.

Second, our companion studies of holistic face processing examining attractiveness ratings at extreme levels of blur (Fatke et al., under revision; Sadr et al., 2002) clearly establish that these stimuli do not become undifferentiated average-/prototype-seeming faces (at levels even slightly below the 6 cycles/face level), because, in fact, in that

range the individual faces' relative attractiveness rankings/ratings are still very highly correlated with those obtained for the same baseline faces at high resolutions; that is, the ratings/rankings are simply elevated from the high-resolution evaluations, as we demonstrate here in experiment 1, but do not become disordered, undifferentiated, and/or converge to a few prototypes' elevated evaluations – at least not at 6 cycles/face or above. (Indeed, the latter restates, in a way, one important reason behind experiment 1's designated blur levels in the first place: to span the range in which we have confirmed that attractiveness rankings remain highly reliable and do not become undifferentiated noise nor clustered into a few prototypes.)

Third, while extreme blur beyond our examined range does indeed compromise face recognition, low-pass filtering does not actually manipulate the “averageness” of the faces. The latter entails, by definition, convergence toward what would be non-individuable average/composite/prototype faces (Galton, 1883; Langlois & Roggman, 1990; Symons, 1979). By comparison, as our baseline images are progressively blurred, the stimulus faces do not “move” in any sense toward one another or toward pair-wise or group averages/composites/prototypes in some metrical face space (nor does this occur in the image manipulations for experiments 2 and 3, which show the same attractiveness-enhancement effect). Rather, as its high frequency content is progressively diminished, each face retains (or, one might say, remains at) its own individual, unique, original, and identifiable low spatial frequency facial structure. However much this might superficially remind one of other stimuli produced by averaging (or: however much extending this blurring to/below 4 cycles/face would eventually result in perceptual failures of face identification/individuation, due to far too little discriminative low spatial frequencies remaining), the latter is a very different manipulation indeed. It may also be worth noting, as a general consideration, that however much subjective familiarity may influence attractiveness judgments, it need not be imagined that the perception of attractiveness is either directly or entirely built/dependent on mechanisms of face recognition per se, as we have seen in related studies revealing normal attractiveness perception in the absence of face recognition (Sadr, Duchaine, & Nakayama, 2004), never mind the mere exposure and fluency research dissociating recognition from affective response (e.g., Bornstein & D'Agostino, 1992; Kunst-Wilson & Zajonc, 1980; Wilson, 1979). For the current experiment, at certain points we have, for reference, framed the manipulated blur levels in the context of the spatial frequencies needed for successful vs compromised recognition, but more to serve as a touchstone for the reader to develop an intuition about the extent of the image degradation, rather than to imply any necessary connection between attractiveness enhancement and recognition failure (which would not be expected to occur in these frequency ranges, never mind that these are all novel faces, which can't be recognized).

That said, it's interesting to consider that there may be some dimensions of *subjective familiarity*, “typicality”, or “distinctiveness” – i.e., as previously formulated, subjective attributes of individual faces,

not necessarily indicative of objective “distances” between faces in some metric face space (especially as highlighted by, e.g., [Burton & Vokey, 1998](#), and [Faerber, Kaufmann, Leder, Martin, & Schweinberger, 2016](#)) – that might conceivably be modulated here in some sense. If so, some aspect of a blur-mediated modulation of subjective familiarity, typicality, and/or distinctiveness might be associated at least in part with some of this observed increase in attractiveness (e.g., [Peskin & Newell, 2004](#); [Vokey & Read, 1995](#)). In essence, this idea would not fundamentally differ from the theoretical points already made above regarding, e.g., goodness-of-fit as a perceptual marker driving hedonic evaluations; rather, it simply points to further connections within this literature, relating these various subjective evaluations to one another, including bidirectional effects (e.g., between attraction and subjective/illusory familiarity; [Monin, 2003](#)) as well as the influence of objectively manipulated familiarity (e.g., through exposure and/or adaptation; [Cooper & Maurer, 2008](#); [Moreland & Beach, 1992](#); [Moreland & Zajonc, 1982](#); [Peskin & Newell, 2004](#); [Zajonc, Reimer, & Hausser, 1973](#)).

Thus, as established above, while it is not likely that the gains seen at 18, 12, and 6 cycles can be attributed to the faces’ undergoing some kind of averaging effect per se, along somewhat different lines it might be possible, at least to some extent, that while remaining identifiably distinct faces and retaining/remaining at their own original, unique low/mid frequency structure, the faces could in a different sense be reduced in their subjective distinctiveness, a dimension negatively associated with attractiveness in some previous work (e.g., [Deffenbacher, Vetter, Johanson, & O’Toole, 1998](#); [Light, Hollander, & Kayra-Stuart, 1981](#); [Peskin & Newell, 2004](#); [Rhodes & Tremewan, 1996](#)). Nevertheless – and forgetting that such an effect specifically would not carry much explanatory power across all three of our experiments – even this, on its own, could at best suggest only a partial account, given that attractive faces have also been shown to be distinctive, atypical, and in other important ways decidedly not average (e.g., [Alley & Cunningham, 1991](#); [Perrett, May, & Yoshikawa, 1994](#); [Vokey & Read, 1995](#); [Perrett et al., 1998](#); [Pollard, Shepherd, & Shepherd, 1999](#); [Sporer, 1992](#); c.f. [Sadr, Troje, & Nakayama, 2005](#)). That is to say, ultimately there may be a U-shaped association between distinctiveness/typicality and attractiveness (with both very unattractive and very attractive faces being distinctive; [Shepherd & Ellis, 1973](#); [Vokey & Read, 1995](#)); indeed, powerful influences such as sexual dimorphism or other face-shape preferences ([Perrett et al., 1994, 1998](#)) can readily produce attractive, distinctive, and atypical faces that are quantifiably distant from – and more attractive than – average faces.

Reviewing such results as seen in [Figs. 2.2 and 2.3](#), there is the understandable temptation to roguishly brand such an orderly effect (or pithy equation thereof) as “Sadr’s Law” or somesuch, for there does indeed appear to be, from these data and within this manipulated and measured range of spatial frequencies and perceived attractiveness (i.e., subjective attraction), a very fine fit between the subjects’ responses and a simple exponential function. This may be put simply in the form  $attraction = a \cdot \exp(b/blur) + c$

with “blur” expressed, as in the experiment, as roughly the maximum spatial frequencies present in the image, here from roughly 60 cycles/face down to six.

It may be interesting to note that while it seems quite clear that there are no sex differences whatsoever in this effect (as anticipated; [Iliffe, 1960](#); [Korthase & Trenholme, 1982](#)), we did observe a few limited examples of individual differences in the direction of the effect: a very small number of subjects occasionally exhibited – and verbally reported, either during the task or in debriefing – an aversion to some of the most blurry faces, e.g., one face at 6 cycles/face being described as a “scary clown”, another as a “Romanian power lifter” (in this case not meant as a compliment). One is rightly reminded, as was also observed with our earlier RISE technique ([Sadr & Sinha, 2001, 2004](#)), of the nature of such limited- or ambiguous-information paradigms to serve in some cases as a “projective test” of the subjects’ mental or emotional

state or perhaps even stable personality traits (e.g., [Klopfer & Taulbee, 1976](#); [Wood, Harms, & Vazire, 2010](#)). Appropriately enough, this recalls another well-worn quotation from Bovee: “Melancholy sees the worst of things – things as they may be, and not as they are. It looks upon a beautiful face, and sees but a grinning skull.” In the Conclusion, we revisit this idea in a more universal sense – of pared-down, under-specified input serving to characterize a black-box system.

Finally, alongside the success of this first experiment come two interrelated questions, one regarding the findings themselves and one regarding the technique. In the former, one may wonder how much of the effect might have been carried by (or perversely, perhaps, undermined by) the small concurrent reduction in image-wide contrast that occurs with increasing levels of blur (a roughly 17.2% reduction in RMS contrast on average for these 100 images across the total blur manipulation from 60 cycles/face down to 6 cycles/face). In the latter, one may wonder whether this striking attractiveness enhancement effect is specific to blur and spatial frequencies or whether it may be replicated with other – and perhaps computationally/conceptually simpler, yet equally ecologically important – image-degradation techniques...

### 3. Experiment 2: Image Contrast

#### 3.1. Introduction

Conveniently, both questions above can be addressed easily enough by a roughly homologous experiment in which the images are adjusted to various levels of contrast rather than various levels of blur/resolution. Not only might this be, for many readers, a more technically transparent and intuitively graspable method of pixel-based (as opposed to Fourier-space) image manipulation and stimulus degradation, it simultaneously expands our examination of common, real-world influences and processes which may degrade or impoverish images of faces stimulating the visual system (either as onto the retina directly or, as an intermediary, via photographs, now ubiquitous surrogates in our arguably-social interactions). In turn, very crucially, expanding our examination from blur to contrast further ensures that our treatment of this overall goodness-of-fit attractiveness enhancement effect is not specifically tied to any one low-level stimulus manipulation, viewing scenario, or associated/specialized perceptual routine.

#### 3.2. Methods

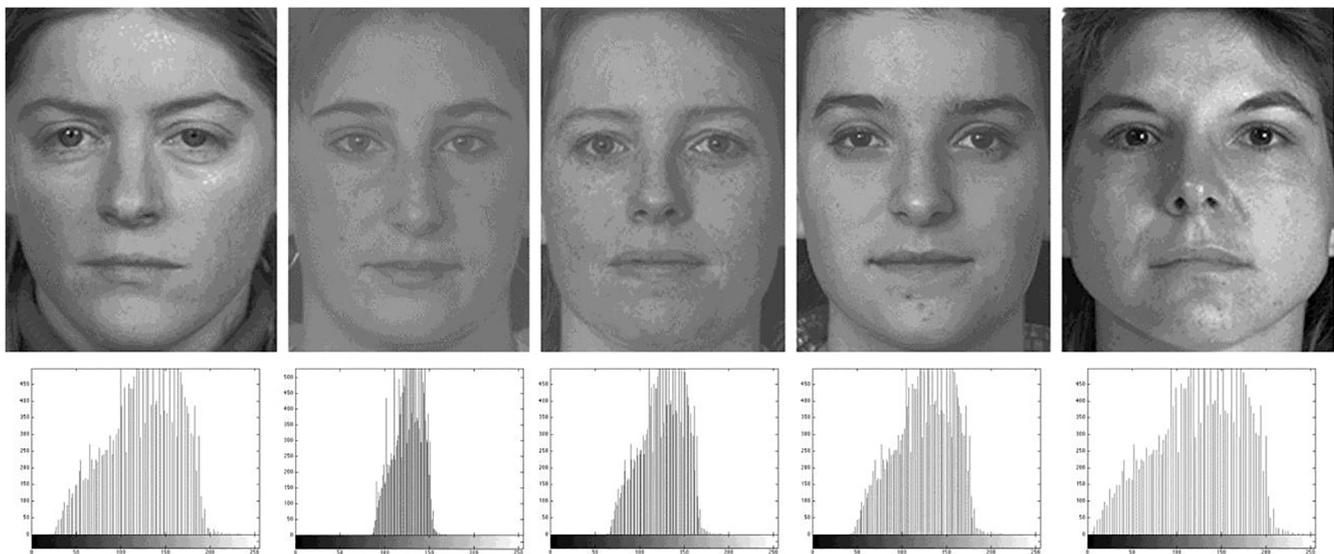
##### 3.2.1. Participants

Sixty-three subjects (22 male, 41 female; mean age = 20 years,  $SD = 3.7$ ) participated in this study. One additional subject did not complete the experiment, due to errant mouse/pointer responses disrupting the experiment software, and the partial data collected from her session could not be used. Please see experiment 1 ([Section 2.2.1](#)) for full details, equally true here, regarding subject recruitment, eligibility/exclusion criteria, ethics and informed consent, etc.

##### 3.2.2. Stimuli

The baseline (original/highest contrast) stimuli for this experiment consisted of the same 100 female face images used in the blur experiment, with the same cropping, eye-leveling bicubic rotation, and luminance mean, contrast, and histogram normalization (see [Section 2.2.2](#)).

Depending on the random assignment for each subject, each face was treated to one of five levels of contrast, in sixths, comprising the five experimental levels of the independent variable: from “1.00”, corresponding to the original-contrast source image, to 0.833, 0.667, 0.5, and 0.333 (lowest contrast). This contrast attenuation was performed by a very simple linear process, again in MATLAB, on the pixel luminances directly (as opposed to, e.g., the Gaussian blur, above, performed in the Fourier domain): all the pixel luminance values for a given image were subtracted by the mean luminance (roughly 128 on



**Fig. 3.1.** Sample set of five randomly arrayed and variably contrast-attenuated female face images (top row) as might be presented to a subject for ordinal ranking of attractiveness in one of the 20 trials per block in experiment 2. Below each are representative luminance histograms reflecting the distribution and range of luminance values at each level of contrast, as linearly scaled at the pixel-luminance level for the experimental manipulation. From left to right, the contrast levels for this set are: 0.83333, 0.33333, 0.5, 0.66667, and 1.0.

the 8-bit scale of 0 to 255, due to the baseline global normalization already performed) to center the histogram at zero; these values were multiplied by one of five scaling factors (1.00, 0.83333, 0.66667, 0.5, 0.33333), contracting the histogram (except in the case of 1.00) to a smaller spread of luminance values about the zero mean; and finally the original mean luminance was re-added, re-centering the histogram at the original normalized mean luminance, but now with the image outfitted with a compressed luminance histogram and thus corresponding to a reduced contrast overall (again, except for the baseline 1.00 condition), resulting in an increasingly “washed out” (but not darker or lighter) appearance. Fig. 3.1 depicts a sample set of five stimuli, with luminance histograms included to illustrate this experiment’s pixel-luminance-level contrast-scaling manipulation.

Finally, while the data collection laboratory and the computer display were exactly the same as in the blur experiment, in this case the monitor’s gamma correction was performed using the free “QuickGamma” utility on a Microsoft Windows XP computer.

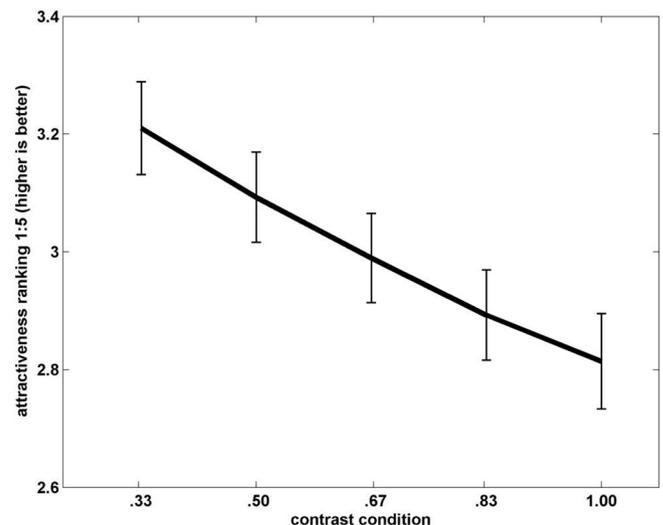
### 3.2.3. Procedure

Excepting that the stimuli in this experiment were contrast-attenuated as opposed to Gaussian-blurred, the procedure, task, design, randomization, counterbalancing, etc were all precisely identical to those in experiment 1 (see Section 2.2.3).

### 3.3. Results

The results demonstrated a very clear and consistent effect of decreased contrast producing an increase in perceived attractiveness. The data were examined using a 5 contrast-level (within-) × 2 block (within-) × 2 sex (between-subject) repeated measures analysis of variance in R. As should be evident from visual inspection (see Fig. 3.2 for all subjects’ block 1 data), there was a strong and significant effect of contrast:  $F(4,244) = 15.22$ ,  $MSE = 39.43$ ,  $p = 3.98 \times 10^{-11}$ , generalized  $\eta^2 = 0.128$ , for the two blocks combined; adjusted for sphericity (Mauchly’s test:  $W = 0.615$ ,  $p < 0.001$ ), with a Greenhouse-Geisser correction (epsilon = 0.775) this gives  $F(3.1,189.1) = 15.22$ ,  $MSE = 39.43$ ,  $p = 4.14 \times 10^{-9}$ .

