Do the eyes have it?

The role of stimulus content, visual context, and task settings in social attention

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Abstract

Faces convey a wide range of information that is important for behaviour, emotional responses, and survival. As such, it is not surprising that visual and cognitive processing of faces in the human brain is facilitated by specialized neural systems. Research also suggests that this processing advantage extends into the attentional domain, with previous work showing that attention is spontaneously and preferentially biased towards faces and their features like eyes, an effect known as *social attention*.

However, past studies on social attention have typically not accounted for the influence of extraneous factors that are known to play a powerful role in biasing attention spontaneously. Specifically, these factors influence attention by communicating *stimulus content*, which are tied to the physical properties of the stimuli, such as size, distance from central fixation, global luminance, featural configuration, and perceived attractiveness; *visual context*, which impact how stimuli are perceived, such as background information and novelty; and *task settings*, which are external to the stimuli, such as stimulus predictability, method of manual response, and comparison stimuli.

The work presented in this dissertation examined the contribution of stimulus content, visual context, and task setting factors to social attentional biasing when participants' eye movements were restricted and when they were not restricted. Chapter 2 controlled for all content, context, and task factors and found that faces did not robustly bias attention. Chapter 3 investigated the role of stimulus content factors of global luminance, featural configuration, and perceived attractiveness and found that facial attractiveness was the only factor that resulted in reliable social attention biasing, but only when eye movements were not restricted. Chapters 4 and 5 investigated the contribution of visual context factors of background information and novelty, respectively. Both manipulations resulted in social attention biasing, but again only when eye movements were not restricted. No stimulus content or visual context manipulation reinstated social attentional biasing when eye movements were restricted.

Together, these data show that faces do not bias attention spontaneously, independent from extraneous factors conveyed by stimulus content, visual context, and task settings. They also show dissociations in social attention when eye movements are restricted versus when they are not restricted. As such, this work makes significant contributions to the understanding of social attention and its mechanisms, and re-conceptualizes social attention from a singular ability that is driven by facial information alone to a more complex process that may be driven and influenced by a multitude of external factors.

Résumé

Les visages transmettent une grande quantité d'informations qui sont importantes pour le comportement, les réponses émotionnelles, et la survie. En tant que tel, il n'est pas surprenant de constater que des systèmes neuronaux spécialisés facilitent le traitement visuel et cognitif des visages dans le cerveau humain. La recherche suggère également que cet avantage de traitement s'étend à l'attention, les travaux antérieurs montrant que l'attention est spontanément et préférentiellement biaisé en faveur des visages et de leurs caractéristiques comme les yeux, un effet connu comme *l'attention sociale*.

Cependant, les études antérieures sur l'attention sociale n'ont généralement pas tenu compte de l'influence importante de facteurs externes qui sont connus pour jouer un rôle puissant en biaisant attention spontanément. Spécifiquement, ces facteurs influencent l'attention par l'intermédiaire *du contenu du stimulus*, qui est lié aux propriétés physiques des stimuli, telles que la taille, la distance de la fixation centrale, la luminance globale, la configuration des caractéristiques, et l'attractivité perçue; *du contexte visuel*, qui a un impact sur la perception des stimuli, telles que les informations de fond et la nouveauté; et *des paramètres de la tâche*, qui sont externes aux stimuli, telles que la prédictibilité des stimuli, la méthode de réponse manuelle, et les stimuli de comparaison.

Le travail présenté dans cette thèse examine la contribution des facteurs qui relèvent du contenu du stimulus, du contexte visuel, et des paramètres de la tâche sur le biais d'attention sociale lorsque les mouvementes oculaires des participants sont restreints et lorsqu'ils ne sont pas restreints. Le chapitre 2 montre que les visages ne biaisent pas l'attention de façon robuste lorsque l'ensemble des facteurs de contenu, de contexte, et de tâche sont contrôlés. Le chapitre 3 examine l'influence des facteurs de contenu du stimulus comme la luminance globale, la

configuration des caractéristiques, et l'attractivité perçue, et montre que l'attractivité faciale représente le seul facteur qui biaise fiablement l'attention sociale, mais uniquement lorsque les mouvements oculaires ne sont pas restreints. Les chapitres 4 et 5 investiguent la contribution des facteurs de contexte visuel, à savoir les informations de fond et la nouveauté, respectivement. Ces travaux révèlent que ces deux facteurs produisent un biais d'attention sociale, mais à nouveau uniquement lorsque les mouvements oculaires ne sont pas restreints. Aucune des manipulations de contenu du stimulus et de contexte visuel n'a rétabli le biais d'attention sociale lorsque les mouvements oculaires sont restreints.

Ensemble, ces résultats montrent que les visages ne biaisent pas attention spontanément indépendamment des facteurs externes qui transmettent le contenu du stimulus, le contexte visuel, et les paramètres de la tâche. Ils révèlent également des dissociations importantes dans l'attention sociale lorsque les mouvements oculaires sont restreints contre lorsqu'ils ne sont pas restreints. En tant que tel, ce travail contribue de manière significative à notre compréhension de l'attention sociale et de ses mécanismes, et reconceptualise l'attention social d'une capacité cognitive singulière purement dirigée par l'information faciale à un processus plus complexe qui dépend également de l'influence de plusieurs facteurs externes.

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Contribution to original knowledge

The notion that faces and facial features are highly relevant to our visual environment has been demonstrated in evolutionary, developmental, social, cognitive, and neurological work. As such, it would be intuitive to expect that these stimuli would also lead to spontaneous biasing of attention. Although a number of studies have been published in support of this intuition, distinct methodological issues from past work made it difficult to ascertain whether these results were due to the unique influence of faces themselves or the influence of extraneous factors of stimulus content, visual context, and/or task settings.

The studies contained within this dissertation investigated the specific role that these extraneous factors play in social attention. Across four chapters, the data indicated that robust social attentional biasing is highly dependent on extraneous factors, such that when faces are devoid of stimulus content, visual context, and task setting information, they do not elicit robust social attentional effects. As such, this work provides one of the first systematic investigations that show the fragility of spontaneous social attentional biasing within standard laboratory tasks. Furthermore, they also challenge the prevailing notion that faces and facial features spontaneously bias human attention and make a significant theoretical contribution in understanding the nature of social attention and its underlying mechanisms.

Contribution of authors

I am the primary author on all four of the manuscripts presented within this dissertation. I designed, implemented, analyzed, and wrote all of the papers with direction from my supervisor Dr. Jelena Ristic and our collaborator Dr. Elina Birmingham.

General Introduction

The answer to the question "*are faces special*" is often an obvious one. Routine behaviours like looking for a friend in a café or people watching while walking down the street anecdotally support the notion that faces are a special type of stimulus – they convey unique information about others' gaze, emotional expressions, and/or identity, which is often beneficial and sometimes critically important for our behaviour, emotional wellbeing, and/or survival (V. Bruce & Young, 1986; Darwin, 2013; Willis & Todorov, 2006).

The answer to the question "*do faces engage human cognitive and perceptual processes in a unique manner"* is a less obvious one, and remains a topic of wide interest among neuroscientists, cognitive psychologists, and social psychologists. The main aim of the studies in this dissertation was to address this question by investigating the degree to which faces spontaneously attract human attention, both under conditions when participants' eye movements are withheld and when they are measured. This was accomplished by examining the role that stimulus content within the face, visual context surrounding the face, and specific task settings play in how attention is attracted by faces and their features like eyes. Surprisingly, and in contrast to a large body of existing work, the present experiments showed that when these factors are controlled, attention towards faces is often abolished or muted at best.

To introduce the theoretical question and the experimental manipulations, the following literature review is organized into five sections. Section I reviews the literature on the functional importance of faces and the cognitive and perceptual processes that facilitate the rapid acquisition of facial information. Section II provides an overview of attentional processes and the different ways in which attention may be engaged. Section III reviews work on social attention, or attention to faces and facial features like eyes. Section IV outlines the main theoretical question, and Section V presents an overview of the research methodology and the four experimental manuscripts that comprise this dissertation.

Literature Overview

Section I: The functional and cognitive importance of faces

Faces are one of the key carriers of social information, conveying important knowledge about others such as intentions, interests, identity, sex, age, race, mood, and/or current goals. Social cues from faces are often prioritized given their importance for survival within social groups, as our evolutionary ancestors would have relied heavily on this source of information in order to promote survival (Argyle, 1969; Brüne & Brüne-Cohrs, 2006). As such, the visual system may have evolved to process social visual signals quickly and efficiently in order to enhance one's ability to accurately perceive and respond to social cues (Corballis & Lea, 2000; Whiten & Byrne, 1988).

Primate data. Humans are not the only species with the ability to quickly and effectively process social cues. Non-human primates, such as macaques, chimpanzees, orangutans, and gorillas, also process facial information efficiently. Single cell recordings from primates have established that specific neurons in the temporal cortex, particularly the temporal polysensory area and the ventral bank of the superior temporal sulcus, are highly responsive to stimuli like eyes, faces, and head direction (C. Bruce, Desimone, & Gross, 1981; Desimone, Albright, Gross, & Bruce, 1984; Gross, Bender, & Rocha-Miranda, 1969; Perrett, Rolls, & Caan, 1982). This finding is supported by research conducted using eye movements or looking time to demonstrate that infant macaques and gibbons preferentially process face-like objects relative to non-face objects (Keating & Keating, 1982; Myowa-Yamakoshi & Tomonaga, 2001; Parr, 2011;

Sugita, 2008). This general preference for faces also extends to information coming from facial features, specifically the eyes, as chimpanzees also appear to spontaneously follow the direction of both human and primate gaze (Povinelli & Eddy, 1996, 1997; Tomasello, Call, & Hare, 1998; Tomasello, Hare, & Agnetta, 1999). Although eye gaze cues in humans are more visually salient than eye gaze cues in primates due to the larger contrast between iris and sclera (Campbell, 1957; Kobayashi & Kohshima, 2001), both humans and primates have similar anatomical and musculature structures around the eye region that support an elaborate repertoire of facial signals (Burrows, Waller, Parr, & Bonar, 2006; E. Huber, 1931; P. J. Huber, 1961). Together, this research illustrates that functional specialization within the primate visual and anatomical systems may facilitate social communication through a quick and accurate reading of facial signals.

Neurological research. Similar to this work, the human brain has also been shown to posses a distributed network of specialized processing hubs in support of visual processing of faces and facial features. These structures are located both within the right temporal lobe (i.e., the fusiform face area, the superior temporal sulcus, and the occipital face area), and among subcortical and cortical structures (i.e., the limbic system, insula, amygdala, lateral prefrontal cortex), that are specifically tuned to processing of faces, gaze information, and other socio-biological signals (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Gauthier, Tarr, et al., 2000; Haxby & Gobbini, 2012; Haxby et al., 1994; Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; Little, Jones, & DeBruine, 2011; Nummenmaa & Calder, 2008; Perrett, Hietanen, Oram, Benson, & Rolls, 1992; Perrett et al., 1985; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Thomas, De Bellis, Graham, & LaBar, 2007; Yovel, Levy, Grabowecky, & Paller, 2003). Research on cell responses within the temporal region has shown a spectrum of sensitivity for social information (Oram & Perrett, 1994; Perrett et al., 1985), with face perception marked by a specific time course that shows a large negative potential at 170ms after face presentation (Amihai, Deouell, & Bentin, 2011; Bentin et al., 1996; Eimer, 2000b; Itier & Taylor, 2004; Puce et al., 1998; Rousselet, Mace, & Fabre-Thorpe, 2003). This N170 response appears to be driven by the eye region (Itier, Alain, Sedore, & McIntosh, 2007; Itier & Batty, 2009; Nummenmaa & Calder, 2008), and is lateralized in the right hemisphere, such that superior processing effects for faces and facial features are seen when faces are presented in the left visual field (Yovel et al., 2003).

This work is also supported by neuropsychological investigations in humans who have deficits or damage to face processing regions in the right temporal lobe, which typically results in prosopagnosia, a neurological syndrome which affects one’s ability to process and recognize faces (Barton & Cherkasova, 2003; Damasio, Damasio, & Van Hoesen, 1982). In addition, deficits within these critical neural systems have been associated with the development of social-cognitive disorders such as social anxiety, autism spectrum disorder, and/or schizophrenia (Avery, VanDerKlok, Heckers, & Blackford, 2016; Baron-Cohen, 1995; Harvey & Penn, 2010; Tsunoda et al., 2012).

Human development. Reflecting these neural specializations, prioritization of faces and facial features is also found early in human development. Studies suggest that newborns show a strong preference for face and face-like features soon after birth (Farroni, Csibra, Simion, & Johnson, 2002; Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Simion & Giorgio, 2015; Valenza, Simion, Cassia, & Umilta, 1996). In the days and months thereafter, there is rapid development in the sophistication with which infants respond to faces compared to other objects in their environment. Facial recognition occurs during the first few days and months of life (Johnson et al., 1991; Pascalis & de Schonen, 1994), with infants showing preferential processing of faces (Fagan, 1972), and particularly faces of caregivers over strangers (Maurer & Salapatek, 1976) and face categorized by gender (Cohen & Strauss, 1979) and emotion (Ludemann & Nelson, 1988). During this time, prioritization of information relayed by eye gaze is also observed, as infants start to follow gaze direction within the first few months of life (Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998), leading to differential processing for gazed-at objects (Hoehl, Reid, Mooney, & Striano, 2008; Reid & Striano, 2005; Reid, Striano, Kaufman, & Johnson, 2004). These findings demonstrate that specialized processing systems allow for a prioritization of social information from very early on in development.

Specialized processing by the visual system. Given these critical neural components that are present early in development, it is not surprising that the human visual system demonstrates specific specializations for processing of faces and eyes. Numerous studies have demonstrated that face processing proceeds in a differential and unique manner than processing of other stimuli. Three features are particularly prominent. One, faces are typically faster to perceive and identify when presented in an upright rather than inverted orientation (Frank, Vul, & Johnson, 2009; Hochberg & Galper, 1967; Simion & Giorgio, 2015; Yin, 1969). This upright advantage is more stable for faces than other stimuli, as inversion effects for letters and objects have been found to fade with repeated practice (Corballis, Zbrodoff, Shetzer, & Butler, 1978; McKone & Grenfell, 1999), whereas inversion effects for faces are sustained even after tens of thousands of trials (McKone, Martini, & Nakayama, 2001; Robbins & McKone, 2003). Two, faces appear to be processed in a holistic rather than piecemeal fashion, with research finding superior processing and recognition of faces when they are presented as a whole as opposed to in parts, an advantage that is not found for inverted faces or non-social stimuli (Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993; Tanaka & Simonyi, 2016). Finally, processing for faces is found to be less viewpoint-dependent than processing of non-social stimuli, such that individual faces can be recognized and distinguished at various angles (Burke, Taubert, & Higman, 2007; Pike, Kemp, Towell, & Phillips, 1997), whereas recognition accuracy for non-social objects decrease linearly with viewpoint size change (W. G. Hayward, 2003; Tarr & Cheng, 2003).