Again, as expected, there were no effects (nor interaction effects) of block number or of subjects’ sex (see Fig. 3.3(a) and (b) respectively). Finally, as apparent from these figures, a one-way within-subjects



**Fig. 3.2.** Data from all 63 subjects’ first block of trials in the contrast experiment, revealing a strong and significant effect of reduced image contrast producing a pronounced increase in perceived attractiveness;  $F(3.1,189.1) = 15.22$ ,  $MSE = 39.43$ ,  $p = 4.14 \times 10^{-9}$ , generalized  $\eta^2 = 0.128$ , for the two blocks combined. Error bars are 95% confidence intervals about the mean.

ANOVA confirms a significant linear trend of contrast, with  $F(1,62) = 33.50$ ,  $MSE = 0.072$ ,  $p < 0.001$  for the two blocks combined.

### 3.4. Discussion

Clearly, the loss of visual stimulation from an image-wide reduction in contrast has a pronounced effect of increasing perceived facial attractiveness. It is very interesting also, in connection with experiment 1 (in which some contrast reduction necessarily occurs; see above), to notice that this contrast effect alone cannot account for the full strength of the blur-mediated effect: as effective and consistent as the reduction of contrast is in amplifying attractiveness here in experiment 2, in absolute terms the magnitude of experiment 1’s blur manipulation is quantifiably larger. More importantly, the blur manipulation achieves

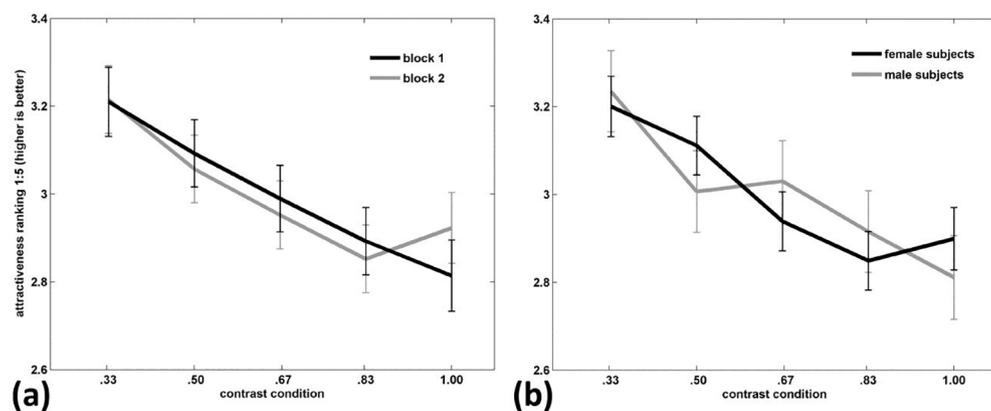


Fig. 3.3. As with the other two experiments, in the contrast experiment there were no differences between the first block and second block of trials (a), nor between male and female subjects' responses (b). Error bars are 95% confidence intervals about the mean.

its larger boost in attractiveness with a far smaller reduction in contrast overall (approx. 17.2% in total from 60 cycles/face down to 6 cycles/face – i.e., roughly equivalent to the first single step down from 1.0 to 0.83333 contrast in experiment 2), again establishing that it cannot be indirect contrast reduction that drives experiment 1's blur-mediated increase in attractiveness and, as expected, suggesting that, at an earlier stage closer to the low-/mid-level processing of the incoming stimulus, different perceptual routines may be engaged by each of these manipulations

Simply put, this brings us to a propitious point to reassert the notion that, across this paper as a whole, we hope to observe and illustrate the general phenomenon of a less-is-more attractiveness enhancement effect through a series of very different stimulus manipulations, each not only representing different real-world analogs (blur and distance, eccentric, or unaccommodated viewing in experiment 1; contrast and low light, shade, etc in experiment 2; occlusion and interposition in experiment 3) but also, as a consequence, coinciding with almost certainly different underlying low- and mid-level vision mechanisms. That is, given the somewhat different nature of contrast-sensitivity based (as opposed to acuity-based and spatial) manipulations and effects in face perception (e.g., Albonico et al., 2018; Oruç & Barton, 2010a; Owsley & Sloane, 1987; Oruç, Guo, & Barton, 2011; Rostamirad, Barton, & Oruç, 2009), we wouldn't expect our face-perceptual system to respond identically to a loss of high spatial frequencies (experiment 1) as it would to a loss in contrast (experiment 2). As such, we have no reason to expect the resulting enhancement effect to have the same parametric profile across these two experiments' manipulations (e.g., exponential for blur, linear for contrast) – only that the same general monotonic principle should be observed.

Across both experiments, we do indeed consistently observe that with the objective, manipulated loss of visual information/input (across five levels for the first two experiments and two levels for the third experiment) there results a significant increase in our subjective sense of attractiveness. Neural/perceptual mechanisms supporting vision under low-contrast regimes should be expected to deal with the paucity of incoming visual stimulation very differently than were the input instead diminished through the loss of high spatial frequencies (e.g., Costen, Parker, & Craw, 1996; Nasanen, 1999; Oruç & Barton, 2010a; Owsley & Sloane, 1987) – or, below, through the raw absence of large regions of input as a result of occlusion, particularly as we may see in that case some involvement of symmetry as well. Conversely, while observing different characteristic profiles for the monotonic effects of contrast versus blur (appropriately both tested over five stimulus levels each, to allow for this specific comparison across two very different stimulus degradation regimes), it is extremely rewarding, as mentioned above, to demonstrate in both these cases (and further in experiment 3) analogous and converging evidence for the “less-is-more” partial information effect put forward in this paper as a general phenomenon,

both consistent with an increased goodness-of-fit deriving from *decreased* stimulus information. Future work on this could continue to examine this effect in a contrast-sensitivity framework very specifically, akin to related studies of gender adaptation/perception (Oruç et al., 2011), particularly considering the established role of sexual dimorphism in attractiveness (Perrett et al., 1994, 1998; Sadr et al., 2005).

Thus far, then, we can say that the contrast-mediated effect cannot be (wholly, at least) the mechanism underlying the blur-mediated effect – nor, obviously, vice versa – and yet both, at whatever low- to mid-level of vision they may operate, do very well drive a substantial hedonic boost reflected in these attractiveness judgments. Across various types of stimulus manipulations, in fact, one might also be curious as to how much “information” in a formal, quantitative sense is lost as the image of a face is blurred or contrast-attenuated to these levels. Indeed, those with a face-metric focus on attractiveness may subsequently wish to not so much quantify this image-wide loss of information as to identify and track isolated face-level dimensions as they may be modulated by these image-wide manipulations (see below, General Discussion). Whenever working with standard grayscale two-dimensional photographs of faces, however, from the outset there is an irreconcilable surface/shape ambiguity resulting from the convolution of the faces' univariate surface/skin lightness properties and the faces' true three-dimensional shape/depth information; and the latter is transmitted not only as unambiguous two-dimensional landmarks/locations in the image but more extensively and continuously in the (likewise univariate) depth-based shape-from-shading luminance variations from pixel to pixel in the 2D array (Ramachandran, 1988a, 1988b). Thus, not only is it in a general sense decidedly contrary to the original intent and design of the current experiments and stimuli to revert focus back to face-metric (vs image-wide) influences and explanations, with such photographs it's simply not possible to unambiguously parcel out face-level shape vs skin influences specifically, as may have been parametrically modulated image-wide (along with all other facial variables) by blur or contrast. Rather, as mentioned in the General Discussion, such questions could be examined by subsequent experiments carefully isolating and manipulating/measuring any such face-level dimension of interest in tandem with the application of these image-level manipulations.

At the image (rather than face) level alone, however, it is indeed an interesting question to relate the manipulated stimulus degradation to the observed attractiveness enhancement in a quantitative though abstract information-theoretic way. Though this is outside the scope of the current paper, it is a question we might nevertheless easily address in the design of a third, even simpler, “partial information” paradigm that may (if our hedonic notions of perceptual “filling-in” and “auto-resonance” goodness-of-fit are correct) likewise amplify attractiveness – a paradigm in which it might be trivial to quantify the amount of visual

information lost: say, exactly 50%. Again, we do not seek at this point to further examine lower-level contrast- or blur-mediated mechanisms per se but rather, quite the opposite, to test an entirely different framework for stimulus information loss, to demonstrate the generality of the above attractiveness-enhancement effect across very different regimes: in this case, naturalistic occlusion producing the loss of visual input spanning an entire half of the face.

#### 4. Experiment 3: Occlusion / Half-Faces

##### 4.1. Introduction

In many ways the conceptually simplest of our three partial-information manipulations, in the third and final experiment here we proposed to examine the effect on attractiveness of completely withholding half of the face. This may seem either odd or obvious, depending on one's having developed an appreciation thus far of exactly why the first two experiments incorporated the image-degradation approaches they did: it was simply to reduce the amount of visual input in a controlled and ecologically meaningful way. Perhaps nothing is more natural and basic in this regard than to consider the loss of visual input simply due to occlusion. Indeed, here we do pursue the question of stimulus loss specifically through a naturalistic occlusion (rather than, e.g., merely the artificial erasure of part of the image, as is trivial when manipulating artifacts such as digital or printed photographs), given that our interest is in the visual system's particularly well-adapted ability not only to negotiate occlusion but to exploit it for depth perception and the implicit explanation of reduced or missing input. We should expect that the visual system most adeptly contends with the abrupt loss of continuous visual structure in the context of precisely such simple cues as occlusion; as discussed below in Sections 4.4 and 5, it should be in just such a mode of perceptual "filling-in", implicit "completion", or tacitly-explained or disregarded missing input that a (rather ironic) feeling of goodness-of-fit may, again, trigger a boost in perceived attractiveness – a goodness-of-fit either with one's own contribution to the missing stimulus structure, or with only the partial stimulus and ignoring the missing residuals.

##### 4.2. Methods

###### 4.2.1. Participants

Twenty-four subjects (10 male, 14 female; mean age = 20.4 years,  $SD = 2.5$ ) participated in this study. Two subjects performed the task unusually slowly, completing only one block of trials during the session; these block 1 data are included in Fig. 4.2 but cannot be included in the ANOVA, which requires balanced design across both blocks of trials (see Results, below; Section 4.3). Again, details on subject recruitment, criteria, informed consent, etc were entirely equivalent to the previous two experiments and can be found in full in Section 2.2.1. The data collection for experiment 3 partially overlapped in time with the completion of data collection for experiment 1, and due to the strict subject-anonymity dictated by our ethical guidelines and enforced by the university's subject recruitment system (as well as our own internal procedures), there was the possibility of some unavoidable and unidentifiable overlap in the subjects who volunteered for these two studies in this period. To avoid any risk of interference between the two studies, from the outset experiment 3 was constructed using an entirely different set of 100 faces (see below, Section 4.2.2), with all subjects being, as always, completely unfamiliar with the stimulus faces and naive to the experiment's purpose.

###### 4.2.2. Stimuli

This experiment used 100 new female face images taken from the FERET database, this being done, as stated above, simply so that any

subjects who participated in the blur or contrast experiments need not be excluded from the occlusion experiment in our efforts to protect the sanctity of the stimuli. In compiling this new set of 100, the exact same cropping, eye-leveling rotation, and image-level pre-processing/normalization (luminance mean, contrast, histogram) was performed as described above in Section 2.2.2.

The experimental manipulation of these images was in many ways far more simple and straightforward than those for the above two experiments operating in the Fourier-domain and on the luminance histograms; also, for simplicity and to maximize data collected per stimulus level, there were two conditions/levels for the independent variable, not five: the original whole/fully-visible faces, and an equal number of faces that were precisely half-occluded by a grey rectangular "panel" of a luminance equal to the mean luminance of the face image itself. A sample set of five stimuli appears in Fig. 4.1. (Technically, as will become relevant below, there were three categories of stimuli, because for careful counterbalancing the set of occluded faces was further sub-divided into equal numbers of left- versus right-visible images [25 + 25]. Our primary interest was in comparing the fully-visible vs occluded faces, of course, with left- and right-visible stimuli simply combined in the latter condition for good experimental design, but within this there would naturally be collected a subset of data with which one could attempt a secondary comparison within the occluded condition, i.e., between the left- and right-visible sub-conditions.) Finally, one subtle enhancement was introduced in this study by the experimenter's first roughly pre-sorting all the source images by attractiveness, to allow for a somewhat more balanced division of half the set into each of the two main conditions. That is, an equal number of faces across the full spectrum of least- to most-attractive could be randomly assigned to each of the two conditions (whole vs occluded) without concern that, for any given subject, the subsequent randomization could create blocks in which an excessive proportion of more- or less-attractive faces were assigned to either of the experimental conditions, skewing the results for any individual subject and thus requiring a yet larger subject sample to redress.

A critical point regarding this "occluding" grey panel must be made – that, indeed, a compelling pictorial illusion of occlusion (i.e., of a background face being obstructed by a foreground grey surface) was produced by the use of one Gestalt-like cue and one shape-from-shading cue. First, the panel was sized to extend beyond (or "overhang") the edges of the face image, generating occlusion-consistent T junctions where it was met by the edges of the face image (e.g., Lowe, 1985). Second, a simple three-pixel wide, three-step gradient "drop shadow" was created below and beside two edges of the occluding panel, again mimicking a depth separation between the occluder (foreground, floating above) and the face image (background), naturally assuming a light source just above and to the side. The use of occlusion, rather than mere erasure, absence, or cropping of the face image, was an approach deemed crucial to presenting this particular loss of visual input/information in a realistic, "ecological" way (e.g., Gibson, 1966), one which would most likely activate the visual mechanisms that typically engage in negotiating instances of real-world occlusion (e.g., amodal completion in a general sense; Michotte, Thinès, & Crabbé, 1964). It happens routinely that, as seen from a given viewpoint, an interposed object/surface occludes a distal face (or any object or surface); it virtually never happens that a partial face is simply encountered on its own, with the unseen portion simply missing or erased from existence yet without any explanatory visual structure for this visible in the world (i.e., with the missing region filled with the scene's background, rather than by a foreground object/surface). This is a distinction we intend to examine in future studies, in the specific domain of faces, e.g., in relation to the digital erasure manipulation we previously employed in studying the role of eyebrows in face recognition (Sadr, Jarudi, & Sinha, 2003).



Fig. 4.1. Sample set of five randomly arrayed female face images with two assigned to the occlusion condition, as might be presented to a subject for ordinal ranking of attractiveness in one of the 20 trials per block in experiment 3. In each set of five faces to rank, either two or three were thus occluded and placed in random starting positions within the set.

#### 4.2.3. Procedure

The procedure, experimental design, task, etc. were all exactly the same as the previous two experiments (see Sections 2.2.3 and 3.2.3), except for one aspect of the re-randomization between blocks 1 and 2: as before, the ordering of faces within and across the 20 trials were re-randomized for the second block, but in this experiment we did not at this point also randomly re-assign each face to a (potentially) new whole/occluded condition. This disallowed the possibility that, across blocks 1 and 2, faces could switch from half to whole (or vice versa) or from left-side-visible to right-side-visible (or vice versa). Also, it was ensured in each trial of five that either two or three faces be of the occluded/half-face condition, to allow every trial the opportunity to contribute meaningful data as to whether any preference exists for one of the two experimental conditions, which could not be measured at all if ever sets of five faces were all taken from the same experimental condition (i.e., all whole or all occluded/half).

#### 4.3. Results

Once again, the results demonstrated an extremely powerful effect of decreased visibility increasing perceived attractiveness, with occluded faces ranked as far more attractive than the fully-visible faces. The data were examined using a 2 occlusion-level (i.e., whole face vs occluded face; within-)  $\times$  2 block (within-)  $\times$  2 sex (between-subject) repeated measures analysis of variance in R. Consistent with what can be seen from the plotted data (see Fig. 4.2 for all subjects' block 1 data), there was an extremely large and significant effect of occlusion:  $F(1,20) = 254$ ,  $MSE = 1.48$ ,  $p = 7.67 \times 10^{-13}$ , generalized  $\eta^2 = 0.914$ , for the two blocks combined.

As in experiments 1 and 2, there were no differences whatsoever between data collected from the male and female subjects (see Fig. 4.3(a)), nor between the two blocks (not pictured). Finally, we did observe the indication of a small difference within the occluded face condition (see Fig. 4.3(b)), between the left-side- versus right-side-visible subsets of these higher-ranked occluded faces: that the left-side-visible stimuli were ranked slightly higher than the right. An analogous ANOVA as above does not show this difference to be significant, however –  $F(1,20) = 3.11$ ,  $MSE = 2.05$ ,  $p = 0.09$ , generalized  $\eta^2 = 0.068$  – possibly due in part to there being only half as much data included in this test, compared to the above: for each block of 100 faces ranked, only 50 rankings enter into this test (25 left-side-visible plus 25 right-side-visible) as opposed to 100 (50 whole plus 50 occluded faces) for the main effect of occlusion tested above.

#### 4.4. Discussion

Besides the striking magnitude of the effect of occlusion on perceived facial attractiveness (cf. Inter-Ocular Trauma Test), it's worth

noting two points that should not be left to be read between the lines: one, here, regarding the small indication of a difference between left-versus right-visible images; the other, within the General Discussion to follow, regarding the very notion of symmetry (as opposed to asymmetry) as a cue for (un)attractiveness.

Here, it's simply important to note the tricky matter of left/right reversal in these stimuli versus the actual faces of the women photographed: when we talk of the left side of the stimulus image being visible from the perspective of the viewer (i.e., the sub-condition garnering slightly higher rankings), we are talking, anatomically, of the right side of that photographed woman's face. This is crucial to consider in that, following this subtle trend in the data, we are able to connect this result back quite nicely to Zaidel, Chen, and German (1995) who for female faces showed that artificially-symmetric faces created from duplications/reflections of the right side of the face were deemed more attractive than those constructed from the left. Confirmatory results have been reported by Burt and Perrett (1997) and Dunstan and Lindell (2012), with contrary results from Sitton, Waite, and Rivers (2006) almost certainly due to their significant artifact of a left versus right difference in face widths (Cunningham, 1986) – doubled, in fact, by their reflection/chimera operation. This right-side advantage is exactly what we observe here (as an incidental finding, of course, and not significantly), though without having gone the extra – and rather

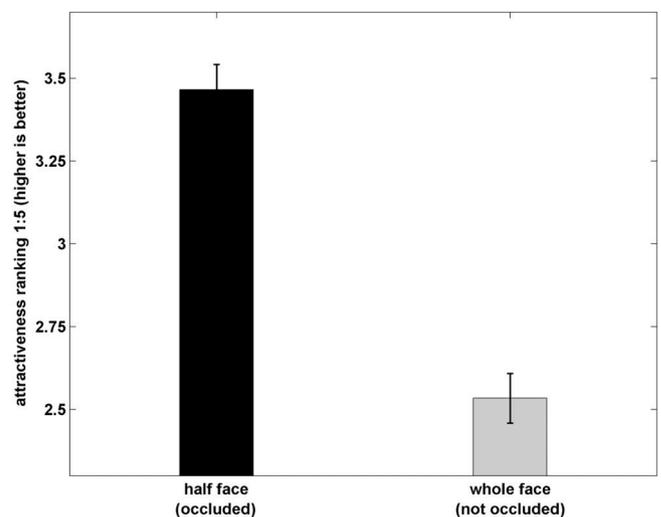
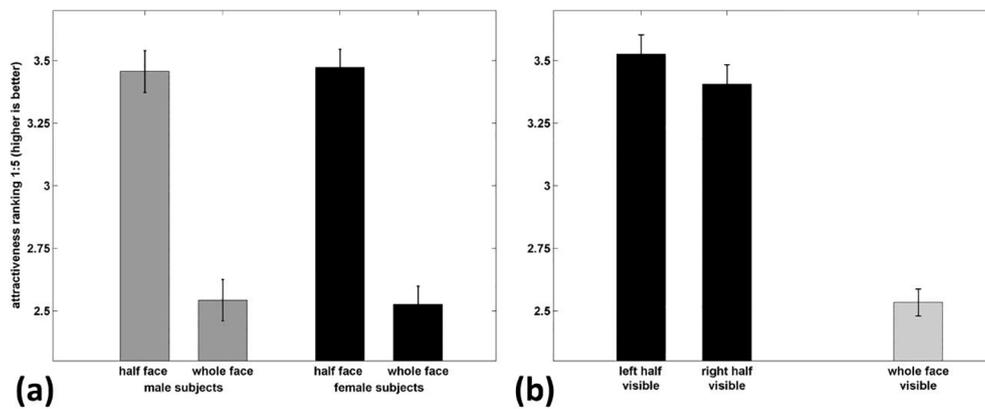


Fig. 4.2. Data from all 24 subjects' first block of trials in the occlusion experiment, revealing a very strong and significant effect of reduced face visibility producing a pronounced increase in perceived attractiveness;  $F(1,20) = 254$ ,  $MSE = 1.48$ ,  $p = 7.67 \times 10^{-13}$ , generalized  $\eta^2 = 0.914$ , for the two blocks combined. Error bars are 95% confidence intervals about the mean.



**Fig. 4.3.** As with the first two experiments, in the occlusion experiment there were no differences whatsoever between male and female subjects' responses (a), nor between the first block and second block of trials (not pictured). (b) A small difference appeared within the occluded condition, with subjects slightly preferring left-side-visible images (i.e., anatomically, the right side of the photographed woman's face) over right-side-visible images, though this was not found to be significant at  $p < 0.05$  (see text). Error bars are 95% confidence intervals about the mean.

fraught – step of creating artificial, symmetrical faces; we simply presented only one side, plausibly occluded, and obtained an attractiveness judgment.

The correspondence with these earlier reports is also reassuring in the sense that, as currently designed and on its own merits alone, we would have been suitably cautious in considering whether this small effect in the third experiment speaks to a property of the stimulus (i.e., that the right side of female faces is “objectively” more attractive) or to a property of the subject's visual system (i.e., that, in the subjective sense, one prefers face halves appearing on the left – or, in suitably neural language, projecting to the right hemisphere, etc). In all, however, we would most hasten to note the relative magnitude of this small left/right difference, compared to the order-of-magnitude larger primary effect of occlusion in the first place, i.e., of seeing only half a face regardless of side. As much as one might say that one half of the face may be slightly more attractive than the other, seeing either half – alone – is *overwhelmingly* better than seeing a whole face. This, along with certain topics in symmetry and perceptual “filling-in”, is discussed in further detail below as it connects to considerations deriving from the blur and contrast experiments and findings.

## 5. General Discussion

Summing up the core of these findings and focusing on the main effect of occlusion alongside those of the contrast and blur manipulations, one has the weight and breadth of evidence to invoke in eminently quantifiable terms the otherwise nebulous phrase “less is more”. Indeed, were one inclined to be provocative, besides the exponential “law” of the blur-mediated effect and the comely linearity of the contrast results, from the occlusion data alone one could simply (if mischievously) declare that “50% less face” produces “40% more attractiveness”. As a less formal alternative to “the partial information effect”, it's particularly apt that “less is more” is self-referentially so short-and-sweet. None of this work undermines, of course, the wealth of research establishing the influence of facial morphology (e.g., sexual dimorphism), surface properties (e.g., skin colour, homogeneity, etc), and cues to height, age, personality, etc (e.g., Fink, Grammer, & Matts, 2006; Korthase & Trenholme, 1982; Lefevre & Perrett, 2015; Little et al., 2006; Perrett et al., 1994, 1998; Re & Perrett, 2012) on attractiveness judgments, especially as put forward within evolutionary-psychology frameworks relating to ultimate functions in mate selection and reproductive fitness (e.g., Barber, 1995; Buss & Barnes, 1986; Feinberg, 2008; Fink & Penton-Voak, 2002; Scheib et al., 1999; Symons, 1979). Rather it simply points to the very unexpected power of numerous variables pertaining to the viewing circumstances – distance, eccentricity, lighting, interposition, etc – which, in essence, inextricably *convolve* with the veridical distal structure of the face to produce the proximate visual stimulus operated on by the perceptual system. (Along these lines, it's interesting to note that even simply the external framing

of a face can profoundly influence its processing; Curby & Entenman, 2016; Sinha & Poggio, 1996.)

It is this convolution – very commonly coinciding with the loss or degradation/distortion of visual information from the distal object – that, as we show here, has such a profound effect on the associated hedonic appraisal, typically presumed to be a direct evaluation or reading of the distal object yet in practice quite removed from this source. In day-to-day life, of course, as observers we rarely orient to and identify these “extraneous” image-level factors (blur, contrast, occlusion, etc), as we do the otherwise salient features of the distal face in question (e.g., eye colour, bone structure, skin quality, etc – the bread and butter of experimental psychology and folk psychology alike). We discount the medium through which the information travels. Yet, just as the received wavelengths of light on the retina are likewise a convolution of the ambient illuminant's spectrum and various surfaces' reflectance properties (e.g., McCann, McKee, & Taylor, 1976; and similarly Farid & Adelson, 1999, in the domain of transparency and intervening reflectance), these two categories of influence on attractiveness are deeply intertwined by the time our retinas are stimulated. In this vein, one is reminded of Adelson's (1981) very “Alpern's razor” rose-coloured ganzfeld, with the most elegant and compelling proximal manipulations performed *literally* in the eye of the beholder.

It's no accident for us to have arrived at the theoretical motivations and unique design of these three experiments through an examination of the existing groundwork in perceptual fluency (e.g., Reber et al., 1998; Winkielman et al., 2006), bottom-up/top-down integration and goodness of fit, mid- and high-level visual routines, and the robustness of face-perceptual expertise across compromised viewing conditions, rather than as an extension or refinement of existing face-metric approaches to attractiveness – the latter being neither our intent nor our methodology. It is through this same perspective of image-level proximate mechanisms that these experiments and their findings can be most meaningfully understood. Explanations beyond (or orthogonal to) face-level analyses of attractiveness – and, equally, beyond high-level “eye-of-the-beholder” cognitive processes – must be explored to understand and interpret these previously ignored *intervening* effects on subjective attraction. (Indeed, even ostensibly random neural activity preceding the stimulus might have such an intervening influence, attributable neither to the objective stimulus nor to typically characterized higher-order cognitive influences; Hsieh, Colas, & Kanwisher, 2012.)

Nevertheless, while constituting two very different categories of influence, relationships between image-level and face-level influences could be explicitly studied in future research by anyone interested in individually quantifying the effect of blur, contrast, etc on specific, isolated facial characteristics, i.e., dimensions of face shape/structure and skin/surface properties (e.g., Fink, Grammer, & Matts, 2006; Grammer & Thornhill, 1994; Jones et al., 2004; Lefevre & Perrett, 2015; Perrett et al., 1994, 1998; Torrance, Wincenciak, Hahn, DeBruine, &

Jones, 2014) or facial cues of apparent age, health, and/or relevant physical and personal traits (e.g., Coetzee et al., 2009; Foo et al., 2017; Korthase and Trenholme, 1982, 1983; Little et al., 2006; Rhodes et al., 2001, 2007; Re & Perrett, 2012; Lai, Oruç, & Barton, 2013; Stephen, Coetzee, Smith, & Perrett, 2009). Having either systematically manipulated a collection of baseline faces to exhibit pre-set levels of sexual dimorphism, skin colour, or any such face-level dimension of interest (or, alternatively, having specifically quantified unaltered faces' pre-existing natural variation on such dimensions of interest), the same blur, contrast, occlusion, and other image-level stimulus degradation/information reduction manipulations could be very simply and directly applied to study the latter's parametric influence on the former, simulating the effects of different viewing conditions. That is, we could chart the progressive profile of each of these image-level manipulations' elevation of attractiveness rankings when the baseline faces' attractiveness has been pre-determined to vary on specific dimensions of skin texture, homogeneity, etc or of face-shape dimorphism, prototypicality, symmetry, adiposity, etc.

Should one be so inclined, structuring such experiments and stimuli accordingly and with appropriate subject samples, such questions could be studied as well in relation to pre-existing individual differences in attractiveness judgments (e.g., known variations in female subjects' evaluations of male faces, as influenced by reproductive strategy [“sociosexual orientation”], self-perceived attractiveness, personality traits, etc; Little et al., 2001; Waynforth, Delwadia, & Camm, 2005; Welling et al., 2009). In a somewhat related vein, in our own ongoing work one aim is to also explore the specific benefit of this less-is-more partial information effect on individual faces; from the outset, the perhaps obvious prediction should be that simple ceiling effects will limit these image-level manipulations' opportunity to increase the most attractive baseline faces' ratings/rankings (Sadr et al., 2002), thereby appearing to confer greater benefits to faces with relatively lower – or, at least, not near-ceiling – baseline attractiveness.

In surveying these various image-level influences, on arriving at the third experiment in particular it should be noted that we did not necessarily set out with any particular focus on facial symmetry as a discrete source of face-level information to be degraded or lost. Remarkably, however, through our occlusion experiment we have nevertheless discovered, however heretical it may seem, that there is a very real sense in which it may be incorrect to say that facial symmetry is attractive and distinctly more accurate to say, perhaps, that asymmetry is unattractive. The occluded/bisected faces are far more attractive – when they have no symmetry to be seen at all – and the fully-visible faces are far less attractive – when they are the ones that are symmetric. The latter is a minutely-flawed symmetry, however, and it may be that this small but visible asymmetry confers its own disadvantages, quite surprisingly worse than the occluded faces' unnatural and complete absence of bilateral symmetry.

To be sure, the original research proposing symmetry as a key determinant of attractiveness (Grammer & Thornhill, 1994; Perrett et al., 1999; Rhodes, Proffitt, Grady, & Sumich, 1998; Scheib et al., 1999) has from the outset been challenged by a number of results to the contrary (e.g., Rhodes et al., 2001, 2007; Samuels, Butterworth, Roberts, Graupner, & Hole, 1994; Swaddle & Cuthill, 1995; Zaidel, Aarde, & Baig, 2005; Zaidel & Cohen, 2005; Zaidel & Deblieck, 2007), but this seems to have done little to slow its continued pursuit as one of the central (and perhaps singularly popularized) facial dimensions of attractiveness and mate quality (e.g., Cruz, 2018; Dixon, Little, Dixon, & Brooks, 2017; Fink, Neave, Manning, & Grammer, 2006; Jones, DeBruine, & Little, 2007; Little, 2014a; Little, Apicella, & Marlowe, 2007; Little, DeBruine, & Jones, 2011; Little, Jones, DeBruine, & Feinberg, 2008; Oinonen & Mamanian, 2007; Pisanski & Feinberg, 2013; Young, Sacco, & Hugenberg, 2011). In light of experiment 3, not to mention in the context of decades of symmetry research, it's somewhat startling to discover in such a simple paradigm that the archetypally bilaterally-symmetric human face appears far more attractive

when, half gone, it presents us with no symmetry at all. The partial information effect here seems to veer from “less is more” to “ignorance is bliss” – or perhaps “absence makes the heart grow fonder”.

Not only is it *not* a handicap to present to a viewer a partial face stimulus which provides no signal of bilateral symmetry, this confers the great *benefit* of inflating the viewer's evaluation. If symmetry is so prized (as we, too, have previously claimed, in the domain of human biological motion; Sadr, Troje, & Nakayama, 2006), one can neither predict nor explain the superiority of an utterly symmetry-less half-face over a bilaterally symmetric (if imperfectly so) whole face – and yet, this is precisely what our third experiment reveals. This, then, delivers us to the obverse: that, all else being equal, *asymmetry*, however slight, is unattractive – sufficiently unattractive, in fact, that it is far better for a face to have no symmetry at all than an imperfect symmetry; earlier manipulations demonstrating the attractiveness benefit of symmetry (e.g., Perrett et al., 1999) may have worked less by establishing symmetry than by removing asymmetry. Moreover, this might even suggest that, when half the face is lost, part of the “meta-data” lost with it is not so much symmetry information as asymmetry information, given that the latter is apparently more salient.

It's also important to notice that quite apart from the question of symmetry or asymmetry, the missing/occluded half of the face is obviously needed by the viewer to generate an accurate sense of many configural (e.g., eye-to-eye distance) and featural (e.g., face-, nose-, and mouth-widths) characteristics that serve as fundamental variables in attractiveness judgments – characteristics that, as confirmed by these results, clearly cannot be accurately or veridically (as opposed to idealistically) estimated/extrapolated from only half a face; when actually visible in the original full face, their presence sharply diminishes the face's attractiveness. And yet, just as surprisingly, there doesn't appear to be any glaring, disruptive loss of natural holistic face processing in the case of these half-faces, though fully half the face is absent, with subjects not only operating on these hemi-faces with speed and facility but with relish, finding them far more attractive as a result. (From this one might colourfully imagine that, with the aid of a plausible occluder or by simply staying half out of the shot, Batman's hemi-disfigured friend/enemy Two-Face would do very well to place a half “selfie” portrait on a Gotham Singles website. We seem to have no compunction about generating a compelling percept of attractiveness when fully 50% of the to-be-scrutinized stimulus is nowhere to be seen – nor might we then hesitate to convert this percept into a halo of goodness surrounding that face's owner; Dion et al., 1972.)