Section II: Attentional processing

Given the high degree of specialization for face processing within our cognitive and perceptual systems, it would not be surprising to find that faces and facial features also engage human attention preferentially. Before examining the evidence for this hypothesis in Section III, a brief overview of the fundamentals of human attention as they pertain to the work in this dissertation is presented here.

The human visual system is constantly confronted with large amounts of sensory information. Attentional processing aids perception by selecting and prioritizing sensory information based on features, task, or importance. For instance, when driving down a street, attention can filter out irrelevant information like trees or buildings, and select relevant information like the road, other cars, traffic lights, and pedestrians. This latter process, known as *attentional selection* or *attentional biasing*, allows humans to align their attentional and cognitive resources with specific spatial locations (e.g., the road), objects (e.g., other cars, traffic lights), or sensory features (e.g., the sudden appearance of a pedestrian running into the street) in order to select that information for further processing. The aligning of attentional resources with specific spatial locations, objects, and/or stimulus features has been found to increase accuracy and speed of processing for attended events at these locations, which in experimental tasks, lead to faster and more accurate behavioural responses and enhanced neural processing for attended versus unattended locations, objects, and/or features (Carrasco, 2011; Kanwisher & Wojciulik, 2000; Posner, 2016).

Types of attentional biasing. The driving example can be used to illustrate two important characteristics of human attention (Klein & Pontefract, 1994; M. S. Peterson, Kramer, & Irwin, 2004; Van der Stigchel & Theeuwes, 2007). One of these characteristics concerns whether attentional focus moves jointly with our eyes, particularly given that our attentional focus may not always correspond to where we are looking. When attention is engaged independently from eye movements, it is biased in a *covert* manner (Jonides, 1981). Using the driving example, covert attention would be a scenario wherein we keep our eyes on the road but are briefly attending to the console to change the radio station. When attention is engaged together with eye movements such that attentional focus is aligned with where we are looking, it is biased in an *overt* manner (Posner, 1980). In the driving example, overt attention would entail both fixating our eyes and paying attention to the road.

Covert attention is typically assessed in the laboratory using tasks that require participants to keep their eyes fixated at a central location, while attentional cues and response targets are presented in the visual periphery. Critically, during the task, participants' manual performance is measured for targets that occur at a location where attention is captured by a peripheral cue (e.g., a flash of light, a burst of sound) relative to targets that occur at a location where attention was not captured by the cue. If responses are faster and/or more accurate for targets at attended locations, the implication is that covert attention has influenced the speed and quality of target processing.

In contrast, overt attention is typically assessed in the laboratory using tasks that allow participants to freely look at stimuli while measuring and tracking their eye movements, either with a camera or a high-speed eye tracker. During the task, participants' fixation or saccadic frequency, speed, or distribution is measured for regions of interest that contain relevant stimuli or spatial locations relative to other regions. If fixation or saccadic frequency is higher, speed is faster, and/or distribution is larger for relevant regions of interest, the implication is that overt attention has impacted the speed of attentional deployment and associated level of processing for these regions.

Early work examining the links between attention and eye movements, i.e., covert and overt attention, suggested that the two processes were tightly linked, such that preparing an eye movement to a specific spatial location drives attentional focus towards this region (Klein & Pontefract, 1994; Rizzolatti, Riggio, Dascola, & Umiltá, 1987; Shepherd, Findlay, & Hockey, 1986; D. T. Smith & Schenk, 2012). For example, Rafal and colleagues (Posner, Cohen, & Rafal, 1982; Rafal, Calabresi, Brennan, & Sciolto, 1989) examined the neural and oculomotor systems responsible for attention and eye movements, respectively, and found that saccadic preparation to a cue could induce a shift of attention. However, more recent studies have demonstrated that while attention and eye movement preparation are highly interconnected, they are distinct processes (Juan, Shorter-Jacobi, & Schall, 2004; Thompson, Biscoe, & Sato, 2005). Hunt and Kingstone (2003a, 2003b) demonstrated this by using a dual task in which participants were asked to perform a task that simultaneously required attentional and oculomotor processes. They found that eye movement preparation did not influence performance benefits at attended locations, such that benefits from one task did not lead to any benefits for the other task. More recent evidence has also found that shifts of attention are followed by overt shifts in eye movements, i.e., covert shifts of attention typically precede overt eye movements (Deubel & Schneider, 1996; Henderson & Hollingworth, 1999; J. E. Hoffman & Subramaniam, 1995; M. S. Peterson et al., 2004). Together, these results show that attention and eye movements can be engaged differentially depending on task settings. As such, current work now considers attention and eye movements as two interdependent systems that often move together but can diverge when needed (de Haan, Morgan, & Rorden, 2008; Hunt & Kingstone, 2003a, 2003b; Hunt, Reuther, Hilchey, & Klein, 2019; Klein, 2004; MacInnes, Krüger, & Hunt, 2015; G. H. MacLean, Klein, & Hilchey, 2015; Nobre, Gitelman, Dias, & Mesulam, 2000; M. S. Peterson et al., 2004).

Modes of attentional control. The other characteristic of human attention concerns the mode of attentional control or whether attention is being biased voluntarily or spontaneously. When attention is biased *voluntarily*, it is effortfully committed to the task and/or stimuli at hand (Folk, Remington, & Johnston, 1992). Using the previous driving example, voluntary attention would entail deliberately paying attention to an oncoming traffic light. On the other hand, when attention is biased *spontaneously*, it is automatically driven to certain locations or objects that may be perceptually or semantically salient (Jonides, 1981). In the driving example, attention would be biased spontaneously by a pedestrian who suddenly ran into the street.

Past work has demonstrated that both covert and overt attention can be engaged in a voluntary or spontaneous manner (Klein, Kingstone, & Pontefract, 1992). Voluntary attention is typically elicited using tasks that present participants with an attentional cue that gives reliable information about a subsequent target. For example, participants may be presented with a display in which an arrow cue indicates a likely target location 80% of the time. Participants knowingly utilize this spatial contingency to voluntarily bias their attention towards the spatial location that is most likely to contain the response target. Because voluntary attention requires cognitive resources, this mode of attentional control is known to emerge slowly but persist for a longer period of time (Theeuwes, 1991).

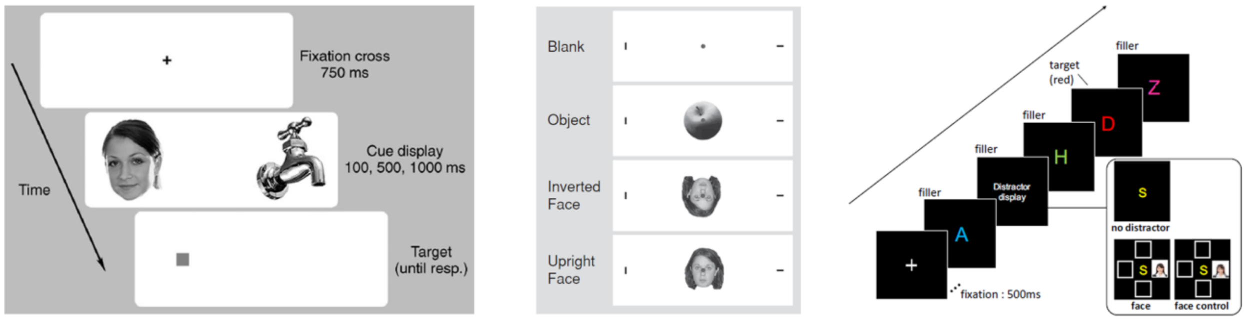
In contrast, spontaneous attention is typically elicited using tasks in which attentional cues provide no reliable information about the target and/or its location. For example, participants may be presented with a luminance cue that flashes on the left or right side of fixation randomly and indicates the correct target location at chance, i.e., with 50% accuracy. Thus, the cue and the target have no spatial relationship, and any performance benefits of the cue to the target are attributed to the cue's ability to attract attention to its location in a spontaneous manner. Because spontaneous attention requires no deliberate effort, this mode of attentional control is known to occur quickly but is short-lived (Jonides, 1981; Posner, 1980).

Similar to the relationship between covert and overt attention, research on the relationship between voluntary and spontaneous modes of attentional control is also complex, with most studies indicating an interdependent relationship in which both modes of control can be engaged in isolation and in conjunction (Berger, Henik, & Rafal, 2005), with interference occurring under specific conditions (Klein, 2009; Ristic & Kingstone, 2012; Ristic & Landry, 2015). These conclusions are supported by behavioural studies that show independent performance benefits for targets attended in a voluntary and spontaneous manner (Egeth & Yantis, 1997; Itti & Koch, 2000), and by neuroimaging work that has revealed two distinct cortical networks associated with each mode of attentional control, with the dorsolateral frontoparietal network being implicated in voluntary attentional control and the ventrolateral frontoparietal network showing involvement in spontaneous attention (Corbetta & Shulman, 2002; Hopfinger & West, 2006; Natale, Marzi, & Macaluso, 2009; Yantis, 2000).

Section III: Social attention

Given the vast literature indicating the functional and cognitive uniqueness of faces, it is intuitive to expect that faces may spontaneously bias attention towards their location and/or features. Paying attention to social information like faces, eyes, and body information, i.e., *social attention* (Birmingham & Kingstone, 2009; Nummenmaa & Calder, 2008), has traditionally been studied using prevailing attentional paradigms wherein faces and/or facial features are used as the cues or stimuli of interest. Covertly, social attention has been measured by indexing manual performance, i.e., response time or accuracy to respond to targets cued by social versus non-social cues. Overtly, social attention has been measured by characterizing eye movements while participants look towards social relative to non-social stimuli. Both types of tasks have shown that social stimuli attract attention spontaneously, with many also demonstrating that faces engage attention in a differential manner compared to non-social stimuli. The main findings from these studies are summarized next.

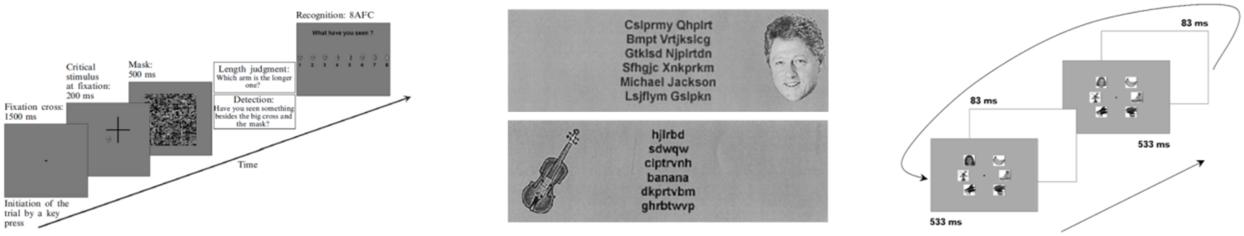
Covert social attention. It is well documented that faces and facial features attract attention covertly (Bindemann, Burton, Hooge, Jenkins, & DeHaan, 2005; Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007; Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009; Langton, Law, Burton, & Schweinberger, 2008; Ro, Russell, & Lavie, 2001; Sato & Kawahara, 2015). Figure 1.1 illustrates examples of behavioural tasks that have been used to demonstrate such effects.



a) Dot-probe task
(Bindemann et al., 2007)

b) Go/No-go task
(Bindemann et al., 2005)

c) RSVP task
(Ariga & Arihara, 2017)



d) Inattentional blindness task
(Devue et al., 2009)

e) Visual search task
(Lavie, Ro, & Russell, 2003)

f) Change detection task
(Ro, Russell, & Lavie, 2001)

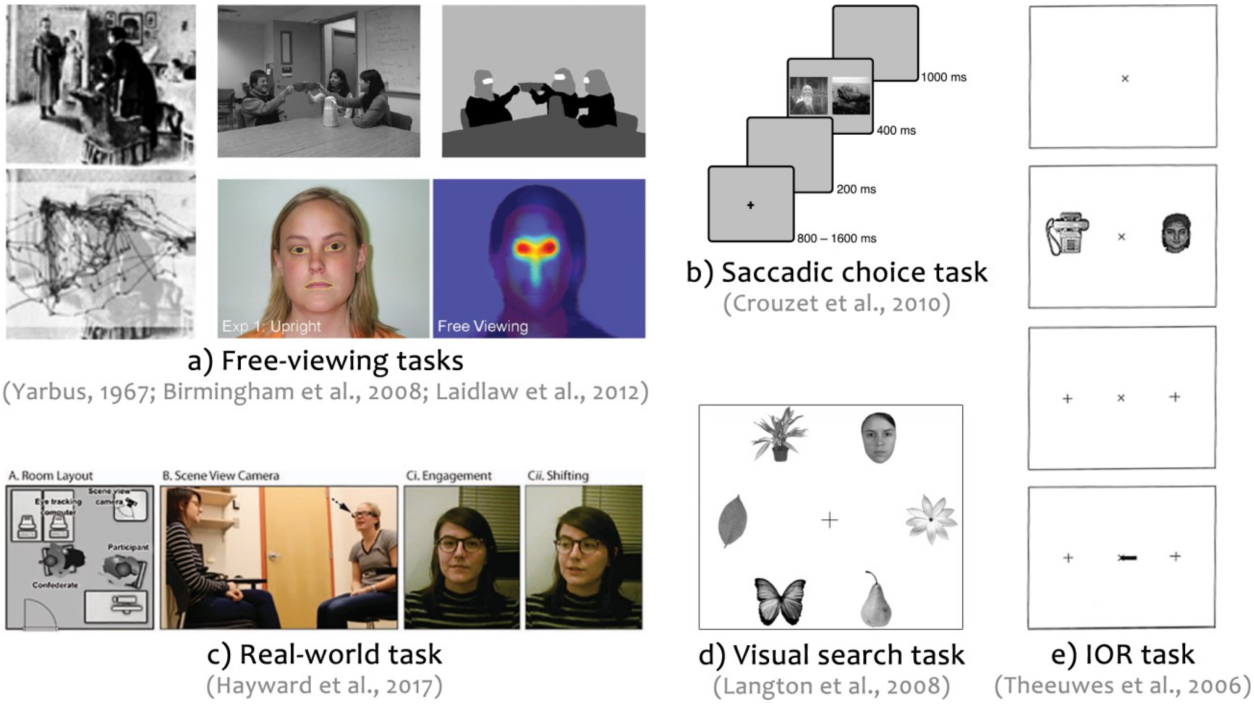
Figure 1.1 Examples of paradigms used to examine covert social attention. Left to right: (a) Dot-probe task from Bindemann et al. (2007), (b) Go/No-go task from Bindemann et al. (2005), (c) RSVP task from Ariga and Arihara (2017), (d) Inattentional blindness task from Devue et al. (2009), (e) Visual search task from Lavie et al. (2003), and (f) Change detection task from Ro et al. (2001).

Bindemann and colleagues (2007) were among the first to show a covert attentional bias for faces. Using a variant of the dot-probe task, illustrated in Figure 1.1a, participants were presented with side-by-side images of a face and a non-social object, and were asked to detect targets that could appear either at the location of the face or the location of the non-social object. Given that the cue images were not informative about the spatial location of the target and that the targets were equally likely to appear at either cue location, participants had no incentive to attend to either faces or objects. However, their results revealed faster response times for targets appearing at the previous location of the face cue relative to targets appearing at the previous location of the non-social object cue. This result was interpreted as evidence that faces spontaneously biased attention to their location, even though they were irrelevant for the task at hand. This is an important point to note because this result shows that faces preferentially bias human attention above non-social cues in the absence of any deliberate intent to do so.