In future work, we would like to evaluate just how important the illusion of occlusion is – as opposed to a T-junction-less, ecologically-inexplicable erasure/truncation (Gibson, 1966; Lowe, 1985) – in preserving such a ready and natural processing of a face when it is, in the most stark terms, half absent. Likewise, follow-up comparisons of top-versus-bottom bisection/occlusion would expand on these questions, minus the role of (a)symmetry, and speak to the relative salience/diagnostic hierarchy of upper versus lower facial features/regions (Brown & Perrett, 1993; Davies, Ellis, & Shepherd, 1977; Fraser, Craig, & Parker, 1990; Gava, Valenza, Turati, & de Schonen, 2008; Haig, 1986; Lai, Pancaroglu, Oruç, Barton, & Davies-Thompson, 2014; Rule, Ambady, & Hallett, 2009; Sadr et al., 2003; Schurgin et al., 2014). These would be expected to coincide with differential partial-information gains, in turn perhaps directly linking certain aspects of this enhancement effect with existing work on facial-featural metrics of attractiveness (Cunningham, 1986; Perrett et al., 1994, 1998).

Equally, and central to the core notions of our work as a whole, one notices that in the face of occlusions (or in the occlusion of faces) – i.e., in the absence of full-face input that would have unambiguously provided configurally/featurally/asymmetrically less attractive stimulation – something about our expert, robust face perception system might handily fill-in the missing half (much as even a very simple neural network might reconstruct or “hallucinate” missing input [see below] given enough of an input pattern to match with stored instances/

experiences, whether in a holographic or otherwise auto-associative instance based memory system; Franklin & Mewhort, 2015; Jones & Mewhort, 2007; O'Toole et al., 1995; see also below) – at least in some effective sense and certainly enough to be able to easily and naturally proceed with sophisticated and hedonically-rich judgments of beauty. Crucially, in doing so the system appears to actively construe or tacitly assume an optimally proportioned and symmetric face by default, with no flaws in the unseen half and imbued with idealized configural and featural characteristics throughout (e.g., perhaps also narrowing the face slightly, in the special case of vertical bisection; Cunningham, 1986) – a literally un-realistic level of beauty of which the perceptual (and hedonic/aesthetic) system would have been unambiguously disabused had the whole face been visible. The latter is no mere speculation or rhetoric, either, given the data in experiment 3 for the exact same faces when seen whole. That is to say, with some inherent mechanistic drive toward the construal, inference, or presumed fit of idealized features, configurations, and symmetry, in the particular case of faces the overwhelming bias is for the viewer to virtually complete and/or otherwise operate on and evaluate an occluded face in the most flattering way possible, rather than whatever might instead generate an affective response of assuming the worst or even of reserving judgment. (Indeed, this may emerge very simply from the basic operation of an instance-based perceptual-memory system; e.g., Franklin & Mewhort, 2015; O'Toole et al., 1995.)

Consequently, it's very interesting to consider the connections between these effects and those observed with other occluded "objects" (which, however simpler than and different from faces, may not be at all odd-looking for our internal visual stores; Cavanagh, 1995): rudimentary line-drawing contours which, though occluded, might display structural regularities belying an interrupted horizontal/vertical symmetry which our half-occluded faces, notably, do not. For such contours/objects, presumed global symmetry (and certain other principles, as proposed by Sekuler, 1994, in addition to Gestalt perceptual "preferences" more generally, e.g., Wagemans et al., 2012; see also Halper, 1997, 2012, for similar treatment of gravity assumptions and right-angle preference), rather than simpler rules for local contour completion, has a powerful influence on perceptual "filling-in" behind the occluder (i.e., amodal completion; Michotte et al., 1964). So, while demonstrating our partial information effect across three very different cases of stimulus degradation, the third – information loss by occlusion – serendipitously has us examining as a *subset* of its lost input some amount of (a)symmetry information, somewhat akin to facial "meta-data", along with the raw 50% of lost visual stimulation more explicitly. The perceptual system's *response* to this particular subset of absent information, presumably built on an all-else-being-equal assumption/expectation/extrapolation of perfect symmetry, can only benefit each thusly occluded face which, in its natural and whole state, unambiguously suffers from some amount of (presumably unattractive) asymmetry. It's possible that the effect of partial information in this regime could be to prompt our effectively filling-in the absent input with an idealized reflection (or infer the continuation of the visible half in this idealized way), resulting in a percept almost universally more attractive than the original.

We might take a moment to appreciate that this is not only surprising but astonishing, however, given that a vertically bisected half-face, unlike Sekuler's (1994) shapes, does not itself provide any structure signaling its own bilateral symmetry to drive this global completion, never mind that (need it be said?) faces are of immeasurably greater complexity than the simple line drawings with which these effects have been previously observed. It's very ambitious to predict this magnitude and quality of amodal completion to occur at all proficiently for an entire half of a human face, never mind its occurring so deftly that the (surreptitiously enhanced) holistic aesthetic of the face glibly carries forward, without apparent pause or qualm, into such a beautiful percept. Of course, as mentioned above, for these subjective perceptual/affective processes to proceed there need not be any actual "filling-

in" or completion at all (Dennett, 1991, 1992), but whatever occurs clearly appears to support a natural, holistic evaluation, which is utterly astounding given the stark absence of half the face. Yet, rather than having trouble evaluating these half-faces, not only do subjects breezily sort through them as easily as the non-occluded faces, they find them markedly more appealing. (So much so, in fact, that for virtually every subject *individually* the results are statistically significant.)

In much the same way, with blurry faces one might conceive of missing facial details and high-spatial frequencies being effectively filled-in (or otherwise compensated for; Dennett, 1991, 1992), in some analogous or metaphorical sense if not literally (e.g., Freeman, Jones, and Pasztor's (2002) instance-based super-resolution technique, and subsequent "face hallucination" system, Liu, Shum, & Freeman, 2007; see also techniques for de-noising coupled with assessments of goodness-of-fit, e.g., Malik, Schummers, Sur, & Brown, 2014), again in a manner curiously biased to be most flattering to the original face. The same can be said, through very different contrast-enhancing mechanisms, for the second experiment's manipulation and results. As above, however, it need not be that missing higher spatial frequencies are filled-in in any sense; the observed effects may simply derive from the relative importance and primacy of low spatial frequencies in face and object perception (e.g., Bar, 2003; Goffaux & Rossion, 2006), certainly in speeded detection in adults as well as identification/discrimination in infants (e.g., de Heering et al., 2008; Quek et al., 2018). Even with some disagreements in this domain, e.g., as to an exclusive role of low spatial frequencies for configural and/or holistic face processing (Cheung, Richler, Palmeri, & Gauthier, 2008; Gilad-Gutnick, Yovel, & Sinha, 2012), there is growing evidence of the great speed, sequential primacy, and even dedicated subcortical processing of low-spatial frequencies in face processing very generally, including affective responses (e.g., Bar, Kassam et al., 2006; Goffaux et al., 2010; Goffaux, Gauthier, & Rossion, 2003; Khalid et al., 2013; Vuilleumier et al., 2003) – with obvious connections between these demonstrations with affective processing in general and our observations with attraction in particular.

Thus we might revisit our primary intent here, across three very different manipulations, to explore this partial information effect as driven by three very different low- and mid-level perceptual subsystems/processes yet all resulting in the same outcome of "less is more" hedonic enhancement at a higher level. Neurally and computationally, recovering a higher-quality image from low-contrast input (requiring very simple approaches to contrast enhancement, some available as early as the retina – or, say, in MATLAB, just multiplying by a scalar) is a very different and tremendously easier enterprise than recovering or, rather, fabricating all the higher-spatial-frequency details missing in a blurry input (particularly about/above certain frequency bands; Costen et al., 1996; Nasanen, 1999) – and precisely such differences may be what we see reflected in the specific profiles, in this case linear versus exponential, of the individual results at a more detailed level – while, nevertheless, in the end both situations are overwhelmingly biased toward producing a hedonic enhancement, just as we see in the remarkable response to occlusion. Yet more support for the generality of this "less is more" phenomenon can be seen in the temporal domain, in the altogether different experiment by Willis and Todorov (2006) varying presentation duration, again without manipulating the faces themselves – nor higher-level "eye of the beholder" cognitive factors, such as repeated exposures, inter-stimulus similarity, etc.

Along these lines, the results of all three experiments recalls work by Vokey and Read (1985), at the time of the so-called "backmasking" scare in popular music, and their discussion of "active construction" (itself, in some ways if not others, evocative of "unconscious inference" à la Helmholtz; Gregory, 1968) in the perceptual/mnemonic dance of bottom-up signals and top-down processing which finds – or rather, imposes – familiar meaning and form where there is little to be had in the poverty of the stimulus. (Once again, in this regard one is also reminded of "projective tests". In this way we might also see, as some

readers in allied fields may note, at least a distant resemblance to the hedonic aspects of top-down and disambiguating processes involved in the appreciation of abstract/modern art, a domain in which ambiguity may be correlated with liking; Muth, Hesslinger, & Carbon, 2015. In the current political and sociotechnological climate of deliberately fabricated “news”, computationally curated in-group “social media bubbles”, and siloed and balkanized “echo chambers”, however, it may be even more important to consider the likely overlap between these mechanisms and the processes underlying the so-called “sleeper effect” and “truth effect”, in which the mere familiarity of repeated arbitrary statements make them more likely to be judged as true; Bacon, 1979; Begg, Anas, & Farinacci, 1992; Hasher, Goldstein, & Toppino, 1977; Jacoby et al., 1989.) Rather appropriately, it’s the resolution of this same interaction between bottom-up and top-down processing – and, ultimately, their mutual fit – that underlies Ullman’s (1995) and Bar’s (2003) grand neural models of visual perception, as well as Kramer, Young, and Burton’s (2018) approach to specifically modeling the complexities of robust familiar-face recognition across multiple views. The latter, in fact, is related to the suggestion that, in terms of recognition/identification in particular, we may be less face experts than familiar-face experts (Young & Burton, 2018).

Appropriately enough, it was the same duo, Vokey and Read (1992, 1995; in some respects following on the heels of their colleagues, Whittlesea et al., 1990; Whittlesea, 1993), who so starkly and metrically put into focus the interplay of familiarity, typicality, memorability, and attractiveness, in some ways recapitulated by Peskin and Newell (2004) and Faerber et al. (2016). Roughly ten years later, the idea resurfaced in the form of the “warm glow heuristic” (Monin, 2003), replicating and highlighting again the double-edged nature of the mere exposure effect (e.g., Moreland & Zajonc, 1982; see also Jacoby et al., 1989), i.e., that the familiar feels attractive, and the attractive feels familiar – and that we, as the entities subjectively experiencing not only the explicit but an affective/hedonic implicit side of these perceptual/mnemonic processes, can hardly tell the two apart. That is, of course, if indeed they are two separable feelings/processes and not, in fact, one – an idea which we may now do well to consider. Nor is there need to imagine such mechanisms necessarily being derived from measures of the stimulus’ nearness to some central, “average” prototype(s), whether innate and archetypal or acquired and malleable, denoting “representations” of idealized and preferred forms. One could do very well not only with systems based on non-amalgamated instances (e.g., Kolers, 1976; Tarr & Pinker, 1989) but with goodness-of-fit taken less as a measure of nearness to any one point or prototype but as a direction – a pleasing deviance – well-aligned with some vector toward a smattering of instances roughly scaffolding a gradient of any given variable in a more emergent sense (Perrett et al., 1994; Sadr et al., 2005; Troje, Sadr, Geyer, & Nakayama, 2006; Vapnik & Chervonenkis, 1964).

This is a concept which the public seems to have stumbled upon, at least implicitly, as evidenced for example in the internet “meme” and website “Totally Looks Like”. To be sure, Brad Pitt is a handsome and skilled actor, but as a young man he was also conferred certain advantages from his striking resemblance to an established Hollywood star, Robert Redford. (In the language of casting directors and modeling agencies, it would be said that Pitt has – or had – a Robert Redford “quality”.) Recalling Jenkins, White, Van Montfort, and Burton’s (2011) “variability in photos of the same face”, propitious pairings of same-age photographs of the two actors shows a greater resemblance between the two than each actor bears with his own photographs over the years. It is very telling indeed that Redford cast the up-and-coming Pitt in “A River Runs Through It”, essentially as a younger version of himself, and that, again, the younger Pitt played protege and successor to Redford as mentor in “Spy Game”. Astute cinephiles have noted much the same of Pitt’s friend and frequent co-star, the now middle-aged yet eminently virile George Clooney, in relation to the flip-initialed Cary Grant: an uncanny resemblance explicitly played up by the time a throwback film

such as Clooney’s “The American” was to be advertised and released. Following this, whether by conscious thought or not, Clooney’s latter-day hairstyle now seems permanently transformed into Grant’s. For his part, Cary Grant (née Archibald Alec Leach) himself exploited ersatz familiarity and movie-goer confusion by choosing the initials of his show-business name to match those of established stars Clark Gable and Gary Cooper (Eliot, 2004). Aswim in celebrity Cs and Gs, George Clooney, at least, came by his honestly.

An implicit or “intuitive” recognition – at times illusory in one sense (i.e., operating on two verifiably different people in the world) yet entirely justified at the level of surface structure (i.e., matching two eerily morphologically, even kinematically, similar faces/bodies), a trap not too removed from some forms of source-memory failure (e.g., cryptoplagiarism; Allen & Jacoby, 1990) – may confer to the object one monolithic or “holistic” degenerate signal of goodness-of-fit that can be variably and contextually (mis)interpreted as reflecting subjective feelings of attraction and liking, of familiarity and objective recognition, etc (e.g., Jacoby & Whitehouse, 1989; Kunst-Wilson & Zajonc, 1980; Monin, 2003; Whittlesea, 1993; Wilson, 1979), and/or of granting the viewer automatic and supposedly objective assessments of attractiveness (which, it must be said, is confused as being identical to subjective feelings of attraction). Worse, through a “beautiful is good” halo effect (Dion et al., 1972), this conjures up a divination of the very goodness of the observed person. We see here almost certainly a seed of sincere confusion underlying the age-old pick-up line, “Do I know you from somewhere?”

More, much as in Julien Green’s apt phrase “thoughts fly and words carry on foot”, these quick, obligatory, half-conscious responses can be contrasted with the slow, laborious, thought-full, “reflective” nature of more explicit evaluative processes. Next time you encounter what you immediately perceive to be a stunningly attractive *face*, try to catch yourself in the irresistible, instantaneous experience of *liking* that *person* (cf. Locher et al., 1993; Olson & Marshuetz, 2005; Willis & Todorov, 2006). Indeed, try to sense whether it ever happens, in that first, automated moment, that one is inspired to such intense feelings for the face without the cross-talk of their carrying over to the (wholly unknown) person, never mind one’s managing to have, simultaneously in that first moment, *contradictory* feelings for the two. And yet – and worse – our research now shows quite clearly that, setting aside the already superficial nature of the face itself (and, in this sense, what an appropriately suspect word “face” is, to begin with), it may be far more the random, senseless happenstance of one’s momentary view of this face (one’s viewing distance, the set of one’s lens, the direction of one’s gaze; an occluding scarf, the demurely covered laugh; an obscuring shadow, the tricks of twilight, the dim romance of candles; ...) – coupled with our visual system’s coming to the rescue, with its glass-all-full jolly robustness and facial expertise – that is to credit and to blame.