Similar results have been found using other attentional paradigms. For example, task-irrelevant faces have been found to capture attention quicker and hold it for longer than non-social objects in a go/no-go task (Figure 1.1b; Bindemann et al., 2005). The presentation of a task-irrelevant face was found to hinder the ability to identify target letters presented in rapid serial visual presentation stream (Figure 1.1c; Ariga & Arihara, 2017; Sato & Kawahara, 2015), as well as impede visual search when faces were presented within multiple visual distractors (Figure 1.1e; Lavie, Ro, & Russell, 2003). This attentional effect has also been found to facilitate performance in inattentional blindness and change detection tasks. Devue and colleagues (Figure 1.1d; Devue et al., 2009) for example, reported higher detection rates for faces versus objects during inattention trials, while Ro and colleagues (Figure 1.1f; Ro et al., 2001) found that changing a face to a different face was detected more rapidly and accurately than when changing an object to another object.

Thus, numerous studies show that faces attract covert attention, as manual responses are facilitated for targets at spatial locations that previously contained a face versus comparison non-social objects.

Overt social attention. Similar findings are reported when overt attention towards faces and facial features are measured (Birmingham, Bischof, & Kingstone, 2008a; Cerf, Frady, & Koch, 2009; Crouzet, Kirchner, & Thorpe, 2010; Theeuwes & Van der Stigchel, 2006). Figure 1.2 illustrates examples of experimental paradigms that have been used to demonstrate overt social attention via the pattern and/or speed of eye movements.



a) Free-viewing tasks
(Yarbus, 1967; Birmingham et al., 2008; Laidlaw et al., 2012)

b) Saccadic choice task
(Crouzet et al., 2010)

c) Real-world task
(Hayward et al., 2017)

d) Visual search task
(Langton et al., 2008)

e) IOR task
(Theeuwes et al., 2006)

Figure 1.2 Examples of oculomotor paradigms used to examine overt social attention. Left to right: (a) Free-viewing tasks from Yarbus (1967), Birmingham et al. (2008), and Laidlaw et al. (2012), (b) Saccadic choice task from Crouzet et al. (2010), (c) Real-world task from Hayward et al. (2017), (d) Visual search task from Langton et al. (2008), and (e) IOR task from Theeuwes et al. (2006).

Yarbus' seminal work (Figure 1.2a; Yarbus, 1967) is one of the first demonstrations of overt social attention. He presented participants with paintings and photographs of social scenes and recorded their eye movements while they freely viewed the images. His results demonstrated that observers preferentially fixated faces and facial features like the eyes and mouth relative to other objects in the environment. This finding has since been replicated extensively, with data showing that faces and facial features bias overt social attention within the first two fixations during natural free-viewing tasks (Birmingham et al., 2008a; Birmingham, Bischof, & Kingstone, 2008b; Cerf et al., 2009; Laidlaw, Risko, & Kingstone, 2012) and during more controlled experimental tasks like visual search (Figure 1.2d; Langton et al., 2008). Studies have also demonstrated that when participants are asked to execute speeded saccades towards specific objects, saccades made towards faces are faster than saccades made towards comparison non-social stimuli (Figure 1.2b; Crouzet et al., 2010; Devue, Belopolsky, & Theeuwes, 2012). Saccades are also found to be inhibited towards spatial locations that previously contained faces, demonstrating a typical attentional effect that occurs once spontaneous attention disengages from an attended spatial location (Figure 1.2e; Theeuwes & Van der Stigchel, 2006). Finally, more recently, similar preferential fixations and faster saccadic responses have been found in tasks that measure social behaviour in more naturalistic paradigms, during real world interactions that manipulate static and dynamic representations of social behaviour (e.g., images and movies depicting social interactions, Boggia & Ristic, 2015; Riby & Hancock, 2009; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006; T. J. Smith, 2013), as well as during dynamic real-life social interactions (Figure 1.2c; D. A. Hayward, Voorhies, Morris, Capozzi, & Ristic, 2017; Kuhn, Teszka, Tenaw, & Kingstone, 2016; Risko, Richardson, & Kingstone, 2016).

Thus, like covert attention, overt attention also appears to be spontaneously biased towards faces and eyes, with oculomotor behaviour drawn towards faces and their facial features over comparison non-social objects.

Section IV: The main question

Although this large amount of converging evidence strongly suggests that attention is preferentially biased towards faces, past social attentional studies have often not systematically controlled for extraneous factors that are known to play a powerful and determining role in biasing attention spontaneously. Broadly, these extraneous factors can be categorized into *(i) stimulus content*, which is tied to the physical properties of the stimuli, such as size, distance from central fixation, global luminance, featural configuration, and/or perceived attractiveness, *(ii) visual context*, which impacts stimulus perception, such as whether stimuli are presented with background information and/or whether they are novel or familiar, and *(iii) task settings*, which are external to the stimuli but may bias performance, such as including predictable links between cues and targets, overlap in the type and method of response, and/or improper use of comparison stimuli. Each of these extraneous factors are known to attract attention spontaneously, irrespective of any bias from the stimuli being manipulated.

Stimulus content. A number of studies have demonstrated that stimulus content factors, namely physical size, distance from central fixation, global luminance, featural configuration, and perceived attractiveness, reliably capture and engage attention, irrespective of other stimuli and task factors.

Physical size and *distance from central fixation* are considered simple stimulus features that are rapidly extracted, thus influencing a wide variety of subsequent processing (Mangun, 1995; Quinlan & Humphreys, 1987; Treisman & Gormican, 1988). For example, many researchers have examined the attentional effects of size by varying the dimensions of target or distractor stimuli during visual search tasks, and have found that stimuli that were larger captured and biased attention faster (Proulx, 2010; Treisman & Souther, 1985). Furthermore, multiple studies have demonstrated that fixation distance to stimuli can influence the quality of both early and late attentional processing (Domínguez-Martínez, Parise, Strandvall, & Reid, 2015; Luck, Woodman, & Vogel, 2000; Mangun & Hillyard, 1988).

Global luminance, represented by the intensity or brightness of a stimulus based on local or global contrast, also strongly biases attention. One of the most prominent tasks in the field, the attentional cuing task (Posner, 1980), is founded on this notion whereby changes in luminance in the periphery are known to reliably capture attention in a spontaneous manner. Studies have also shown that luminance changes often signal increased contrast or enhanced saliency, thereby resulting in robust biasing effects (Spehar & Owens, 2012).

Featural configuration, which within faces represents the consistent spatial relationship between the two eyes on top and one mouth centrally located on the bottom, can affect attention and processing at an early stage (Dakin & Watt, 2009; Goffaux & Dakin, 2010; Maurer, Grand, & Mondloch, 2002; Pachai, Sekuler, & Bennett, 2013a). Studies have demonstrated that face perception is strongly guided by featural configuration within the face, such that faces with consistent canonical representations are easier to perceive and identify (Frank et al., 2009; Hochberg & Galper, 1967; Simion & Giorgio, 2015; Yin, 1969) and can preferential capture attention (Johnson et al., 1991; Mondloch et al., 1999). More broadly, configuration information in non-social stimuli, such as highly-structured content or consistent regularities, is also found to bias attention (B. Wang & Theeuwes, 2018; Yu & Zhao, 2015; Zhao, Al-Aidroos, & Turk-Browne, 2013).

Finally, *perceived attractiveness*, defined within faces as an internal representation of aesthetically pleasing information, has been found to be processed in an automatic and rapid manner (Locher, Unger, Sociedade, & Wahl, 1993; Olson & Marshuetz, 2005), supporting the likelihood that this factor can guide social attention. For example, previous studies demonstrate that attention is strongly biased towards attractive relative to unattractive faces, such that this effect is difficult to inhibit even when faces are irrelevant to the task (Aharon et al., 2001; Maner, Gailliot, Rouby, & Miller, 2007; Sui & Liu, 2009). Similar findings are also observed when non-social stimuli are used, such that visual textures or objects that are rated as more visually appealing are preferentially attended (Jacobs, Renken, & Cornelissen, 2012; Locher, 2015).

Thus, each of these stimulus content factors have been shown to spontaneously bias attention. This is particularly problematic as most previous studies conducted on social attention have not controlled for these factors. More specifically, faces and non-social objects have not been equated for size (Bindemann & Burton, 2008; Bindemann et al., 2007), distance from central fixation (Birmingham, Bischof, & Kingstone, 2007; Smilek et al., 2006), global luminance (Bindemann et al., 2007; Langton et al., 2008), featural configuration (Guillon et al., 2016; Tomalski, Johnson, & Csibra, 2009; Vuilleumier, 2000), and perceived attractiveness (Bindemann et al., 2007). As such, it remains unknown whether the social attentional effects that have been reported reflect attentional biasing by faces or by one or more of these stimulus content factors.

Visual context. Similar to stimulus content, visual context factors like background information and stimulus novelty have also been demonstrated to affect attentional biasing.

Background information, depicting either local details that are extraneous to the stimuli or global contextual scene representations that stimuli can be embedded into, are known to substantially modulate perceptual and neural processing of objects (Bar, 2004). Within faces specifically, the surrounding role of background information (e.g., hair or body information or scene contexts that individuals are depicted in) not only impacts facial processing (Aviezer, Bentin, Dudarev, & Hassin, 2011; Bentin, Sagiv, Mecklinger, Friederici, & von Cramon, 2002), but it can also lead to categorical changes in how faces are perceived and attended (Hassin, Aviezer, & Bentin, 2013). Additional studies have also demonstrated that the effect of context on face processing can be seen at early stages in face-sensitive neural areas (Haxby & Gobbini, 2012; MacNamara, Foti, & Hajcak, 2009; MacNamara, Ochsner, & Hajcak, 2011; Morel, Beaucousin, Perrin, & George, 2012; Righart & de Gelder, 2006; Wieser et al., 2014).

Similarly, *novelty*, or how new or different a stimulus appears within the context of the task, is known to impact attention and processing for both objects and faces. For objects, attention is found to be strongly biased towards novel stimuli due to neural and perceptual biases that prioritize new information within our environment (Cohen & Gelber, 1975; Fantz, 1964; Horstmann & Herwig, 2016). Novelty within faces however show differential effects on attentional biasing, such that some studies demonstrate that novel faces are robust to typical face inversion effects due to distinct processing strategies (Megreya & Burton, 2006), whereas others demonstrate that novel faces are processed in a manner similar to non-social objects (V. Bruce, 1982; Ganel & Goshen-Gottstein, 2004; Russo, Ward, Geurts, & Scheres, 1999). Although some of these differences may be attributable to the frequency of face presentation (Heisz, Watter, & Shedden, 2006; Winston, Henson, Fine-Goulden, & Dolan, 2004; Yi, Kelley, Marois, & Chun, 2006), it is still well documented that novelty has an impact on how attention is directed towards faces and facial features.

Thus, visual context factors also influence how stimuli are attended. Much of the past work conducted on social attentional biasing has often not equated background information across the face and comparison stimuli (Bindemann & Burton, 2008; Bindemann et al., 2007; Birmingham et al., 2008a; Flechsenhar, Larson, End, & Gamer, 2018) nor have they accounted for the impact of novelty within their task (Bindemann et al., 2005; Bindemann et al., 2007; Birmingham et al., 2008a; Devue et al., 2012; Lavie et al., 2003; Ro et al., 2001). As such, it is possible that these past results may not reflect attentional biases by faces but strategic processes engaged by differences in visual context factors.

Task settings. Finally, attention is also known to be affected by task settings. The most critical settings for the present dissertation include the factors of stimulus predictability, nature of response and associated key-response mapping, and the choice of comparison stimuli.

Stimulus predictability, as reviewed in Section II, plays a key role in how attention is experimentally engaged. Eliciting spontaneous attentional effects requires the use of spatially uninformative attentional cues or the presentation of cues and targets that are linked at chance levels; otherwise, observed effects could be attributed to voluntary attentional effects or individual strategies developed in an effort to interpret cue-target contingencies (Lavie, Hirst, de Fockert, & Viding, 2004; Rizzolatti, Riggio, & Sheliga, 1994; Treisman, 1969). This factor can also be implicitly engaged by the task if conditions within the study design are not evenly distributed throughout the task. Many well-known attentional paradigms (e.g., the dot-probe task, MacLeod, Mathews, & Tata, 1986; the cuing task, Posner, 1980) require such even counterbalancing in order to ensure that no task relevant spatial contingencies develop that could influence attentional allocation. Studies have previously demonstrated that when cues are spatially predictive or biased towards the target due to study design, attention can be rapidly adjusted on a trial-by-trial basis (Appelbaum, Boehler, Won, Davis, & Woldorff, 2012) such that the degree of predictability within the task is directly reflected within both behavioural and neuroimaging data (Vossel, Thiel, & Fink, 2006).

Method of manual response, similar to cue-target predictability, has also been well-documented to influence processing time due to the degree of correspondence between the spatial location of the stimulus and the response key, a finding known as the Simon effect (Hommel, 1993; Rubichi, Nicoletti, Iani, & Umiltà, 1997; Simon, 1969). For example, if participants are asked to respond with their left hand to a stimulus appearing in the left visual field, this motor correspondence between the stimulus and response location will facilitate left-hand responses simply due to their spatial congruence, irrespective of the stimulus. Furthermore, Proctor, Lu, and Zandt (1992) demonstrated that the Simon effect can be further enhanced if stimulus predictability is additionally confounded within the task, suggesting that both stimulus predictability and the method of response are important factors to control in attentional tasks.

Finally, for *comparison stimuli*, the effects of social cues are by necessity measured in relation to the effects elicited by non-social cues. However, creating an adequate comparison in this regard has not always been straightforward (see literature on attentional effects for gaze cues versus comparison arrows, D. A. Hayward & Ristic, 2015; Ristic, Wright, & Kingstone, 2007; Tipples, 2002), and typically attentional effects for social and non-social cues are seldom examined against a common comparison cue, such as a neutral checkerboard or a composite scrambled social/non-social stimulus (Bindemann et al., 2007; Birmingham et al., 2008a; Crouzet et al., 2010; Ro et al., 2001; Smilek et al., 2006; Võ, Smith, Mital, & Henderson, 2012). Such contrasts would be beneficial for revealing differential facilitation for social versus non-social information in relation to the neutral comparison stimulus. As such, the use of comparison stimuli can reveal the magnitude of social attentional biasing relative to a neutral comparison (Birmingham & Kingstone, 2009).

Given the critical role of task factors in attentional paradigms, it is possible that previously reported social attention effects may have been contaminated by the contribution of one or more of these factors. Thus, controlling for these task-related effects is critical in ensuring that any social attention biasing can be attributed to faces and to spontaneous attention rather than extraneous task factors.