It’s both natural and worthwhile (and, indeed, the point which inspires this research) to see connections between our findings here and phenomena in the real world: people on a date who are less interested in their companion than with new prospects in the distance or on tiny telephone screens (the proverbial “two in the bush”); the occasional overestimation of a distant person’s attractiveness, surprisingly disambiguated at closer proximity – a phenomenon that rarely occurs in the reverse. These can be well predicted and understood just from our first experiment manipulating blur and effective image resolution. Does the traditional gauzy-white wedding veil merely restrain an unenthused groom from superficial judgments that could scuttle the nuptials, or does this veil go further, to unsuspectingly enhance his desire for the barely discernible face beneath? Such would be reasonably claimed now from our study in contrast. The obfuscatory effect of the veil carries us to the topic of occlusion and half- (or less) visible faces and, along those lines, from the elaborate coquettish behaviour of courtiers and their playful routines with decorative, face-obscuring fans to the quotidian yet rarely mundane cascade of long hair falling across a face, intentionally or otherwise. It even calls into question whether, for

example, the world-wide phenomenon of women's religious coverings of the face, head, and hair (compounded by these women's often being sequestered at some spatial remove during social and religious occasions, thus additionally applying our first experiment's manipulation) might have an effect precisely the opposite of forestalling, through a vested modesty, the inflammation of devout men's passions. Indeed, the results of our third experiment would suggest that in such a context we should rather predict a fetishizing of the uniquely-visible eyes and eyebrows, around which the most enchanting occluded faces might be imagined (or amodally completed).

Before concluding, however, it's important to note that while our discussion and above real-world examples have, as is common in the study of facial attractiveness, considered our findings and interpretations in the context of overt physical attraction, the perception of and positive social-attribution bias toward attractiveness is not remotely confined to matters of post-pubescent mate selection and sexual interest (which, to begin with, might be considered two overlapping but separate concepts; Lott, 1979). These processes and proclivities are firmly in place by infancy and childhood (e.g., Dion, 1973, 1977; Langlois et al., 1987; Samuels & Ewy, 1985) and readily observable in their bidirectional influence on parent/infant interactions (Langlois, Ritter, Casey, & Sawin, 1995), long before we encounter their prompting romantic or sexual interest or see their assortative influence not only on marriage (Murstein, 1972) but on platonic friendships (Cash & Derlega, 1978), their inarguable social sway in the boardroom, courtroom, and classroom (Ambady & Rosenthal, 1993; Hamermesh & Parker, 2003; Rule and Ambady, 2008, 2009; Zebrowitz & McDonald, 1991), and much more. The relative success of attractive plaintiffs or babyfaced defendants (Zebrowitz & McDonald, 1991), for example, seems well established already in childhood when, from an early age, attractive children's bad behaviour is evaluated less negatively by adults and excused as short-term and not dispositional (Dion, 1972). Simultaneously, while still years away from exhibiting other adult-like social perceptions and inferences (e.g., Balas, Kanwisher, & Saxe, 2012), very young children can already be seen to exhibit not only adult-like attractiveness judgments (Langlois et al., 1987; Samuels & Ewy, 1985; Slater et al., 1998, 2000a, 2000b) and substantially more instrumental motivation to see attractive faces (Dion, 1977) but the associated beautiful-is-good halo effect as well, themselves also judging attractive children, as adults do, as being more pro-social (Dion, 1973). At that age, they even exhibit such aesthetic/affective nuances as, e.g., the younger-is-better attractiveness bias for adults' facial attractiveness (Korthase & Trenholme, 1983).

Carrying into adulthood, again the ubiquitous, irrepressible, “always on” perception of and positive bias toward attractiveness seem to mark a general psychological phenomenon by no means limited to matters of sexual interest. Certainly, in shifting focus from the powerful role of attractiveness in overtly mate-selective circumstances in the real world, e.g., seeking a dance partner (Walster et al., 1966) or expecting, accepting, or refusing one's dinner being paid for on a date (Stirrat, Gumert, & Perrett, 2011), to its consistently and pervasively biasing the evaluation of job applicants (Dipboye, Fromkin, & Wiback, 1975), financial success over one's lifetime (Hamermesh & Biddle, 1994), success in litigation (Zebrowitz & McDonald, 1991), students' evaluations of peers' schoolwork (Landy & Sigall, 1974) and of their professors' teaching (Ambady & Rosenthal, 1993; Hamermesh & Parker, 2003), etc, one's first intuition might reasonably be that the mechanisms underlying the latter interpersonal effects are nothing more than a re- or misapplication of the former reproductive concerns in a different context. However, to appreciate the fundamental phenomenon of attraction – through familiarity, goodness-of-fit, etc – as a universal and virtually obligatory perceptual/hedonic experience well beyond the instrumental evaluation of presumed mate quality, can we not recall countless circumstances where there is no involvement of sexual interest and potential-mate selection in any form, motivating subjective states of attraction and prompting these evaluative and behavioural biases?

Adults not only look longer at attractive babies (Hildebrandt and Fitzgerald, 1978, 1981; just as newborns and infants look longer at attractive adults; e.g., Samuels & Ewy, 1985), they consistently judge attractive babies to be more sociable, more active, more competent, and easier to care for (Karraker & Stern, 1990; Ritter, Casey, & Langlois, 1991; Stephan & Langlois, 1984). No surprise, then, to also find that mothers are less affectionate and less attentive toward their own newborn infants if the latter are unattractive (Langlois et al., 1995). In one sense, this might recall Cunningham's (1986) finding that, not surprisingly, adult men report being more inclined to perform altruistic acts for attractive women; but to find the same don't-help-the-homely dynamic between mothers and their own babies (newborn to three-months-old, in this study) is both startling and illuminating – that while newborns arrive predisposed to orient to faces (Goren, Sarty, & Wu, 1975), mothers of unattractive infants might not reciprocate as readily, perhaps immediately sowing the seeds of future social/personality differences seen between attractive and unattractive children and adults (Feingold, 1992; Langlois et al., 2000). More, emphasizing the power of appearances, this maternal judgment of and differential response to one's own infants' attractiveness is not remotely in the domain of craniofacial deformities, physical handicaps, chronic illness, etc (Barden, 1990; Barden, Ford, Jensen, Rogers-Salyer, & Salyer, 1989) where some cold and calculating evolutionary claim could be made about reducing parental investment in unviable offspring, but simply on the basis of relative attractiveness in otherwise healthy infants; further, this effect has been observed with the first-born (i.e., only) child, i.e., when there is no differential investment to be made between multiple offspring (i.e., more attractive siblings) competing for maternal resources, and at such a young age that the mother is in no wise already transitioning to the production of her next offspring.

Indeed, the allusion to Cunningham (1986) is only a distant one; it is not a case of adaptive and self-serving attraction-regulated “altruism” when a lesser degree of maternal attraction prompts one to care less for and bond less with one's own infant (Langlois et al., 1995), already carrying 50% of one's own genes. Worse, our research here at low resolutions would now suggest the added “grass is greener” disadvantage of perceiving other children, viewed at a distance, as being more attractive than one's own, at hand. When the apparently reflexive experience and influence of attraction invades adult/infant interactions and even runs counter to the adaptive incentive of safeguarding one's own genes, it seems we must return to a more basic and general appreciation of the proximate perceptual/cognitive genesis of subjective attraction, conceived less narrowly than as an isolated, dedicated module specifically evolved to optimize reproductive success via fine-tuned detection and evaluation of postpubescent signs of fecundity – however much it may be that cross-talk with the latter could be used to explain, for example, why (likely obscuring the Langlois et al. (1995) effect now in the Instagram age) even trained, predominantly female judges of parent/child interactions rate attractive mothers' behaviour more favourably (Ritter & Langlois, 1988).

## 6. Conclusion

As arguably expert and largely effortless perceivers, thinkers, and actors we believe we are basically rational, analytical, and objective. Within and beyond the subset of our impressive complement of face-specific mental and neural machinery we believe that we consciously make critical choices using information we have gathered accurately and weighed thoughtfully; that our perceptions are not only robust and acute but also bias-free, objective, and accurate reflections of the world; that our memories, visual and otherwise, are like re-played recordings that, while sometimes a little faded, are essentially a re-experiencing of the past as it was. In all this, we are very wrong. Findings from our and others' research reveals a much clearer and starker view of the subjective processes that guide our daily behaviour – from seemingly quotidian perceptual tasks, such as reading poor handwriting and

obscured text or choosing between brands of pantyhose, to the most profound deliberative processes, such as the true forces that drive how we choose our spouses and friends; how we judge our children, co-workers, students, and teachers; how we promote and elect leaders into positions of incredible economic and political power.

The incredibly brisk, unconscious/subliminal, and largely non-rational processes studied in this class of research (e.g., Locher et al., 1993; Olson & Marshuetz, 2005; Todorov et al., 2005) are, in fact, not at all removed from what we believe to be the loftier, conscious, and deliberate evaluations, decisions, and acts we engage in at every moment, whether or not tied to the particularly salient social processes built on our deft and automatic (even obligatory) perception and evaluation of faces and bodies. In fact, these more inscrutable processes are very likely the ones more dominant in their ubiquity and power. In the case of face processing and the especially rarefied domain of facial beauty and attractiveness, we now even come equipped, lay and scientific people alike, to (mis- or only partially) understand our responses, internal and external, with help from the very reasonable vocabulary of “symmetry”, “averageness”, “dimorphism”, and so on – all reasonable and true enough, and yet, as our experiments here now demonstrate, equally or more influential visual factors and stimulus features seem to exist that exert profound control over our deepest, most personal subjective experiences – factors and features which wield their powerful influence covertly, even humbly, at a much lower and more pervasive level, almost dishearteningly mundane and well beyond (or beneath) what we, the beguiled, the expert face-perceivers and vision scientists, may have considered plausible, never mind intuitive or likely.

In considering our results across all three experiments, it's worthwhile adopting the mindset of a vision researcher approaching a perceptual or cognitive illusion – a compromised perceptual or cognitive evaluation – that might occur, in certain circumstances, due to otherwise beneficial functional properties of general-purpose perceptual/cognitive machinery which evolved to successfully navigate and operate within the world (e.g., Gibson, 1966; Gregory, 1968; Shepard, 1990). In this light, it would not be profitable to straddle multiple levels of analysis (Morgan, 1894; Tinbergen, 1963) and perhaps claim that being vulnerable to the illusion (or, worse, deliberately operating on its compromised or illusory percepts and evaluations) is itself an adaptation, specifically evolved for some direct reproductive or survival benefit. Rather, side-stepping the perils of ad hoc interpretations, “just so” stories (Symons, 1992), and spurious linkages (Teller, 1984; though between perception and evolution, not physiology), the discovery that we suffer from such an illusion (in certain circumstances; e.g., artificially enhanced attraction to blurry, low-contrast, or occluded images of faces in particular) most directly offers us scientific insight into the *otherwise*-successful and -beneficial structure and functioning of our perceptual/cognitive machinery (in most other circumstances and/or ancestral setting; e.g., the mere ability to robustly and veridically process blurry, low-contrast, and occluded images in general) – i.e., other, more fundamental adaptations.

This is particularly true if the underlying mechanisms, subverted in the illusion, evolved for entirely other functional considerations, e.g., in our case here perhaps simply to support robust mid- and high-level vision routines in a more general sense (not to mention associated mechanisms supporting recognition, familiarity, etc), contending with degraded or incomplete visual input universally, and perhaps not uniquely evolved for and exclusively dedicated to facial attractiveness or mate search/approach. Combined with the positive hedonic/affective qualia of fluent processing and enhanced goodness-of-fit, perhaps, the associated elevation in subjective attraction certainly would seem to fuel a heightened receptivity and initial interest, which may well drive mechanisms ultimately in support of “satisficing” (Simon, 1956), but not so much the more common view of an exquisite selectivity in mate

quality (e.g., Buss & Barnes, 1986; Symons, 1979; see above). Of course, there are other ways in which this selectivity might still assert itself (Walster, Walster, Piliavin, & Schmidt, 1973).

In placing our work in the context of face-perceptual processes in particular, we would put forward – fundamentally – that in building expertise, one also builds, necessarily, an aesthetic. However much our expertise in perceiving faces is evolved and innate, and however much in each person's lifetime it is also (as the empiricists and behaviourists must rightly remind us) a product of countless individual experiences (e.g., Jackson et al., 2013; Turk-Browne, Junge, & Scholl, 2005), the multifarious, concerted machinery that gives us the ability to detect, categorize, and recognize faces, perforce is intrinsically twinned with the hedonic, affective, evaluative phenomenology of its operation, experienced at least in part from the very goodness of a face as a face. Above some phenomenological criterion, for a previously encountered actually-familiar face we may call the experience of such goodness-of-fit a successful “recognition”, but how might we label precisely this same subjective feeling when it occurs for a new face – a new person whom we have never encountered but who, by virtue of his or her physical appearance, structural or kinematic, nevertheless resonates perfectly well with our evolutionarily-inherited and experience-trained machinery? What of the sense that over time adults might acquire an idiosyncratic “type” (or “types”) of face or body they find most attractive, likely from a life-long accrual of socially-reinforced or merely classically conditioned experiences (not to mention mere exposure) layering visuo-social associations atop early imprinting (Bates & Perrett, 2017; Little, Penton-Voak, Burt, & Perrett, 2003; Perrett et al., 2002)?

Not only would we hesitate to claim this feeling of attraction-mingled-with-familiarity to be unique to humans (e.g., Zajonc et al., 1973), we may not wish to restrict our view of its operation and hedonic consequences to the domain of faces per se (e.g., considering possible connections with the emerging “desirable difficulty” literature; Rosner, Davis, & Milliken, 2015; Yue, Castel, & Bjork, 2013) – nor even to perception alone, when memory (if indeed it may be separated from perception) likely operates no differently (Franklin & Mewhort, 2015; Jacoby et al., 1989; Jacoby & Whitehouse, 1989; Whittlesea et al., 1990; Whittlesea, 1993). From what we have seen in light of the stimulus manipulation and task performance above, and as previously seen in the realm of mere exposure and perceptual fluency (Moreland & Topolinski, 2010; Reber et al., 1998; Zajonc, 1968), we may consider that such a phenomenological experience is simply the feeling of a mental/neural system operating smoothly – and here, in the case of situations presenting incomplete or degraded stimuli prompting a perceptual filling-in (or inferential “finding out”; Dennett, 1991, 1992) or partial fit and extrapolation, perhaps not only operating smoothly but self-referentially or self-reflexively.

As such, we see here that this hedonic flavour is not based on a fluency (e.g., Reber et al., 1998) that always *trivially* derives from objectively clean and clear-cut, overspecified and disambiguated stimuli (e.g., Tinio & Leder, 2009) – quite the opposite, in fact, as we have now shown: this pleasing ease likely derives, in the dynamics of bottom-up and top-down integration, from the not-disambiguated closeness of *underspecified* stimuli's fit to the contents and workings of one's own mind, its machinery, experiences, etc. It is as if, besides the metaphor of the tiny spark that sets off a blaze (i.e., merely serving to prompt the house to burn *itself* down), in the metaphor of “resonance” with one's environment the most bare and stripped-down delta function “ping” of input is consequently the most likely to make us ring at our own resonant frequency. Indeed, in the delightful repercussions of a ping-and-ring metaphor, the more pared-down ping may produce a more resonant ring precisely because it lacks additional frequencies of its own that would dissonate and dampen the system's auto-echoic response. It is here, in this “partial information effect” as we might call it, that we

see our curious and somewhat charming bias, when faced with uncertainty and obscurity, to imagine the best.

“Tell me where is fancy bred.  
Or in the heart or in the head?”  
- W. Shakespeare

## Acknowledgments

This research was funded in part by a ULRF grant and an HHMI fellowship to JS. Portions and early versions of this work were presented at the Vision Sciences Society (2002), Society for Neuroscience (2013), and BASICS and NOWCAM (2014, 2016, 2017). Our experiments used the FERET database of facial images, collected under the FERET program sponsored by the DOD Counterdrug Technology Development Program Office. For valuable discussions, statistical expertise, general support, and inspiration both explicit and implicit, the authors wish to thank J R Vokey, S W Allen, E Adelson, P Cavanagh, F Halper, G Geiger, H Farid, A Torralba, A Treisman, S Pinker, W T Freeman, D Teller, D Perrett, P Sinha, K Aucouin, T Warner, T Spagnolo, J Poplawski, J M Harrison, K Watson, C Richards, R Fitton, N Snyder, H C Barth, V A Bell, J S Lipton, C N Turlington, K M Fjordbotten, C M Wallace, M Chambers, J Chew, T Whittaker, A Mazkooi, M Shannon, A T Shapiro, Hobbes, and, above all, J L S Sadr.

## References

- Adelson, E. H. (1981). Looking at the world through a rose-colored ganzfeld. *Vision Research*, 21(5), 749–750.
- Albonico, A., Furubacke, A., Barton, J. J. S., & Oruç, I. (2018). Perceptual efficiency and the inversion effect for faces, words and houses. *Vision Research*, 153, 91–97.
- Allen, S. W., & Jacoby, L. L. (1990). Reinstating study context produces unconscious influences of memory. *Memory & Cognition*, 18(3), 270–278.
- Alley, T. R., & Cunningham, M. R. (1991). Average faces are attractive, but very attractive faces are not average. *Psychological Science*, 2(2), 123–125.
- Alonso-Prieto, E., Pancaroglu, R., Dalrymple, K. A., Handy, T., Barton, J. J. S., & Oruç, I. (2015). Temporal dynamics of the face familiarity effect: Bootstrap analysis of single-subject event-related potential data. *Cognitive Neuropsychology*, 32(5), 266–282.
- 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, 431–441.
- Bacon, F. T. (1979). Credibility of repeated statements: Memory for trivia. *Journal of Experimental Psychology: Human Learning and Memory*, 5, 241–252.
- Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. *Behavior Research Methods*, 37(3), 379–384.
- Balas, B., Kanwisher, N. G., & Saxe, R. (2012). Thin-slice perception develops slowly. *Journal of Experimental Child Psychology*, 112(2), 257–264.
- Ballew, C. C., & Todorov, A. (2007). Predicting political elections from rapid and unreflective face judgments. *Proceedings of the National Academy of Science*, 104(46), 17948–17953.
- Banks, M. S., & Salpatek, P. (1978). Acuity and contrast sensitivity in 1-month-old, 2-month-old, and 3-month-old human infants. *Investigative Ophthalmology & Visual Science*, 17(4), 361–365.
- Bar, M. (2003). A cortical mechanism for triggering top-down facilitation in visual object recognition. *Journal of Cognitive Neuroscience*, 15, 600–609.
- Bar, M., Kassam, K. S., Ghuman, A. S., Boshyan, J., Schmid, A. M., Dale, A. M., ... Halgren, E. (2006). Top-down facilitation of visual recognition. *Proceedings of the National Academy of Science*, 103(2), 449–454.
- Bar, M., Neta, M., & Linz, H. (2006). Very first impressions. *Emotion*, 6(2), 269–278.
- Barber, N. (1995). The evolutionary psychology of physical attractiveness: Sexual selection and human morphology. *Ethology and Sociobiology*, 16(5), 395–424.
- Barden, R. C. (1990). The effects of craniofacial deformity, chronic illness, and physical handicaps on patient and familial adjustment: Research and clinical perspectives. In B. B. Lahey, & A. E. Kazdin (Eds.). *Advances in clinical child psychology* (pp. 343–375). New York: Plenum Press.
- Barden, R. C., Ford, M. E., Jensen, A. G., Rogers-Salyer, M., & Salyer, K. E. (1989). Effects of craniofacial deformity in infancy on the quality of mother-infant interactions. *Child Development*, 60, 819–824.
- Batres, C., & Perrett, D. I. (2017). How the harsh environment of an army training camp changes human (homo sapiens) facial preferences. *Ethology*, 123(1), 61–68.
- Begg, I. M., Anas, A., & Farinacci, S. (1992). Dissociation of processes in belief: Source recollection, statement familiarity, and the illusion of truth. *Journal of Experimental Psychology: General*, 121, 446–458.
- Bornstein, R. F. (1989). Exposure and affect – Overview and meta-analysis of research, 1968–1987. *Psychological Bulletin*, 106(2), 265–289.
- Bornstein, R. F., & D’Agostino, P. R. (1992). Stimulus recognition and the mere exposure effect. *Journal of Personality and Social Psychology*, 63, 545–552.
- Bregman, A. S. (1981). Asking the “what for” question in auditory perception. In M. Kubovy, & J. R. Pomerantz (Eds.). *Perceptual organization* (pp. 99–118). Hillsdale, NJ: Erlbaum.
- Broerse, J., Vladusich, T., & O’Shea, R. P. (1999). Colour at edges and colour spreading in McCollough effects. *Vision Research*, 39, 1305–1320.
- Brown, E., & Perrett, D. I. (1993). What gives a face its gender? *Perception*, 22, 829–840.
- Burt, D. M., & Perrett, D. I. (1997). Perceptual asymmetries in judgements of facial attractiveness, age, gender, speech and expression. *Neuropsychologia*, 35, 685–693.
- Burton, A. M., & Vokey, J. R. (1998). The face-space typicality paradox: Understanding the face-space metaphor. *Quarterly Journal of Experimental Psychology*, 51(3), 475–483.
- Buss, D. M. (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. *Behavioral and Brain Sciences*, 12(1), 1–14.
- Buss, D. M., & Barnes, M. (1986). Preferences in human mate selection. *Journal of Personality and Social Psychology*, 50, 559–570.
- Buss, D. M., & Schmitt, D. P. (1993). Sexual strategies theory: An evolutionary perspective on human mating. *Psychological Review*, 100(2), 204–232.
- Carey, S. (1992). Becoming a face expert. *Proceedings of the Royal Society of London B*, 335(1273), 95–103.
- Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science*, 195(4275), 312–314.
- Cash, T. E., & Derlega, V. J. (1978). The matching hypothesis: Physical attractiveness among same-sexed friends. *Personality and Social Psychology Bulletin*, 4, 240–243.
- Cavanagh, P. (1995). Vision is getting easier every day. *Perception*, 24(11), 1227–1232.
- Cheung, O. S., Richler, J. J., Palmeri, T. J., & Gauthier, I. (2008). Revisiting the role of spatial frequencies in the holistic processing of faces. *Journal of Experimental Psychology: Human Perception and Performance*, 34(6), 1327–1336.
- Coetzee, V., Perrett, D. I., & Stephen, I. D. (2009). Facial adiposity: A cue to health? *Perception*, 38(11), 1700–1711.
- Cohen, M. A., Dennett, D. C., & Kanwisher, N. (2016). What is the bandwidth of perceptual experience? *Trends in Cognitive Sciences*, 20(5), 324–335.
- Cooper, P. A., & Maurer, D. (2008). The influence of recent experience on perceptions of attractiveness. *Perception*, 37(8), 1216–1226.
- Costen, N. P., Parker, D. M., & Craw, I. (1996). Effects of high-pass and low-pass spatial filtering on face identification. *Perception and Psychophysics*, 58(4), 602–612.
- Cruz, G. V. (2018). The impact of face skin tone vs face symmetry on perceived facial attractiveness. *Journal of General Psychology*, 145(2), 183–198.
- Cunningham, M. R. (1986). Measuring the physical in physical attractiveness: Quasi-experiments on the sociobiology of female facial beauty. *Journal of Personality and Social Psychology*, 50, 925–935.
- Curby, K. M., & Entenman, R. (2016). Framing faces: Frame alignment impacts holistic face perception. *Attention, Perception, and Psychophysics*, 78, 2569–2578.
- Damon, F., Mottier, H., Meary, D., & Pascalis, O. (2017). A review of attractiveness preferences in infancy: From faces to objects. *Adaptive Human Behavior and Physiology*, 3(4), 321–336.
- Davies, G., Ellis, H., & Shepherd, J. (1977). Cue saliency in faces as assessed by the “Photofit” technique. *Perception*, 6, 263–269.
- de Heering, A., Turati, C., Rossion, B., Bulf, H., Goffaux, V., & Simion, F. (2008). Newborns’ face recognition is based on spatial frequencies below 0.5 cycles per degree. *Cognition*, 106, 444–454.
- Defenbacher, K. A., Vetter, T., Johanson, J., & O’Toole, A. J. (1998). Facial aging, attractiveness, and distinctiveness. *Perception*, 27(10), 1233–1243.
- Dennett, D. C. (1991). *Consciousness explained*. Allen Lane: Little, Brown.
- Dennett, D. C. (1992). “Filling in” versus finding out: A ubiquitous confusion in cognitive science. In H. L. Pick, P. van den Broek, & D. C. Knill (Eds.). *Cognition: Conceptual and methodological issues* (pp. 33–49). Washington: American Psychological Association.
- Dion, K. (1972). Physical attractiveness and evaluation of children’s transgressions. *Journal of Personality and Social Psychology*, 24, 207–213.
- Dion, K. (1973). Young children’s stereotyping of facial attractiveness. *Developmental Psychology*, 9, 183–188.
- Dion, K. (1977). The incentive value of physical attractiveness for young children. *Personality and Social Psychology Bulletin*, 3, 67–70.
- Dion, K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of Personality and Social Psychology*, 24(3), 285.
- Dipboye, R. L., Fromkin, H. L., & Wiback, K. (1975). Relative importance of applicant sex, attractiveness, and scholastic standing in evaluation of job applicant resumes. *Journal of Applied Psychology*, 60(1), 39–43.
- Dixson, B. J., Little, A. C., Dixson, H. G., & Brooks, R. C. (2017). Do prevailing environmental factors influence preferences for facial morphology? *Behavioral Ecology*, 28(5), 1217–1227.
- Dobson, V., & Teller, D. Y. (1978). Visual acuity in human infants: Review and comparison of behavioral and electrophysiological studies. *Vision Research*, 18(11), 1469–1483.
- Dunstan, C. J., & Lindell, A. K. (2012). Hemifacial preferences for the perception of emotion and attractiveness differ with the gender of the one beheld. *Cognition and Emotion*, 26, 907–915.
- Eliot, M. (2004). *Cary grant: A biography*. New York: Crown Publishing Group.
- Etcoff, N. (1999). *Survival of the prettiest*. New York: Anchor.
- Faerber, S. J., Kaufmann, J. M., Leder, H., Martin, E. M., & Schweinberger, S. R. (2016). The role of familiarity for representations in norm-based face space. *PLoS One*, 11(5), e0155380.
- Farid, H., & Adelson, E. H. (1999). Separating reflections from images by use of independent component analysis. *Journal of the Optical Society of America A – Optics, Image Science, and Vision*, 16(9), 2136–2145.
- Fatke, B., Sadr, J., Corsbie-Massay, C. L., & Sinha, P. (under revision). Perception of facial attractiveness in degraded images.

- Feinberg, D. R. (2008). Are human faces and voices ornaments signaling common underlying cues to mate value? *Evolutionary Anthropology*, 17(2), 112–118.
- Feingold, A. (1992). Good-looking people are not what we think. *Psychological Bulletin*, 111, 304–341.
- Fink, B., Grammer, K., & Mads, P. J. (2006). Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces. *Evolution and Human Behavior*, 27(6), 433–442.
- Fink, B., Neave, N., Manning, J. T., & Grammer, K. (2006). Facial symmetry and judgments of attractiveness, health, and personality. *Personality and Individual Differences*, 41(3), 491–499.
- Fink, B., & Penton-Voak, I. (2002). Evolutionary psychology of facial attractiveness. *Current Directions in Psychological Science*, 11(5), 154–158.
- Foo, Y. Z., Simmons, L. W., & Rhodes, G. (2017). Predictors of facial attractiveness and health in humans. *Scientific Reports*, 7, 39731.
- Franklin, D. R., & Mewhort, D. J. (2015). Memory as a hologram: An analysis of learning and recall. *Canadian Journal of Experimental Psychology*, 69(1), 115–135.
- Fraser, I. H., Craig, G. L., & Parker, D. M. (1990). Reaction time measures of feature saliency in schematic faces. *Perception*, 19, 661–673.
- Freeman, W. T., Jones, T. R., & Pasztor, E. C. (2002). Example-based super-resolution. *IEEE Computer Graphics and Applications*, 22(2), 56–65.
- Galton, F. (1883). *Inquiries into human faculty and its development*. London: Macmillan.
- Gangestad, S. W., & Scheyd, G. J. (2005). The evolution of human physical attractiveness. *Annual Review of Anthropology*, 34, 523–548.
- Gao, X., & Maurer, D. (2011). A comparison of spatial frequency tuning for the recognition of facial identity and facial expressions in adults and children. *Vision Research*, 51, 508–519.
- Gauthier, I., & Tanaka, J. (1997). Expertise in object and face perception. *Psychology of Learning and Motivation*, 36, 83–125.
- Gava, L., Valenza, E., Turati, C., & de Schonen, S. (2008). Effect of partial occlusion on newborns' face preference and recognition. *Developmental Science*, 11(4), 563–574.
- Gerger, G., Leder, H., Timio, P. P., & Schacht, A. (2011). Faces versus patterns: Exploring aesthetic reactions using facial EMG. *Psychology of Aesthetics, Creativity, and the Arts*, 5(3), 241–250.
- Gibson, J. J. (1966). *The senses considered as perceptual systems*. Oxford, England: Houghton Mifflin.
- Gilad-Gutnick, S., Yovel, G., & Sinha, P. (2012). Recognizing degraded faces: The contribution of configural and featural cues. *Perception*, 41, 1497–1511.
- Ginsburg, A. P. (1978). *Visual information processing based on spatial filters constrained by biological data* (PhD Thesis). University of Cambridge, England. AFAMRL Technical Report AMRL-TR-78-129.
- Goffaux, V., Gauthier, I., & Rossion, B. (2003). Spatial scale contribution to early visual differences between face and object processing. *Cognitive Brain Research*, 16(3), 416–424.
- Goffaux, V., Peters, J., Haubrechts, J., Schiltz, C., Jansma, B., & Goebel, R. (2010). From coarse to fine? Spatial and temporal dynamics of cortical face processing. *Cerebral Cortex*, 21(2), 467–476.
- Goffaux, V., & Rossion, B. (2006). Faces are “spatial” – Holistic face perception is supported by low spatial frequencies. *Journal of Experimental Psychology: Human Perception and Performance*, 32(4), 1023–1039.
- Goldstein, A. G. (1983). Behavioral scientists' fascination with faces. *Journal of Nonverbal Behavior*, 7(4), 223–255.
- Goren, C. C., Sarty, M., & Wu, P. Y. (1975). Visual following and pattern-discrimination of face-like stimuli by newborn infants. *Pediatrics*, 56, 544–549.
- Grammer, K., & Thornhill, R. (1994). Human (*homo sapiens*) facial attractiveness and sexual selection: The role of symmetry and averageness. *Journal of Comparative Psychology*, 108(3), 233–242.
- Gregory, R. L. (1968). Visual illusions. *Scientific American*, 219(5), 66–79.
- Haig, N. D. (1986). Exploring recognition with interchanged facial features. *Perception*, 15, 235–247.
- Halper, F. (1997). The illusion of the Future. *Perception*, 26(10), 1321–1322.
- Halper, F. (1999). Construals of occlusion in the paintings of René Magritte. *Perception*, 28, 119.
- Halper, F. (2012). The parallelogram: A perceptual enigma. *Perception*, 41(1S), 94.
- Hamermesh, D. S., & Biddle, J. (1994). Beauty and the labor market. *American Economic Review*, 84, 1174–1194.
- Hamermesh, D. S., & Parker, A. M. (2003). Beauty in the classroom: Professors' punctitude and putative pedagogical productivity. *Economics of Education Review*, 23, 369–376.
- Hansen, R. M., & Fulton, A. B. (1993). Development of scotopic retinal sensitivity. In K. Simons (Ed.), *Early visual development, normal and abnormal* (pp. 130–142). New York: Oxford University Press.
- Harmon, L. D. (1973). The recognition of faces. *Scientific American*, 229(5), 70–83.
- Harmon, L. D., & Julesz, B. (1973). Masking in visual recognition: Effects of two-dimensional filtered noise. *Science*, 180(4091), 1194–1197.
- Hasher, L., Goldstein, D., & Toppino, T. (1977). Frequency and the conference of referential validity. *Journal of Verbal Learning and Verbal Behavior*, 16, 107–112.
- Hassin, R., & Trope, Y. (2000). Facing faces: Studies on the cognitive aspects of physiognomy. *Journal of Personality and Social Psychology*, 78(5), 837–852.
- Hildebrandt, K. A. (1983). Effect of facial expression variations on ratings of infants' physical attractiveness. *Developmental Psychology*, 19(3), 414–417.
- Hildebrandt, K. A., & Fitzgerald, H. E. (1978). Adults' responses to infants varying in perceived cuteness. *Behavioral Processes*, 3, 159–172.
- Hildebrandt, K. A., & Fitzgerald, H. E. (1981). Mothers' responses to infant physical appearance. *Infant Mental Health Journal*, 9, 32–42.
- Hsieh, P. J., Colas, J. T., & Kanwisher, N. G. (2012). Pre-stimulus pattern of activity in the fusiform face area predicts face percepts during binocular rivalry. *Neuropsychologia*, 50(4), 522–529.
- Ilfie, A. H. (1960). A study of preferences in female beauty. *British Journal of Psychology*, 51(3), 267–273.
- Jackson, T. H., Mitroff, S. R., Clark, K., Proffit, W. R., Lee, J. Y., & Nguyen, T. T. (2013). Face symmetry assessment abilities: Clinical implications for diagnosing asymmetry. *American Journal of Orthodontics and Dentofacial Orthopedics*, 144(5), 663–671.
- Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 9, 21–38.
- Jacoby, L. L., Kelley, C. M., Brown, J., & Jasechko, J. (1989). Becoming famous overnight: Limits on the ability to avoid unconscious influences of the past. *Journal of Personality and Social Psychology*, 56, 326–338.
- Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General*, 118, 126–135.
- Jenkins, R., White, D., Van Montfort, X., & Burton, A. M. (2011). Variability in photos of the same face. *Cognition*, 121(3), 313–323.
- Johansson, P., Hall, L., Sikstrom, S., & Olsson, A. (2005). Failure to detect mismatches between intention and outcome in a simple decision task. *Science*, 310, 116–119.
- Johnston, V. S., Hagel, R., Franklin, M., Fink, B., & Grammer, K. (2001). Male facial attractiveness: Evidence for hormone-mediated adaptive design. *Evolution and Human Behavior*, 22(4), 251–267.
- Jones, A. L., Kramer, R. S. S., & Ward, R. (2012). Signals of personality and health: The contributions of facial shape, skin texture, and viewing angle. *Journal of Experimental Psychology: Human Perception and Performance*, 38(6), 1353–1361.
- Jones, B. C., DeBruine, L. M., & Little, A. C. (2007). The role of symmetry in attraction to average faces. *Perception & Psychophysics*, 69(8), 1273–1277.
- Jones, B. C., Little, A. C., Burt, D. M., & Perrett, D. I. (2004). When facial attractiveness is only skin deep. *Perception*, 33(5), 569–576.
- Jones, B. T., Jones, B. C., Thomas, A. P., & Piper, J. (2003). Alcohol consumption increases attractiveness ratings of opposite-sex faces: A possible third route to risky sex. *Addiction*, 98(8), 1069–1075.
- Jones, M. N., & Mewhort, D. J. (2007). Representing word meaning and order information in a composite holographic lexicon. *Psychological Review*, 114(1), 1–37.
- Kalick, S. M., Zebrowitz, L. A., Langlois, J. H., & Johnson, R. M. (1998). Does human facial attractiveness honestly advertise health? Longitudinal data on an evolutionary question. *Psychological Science*, 9(1), 8–13.
- Karraker, K. H., & Stern, M. (1990). Infant physical attractiveness and facial expression: Effect on adult perceptions. *Basic and Applied Social Psychology*, 11(4), 371–385.
- Kenrick, D. T., Li, N. P., & Butner, J. (2003). Dynamical evolutionary psychology: Individual decision rules and emergent social norms. *Psychological Review*, 110(1), 3–28.
- Khalid, S., Finkbeiner, M., König, P., & Ansoorge, U. (2013). Subcortical human face processing? Evidence from masked priming. *Journal of Experimental Psychology: Human Perception and Performance*, 39(4), 989–1002.
- Klopfier, W. G., & Taulbee, E. S. (1976). Projective tests. *Annual Review of Psychology*, 27, 543–567.
- Kolers, P. A. (1976). Reading a year later. *Journal of Experimental Psychology: Human Learning and Memory*, 2(5), 554–565.
- Korthase, K. M., & Trenholme, I. (1982). Perceived age and perceived physical attractiveness. *Perceptual and Motor Skills*, 54, 1251–1258.
- Korthase, K. M., & Trenholme, I. (1983). Children's perceptions of age and physical attractiveness. *Perceptual and Motor Skills*, 56, 895–900.
- Kramer, R. S., Young, A. M., & Burton, A. M. (2018). Understanding face familiarity. *Cognition*, 172, 46–58.
- Kunst-Wilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science*, 207(4430), 557–558.
- Kveraga, K., Boshyan, J., & Bar, M. (2007). Magnocellular projections as the trigger of top-down facilitation in recognition. *Journal of Neuroscience*, 27(48), 13232–13240.
- Lai, M., Oruç, I., & Barton, J. J. S. (2013). The role of skin texture and facial shape in representations of age and identity. *Cortex*, 49(1), 252–265.
- Lai, J., Pancaroglu, R., Oruç, I., Barton, J. J., & Davies-Thompson, J. (2014). Neuroanatomic correlates of the feature-saliency hierarchy in face processing: an fMRI-adaptation study. *Neuropsychologia*, 53, 274–283.
- Landy, D., & Sigall, H. (1974). Beauty is talent: Task evaluation as a function of the performer's physical attractiveness. *Journal of Personality and Social Psychology*, 29(3), 299–304.
- 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), 390–423.
- Langlois, J. H., Ritter, J. M., Casey, R. J., & Sawin, D. B. (1995). Infant attractiveness predicts maternal behaviors and attitudes. *Developmental Psychology*, 31, 464–472.
- Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science*, 1, 115–121.
- Langlois, J. H., Roggman, L. A., Casey, R. J., Ritter, J. M., Rieser-Danner, L. A., & Jenkins, V. Y. (1987). Infant preferences for attractive faces: Rudiments of a stereotype? *Developmental Psychology*, 23(3), 363–369.
- Lau, S. (1982). The effect of smiling on person perception. *Journal of Social Psychology*, 117, 63–67.
- Lefevre, C. E., & Perrett, D. I. (2015). Fruit over sunbed: Carotenoid skin colouration is found more attractive than melanin colouration. *Quarterly Journal of Experimental Psychology*, 68(2), 284–293.
- Light, L. L., Hollander, S., & Kayra-Stuart, F. (1981). Why attractive people are harder to remember. *Personality and Social Psychology Bulletin*, 7(2), 269–276.
- Little, A. C. (2014a). Domain specificity in human symmetry preferences: Symmetry is most pleasant when looking at human faces. *Symmetry*, 6, 222–233.
- Little, A. C. (2014b). Facial attractiveness. *Wiley Interdisciplinary Reviews: Cognitive*