Section V: Dissertation overview

Although numerous studies conducted to date show that covert and overt attention is biased towards faces, much of this work has included confounding factors relating to stimulus content, visual context, and task setting. As such, it remains unclear whether faces attract human attention irrespective of these extraneous factors. The studies contained within the four experimental chapters in this dissertation have been designed to systematically test the contribution of each of these factors to social attention. If one or more of these factors contributed significantly to social attentional effects reported by previous literature, it would imply that social attention is significantly influenced by extraneous stimulus content, visual context, and/or task factors. If not, the implication is that social attention is biased strongly towards faces irrespective of any influence of irrelevant confounding factors.

This dissertation follows a manuscript-based format with four experimental chapters, two of which have been published (Chapters 2 and 4), one of which is under review (Chapter 3), and one of which is in preparation (Chapter 5). These experimental chapters report a total of 14 experiments and include data from 420 participants. Please note that the chapters, which constitute journal articles, must be taken verbatim from published records, and thus may present overlapping information.

Research approach. All studies in this dissertation measure spontaneous attentional biasing using the dot-probe task (MacLeod et al., 1986). In a typical dot-probe task, a pair of stimuli (e.g., words, pictures, faces) are presented on opposing sides of the computer screen. After a variable amount of time, a target probe is presented with equal probability at the previous location of one of the two stimuli. The task is to detect the target as quickly as possible. Because participants should respond faster to targets that appear in the spatial region that they were attending to, faster responding to targets occurring at the previous location of stimuli of interest can be interpreted as evidence that attention has been attracted by that specific stimulus.

There are four key reasons why we chose this particular paradigm. First, the dot-probe task is one of the most utilized attentional paradigms, having been used in over 2,600 studies to date when examining biasing effects across attentional, perceptual, memorial, and psychopathological domains (based on an electronic literature search for the task performed in PsycINFO on June 15, 2020, using the keywords ‘dot-probe task’ OR ‘dot probe task’). The popularity of the task reflects its ability to experimentally manipulate attentional biasing and to measure behavioural response modulations across different stimuli and/or spatial locations (Cooper & Langton; Frewen, Dozois, Joanisse, & Neufeld, 2008; Klein & MacInnes, 1999; Navon & Margalit, 1983). Second, the dot-probe task is ideal for investigating spontaneous attentional biasing since the parameters of the task allow for cues and targets to be task-irrelevant and spatially uninformative. Third, the task is equally amenable for measuring both manual responses and oculomotor performance. That is, manual responses, such as reaction time and/or accuracy, can be measured in response to targets, while oculomotor performance, such as fixation or saccadic frequency, speed, and/or distribution can be measured in response to cues or targets. Fourth and finally, numerous existing studies on social attention have been carried out using this task. For example, one of the first studies on covert social attentional biasing from Bindemann and colleagues (2007) used face and non-social object cues within a dot-probe task to demonstrate that faces spontaneously bias attention (see also Bindemann et al., 2005; Torrence & Troup, 2018). Together, these factors make the dot-probe task an ideal paradigm to examine spontaneous social attentional biasing effects across both manual and oculomotor measures.

Sample size determination. Sample size for all experiments were determined via a priori power analyses. Prior research has found medium-to-large effect sizes for the magnitude of social attentional biasing, with Cohen's *f* ranging from .41–1.36 (as estimated from Bindemann & Burton, 2008; Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2001). Therefore, we used G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to calculate the minimum required sample size on the basis of these prior effects. Given an α of .05 and power ($1 - \beta$) of .95, the analysis indicated that a sample size of 6 participants would be needed to detect a large effect of 1.36 and a sample size of 38 participants would be needed to detect a medium effect of .41. Thus, we recruited 30 participants for each experiment within this dissertation in order to fall within this sample range.

The current task. For the dot-probe task used in this dissertation, participants were presented with two or four images (depending on the experimental chapter) of a social face cue and a non-social house cue, and/or scrambled face/house cue images. This cue display was followed by the presentation of a response target (circle or square) that occurred with equal probability at the previous location of one of these cues. Participants were asked to discriminate the target between a circle and a square (e.g., Bradley, Mogg, Falla, & Hamilton, 1998). For each experimental chapter, two versions of the dot-probe task were run. One, where participants were asked to withhold eye movements and manual responses to targets were measured; and two, where no information about eye movements was given and both manual responses to the target and eye movements during the cue period were measured. Manual responses compared reaction time to targets occurring at the previous location of the face relative to targets occurring at the previous location of the comparison stimuli. Eye movements compared whether greater proportion of saccades were launched towards the face region relative to the comparison stimuli region during the cue period.

Chapter 2 (Pereira, Birmingham, & Ristic, 2019a; *Psychological Research*). The studies in this chapter examined how controlling the face and comparison cues for stimulus content (size, distance from fixation, global luminance, featural configuration, and perceived attractiveness) and visual context (background information and novelty) and controlling the task for parameter settings (stimulus predictability, method of response, and comparison stimuli) influenced resulting social attentional biasing. Surprisingly, the results revealed that once the contribution of these external factors was removed, no evidence of spontaneous attentional biasing towards faces was found. That is, there were no effects in manual data when eye movements were restricted, and a minor although reliable oculomotor bias towards the eyes of the face occurred when eye movements were not restricted. Importantly, to demonstrate that these results were not an artifact of our particular settings, we replicated previous social attentional biasing effects by using the same stimuli and procedures employed in past literature (i.e., Bindemann et al., 2007). As such, experiments within this first chapter show that social attentional biasing reported in past research was likely influenced by extraneous factors, thus challenging the prevailing notion that faces and facial features spontaneously and preferentially bias attention.

Chapter 3 (Pereira, Birmingham, & Ristic; *under review, Quarterly Journal of Experimental Psychology*). The studies in this chapter investigated the role of stimulus content. Across six experiments, global luminance, featural configuration, and perceived attractiveness were manipulated, while equating other visual context factors and task settings. That is, Experiments 1a and b measured attentional biasing to face and comparison cues when the face cue had a higher global luminance than the comparison cue; Experiments 2a and b measured attentional biasing when face and comparison stimuli did not match on internal configuration of features; and Experiments 3a and b measured attentional biasing when the face cue had higher ratings of attractiveness than the comparison cue. The results across all studies showed that global luminance and featural configuration contributed little to the re-instantiation of social attentional biasing in both manual and oculomotor data regardless of whether eye movements were restricted or not. However, Experiment 3 showed that perceived attractiveness played an important role in attentional effects, such that reliable social attentional biases were found when eye movements were not restricted. Specifically, we found that manual responses were facilitated for targets occurring at the location of the overall face and oculomotor biasing occurred towards the eye region of the face. Thus, perceived facial attractiveness may play an important role in attentional biasing towards faces and its features when eye movements occur.

Chapter 4 (Pereira, Birmingham, & Ristic, 2019b; *Vision*). The studies in this chapter investigated the role of visual context by examining social attentional biasing when the face and comparison cues were presented with appropriate background information. Here, the cues were positioned within a consistent background context, with the face showing a person (i.e., including their hair and body) sitting in a room, and the house positioned within a picture on a wall. As before, all other stimulus content, visual context, and task setting factors were controlled. The results once again indicated no evidence of attentional biasing towards faces or facial features in manual responses when eye movements were restricted, but once again indicated an infrequent but statistically reliable overt bias towards the eyes of the face when eye movements were not restricted. Thus, it appears that background context contributes little to social attentional biasing in manual responses, although it may act to facilitate overt attentional measures in oculomotor data.

Chapter 5 (Pereira, Birmingham, & Ristic; *in preparation*). The final experimental chapter investigated how the visual context factor of novelty influenced social attentional biasing. Here, social attention was examined in response to face and comparison cues that were presented frequently (i.e., making them less novel) or infrequently (i.e., making them more novel) during the task. As before, all other stimulus content, visual context, and task setting factors were equated. The results once again revealed no evidence of attentional biasing towards frequent or infrequent novel faces in manual data when eye movements were restricted. Once again, there was a reliable oculomotor effect when eye movements were not restricted, such that manual responses were facilitated for targets occurring at the location of infrequently presented novel faces and overt biasing occurred towards the eyes of infrequently presented novel faces. This chapter establishes that novelty, regardless of the frequency of presentation, has no effect on social attentional biasing when eye movements are restricted, but infrequent novel face identities may facilitate social attention in both manual and oculomotor data when eye movements are not restricted.

All experimental chapter manipulations and main results for manual and oculomotor measures when eye movements were restricted or not restricted are summarized in Table 1.

Table 1. Summary of manipulations and main results for the four experimental chapters.

Manipulations		**Eye movements restricted**	**Eye movements not restricted**	
		Manual RT	**Oculomotor**	**Manual RT**
Chapter 2 **All factors**	*Stimulus content, visual context, and task settings*	✗	✓	✗
Chapter 3 **Stimulus content**	*E1. Global Luminance*	✗	✗	✗
	E2. Featural configuration	✗	✗	✗
	E2. Perceived attractiveness	✗	✓	✓
Chapter 4 **Visual context**	*Background information*	✗	✓	✗
Chapter 5 **Visual context**	*Novelty*	✗	✓	✓

* ✗ *denotes the absence of social attentional biasing;* ✓ *denotes the presence of social attentional biasing.*

Finally, **Chapter 6 presents the General Discussion**, in which the results of the studies are summarized and discussed with respect to the existing literature and functional relevance of social attention, the mechanisms of attentional processing, and methods of attentional measurement.

The eyes do not have it after all?

Attention is not automatically biased towards faces and eyes

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Abstract

It is commonly accepted that attention is spontaneously biased towards faces and eyes. However, the role of stimulus features and task settings in this finding has not yet been systematically investigated. Here we tested if faces and facial features bias attention spontaneously when stimulus factors, task properties, response conditions, and eye movements are controlled. In three experiments, participants viewed face, house, and control scrambled face-house images in an upright and inverted orientation. The task was to discriminate a target that appeared with equal probability at the previous location of the face, house, or the control image. In all experiments, our data indicated no spontaneous biasing of attention for targets occurring at the previous location of the face. Experiment 3, which measured oculomotor biasing, suggested a reliable but infrequent saccadic bias towards the eye region of upright faces. Importantly, these results did not reflect our specific laboratory settings, as in Experiment 4, we present a full replication of a classic finding in the literature demonstrating reliable social attention bias. Together these data suggest that attentional biasing for social information is task and context mediated, and less robust than originally thought.

Keywords: social attention; attentional selection; faces; eye movements

Introduction

Faces are perhaps the most important stimuli that humans encounter in their visual environment, conveying key information for survival, emotional wellbeing, and social function. These aspects of social communication are supported both by the morphology of the human eye, which facilitates an easy reading of social signals due to the high contrast between the iris and the sclera (Campbell, 1957; Kobayashi & Kohshima, 2001), and by the specialized distributed network of brain structures (e.g., fusiform face area, superior temporal sulcus, occipital face area) that are specifically tuned for the processing of faces, gaze information, and other socio-biological signals (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Gauthier et al., 2000; Haxby et al., 1994; Kanwisher & Yovel, 2006; Nummenmaa & Calder, 2008; Perrett, Hietanen, Oram, Benson, & Rolls, 1992; Perrett et al., 1985; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Yovel, Levy, Grabowecky, & Paller, 2003). These structures are thought to enable basic functions that lead to well-documented face processing benefits across the lifespan, such as enhanced facial recognition abilities (Little, Jones, & DeBruine, 2011; Thomas, De Bellis, Graham, & LaBar, 2007) and upright face processing biases (Frank, Vul, & Johnson, 2009; Simion & Giorgio, 2015), as well as to furnish the extraction of social meaning from faces to facilitate more complex social processes, like theory of mind and language development (Baron-Cohen, 1995; Dunbar & Shultz, 2007; Emery, 2000; Schaller, Park, & Kenrick, 2007).

Given the importance of information conveyed by faces, it is intuitive to expect that faces and their features like eyes would lead to spontaneous biasing of attention. A number of studies that have examined both overt and covert attentional selection support this intuition. In overt tests, attentional selection is indexed by the degree of oculomotor biasing, like the proportion of fixations and/or dwell time associated with the presentation of task-irrelevant faces relative to other stimuli. Yarbus' seminal work (1967) provided one of the first demonstrations of such biasing. In his investigations, Yarbus showed that observers preferentially fixated faces and their features, like eyes, relative to other objects while freely viewing images of real world scenes. This general finding has since been replicated by numerous studies, which collectively show that faces and facial features bias oculomotor behavior within the first two fixations (Birmingham, Bischof, & Kingstone, 2008a, 2008b; Cerf, Frady, & Koch, 2009; Laidlaw, Risko, & Kingstone, 2012), and elicit faster saccades relative to comparison stimuli (Crouzet, Kirchner, & Thorpe, 2010; Devue, Belopolsky, & Theeuwes, 2012). These behaviors are observed in investigations using various laboratory paradigms (e.g., inhibition of return (IOR), Theeuwes & Van der Stigchel, 2006), in tests that manipulate static and dynamic representations of social behavior (e.g., images and movies depicting social interactions, Boggia & Ristic, 2015; Riby & Hancock, 2009; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006; Smith, 2013), as well as during real life interactions (e.g., Hayward, Voorhies, Morris, Capozzi, & Ristic, 2017; Kuhn, Teszka, Tenaw, & Kingstone, 2016; Risko, Richardson, & Kingstone, 2016).

The results from studies that have measured covert behavior dovetail well with these findings. Here, attentional selection is indexed using manual performance within typical attentional paradigms (e.g., dot-probe, visual search, inattentional blindness tasks), with overall results showing that task-irrelevant faces both capture and hold attention (Bindemann, Burton, Hooge, Jenkins, & DeHaan, 2005; Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007). Using a variant of the dot probe task, Bindemann and colleagues (2007) also demonstrated that presenting response targets on a task-irrelevant face resulted in faster response times for targets appearing at the previous location of the face relative to targets appearing at the previous location of the control non-social object. Similarly, the presentation of distractor faces has been found to hinder visual search (Lavie, Ro, & Russell, 2003) and target performance in an RSVP task (Ariga & Arihara, 2017a; Sato & Kawahara, 2015), but facilitate target detection in change-detection tasks when faces are the changed item. For example, Ro and colleagues (2001) reported that changing a face to a different face was detected more rapidly and accurately relative to changing an object to another object, while Devue and colleagues (2009) found higher detection rates for faces versus objects during inattention trials in an inattentional blindness paradigm.