- Science, 5(6), 621–634.
- 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 of London B*, 274(1629), 3113–3117.
- Little, A. C., Burt, D. M., Penton-Voak, I. S., & Perrett, D. I. (2001). Self-perceived attractiveness influences human female preferences for sexual dimorphism and symmetry in male faces. *Proceedings of the Royal Society of London B*, 268, 39–44.
- Little, A. C., Burt, D. M., & Perrett, D. I. (2006). What is good is beautiful: Face preference reflects desired personality. *Personality and Individual Differences*, 41(6), 1107–1118.
- Little, A. C., DeBruine, L. M., & Jones, B. C. (2011). Facial attractiveness: evolutionary based research. *Philosophical Transactions of the Royal Society B*, 366(1571), 1638–1659.
- Little, A. C., Jones, B. C., DeBruine, L. M., & Feinberg, D. R. (2008). Symmetry and sexual dimorphism in human faces: Interrelated preferences suggest both signal quality. *Behavioral Ecology*, 19(4), 902–908.
- Little, A. C., Jones, B. C., Penton-Voak, I. S., Burt, D. M., & Perrett, D. I. (2002). Partnership status and the temporal context of relationships influence human female preferences for sexual dimorphism in male face shapes. *Proceedings of the Royal Society B*, 269(1496), 1095–1100.
- Little, A. C., Penton-Voak, I. S., Burt, D. M., & Perrett, D. I. (2003). Investigating an imprinting-like phenomenon in humans: Partners and opposite-sex parents have similar hair and eye colour. *Evolution and Human Behavior*, 24(1), 43–51.
- Liu, C., Shum, H. Y., & Freeman, W. T. (2007). Face hallucination: Theory and practice. *International Journal of Computer Vision*, 75(1), 115–134.
- Locher, P., Unger, R., Sociadade, P., & Wahl, J. (1993). At first glance: Accessibility of the physical attractiveness stereotype. *Sex Roles*, 28, 729–743.
- Lott, D. F. (1979). A possible role for generally adaptive features in mate selection and sexual stimulation. *Psychological Reports*, 45(2), 539–546.
- Lowe, D. G. (1985). *Perceptual organization and visual recognition*. Boston: Kluwer.
- Malik, W. Q., Schummers, J. M., Sur, M., & Brown, E. N. (2014). *U.S. Patent No. US8903192B2*. Washington, DC: U.S. Patent and Trademark Office.
- Mandler, G., Nakamura, Y., & Van Zandt, B. J. (1987). Nonspecific effects of exposure on stimuli that cannot be recognized. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 646–648.
- McCann, J. J., McKee, S. P., & Taylor, T. (1976). Quantitative studies in retinex theory. A comparison between theoretical predictions and observer responses to the “color Mondrian” experiments. *Vision Research*, 16, 445–458.
- Michotte, A., Thinès, G., & Crabbé, G. (1964). *Les compléments amodaux des structures perceptives*. Leuven, Belgium: Publications Universitaires de Louvain.
- Mita, T. H., Dermer, M., & Knight, J. (1977). Reversed facial images and the mere-exposure hypothesis. *Journal of Personality and Social Psychology*, 33(8), 597–601.
- Monin, B. (2003). The warm glow heuristic: When liking leads to familiarity. *Journal of Personality and Social Psychology*, 85(6), 1035.
- Montepare, J. M. (2010). “Cue, vue, action”: An ecological approach to person perception. In E. Balci, & G. D. Lassiter (Eds.). *Social psychology of visual perception* (pp. 299–323). New York: Psychology Press.
- Moreland, R. L., & Beach, S. R. (1992). Exposure effects in the classroom: The development of affinity among students. *Journal of Experimental Social Psychology*, 28(3), 255–276.
- Moreland, R. L., & Topolinski, S. (2010). The mere exposure phenomenon: A lingering melody by Robert Zajonc. *Emotion Review*, 2(4), 329–339.
- Moreland, R. L., & Zajonc, R. B. (1982). Exposure effects in person perception: Familiarity, similarity, and attraction. *Journal of Experimental Social Psychology*, 18, 395–415.
- Morgan, C. L. (1894). *An introduction to comparative psychology*. London: The Walter Scott publishing Co.
- Most, S. B., Smith, S. D., Cooter, A. B., Levy, B. N., & Zald, D. H. (2007). The naked truth: Positive, arousing distractors impair rapid target perception. *Cognition and Emotion*, 21(5), 964–981.
- Murstein, B. I. (1972). Physical attractiveness and marital choice. *Journal of Personality and Social Psychology*, 22, 8–12.
- Muth, C., Hessleringer, V. M., & Carbon, C. C. (2015). The appeal of challenge in the perception of art: How ambiguity, solvability of ambiguity, and the opportunity for insight affect appreciation. *Psychology of Aesthetics, Creativity, and the Arts*, 9(3), 206–216.
- Nasanen, R. (1999). Spatial frequency bandwidth used in the recognition of facial images. *Vision Research*, 39, 3824–3833.
- Norcia, A. M., Tyler, C. W., & Hamer, R. D. (1990). Development of contrast sensitivity in the human infant. *Vision Research*, 30(10), 1475–1486.
- Oinonen, K. A., & Mamanian, D. (2007). Facial symmetry detection ability changes across the menstrual cycle. *Biological Psychology*, 75(2), 136–145.
- Ojanpaa, H., & Nasanen, R. (2003). Utilization of spatial frequency information in face search. *Vision Research*, 43(24), 2505–2515.
- Olson, I. R., & Marshuetz, C. (2005). Facial attractiveness is appraised in a glance. *Emotion*, 5(4), 498–502.
- Oruç, I., & Barton, J. J. S. (2010a). A novel face aftereffect based on recognition contrast thresholds. *Vision Research*, 50, 1845–1854.
- Oruç, I., & Barton, J. J. S. (2010b). Critical frequencies in the perception of letters, faces, and novel shapes: Evidence for limited scale invariance for faces. *Journal of Vision*, 10:20(12), 1–12.
- Oruç, I., Guo, X. M., & Barton, J. J. S. (2011). Gender in facial representations: A contrast-based study of adaptation within and between the sexes. *PLOS One*, 6(1), e16251.
- O’Toole, A. J., Abdi, H., Deffenbacher, K. A., & Valentin, D. (1995). A perceptual learning theory of the information in faces. In T. Valentine (Ed.). *Cognitive and computational aspects of face recognition: Explorations in face space* (pp. 159–182). London: Routledge.
- Owsley, C., & Sloane, M. E. (1987). Contrast sensitivity, acuity, and the perception of ‘real-world’ targets. *British Journal of Ophthalmology*, 71, 791–796.
- Penton-Voak, I. S., Perrett, D. I., Castles, D. L., Kobayashi, T., Burt, D. M., Murray, L. K., & Minamisawa, R. (1999). Menstrual cycle alters face preference. *Nature*, 399(6738), 741–742.
- Perrett, D. I. (2010). *In your face*. London: Palgrave Macmillan.
- 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.
- Perrett, D. I., Lee, K. J., Penton-Voak, I., Rowland, D., Yoshikawa, S., Burt, D. M., ... Akamatsu, S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature*, 394, 884–887.
- Perrett, D. J., May, K. A., & Yoshikawa, S. (1994). Facial shape and judgements of female attractiveness. *Nature*, 368, 239–242.
- Perrett, D. I., Penton-Voak, I. S., Little, A. C., Tiddeman, B. P., Burt, D. M., Schmidt, N., ... Barrett, L. (2002). Facial attractiveness judgements reflect learning of parental age characteristics. *Proceedings of the Royal Society of London B*, 269, 873–880.
- 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.
- Peterzell, D. H., & Teller, D. Y. (1996). Individual differences in contrast sensitivity functions: The lowest spatial frequency channels. *Vision Research*, 36(19), 3077–3085.
- Phillips, P. J., Moon, H., Rizvi, S. A., & Rauss, P. (2000). The FERET evaluation methodology for face recognition algorithms. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22, 1090–1104.
- Phillips, P. J., Wechsler, H., Huang, J., & Rauss, P. (1998). The FERET database and evaluation procedure for face recognition algorithms. *Image and Vision Computing Journal*, 16(5), 295–306.
- Pinna, B., Brelstaff, G., & Spillmann, L. (2001). Surface color from boundaries: A new ‘watercolor’ illusion. *Vision Research*, 41, 2669–2676.
- Pisanski, K., & Feinberg, D. R. (2013). Cross-cultural variation in mate preferences for averageness, symmetry, body size, and masculinity. *Cross-Cultural Research*, 47(2), 162–197.
- Pollard, J., Shepherd, J., & Shepherd, J. (1999). Average faces are average faces. *Current Psychology*, 18(1), 98–103.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Quek, G. L., Liu-Shuang, J., Goffaux, V., & Rossion, B. (2018). Ultra-coarse, single-glance human face detection in a dynamic visual stream. *Neuroimage*, 176, 465–476.
- Ramachandran, V. S. (1988b). Perceiving shape from shading. *Scientific American*, 259(2), 76–83.
- Ramachandran, V. S. (1988a). Perception of shape from shading. *Nature*, 331, 163–166.
- Re, D. E., & Perrett, D. I. (2012). Concordant preferences for actual height and facial cues to height. *Personality and Individual Differences*, 53(7), 901–906.
- 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., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science*, 9(1), 45–48.
- 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, 259–267.
- Rhodes, G., Proffitt, F., Grady, J. M., & Sumich, A. (1998). Facial symmetry and the perception of beauty. *Psychonomic Bulletin & Review*, 5(4), 659–669.
- Rhodes, G., & Tremewan, T. (1996). Averageness, exaggeration, and facial attractiveness. *Psychological Science*, 7(2), 105–110.
- Rhodes, G., Yoshikawa, S., Palermo, R., Simmons, L. W., Peters, M., Lee, K., ... Crawford, J. R. (2007). Perceived health contributes to the attractiveness of facial symmetry, averageness, and sexual dimorphism. *Perception*, 36(8), 1244–1252.
- Rhodes, G., Zebrowitz, L. A., Clark, A., Kalick, S. M., Hightower, A., & McKay, R. (2001). Do facial averageness and symmetry signal health? *Evolution and Human Behavior*, 22(1), 31–46.
- Ritter, J. M., Casey, R. J., & Langlois, J. H. (1991). Adults’ responses to infants varying in appearance of age and attractiveness. *Child Development*, 62, 68–82.
- Ritter, J. M., & Langlois, J. H. (1988). The role of physical attractiveness in the observation of adult-child interactions: Eye of the beholder or behavioral reality? *Developmental Psychology*, 24(2), 254–263.
- Roberts, S. C., Little, A. C., Gosling, L. M., Perrett, D. I., Carter, V., Jones, B. C., ... Petrie, M. (2005). MHC-heterozygosity and human facial attractiveness. *Evolution and Human Behavior*, 26(3), 213–226.
- Roney, J. R., & Simmons, Z. L. (2008). Women’s estradiol predicts preference for facial cues of men’s testosterone. *Hormones and Behavior*, 53, 14–19.
- Rosner, T. M., Davis, H., & Milliken, B. (2015). Perceptual blurring and recognition memory: A desirable difficulty effect revealed. *Acta Psychologica*, 160, 11–22.
- Rossion, B. (2014). Understanding face perception by means of human electrophysiology. *Trends in Cognitive Sciences*, 18(6), 310–318.
- Rostamirad, S., Barton, J. J. S., & Oruç, I. (2009). Center-surround organization of face-space: Evidence from contrast-based face-priming. *Neuroreport*, 20(13), 1177–1182.
- Ruiz-Soler, M., & Beltran, F. S. (2006). Face perception: An integrative review of the role of spatial frequencies. *Psychological Research*, 70(4), 273–292.
- Rule, N. O., & Ambady, N. (2008). The face of success: Inferences from chief executive officers’ appearance predict company profits. *Psychological Science*, 19(2), 109–111.
- Rule, N. O., & Ambady, N. (2009). She’s got the look: Inferences from female chief executive officers’ faces predict their success. *Sex Roles*, 61, 644–652.
- Rule, N. O., Ambady, N., & Hallett, K. C. (2009). Female sexual orientation is perceived accurately, rapidly, and automatically from the face and its features. *Journal of*

- Experimental Social Psychology*, 45, 1245–1251.
- Sadr, J., Duchaine, B., & Nakayama, K. (2004). The perception of facial attractiveness in prosopagnosia. *Journal of Vision*, 4(8), 914a.
- Sadr, J., Fatke, B., Massay, C. L., & Sinha, P. (2002). Aesthetic judgments of faces in degraded images. *Journal of Vision*, 2(7), 743.
- Sadr, J., Jarudi, I., & Sinha, P. (2003). The role of eyebrows in face recognition. *Perception*, 32(3), 285–293.
- Sadr, J., & Sinha, P. (March 2001). Exploring object perception with Random Image Structure Evolution. MIT Artificial Intelligence Laboratory Memo No. 2001-06. Cambridge, MA: Massachusetts Institute of Technology. <https://dspace.mit.edu/handle/1721.1/7221>.
- Sadr, J., & Sinha, P. (2004). Object recognition and Random Image Structure Evolution. *Cognitive Science*, 28, 259–287.
- Sadr, J., Troje, N. F., & Nakayama, K. (2005). Axes vs averages: High-level representations of dynamic point-light forms. *Visual Cognition*, 14, 119–122.
- Sadr, J., Troje, N. F., & Nakayama, K. (2006). A pedestrian courtship: Attractiveness and symmetry of humans walking. *Journal of Vision*, 6(6), 797a.
- Samuels, C. A., Butterworth, G., Roberts, T., Graupner, L., & Hole, G. (1994). Facial aesthetics: Babies prefer attractiveness to symmetry. *Perception*, 23(7), 823–831.
- Samuels, C. A., & Ewy, R. (1985). Aesthetic perception of faces during infancy. *British Journal of Developmental Psychology*, 3, 221–228.
- 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*, 266(1431), 1913–1917.
- Schurgin, M. W., Nelson, J., Iida, S., Ohira, H., Chiao, J. Y., & Franconeri, S. L. (2014). Eye movements during emotion recognition in faces. *Journal of Vision*, 14(13), 14.
- Scott, N. J., Kramer, R. S. S., Jones, A. L., & Ward, R. (2013). Facial cues to depressive symptoms and their associated personality attributions. *Psychiatry Research*, 206(1), 47–53.
- Secord, P. (1958). Facial features and inference processes in interpersonal perception. In R. Tagiuri, & L. Petrullo (Eds.), *Person perception and interpersonal behaviour* (pp. 300–315). Stanford, CA: Stanford University Press.
- Sekuler, A. B. (1994). Local and global minima in visual completion – Effects of symmetry and orientation. *Perception*, 23(5), 529–545.
- Sergent, J. (1986). Microgenesis of face perception. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. Young (Eds.), *Aspects of face processing* (pp. 17–33). Dordrecht: Springer.
- Shahangian, K., & Oruç, I. (2014). Looking at a blurry old family photo? Zoom out!. *Perception*, 43, 90–98.
- Shepard, R. N. (1990). *Mind sights: Original visual illusions, ambiguities, and other anomalies, with a commentary on the play of mind in perception and art*. New York: WH Freeman & Co.
- Shepherd, J. W., & Ellis, H. D. (1973). The effect of attractiveness on recognition memory for faces. *American Journal of Psychology*, 86(3), 627–633.
- Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, 63(2), 129–138.
- Singh, D. (1993). Adaptive significance of female physical attractiveness: Role of waist-to-hip ratio. *Journal of Personality and Social Psychology*, 65(2), 293–307.
- Sinha, P. (2002). Identifying perceptually significant features for recognizing faces. *Proceedings of SPIE: Human Vision and Electronic Imaging VII*, 4662, 12–21. <https://doi.org/10.1117/12.469529>.
- Sinha, P., & Poggio, T. (1996). I think I know that face.... *Nature*, 384(6608), 404.
- Sitton, S. C., Waite, L., & Rivers, S. C. (2006). Perception of traits from normal, mirror, and chimeric images of faces. *American Journal of Psychological Research*, 2(1), 14–20.
- Slater, A. M., Bremner, G., Johnson, S. P., Sherwood, P., Hayes, R., & Brown, E. (2000). Newborn infants' preference for attractive faces: The role of internal and external facial features. *Infancy*, 1(2), 265–274.
- Slater, A. M., Quinn, P. C., Hayes, R., & Brown, E. (2000). The role of facial orientation in newborn infants' preference for attractive faces. *Developmental Science*, 3, 181–185.
- Slater, A. M., Von der Schulenburg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S., & Samuels, C. (1998). Newborn infants prefer attractive faces. *Infant Behavior and Development*, 21, 345–354.
- Snyder, M., Tanke, E. D., & Berscheid, E. (1977). Social perception and interpersonal behavior: On the self-fulfilling nature of social stereotypes. *Journal of Personality and Social Psychology*, 35, 656–666.
- Sporer, S. L. (1992). *Das Wiedererkennen von Gesichtern*. Weinheim: Psychologie Verlags Union.
- Stephan, C., & Langlois, J. H. (1984). Baby beautiful: Adult attributions of infant competence as a function of infant attractiveness. *Child Development*, 55, 576–585.
- Stephen, I. D., Coetsee, V., Smith, M. L., & Perrett, D. I. (2009). Skin blood perfusion and oxygenation colour affect perceived human health. *PLOS One*, 4(4), e5083.
- Stirrat, M., Gumert, M., & Perrett, D. (2011). The effect of attractiveness on food sharing preferences in human mating markets. *Evolutionary Psychology*, 9(1), 79–91.
- Swaddle, J. P., & Cuthill, I. C. (1995). Asymmetry and human facial attractiveness: Symmetry may not always be beautiful. *Proceedings of the Royal Society of London B*, 261(1360), 111–116.
- Symons, D. (1979). *The evolution of human sexuality*. Oxford: Oxford University Press.
- Symons, D. (1992). The use and misuse of Darwinism in the study of human behavior. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind*. Oxford: Oxford University Press.
- Symons, D. (1995). Beauty is in the adaptations of the beholder: The evolutionary psychology of human female sexual attractiveness. In P. R. Abramson, & S. D. Pinkerton (Eds.), *Sexual nature, sexual culture*. Chicago: University of Chicago Press.
- Tarr, M. J., & Pinker, S. (1989). Mental rotation and orientation-dependence in shape recognition. *Cognitive Psychology*, 21, 233–282.
- Teller, D. Y. (1984). Linking propositions. *Vision Research*, 24(10), 1233–1246.
- Teller, D. Y. (1997). First glances: The vision of infants. The Friedenwald lecture. *Investigative Ophthalmology & Visual Science*, 38(11), 2183–2203.
- Thornhill, R., & Gangestad, S. W. (1993). Human facial beauty: Averageness, symmetry, and parasite resistance. *Human Nature*, 4(3), 237–269.
- Thornhill, R., & Gangestad, S. W. (1999). Facial attractiveness. *Trends in Cognitive Science*, 3(12), 452–460.
- Thornton, G. R. (1943). The effect upon judgments of personality traits of varying a single factor in a photograph. *Journal of Social Psychology*, 18(1), 127–148.
- Tinbergen, N. (1963). On aims and methods of ethology. *Zeitschrift für Tierpsychologie*, 20, 410–433.
- Tinio, P. P. L., & Leder, H. (2009). Natural scenes are indeed preferred, but image quality might have the last word. *Psychology of Aesthetics, Creativity, and the Arts*, 3(1), 52–56.
- Todorov, A., Mandisodza, A. N., Goren, A., & Hall, C. C. (2005). Inferences of competence from faces predict election outcomes. *Science*, 308, 1623–1626.
- Todorov, A., & Uleman, J. S. (2003). The efficiency of binding spontaneous trait inferences to actors' faces. *Journal of Experimental Social Psychology*, 39, 549–562.
- Torralla, A., & Sinha, P. (Nov 2001). Detecting faces in impoverished images. MIT Artificial Intelligence Laboratory Memo No. 2001-028. Cambridge, MA: Massachusetts Institute of Technology. <https://dspace.mit.edu/handle/1721.1/7242>.
- Torrance, J. S., Wincenciak, J., Hahn, A. C., DeBruine, L. M., & Jones, B. C. (2014). The relative contribution of facial shape and surface information to perceptions of attractiveness and dominance. *PLOS One*, 9(10), e104415.
- Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, 12, 97–136.
- Trivers, R. L. (1972). Parental investment and sexual selection. In B. Campbell (Ed.), *Sexual selection and the descent of man* (pp. 136–179). Chicago: Aldine.
- Troje, N. F., Sadr, J., Geyer, H., & Nakayama, K. (2006). Adaptation after-effects in the perception of gender from biological motion. *Journal of Vision*, 6(8), 850–857.
- Turk-Browne, N. B., Junge, J. A., & Scholl, B. J. (2005). The automaticity of visual statistical learning. *Journal of Experimental Psychology: General*, 134(4), 552–564.
- Ullman, S. (1995). Sequence seeking and counter streams: A computational model for bidirectional information flow in the visual cortex. *Cerebral Cortex*, 1, 1–11.
- Vapnik, V. N., & Chervonenkis, A. Y. (1964). A class of algorithms for pattern recognition learning. *Avtomatika i Telemekhanika*, 25(6), 937–945.
- Vickery, T. J., Chun, M. M., & Lee, D. (2011). Ubiquity and specificity of reinforcement signals throughout the human brain. *Neuron*, 72(1), 166–177.
- Vokey, J. R., & Read, J. D. (1985). Subliminal messages: Between the devil and the media. *American Psychologist*, 40(11), 1231–1239.
- Vokey, J. R., & Read, J. D. (1992). Familiarity, memorability, and the effect of typicality on the recognition of faces. *Memory & Cognition*, 20(3), 291–302.
- Vokey, J. R., & Read, J. D. (1995). Memorability, familiarity, and categorical structure in the recognition of faces. In T. Valentine (Ed.), *Cognitive and computational aspects of face recognition: Explorations in face space* (pp. 113–137). London: Routledge.
- Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience*, 6(6), 624–631.
- Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Sing, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization. *Psychological Bulletin*, 138(6), 1172–1217.
- Walster, E., Aronson, V., Abrahams, D., & Rottman, L. (1966). Importance of physical attractiveness in dating behavior. *Journal of Personality and Social Psychology*, 4(5), 508–516.
- Walster, E., Walster, G. W., Piliavin, J., & Schmidt, L. (1973). "Playing hard to get": Understanding an elusive phenomenon. *Journal of Personality and Social Psychology*, 26(1), 113–121.
- Waynforth, D., Delwadia, S., & Camm, M. (2005). The influence of women's mating strategies on preference for masculine facial architecture. *Evolution and Human Behavior*, 26, 409–416.
- Welling, L. L. M., DeBruine, L. M., Little, A. C., & Jones, B. C. (2009). Extraversion predicts individual differences in women's face preferences. *Personality and Individual Differences*, 47, 996–998.
- Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 1235–1253.
- Whittlesea, B. W. A., Jacoby, L. L., & Girard, K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language*, 29(6), 716–732.
- Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods*, 42(3), 671–684.
- 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, T. D. C., & Nisbett, R. E. (1978). The accuracy of verbal reports about the effects of stimuli on evaluations and behavior. *Social Psychology*, 41(2), 118–131.
- Wilson, W. R. (1979). Feeling more than we can know: Exposure effects without learning. *Journal of Personality and Social Psychology*, 37, 811–821.
- Winkielman, P., & Cacioppo, J. T. (2001). Mind at ease puts a smile on the face: Psychophysiological evidence that processing facilitation elicits positive affect. *Journal of Personality and Social Psychology*, 81(6), 989–1000.
- Winkielman, P., Halberstadt, J., Fazendeiro, T., & Catty, S. (2006). Prototypes are attractive because they are easy on the mind. *Psychological Science*, 17(9), 799–806.
- Wood, D., Harms, P., & Vazire, S. (2010). Perceiver effects as projective tests: What your perceptions of others say about you. *Journal of Personality and Social Psychology*, 99(1), 174–190.
- Yang, N., Shafai, F., & Oruç, I. (2014). Size determines whether specialized expert processes are engaged for recognition of faces. *Journal of Vision*, 14(8), 17 1–12.
- Yip, A. W., & Sinha, P. (2002). Contribution of color to face recognition. *Perception*, 31,

- 995–1003.
- Young, A. W., & Burton, A. M. (2018). Are we face experts? *Trends in Cognitive Sciences*, 22(2), 100–110.
- Young, S. G., Sacco, D. F., & Hugenberg, K. (2011). Vulnerability to disease is associated with a domain-specific preference for symmetrical faces relative to symmetrical non-face stimuli. *European Journal of Social Psychology*, 41(5), 558–563.
- Yue, C. L., Castel, A. D., & Bjork, R. A. (2013). When disfluency is – and is not – a desirable difficulty: The influence of typeface clarity on metacognitive judgments and memory. *Memory & Cognition*, 41(2), 229–241.
- Zaidel, D. W., Aarde, S. M., & Baig, K. (2005). Appearance of symmetry, beauty, and health in human faces. *Brain and Cognition*, 57, 261–263.
- Zaidel, D. W., Chen, A. C., & German, C. (1995). She is not a beauty even when she smiles: Possible evolutionary basis for a relationship between facial attractiveness and hemispheric-specialization. *Neuropsychologia*, 33(5), 649–655.
- Zaidel, D. W., & Cohen, J. A. (2005). The face, beauty, and symmetry: Perceiving asymmetry in beautiful faces. *International Journal of Neuroscience*, 115(5), 1165–2117.
- Zaidel, D. W., & Deblieck, C. (2007). Attractiveness of natural faces compared to computer constructed perfectly symmetrical faces. *International Journal of Neuroscience*, 117, 423–431.
- Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology Monographs*, 9 (2, pt.2).
- Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist*, 35, 151–175.
- Zajonc, R. B. (1984). On the primacy of affect. *American Psychologist*, 39, 117–123.
- Zajonc, R. B., Reimer, D. J., & Hausser, D. (1973). Imprinting and development of object preference in chicks by mere repeated exposure. *Journal of Comparative and Physiological Psychology*, 83(3), 434–440.
- Zebrowitz, L. A. (1997). *Reading faces: Window to the soul*. New York: Westview.
- Zebrowitz, L. A., & McDonald, S. M. (1991). The impact of litigants' babyfacedness and attractiveness on adjudications in small claims courts. *Law and Behavior*, 15, 603–623.