Although this large amount of evidence suggests that the attentional system may be preferentially biased by faces and facial features, there are at least three distinct issues that arise from this past work that make it difficult to ascertain whether the intrinsic importance of faces or extraneous physical and task variables account for these results. The first relates to the observation that past work has typically not controlled for visual and conceptual differences between faces and comparison objects. Typically, faces and non-social objects have not been equated for physical size (Bindemann & Burton, 2008; Bindemann et al., 2007), position and/or distance from fixation (Birmingham, Bischof, & Kingstone, 2007; Smilek et al., 2006), the configuration of internal features (e.g., with a consistent first-order configuration, two eyes above a nose and mouth; Guillon et al., 2016; Tomalski, Johnson, & Csibra, 2009; Vuilleumier, 2000), overall visual features like luminance (Bindemann et al., 2007; Langton, Law, Burton, & Schweinberger, 2008), valence (Crouzet et al., 2010), and/or perceived attractiveness (Bindemann et al., 2007). Importantly, each of these properties individually have been well-documented to engage attention, irrespective of any bias elicited by the social nature of faces alone (size and positioning, Crouzet & Thorpe, 2011; low-level internal features, Ariga & Arihara, 2017b; Devue et al., 2012; Itier, Latinus, & Taylor, 2006; Kendall, Raffaelli, Kingstone,

& Todd, 2016; Rousselet, Ince, van Rijsbergen, & Schyns, 2014; saliency, Cerf, Harel, Einhäuser, & Koch, 2008; valence and attractiveness, Nakamura & Kawabata, 2014; Silva, Macedo, Albuquerque, & Arantes, 2016; Sui & Liu, 2009; Võ, Smith, Mital, & Henderson, 2012). Further, attentional effects for social and non-social cues have usually been examined in direct contrasts and not against a common comparison cue (Bindemann et al., 2007; Crouzet et al., 2010; Ro et al., 2001), the latter of which provides a way to test the magnitude of social relative to non-social attentional biasing (see Birmingham & Kingstone, 2009).

The second issue is that past work measuring manual responses has typically not accounted for the effects of eye movements, raising a question as to whether the reported biases reflected covert or overt processes (Findlay, 2003; Hunt & Kingstone, 2003b). Assessing covert attention requires measuring manual performance under conditions in which eye movements are restricted (e.g., Posner, 1980). Many well-known attentional paradigms (e.g., the dot-probe task, MacLeod, Mathews, & Tata, 1986; the cuing task, Posner, 1980) require observers to maintain fixation on a central stimulus, and index covert attention by contrasting manual performance (i.e., response time, accuracy) for targets that appear at locations previously indicated by a cue (i.e., cued locations) versus those appearing elsewhere (i.e., uncued locations). A number of past studies have relied on verbal instructions to restrict eye movements (Bindemann & Burton, 2008; Bindemann et al., 2005), while others provided no instructions to participants regarding their eye movements (Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2001; Sato & Kawahara, 2015). Accounting for eye movements is especially important given that past work has overwhelmingly demonstrated that the oculomotor system is biased towards faces and facial features, particularly the eyes (Birmingham et al., 2007, 2008a; Cerf et al., 2009; Crouzet et al., 2010; Fletcher-Watson, Findlay, Leekam, & Benson, 2008; Laidlaw et al., 2012).

The third issue is that while past studies presented evidence for an attentional bias for faces as a whole, it remains unclear if any specific facial features drive this bias. That is, studies that have measured manual performance have typically asked participants to respond to a single target appearing somewhere at the location of the face (Bindemann et al., 2007; Devue et al., 2009; Lavie et al., 2003; Ro et al., 2001). Although a bias to spontaneously attend to eyes within faces has been demonstrated using oculomotor measures (Birmingham et al., 2007, 2008a), the role of this facial feature in biasing manual performance has not yet been systematically addressed (but see Bar-Haim, Shulman, Lamy, & Reuveni, 2006). As such, there remains an open question as to whether attentional biasing reported in manual responses reflects a specific bias towards the eyes or a more general bias towards the face.

Against this backdrop, it thus remains surprisingly equivocal if faces and facial features spontaneously bias attention. To address this question, we systematically assessed attentional selection for task-irrelevant faces and their features across multiple experiments. To do so, we measured and controlled *(a)* stimuli and task conditions; *(b)* effects elicited by faces overall and their individual parts; and *(c)* participants' eye movements. In Experiment 1, similar to past work, we measured covert attention by verbally instructing participants to maintain central fixation. In Experiment 2, we measured covert attention by restricting oculomotor behavior during the task using an eye tracker. In Experiment 3, we measured natural overt attention by examining oculomotor behavior during the task. Finally, to ensure that our findings were not due to specific settings in our laboratory, in Experiment 4, we measured covert attention using the stimuli and parameters from Bindemann and colleagues' (2007) study[1]. Based on the past

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[1] We thank Markus Bindemann for providing us with the original stimuli.

literature, we expected to observe a spontaneous attentional bias for faces, with specific effects for eyes across all experiments.

Experiment 1

In Experiment 1, mirroring past work (Bindemann et al., 2007), we employed the dot-probe task (MacLeod et al., 1986), wherein participants are instructed to manually respond to targets following the presentation of task-irrelevant cues while being verbally instructed to maintain central fixation. We achieved experimental control across display and task properties in three ways.

First, the cues were equated for physical properties. The stimuli, illustrated in Figure 2.1a, were gray scale photographs of *(i)* a female face looking straight ahead with a neutral expression and the hairline removed, *(ii)* a house with no contextual background, and *(iii)* a fused overlay of the face and house photographs scrambled using 22-pixel blocks. All stimuli were presented against a uniform gray background and matched for width and height, distance from fixation (as measured from the center of the display to the center of the image), and average luminance (computed using the MATLAB SHINE toolbox; Willenbockel et al., 2010). Face and house images were matched for attractiveness[2] and the configuration of local features, i.e., the spatial placement of the eyes and mouth vs. the windows and door, respectively. To assess the effects of any remaining visual differences across the stimuli and to allow for examinations of upright face effects (Hochberg & Galper, 1967; Yin, 1969), we further manipulated face and

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[2] Twenty-eight additional naïve participants were asked to rate images of various faces and houses using a Likert scale ranging from 1- *Very Unattractive* to 6- *Very Attractive*. The Face and House images that were used here received equivalent attractiveness ratings (Face M=2.93, SD=.77; House M=2.96, SD=.96), which did not differ statistically, $t(27)=.17$, $p=.87$, $d_z=.03$.

house images in an upright and inverted orientation. Finally, to permit an analysis of any biases specific to social processing centers specialized in the right hemisphere of the brain (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; Puce et al., 1998; Rossion, Joyce, Cottrell, & Tarr, 2003; Yovel et al., 2003), the position of the face cue was manipulated between the left and right visual field.

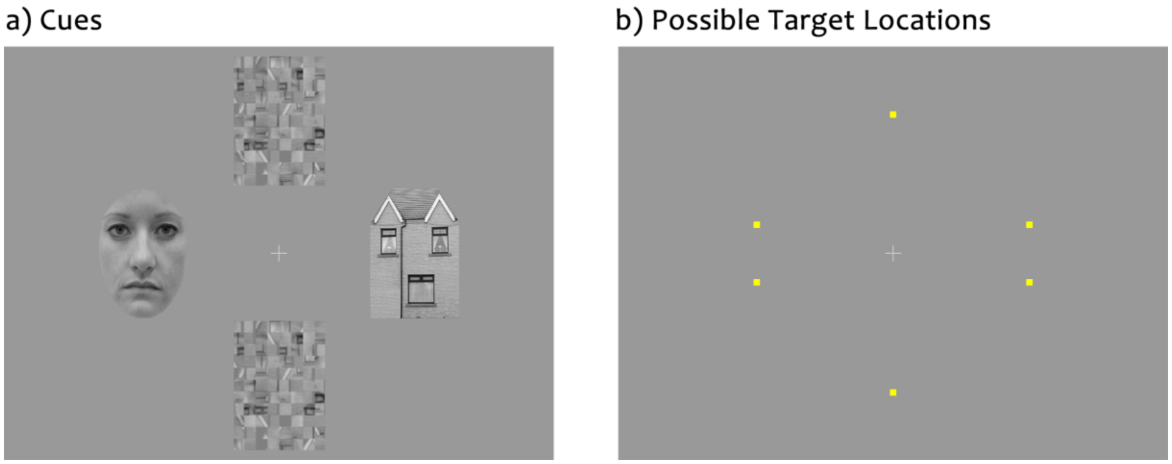

Figure 2.1 a) The cue screen for the upright condition with the face in the left visual field. b) The target screen for square targets with all six possible locations displayed.

Second, response targets were also controlled. Each target, with all possible locations illustrated in Figure 2.1b, was presented against a uniform gray background to ensure the same local contrast between the target and background. Each target occurred with equal probability at the previous location of the eyes or mouth of the face, the top or bottom of the house, and the center of the upper or lower neutral comparison image. All targets were equidistant from fixation, ensuring that no effects were due to distance inequalities between different target positions.

Finally, the parameters of the task ensured that any attentional effects did not reflect task settings. The dot-probe task yields a measure of attentional selection by assessing the speed of target detection when targets are presented at the previous location of the cue of interest vs. the previous location of the comparison stimuli. In our experiments, all combinations of cue location and target positions occurred with equal probability, ensuring that no task relevant spatial contingencies existed between the images and the targets. Furthermore, to ensure equal processing time, cue presentation time was restricted to 250ms, and we sampled performance at both short and long cue-target times (i.e., 250, 360, 560, 1000ms).

Thus, our design allowed for an assessment of attentional biasing elicited by faces and/or facial features when the stimuli were devoid of physical confounds and the task did not encourage the development of spatial attentional effects. If attention is spontaneously biased by faces and/or facial features, we expected to find response facilitation for targets occurring at the previous location of the face relative to the house and comparison stimuli when cues were presented in an upright orientation. If the selection of eyes in particular was important, we further expected to find that responses to targets located at the previous position of the eyes would be preferentially facilitated.

Methods

Participants. Thirty volunteers (24 female; age M=21 years, SD=2 years) with normal or corrected-to-normal vision participated. They were recruited via a volunteer pool and received course credit for their participation. All procedures were approved by the University Research Ethics board. The sample size was selected to fall within the range reflected by an a priori power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) based on the estimated magnitude of the face selection effect from past research (Bindemann & Burton, 2008; Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2001). The analysis indicated that data from 6–38 participants were needed to detect medium-to-large effects ranging from .41–1.36 (as estimated from Cohen's *f*) with corresponding power values from .95–.97.

Apparatus and Stimuli. Stimuli were edited using Adobe Photoshop. They were presented on a 16" CRT monitor at an approximate viewing distance of 60cm, with stimulus presentation timing and sequencing controlled by MATLAB's Psychophysics toolbox (Brainard, 1997).

All stimuli were set on a 60% grey background. They included the central fixation cross, cue images, and target objects. The central fixation subtended 1° x 1° of visual angle. All cue images measured 4.2° x 6° and were positioned at a distance of 6.3° from fixation. Average gray scale luminance (ranging from 0-1) was comparable across cues overall (face = .60, house = .62, neutral = .61) as well as between the upper and lower halves of each cue (eyes = .60, mouth = .60, top house = .63, bottom house = .62, upper neutral = .61, lower neutral = .62). The target was an image of a yellow circle or square measuring 0.3° x 0.3°, positioned 7.2° away from fixation. These stimulus settings are consistent with past studies, which have utilized cue sizes ranging from 2.1º x 2.1º to 8.9º x 12.3º, target sizes ranging from 0.1º x 0.4º to 0.6º x 0.6º, and target eccentricities ranging from 3º to 6.9º (Ariga & Arihara, 2017a; Bindemann & Burton, 2008; Bindemann et al., 2005; Bindemann et al., 2007; Lavie et al., 2003; Ro et al., 2001; Sato & Kawahara, 2015; Theeuwes & Van der Stigchel, 2006).

Design. The target discrimination task was a repeated measures design with five factors: *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target position* (eyes, mouth, top house, bottom house, upper neutral image, lower neutral image), *Target identity* (circle, square), and *Cue-target interval* (250, 350, 560, 1000ms).

Cue orientation was manipulated by presenting the face-house pair in either an upright or inverted orientation. This allowed us to examine the role of low-level properties of the stimuli in biasing attention, and to examine the face inversion effect. *Face position* was manipulated by varying the position of the face cue in either the left or right visual field (with the house image occurring in the opposite visual field), allowing for an assessment of the influence of right-lateralized brain centers in the processing of face cues. *Target position* manipulated the response target across one of six possible locations: at the previous location of Eyes, Mouth, Top House, Bottom House, center of the Upper Neutral image, or center of the Lower Neutral image. This enabled us to capture any performance differences between targets occurring at the location of the face overall and its specific facial features in relation to the house and comparison stimuli. *Target identity* varied between circle and square shapes in order to allow for speeded discrimination response and measurements of both response time (RT) and response accuracy. Half the trials received a square target and the other half received a circle target. Key response-target identity assignment was counterbalanced between participants. *Cue-target interval* varied between 250, 360, 560, and 1000ms in order to assess the time course of attentional selection and to maintain consistency with past work (Bindemann et al., 2007; Theeuwes & Van der Stigchel, 2006).

All factor combinations were equiprobable and presented equally often throughout the experimental sequence. The cues were spatially uninformative about the target location and its identity, as either target was equally likely to occur at any of the six possible locations. Conditions were intermixed and presented in a randomized order.

Procedure. Figure 2.2 illustrates an example stimulus presentation sequence. All trials started with a presentation of a fixation display for 600ms. Then, the cue display was shown for

250ms. After 0, 110, 310, or 750ms (constituting 250, 360, 560, and 1000ms cue-target intervals), the target appeared and remained visible until participants responded or 1500ms had elapsed. Participants were asked to respond quickly and accurately by pressing the ‘b’ or ‘h’ keys on the keyboard to identify the circle and square targets. They were informed that the target was equally likely to be a circle or a square and to appear in any of the six possible locations, and that there was no spatial relationship between target location and cue content, orientation, or placement. Participants completed 960 trials divided equally across 5 testing blocks, with ten practice trials run at the start. Responses were measured from target onset.

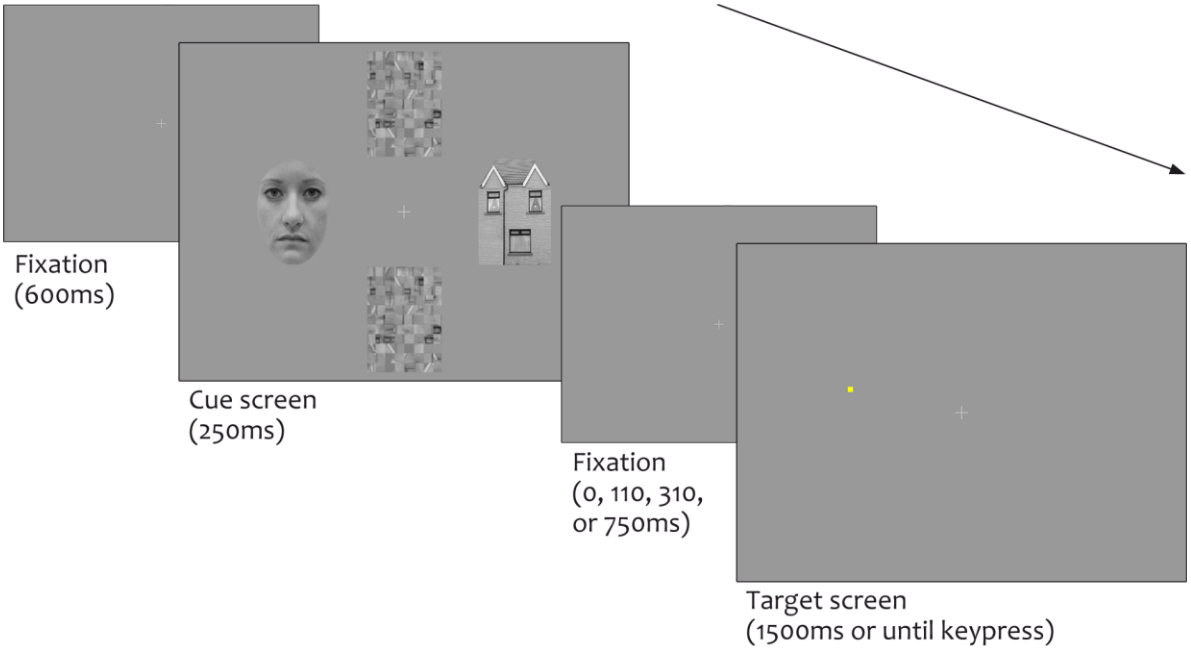

Figure 2.2 Example trial sequence. Trials started with the presentation of the fixation screen for 600ms. The cue screen was then presented for 250ms. After 0, 110, 310, or 750ms, a response target demanding a discrimination response appeared in one of the six possible locations. The target remained visible for 1500ms or until a key press was made. Note: Stimuli are not drawn to scale.

Results

Response anticipations (RTs < 100ms; 0.2% of all trials), timeouts (RTs > 1000ms; 3.4%), and incorrect key presses (key press other than ‘b’ or ‘h’; 0.1%) accounted for 3.7% of data, and were removed from all analyses. Overall, performance accuracy was high at 89%. Interparticipant mean correct RTs were analyzed using repeated measures analysis of variance (ANOVAs) with paired two-tailed t-tests used for post-hoc comparisons where applicable. Multiple comparisons were corrected using the Holm-Bonferroni procedure, which controls for the Type I error while being more powerful than the Bonferroni correction (Holm, 1979). All comparisons are shown with corresponding adjusted *p*-values ($\alpha_{FW} = .05$; Ludbrook, 2000).

We reasoned that if attention was preferentially biased by faces and/or facial features, we would find facilitated responses for targets occurring at the previous location of the face (eyes and/or mouth) relative to targets occurring at the previous location of the house and/or the neutral comparison stimuli, especially when the cue pairs were presented in an upright orientation. Contrary to this hypothesis, our data illustrated in Figure 2.3, depicting mean RTs and accuracy for targets following the presentation of Upright (2.3a) and Inverted (2.3b) cues, indicated no evidence of preferential attentional biasing for faces or any facial feature.

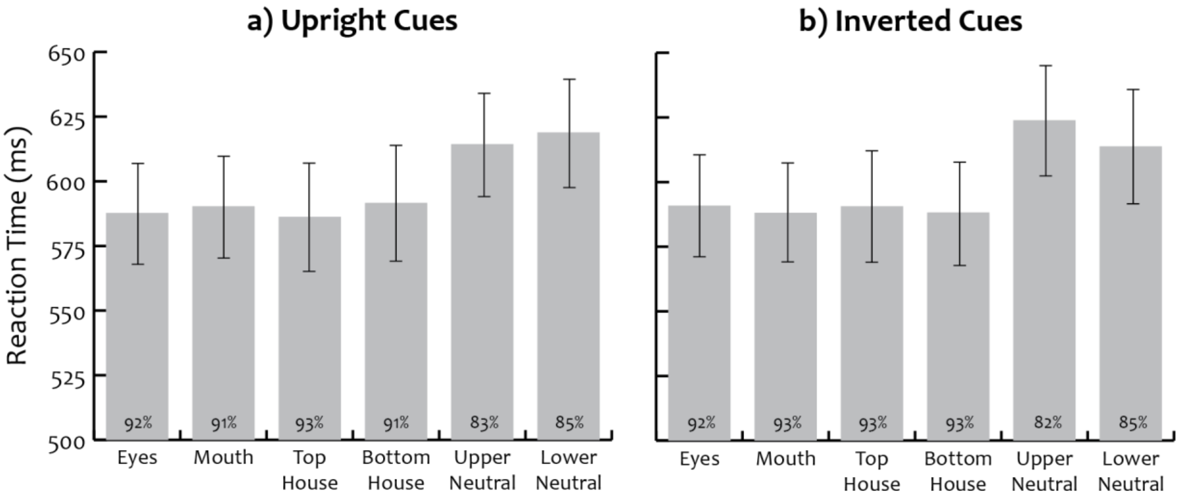

Figure 2.3 Experiment 1 results. Mean interparticipant correct RTs in ms and accuracy rates in percent as a function of Target position for Upright (a) and Inverted (b) cues. Error bars represent 95% CIs.

This observation was confirmed by an omnibus ANOVA run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target position* (eyes, mouth, top house, bottom house, upper neutral, lower neutral), and *Cue-target interval* (250, 360, 560, 1000ms). The ANOVA returned two reliable main effects, which confirmed the efficacy of the task. First, a main effect of *Cue-target interval* [$F(3,87)=65.32$, $p<.001$, $\eta_p^2=.69$] indicated overall faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, ts>9.88, ps<.001, d_zs>1.80; all other ps>.17, d_zs<.37]. This well-established finding in the literature demonstrates an increased preparation to respond with a lengthening of the time between the cue and target, with our results showing that participants performed the task with the proper degree of alertness (e.g., Bertelson, 1967; Hayward & Ristic, 2013). Second, a main effect of *Target position* [$F(5,145)=30.44$, $p<.001$, $\eta_p^2=.51$] indicated differential performance for experimental and control stimuli, with targets appearing at the previous location of the Face and House images detected overall faster than targets appearing at the previous location of the neutral cues. While the slowest overall RTs were observed for targets that occurred at the previous location of neutral cues [upper and lower neutral vs. all others, ts>5.87, ps<.001, d_zs>1.07], responses for targets occurring at the locations of interest (Eyes, Mouth, Top House, Bottom House) did not differ from one another, all *ts*<.71, *ps*>0.99, d_zs<.07; all 95% CIs included the zero point, ranging from –7.72ms to 7.31ms.

This was also reflected in a two-way interaction between *Cue orientation* and *Target position* [$F(5,145)=2.41$, $p=.039$, $\eta_p^2=.08$], which indicated more slowed down RTs for targets at the previous location of the neutral cues (upper, lower) vs. all other targets for inverted [ts>5.60, ps<.001, d_zs>1.02; all other ps>.39, d_zs<.37] relative to upright displays [ts>4.04, ps<.001, d_zs>.74; all other ps>.55, d_zs<.33]. Importantly, no effects or interactions involving *Face position* and *Target position* [*Face position*, $F(1,29)=1.30$, $p=.26$, $\eta_p^2=.04$; *Face position x Target position*, $F(5,145)=1.51$, $p=.19$, $\eta_p^2=.05$; *Face position x Target position x Cue orientation*, $F(15,145)=.89$, $p=.49$, $\eta_p^2=.03$; *Face position x Target position x Cue-target interval*, $F(15,435)=.92$, $p=.54$, $\eta_p^2=.03$; *Face position x Target position x Cue-target interval x Cue orientation*, $F(15,435)=1.34$, $p=.17$, $\eta_p^2=.04$] or any other factors, Fs<1.34, ps$>.27$, $\eta_p^2<.04$, were found[3].

To ensure that these results did not reflect the stricter statistical approach adopted here relative to past work, we have also analyzed the data using the means of median correct RTs as in Bindemann and colleagues (2007) study. A repeated measures ANOVA compared these RTs across overall *Target position* (face, house) and *Cue-target intervals* (250, 360, 560, 1000ms). As before, the data indicated a main effect of *Cue-target interval* [$F(3,87)=38.78$, $p<.001$, $\eta_p^2=.57$] demonstrating the typical foreperiod effect of faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, ts>7.36, ps$<.001$, d_zs>1.37; other ps$>.20$, d_zs$<.24$], but no main effect of *Target position* [$F=.001$, $p=.98$, $\eta_p^2=.00$] and no interaction [$F=.56$, $p=.65$,

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[3] Confirming no speed-accuracy tradeoffs, an additional ANOVA examining mean accuracy rates with the same factors confirmed higher overall accuracy for short relative to long cue-target intervals [*Cue-target interval*, $F(3,87)=9.23$, $p<.001$, $\eta_p^2=.24$; 250ms vs. 560ms & 1000ms, ts>3.36, ps$<.01$, d_zs$>.61$; 360ms vs. 1000ms, $t(29)=2.78$, $p=.036$, $d_z=.51$; all other ps$>.07$, d_zs$<.44$] and overall lowest accuracy for targets appearing at the location of the neutral cues [*Target position*, $F(5,145)=29.74$, $p<.001$, $\eta_p^2=.51$; upper and lower neutral vs. all, ts>5.48, ps$<.001$, d_zs>1.00; all other ps$>.56$, d_zs$<.33$]. A significant interaction between *Cue Orientation* and *Face Position*, $F(1,29)=4.46$, $p=.043$, $\eta_p^2=.13$, indicated lower overall accuracy when inverted faces were presented in the right visual field, $t(29)=3.29$, $p=.006$, $d_z=.60$; other $p=.76$, $d_z=.06$. No other effects involving *Face position* and *Target position* were significant, Fs<2.80, ps$>.11$, $\eta_p^2<.08$.

η_p^2=.02]. Thus, our results do not appear to be an artifact of more conservative statistical methods.

Discussion

If attention was spontaneously biased towards faces, we expected performance to be facilitated for targets occurring at the previous location of the face and/or specific facial features. Our results did not support this prediction.

While we found that responses were overall facilitated for targets at the previous location of the face and house relative to the comparison cues, the response times for targets appearing at the location of face and house cues were equivalent. This result contrasts with past work (Bindemann et al., 2007; Ro et al., 2001), and suggests that those findings may have reflected isolated or combined contributions of attentional modulations elicited by extraneous factors like visual properties of the stimuli (e.g., size, luminance), configuration of features (e.g., spatial placement of eyes vs. other comparison areas), participants' subjective evaluations of the cues (e.g., attractiveness), and/or task settings.

Experiment 2

One potential reason for why we may not have observed an attentional bias for faces in Experiment 1 is that we did not control for participants' eye movements. That is, it is possible that a failure to observe a spontaneous attentional biasing for faces may have resulted from participants' non-compliance with task instructions to maintain central fixation. In turn, participants may have altered their focus of attention on a trial-by-trial basis by moving their eyes to inspect the cues, potentially influencing manual performance results. To test this hypothesis, in addition to controlling for visual and task factors as in Experiment 1, in

Experiment 2, we further controlled for eye movements by instructing participants to maintain central fixation and by monitoring whether they complied with these instructions using an eye tracker.

Methods

Participants, Apparatus, Stimuli, Design, and Procedure. Thirty new volunteers (24 female; age M=20 years, SD=1 years) participated. None took part in the previous experiment and all reported normal or corrected-to-normal vision. All stimuli, design, and procedures were identical to Experiment 1, except that: *(a)* Participants' eye movements were tracked using a remote EyeLink 1000 eye tracker (SR Research; Mississauga, ON) recording with a sampling rate of 500Hz and a spatial resolution of .05°. Although viewing was binocular, only the right eye was tracked; *(b)* Prior to the start of the experiment, a nine-point calibration was performed, and spatial error was rechecked before every trial using a single-point calibration dot. Average spatial error was no greater than .5°, with maximum error not exceeding 1°.

Results

Anticipations (0.1%), timeouts (3.2%), and incorrect key presses (0.1%) were removed from further analyses. To address our main hypothesis and examine covert attention biasing, all trials in which an eye movement had occurred during any part of the trial (18.9%) were also excluded from analyses. Thus, only trials in which no manual errors or eye movements occurred were analyzed. Overall response accuracy was 88%. All analyses mirrored those performed in Experiment 1.

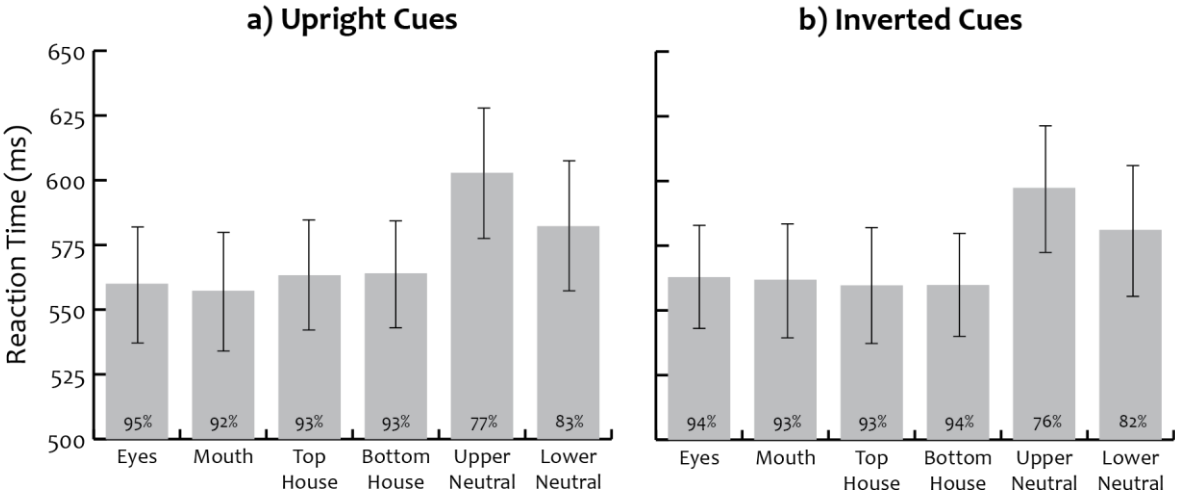

Figure 2.4 Experiment 2 results. Mean interparticipant correct RTs in ms and accuracy rates in percent as a function of Target position for Upright (a) and Inverted (b) cues. Error bars represent 95% CIs.

Figure 2.4 depicts mean correct interparticipant RTs and accuracy for targets following Upright (2.4a) and Inverted (2.4b) cues, and shows that controlling for eye movements did not result in preferential biasing of attention to the location of the face cue. An omnibus ANOVA (*Cue orientation, Face position, Target position, Cue-target interval*) supported this observation, revealing a significant main effect of *Cue-target interval*, $F(3,84)=27.98$, $p<.001$, $\eta_p^2=.50$, with faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, ts>7.00, ps<.001, d_zs>1.28; all other ps>.99, d_zs<.10], and a significant main effect of *Target position*, $F(5,140)=26.43$, $p<.001$, $\eta_p^2=.49$, with slowest RTs for targets that appeared in the previous location of the neutral cues [upper and lower neutral vs. all others, ts>3.90, ps<.008, d_zs>.71]. Once again, responses for targets occurring at the locations of interest (Eyes, Mouth, Top House, Bottom House) did not differ from one another, all ts<.82, ps>.99, d_zs<.15, 95% CIs of all mean differences once again included the zero point, ranging from –11.23ms to 9.88ms. Of little theoretical interest, a significant main effect of *Face position*, $F(1,28)=14.98$, $p=.001$, $\eta_p^2=.35$, indicated that overall responses to targets, regardless of where they appeared, were faster when the face cue was presented in the left visual field compared to when it was presented in the right visual field.

Importantly, and as in Experiment 1, no effects or interactions between *Face position* and *Target position* were found [*Face position x Target position* $F(5,140)=1.15$, $p=.34$, $\eta_p^2=.04$; *Face position x Target position x Cue orientation*, $F(15,140)=.45$, $p=.81$, $\eta_p^2=.02$; *Face position x Target position x Cue-target interval*, $F(15,420)=1.46$, $p=.12$, $\eta_p^2=.05$; *Face position x Target position x Cue-target interval x Cue orientation*, $F(15,420)=1.01$, $p=.44$, $\eta_p^2=.03$; all other Fs<1.98, ps>.17, $\eta_p^2<.07$][4].

As before, to ensure that our lack of effects were not due to stricter statistics, we calculated the means of median correct RTs and conducted a repeated measures ANOVA across *Target position* (face, house) and *Cue-target interval* (250, 360, 560, 1000ms). Once again, the results replicate reported data, with only a reliable main effect of *Cue-target interval* [$F(3,87)=15.22$, $p<.001$, $\eta_p^2=.34$] demonstrating faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, ts>5.10, ps<.001, d_zs>.95; other ps>.43, d_zs<.15], and no other

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[4] Analyses of response accuracy once again indicated no speed-accuracy trade-offs. The ANOVA returned a marginal main effect of *Cue-target interval*, $F(3,87)=2.67$, $p=.052$, $\eta_p^2=.08$, with higher accuracy for targets appearing at short relative to long cue-target intervals [250ms vs. 1000ms, $t(29)=2.83$, $p=.048$, $d_z=.52$; all other ps>.34, d_zs<.35]. A main effect of *Target position*, $F(5,145)=45.18$, $p<.001$, $\eta_p^2=.61$, once again indicated lower accuracy for targets at the previous location of both neutral cues [upper and lower neutral vs. all, ts>5.90, ps<.001, d_zs>1.08]. Lower accuracy was also found for targets occurring at the previous location of the mouth vs. eye cues, $t(29)=3.11$, $p=.028$, $d_z=.57$; all other ps>.10, d_zs<.46. No other effects or interactions were reliable, all Fs<1.63, ps>.18, $\eta_p^2<.05$.

effects [*Target position, F*=.02, *p*=.88, η_p^2=.001; *Target position* x *Cue-target interval, F*=.78, *p*=.51, η_p^2=.03].

Discussion

When we controlled for participants' eye movements in addition to stimulus and task properties, we still did not find a processing advantage for targets occurring at the location of the face. Once again, our data indicated that participants performed the task well, but that their responses for targets occurring at the location of the social face and non-social house stimuli were equivalent. While we did observe that overall RTs were faster when the face was presented in the left visual field, this effect occurred regardless of target location and was not specific to attentional selection.

Experiment 3

Here we examined whether any oculomotor biasing was present in this task. Previous work has demonstrated that when participants are allowed and/or explicitly instructed to make eye movements, their initial fixations are reliably biased towards faces and facial features such as eyes (Birmingham et al., 2008a, 2008b; Smilek et al., 2006; Yarbus, 1967). To test this notion, in Experiment 3 we did not provide participants with any instructions to maintain central fixation but measured their spontaneous oculomotor biasing using an eye tracker while they performed the same task as in the previous two experiments.

Methods

Participants, Apparatus, Stimuli, Design, and Procedure. Thirty additional volunteers (27 female; age M=22 years, SD=2 years) performed the same task as in the previous experiment. The parameters remained identical except that we did not instruct participants about maintaining central fixation. This manipulation in turn preserved their natural oculomotor behavior during the task in order to examine if participants naturally looked at the face cue more frequently during the cue display, i.e., when all cues were available.

Results

Oculomotor data. To assess if participants spontaneously looked at the social face cue more frequently, we analyzed saccades that were launched from fixation towards one of the predefined regions of interest (ROI), i.e., Eyes, Mouth, Top House, Bottom House, Upper Neutral, or Lower Neutral location, during the 250ms cue period. As illustrated in Figure 2.5, each ROI was comprised of its respective cue region and spanned an average of 43° radial window. Saccades were defined as eye movements with an amplitude of at least .5°, an acceleration threshold of $9{,}500°/s^2$, and a velocity threshold of 30°/s.

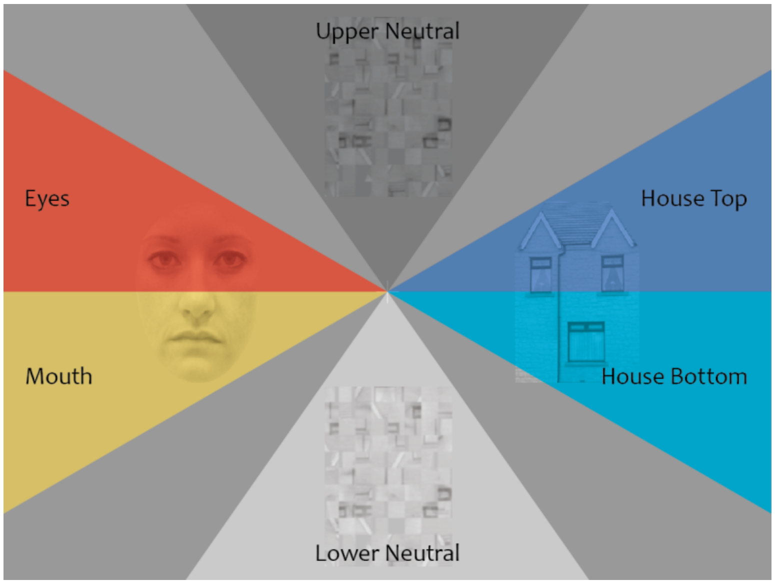

Figure 2.5 Regions of Interest (ROI). ROIs were defined by a radial window, including the area of interest; red = eyes, yellow = mouth, dark blue = top house, light blue = bottom house, dark grey = upper neutral, light grey = lower neutral. ROIs were equated for differences in the size of the visual angle.

For each participant, we calculated the proportion of saccades for each ROI by examining the direction of the very first saccade away from central fixation upon cue onset. For each participant, the number of saccades that were launched from fixation to each ROI were tallied across the entire experiment and then divided by the total number of first saccades that occurred during the cue period. The average number of saccades launched per trial was 0.11, with participants saccading away from fixation infrequently on 11% of all trials. Saccades were launched towards an ROI on 83% of those trials.

A repeated measures ANOVA examined this proportion of breakaway saccades as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (Eyes, Mouth, Top House, Bottom House, Upper Neutral, Lower Neutral). The results indicated that a greater proportion of saccades were launched towards the Eyes, particularly when the face was presented in an upright orientation and when the face was positioned in the left visual field, as illustrated in Figure 2.6. There was a main effect of *ROI*, $F(5,145)=8.94$, $p<.001$, $\eta_p^2=.24$, showing an overall greater proportion of breakaways towards the Eyes compared to the Mouth and House Bottom, ts>3.56, ps<.011, d_zs>.65. Lower proportion of breakaways also occurred towards the lower Neutral cue vs. all other cues, ts>3.07, ps<.045, d_zs>.56 [all other ps>.73, d_zs<.31].

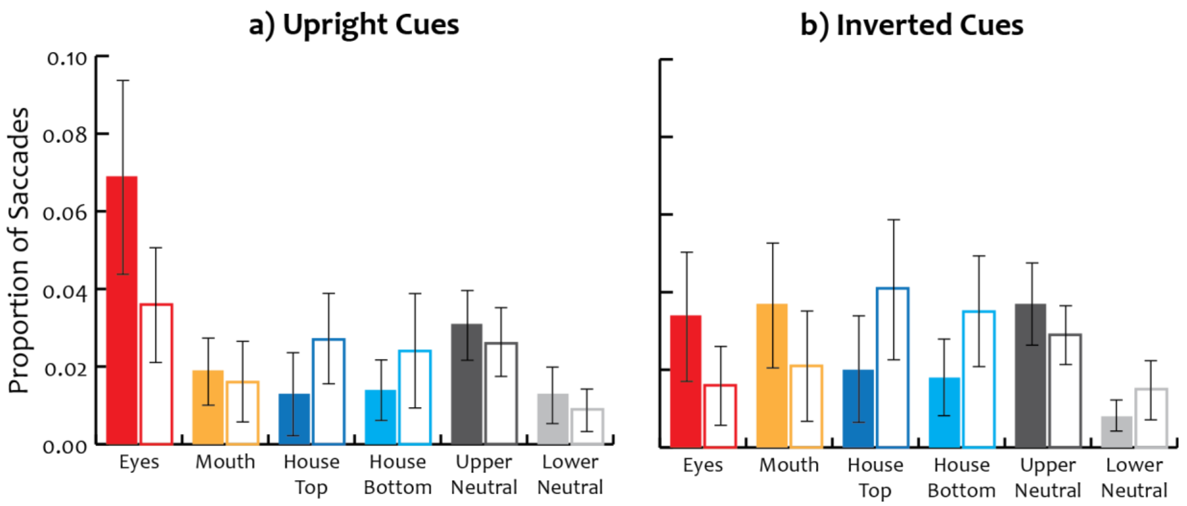

Figure 2.6 Experiment 3 oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of ROI for Upright (a) and Inverted (b) cues. Filled bars = face in the left visual field; Unfilled bars = face in the right visual field. Error bars represent 95% CIs.

There was also a significant interaction between *Cue orientation* and *ROI*, $F(5,145)=4.98$, $p<.001$, $\eta_p^2=.15$, indicating that when the cues were upright, a greater proportion of saccades were directed towards the Eyes compared to the Mouth, House Top, House Bottom, and Lower neutral cue, *t*s>3.88, *p*s<.012, d_zs>.71. Lower proportions of breakaways were also directed towards the Lower Neutral vs. Upper Neutral, $t(29)=3.44$, $p=.022$, $d_z=.63$ [all other *p*s>.08, d_zs<.52]. In contrast, when cues were presented in an inverted orientation, the saccadic bias towards the eyes disappeared [*t*s<2.45, *p*s>.23, d_zs<.45, all 95% CIs spanned the zero point, ranging from –.03 to .06], with the only difference found between Lower Neutral having a lower proportion of breakaways as compared to Upper Neutral and House Top cues, *t*s>4.04, *p*s<.001, d_zs>.74, [all other *p*s>.08, d_zs<.54].

A reliable *Face position* and *ROI* interaction, $F(5,145)=5.96$, $p<.001$, $\eta_p^2=.17$, further suggested that the breakaway bias for Eyes was restricted to the left visual field with a larger proportion of saccades launched towards the Eyes vs. the Mouth, House Top, House Bottom, and

Lower Neutral when the face was presented in the left visual field, *t*s>3.86, *p*s<.011, d_zs>.70. Fewer saccades were also directed towards the Lower Neutral vs. the Mouth and Upper Neutral, *t*s>3.33, *p*s<.02, d_zs<.61 [all other *p*s>.054, d_zs<.55]. When the face was presented in the right visual field, however, no saccadic bias was found towards the eyes, *t*s<2.54, *p*s>.20, d_zs<.46, all 95% CIs spanned the zero point, ranging from –.03 to .02, with fewer breakaways made toward the Lower Neutral as compared to Upper Neutral and House Top positions, *t*s>3.18, *p*s<.042, d_zs>.58 [all other *p*s>.09, d_zs<.53].

Thus, when we assessed participants' natural oculomotor behavior during the dot-probe task, we found that they spontaneously launched saccades more frequently towards the Eyes of the face. This effect was also greater when the face was presented in an upright orientation and when it was presented in the left visual field.

Manual data. Anticipations (0%), timeouts (1.1%), and incorrect key presses (0.1%) were removed from analyses. Overall response accuracy was 95%. As illustrated in Figure 2.7, an examination of mean correct RTs once again revealed no manual performance bias. An omnibus ANOVA with *Cue orientation*, *Face position*, *Target position*, and *Cue-target interval* once again revealed main effects of *Cue-target interval*, *F*(3,87)=48.41, *p*<.001, η_p^2=.63, and *Target position*, *F*(5,145)=52.89, *p*<.001, η_p^2=.65, driven by overall faster RTs at longer cue-target times [250ms vs. all, *t*s>7.93, *p*s<.001, d_zs>1.45; all other *p*s>.99, d_zs<.15], and slower RTs for targets that appeared in the previous location of the neutral cues [upper and lower neutral vs. all, *t*s>7.21, *p*s<.001, d_zs>1.32], respectively. RTs for targets occurring at locations of interest (Eyes, Mouth, Top House, Bottom House) did not differ, all *ts*<1.51, *ps*>.99, d_zs<.28; all 95% CIs spanned the zero point, ranging from –12.57ms to 8.92ms.

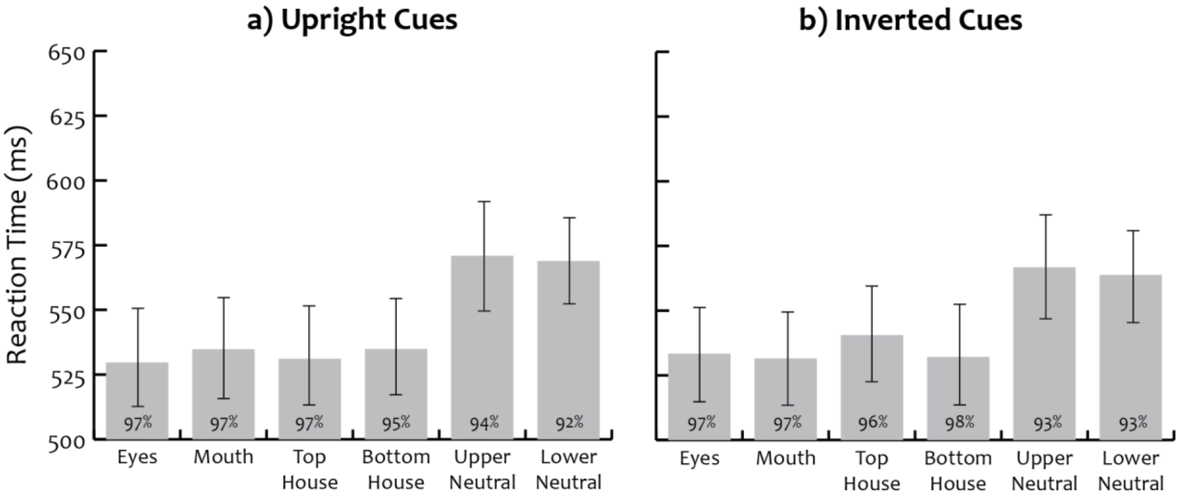

Figure 2.7 Experiment 3 manual results. Mean interparticipant correct RTs in ms and accuracy rates in percent as a function of Target position for Upright (a) and Inverted (b) cues. Error bars represent 95% CIs.

An interaction between *Cue orientation* and *Target position* [$F(5,145)=2.44$, $p=.037$, $\eta_p^2=.08$], indicated slower RTs for targets that occurred at the previous location of both neutral cues vs. all other target locations for upright (ts>7.40, ps<.001, d_zs>1.35; all other ps>.63, d_zs<.32) relative to inverted cues (ts>4.56, ps<.001, d_zs>.83; all other ps>.32, d_zs<.37). Importantly, as before, no interactions involving *Face position* and *Target position* were found [*Face position x Target position* $F(5,145)=.75$, $p=.59$, $\eta_p^2=.02$; *Face position x Target position x Cue orientation*, $F(15,145)=.52$, $p=.76$, $\eta_p^2=.02$; *Face position x Target position x Cue-target interval*, $F(15,435)=.74$, $p=.74$, $\eta_p^2=.02$; *Face position x Target position x Cue-target interval x Cue orientation*, $F(15,435)=.53$, $p=.92$, $\eta_p^2=.02$][5].

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[5] No speed-accuracy trade-off was evident. The same ANOVA conducted on accuracy revealed a main effect of *Target position*, $F(5,145)=15.74$, $p<.001$, $\eta_p^2=.35$, with lower accuracy for targets appearing in the previous location of the upper and lower neutral cues vs. all others [ts>3.60, ps<.008, d_zs>.66; all other ps>.99, d_zs<.25]. An interaction between *Cue orientation* and *Target position*, $F(5,145)=3.42$, $p=.006$, $\eta_p^2=.11$, indicated lower accuracy for targets that occurred at the previous location of the neutral cues (upper, lower) vs. the eyes, mouth, and house top

We also analyzed the means of median correct RTs using a repeated measures ANOVA for *Target position* (face, house) and *Cue-target interval* (250, 360, 560, 1000ms). As before, the results of this analysis replicated our results. There was a main effect of *Cue-target interval* [$F(3,87)=34.60$, $p<.001$, $\eta_p^2=.54$; 250ms vs. all, ts>6.41, ps<.001, d_zs>1.19; other ps>.30, d_zs<.20], with no main effect of *Target position* [$F=.12$, $p=.73$, $\eta_p^2=.004$] and no significant interaction [$F=.22$, $p=.89$, $\eta_p^2=.007$].

Discussion

In Experiment 3, we investigated whether participants' eye movements were spontaneously biased toward faces overall or their facial features by using a manipulation in which we monitored participants' natural oculomotor behavior while they performed the dot-probe task. Without any specific instructions to maintain central fixation, we found that participants broke fixation and explored the cue stimuli on 11% of trials. Within those trials, an oculomotor preference for faces and specifically for eyes emerged for upright faces and when faces were presented in the left visual field. This dovetails with existing literature that shows a preferential bias to look at the eyes of faces (Birmingham et al., 2008b; Laidlaw et al., 2012; Yarbus, 1967) and the specialized role of right-lateralized brain structures in the processing of faces (Yovel et al., 2003). However, once again we found no manual attentional benefits, suggesting dissociations between covert and overt social attention (see also Kuhn et al., 2016 for a similar finding). We return to this point in the Discussion.

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for upright cues [ts>3.60, ps<.011, d_zs>.66; all other ps>.24, d_zs<.43] and lower accuracy for targets that occurred at the previous location of both neutral cues (upper, lower) vs. the eyes, mouth, and house bottom for inverted cues [ts>3.57, ps<.011, d_zs>.65; all other ps>.30, d_zs<.40]. No other main effects or interactions were found, all other Fs<2.64, ps>.12, η_p^2<.08.

It is important to highlight here that although the oculomotor bias was statistically reliable, participants broke fixation and launched saccades towards one of the ROIs during the cue presentation on only 11% of all trials. Within those trials, they looked at the Eye region on 17% of trials. That is, oculomotor biasing toward the eyes was observed on only 1.9% of all trials. As such, although we found evidence for spontaneous oculomotor biasing towards social information in Experiment 3, this behavior occurred on a very small subset of all trials.

Experiment 4

Thus, the results so far indicated no reliable social attentional capture by faces when stimulus and task factors were systematically controlled. To ensure that this result is not an artifact of our specific laboratory settings, in Experiment 4, we conducted a direct replication of Bindemann and colleagues (2007) Experiment 1a, using their stimuli, procedures, and analyses. This study was one of the first demonstrations of spontaneous social attentional biasing while utilizing a covert attentional paradigm. However, unlike the current study, their stimuli were not matched for luminance, attractiveness, or configuration of features. If these stimulus factors are important in driving attention to faces, we expected to replicate Bindemann and colleagues (2007) original findings demonstrating a response facilitation for targets occurring at the previous location of the face relative to the non-social object stimuli.

Methods

Participants. Twenty new volunteers (12 female; age M=24 years, SD=5 years) with normal or corrected-to-normal vision participated. They were recruited via a volunteer pool and received compensation for their participation. None participated in the previous experiments.

The sample size was selected to match Bindemann and colleagues (2007) study. All procedures were approved by the University Research Ethics board.

Apparatus and Stimuli. Original stimuli were obtained from the lead author via personal correspondence. Stimuli were presented on a 16” CRT monitor at an approximate viewing distance of 60cm, with stimulus presentation timing and sequencing controlled by MATLAB’s Psychophysics toolbox (Brainard, 1997).

The central fixation subtended 0.4° x 0.4° of visual angle. The cue stimuli consisted of grey scale photographs of six faces and six objects each measuring 4.2° x 4.2° and positioned at a distance of 3.4° from fixation. The target stimuli consisted of a grey square measuring 0.6° x 0.6°, positioned 5.5° away from fixation. All displays were set on a white background.

Design. The target detection task was a repeated measures design with six factors: *Cue face* (three male, three female), *Cue object* (train, boat, dollhouse, tap, teapot, wall clock), *Face position* (left visual field, right visual field), *Cue-target interval* (100, 500, 1000ms), and *Target position* (face, object). All factor combinations were equiprobable and presented equally often throughout the experimental sequence. The cues were spatially uninformative about the target location.

Procedure. As in Bindemann and colleagues’ (2007) study, all trials began with the presentation of a fixation display for 750ms. Then, the cue display was shown for 100, 500, or 1000ms, after which the target appeared to the left or right of fixation and remained visible until participants responded. Participants were asked to respond quickly and accurately by pressing the ‘3’ or ‘.’ keys on the numpad of the keyboard to localize the target position. Participants completed 432 trials divided equally across 6 testing blocks, with 24 practice trials run at the start. Responses were measured from target onset.

Results

As in the original study, the means of median correct RTs were analyzed using a repeated measures ANOVA across *Target position* (face, object) and *Cue-target interval* (100, 500, 1000ms). The results illustrated in Figure 2.8, revealed an expected main effect of *Cue-target interval* [$F(2,38)=4.92$, $p=.013$, $\eta_p^2=.21$] with overall faster RTs for longer relative to shorter cue-target intervals [1000ms vs. all, ts>2.09, ps<.05, d_zs>.48; other $p=.60$, $d_z=.12$]. More importantly, they also revealed a reliable main effect of *Target position* [$F(1,19)=14.63$, $p=.001$, $\eta_p^2=.44$] with targets appearing at the previous location of the face detected faster than targets appearing at the previous location of the object. No interactions were found [$F=.01$, $p=.99$, $\eta_p^2=.001$].

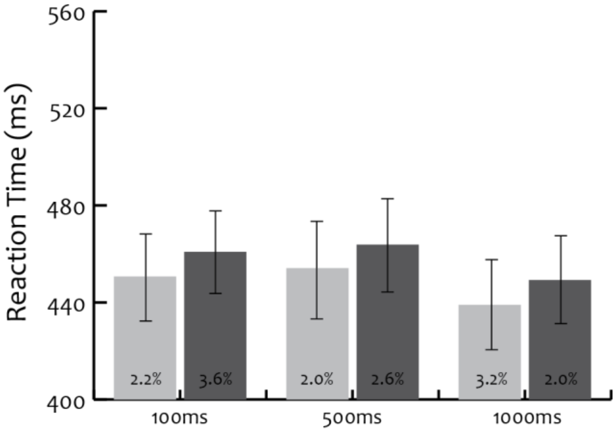

Figure 2.8 Experiment 4 results. Direct replication of Bindemann and colleagues (2007) Experiment 1a. Means of median correct RTs in ms and error rates in percent are shown as a function of Target position and Cue-target interval. Grey bars = face cue; Dark grey bars = object cue. Error bars represent +/– 1 SE.

Discussion

As predicted, when we employed uncontrolled stimuli, we fully replicated the original finding demonstrating social attentional bias towards faces. This result strengthens the findings from our previous experiments and demonstrates that the previous pattern of results do not reflect a failure to replicate but rather show a meaningful influence of stimulus and task settings on social attention.

General Discussion

In the present study, while controlling for stimulus, task, and oculomotor factors, we re-examined the prevailing notion that faces and/or facial features spontaneously bias attention (Ariga & Arihara, 2017a; Bindemann et al., 2007; Langton et al., 2008; Sato & Kawahara, 2015). Using a dot-probe paradigm, we presented participants with a face-house cue pair and comparison neutral cues in upright and inverted orientations, and measured their performance in response to targets that appeared at the previous location of those cues. In Experiment 1, we instructed participants to maintain central fixation. In Experiment 2, in addition to these instructions, we ensured that they maintained central fixation via a high-speed eye tracker and excluded any trials in which eye movements had occurred. In Experiment 3, instead of controlling for eye movements, we specifically measured spontaneous oculomotor behavior. Across all three experiments, we found no preferential attentional bias in manual responses towards faces or any facial features. That is, participants' response times did not differ for targets that were presented at the previous location of the face relative to the previous location of the house. In Experiment 3, we found that when allowed to make eye movements during the task, participants looked towards the eyes of the face more frequently than to other regions of the display, and specifically when faces were presented in an upright orientation and in the left visual field. This social oculomotor biasing however was infrequent, occurring on less than 2% of all trials. Finally, in Experiment 4, we demonstrated that we can measure typical social attention biasing when utilizing uncontrolled stimuli. Taken together, these results indicate that previously reported preferential attentional bias for faces may be more strongly affected by context, stimulus, and task factors than originally thought.

In contrast to the large body of literature demonstrating an attentional bias for social information (Bindemann et al., 2005; Bindemann et al., 2007; Devue et al., 2009; Langton et al., 2008; Ro et al., 2001; Sato & Kawahara, 2015), and in contrast to our own direct replication of Bindemann and colleagues' (2007) study, the results from our experiments surprisingly did not support the notion that faces and/or their features preferentially engage human attention. This result was particularly salient in manual responses, which consistently indicated no reliable differences between responses to targets occurring at the previous location of the face and house images. Dovetailing with existing work that has demonstrated modulation of attention for faces through stimulus and task parameters (Crouzet & Thorpe, 2011; Itier & Taylor, 2002, 2004), our results also suggest that past reports of spontaneous social attentional bias likely reflected the influence of similar stimulus and task factors that may have acted in isolation or in conjunction to bias attention, independently from the social features of faces. This finding highlights the strong role that stimulus and task settings play in social attention, above and beyond the perception of faces alone, and suggests that previously reported attentional effects may not be primarily due to the inherent social nature of faces but instead to their task relevance (Capozzi & Ristic, 2018). The question of which stimulus factor is the most relevant in biasing social attention remains to be addressed in future investigations geared towards directly manipulating and isolating the contribution of task, stimuli, and context to social attention, such as for example by manipulating specific low- and high-level factors, task timing, and target properties.

In contrast to manual data however, natural oculomotor behavior during the task (Experiment 3), revealed small, albeit reliable, biasing of eye movements towards the eyes. This finding held only when faces were presented in an upright orientation and in the left visual field, dovetailing well with existing literature demonstrating preferential processing of upright faces by right-lateralized face sensitive brain areas (McCarthy, Puce, Gore, & Allison, 1997; Rhodes, 1985; Rossion et al., 2003), and with the large volume of data showing preferential oculomotor selection of faces and eyes within the first few fixations of naturalistic free-viewing tasks (Birmingham et al., 2008a, 2008b; Smilek et al., 2006; Yarbus, 1967). However, our data revealed that preferential social oculomotor biasing occurred on a very small subset of all trials, i.e., 1.9%. Even though we were not able to examine more fine-grained saccadic measures (e.g., saccadic reaction time, initial saccade latency) due to these small number of saccadic breakaways, our results suggest that the choice of task and stimuli also modulate the strength of observed oculomotor biasing. This is consistent with data reported by Võ and colleagues (2012) who found that fixations made to the eyes of a video protagonist were modulated by participants' goals rather than an overall preference for fixating the eyes. Thus, while preferential oculomotor biasing by faces is present across different tasks, the magnitude of this response is readily modulated by task settings and observer goals (Birmingham et al., 2008b).

From a theoretical perspective, our results highlight the notion that robust social attentional biasing may require optimal situational, stimulus, and task factors. In line with this reasoning, recent research shows that in some social situations, the potential for social interaction decreases the frequency of social attentional behaviors like gaze following (e.g., looking at an image of a confederate vs. the person themselves; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011), whereas in other settings, the same factors may lead to an increase in similar types of social behavior (e.g., eating with a friend vs. a stranger; Wu, Bischof, & Kingstone, 2013). Past results on differential and contextually situated effects for attention to faces also support this perspective (Birmingham, Ristic, & Kingstone, 2012; Hayward et al., 2017; McPartland, Webb, Keehn, & Dawson, 2011; Võ et al., 2012), along with clinical work demonstrating little-to-no difference in attentional and oculomotor viewing patterns between individuals with autism spectrum disorder and typically-developing individuals when studies utilize static, unimodal, and ecologically impoverished stimuli (Anderson, Colombo, & Shaddy, 2006; Guillon, Hadjikhani, Baduel, & Roge, 2014; McPartland et al., 2011). Thus, factors like social relevancy, context, and/or agency are important to consider when examining spontaneous social attentional biasing, with future work needed to examine the stability of the theoretically-predicted social attention behaviors across different stimuli, measures, and situations.

Our results also raise important questions about the dissociation between manual (i.e., covert) and oculomotor (i.e., overt) measures of social attention. Across all experiments, we found no reliable evidence for a manual performance advantage for targets cued by faces, but nevertheless found a small but reliable oculomotor bias towards the eyes of the face cue when participants maintained natural oculomotor behavior during the task (i.e., in Experiment 3). The dissociation between manual and oculomotor data points to a potential difference in covert and overt responses when faces and eyes serve as stimuli. The relationship between covert (i.e., attention devoid of eye movements; Jonides, 1981) and overt attention (i.e., attention accompanied by oculomotor movements; Posner, 1980) has thus far been studied extensively, with most findings converging on the idea that the two modes of attention can be elicited separately as well as in conjunction (de Haan, Morgan, & Rorden, 2008; Hunt & Kingstone, 2003a; Nobre, Gitelman, Dias, & Mesulam, 2000; Peterson, Kramer, & Irwin, 2004). The examinations of these systems and their associations have typically been conducted using non-social traditional attentional stimuli, such as luminance transients or geometric shapes (Klein & Pontefract, 1994; Peterson et al., 2004; Van der Stigchel & Theeuwes, 2007). In contrast to these classic investigations, our data are consistent with a handful of recent examinations which point to important dissociations in overt and covert attentional systems within the specific domain of social attention (Kuhn et al., 2016; Laidlaw, Badiudeen, Zhu, & Kingstone, 2015; Risko et al., 2016). That is, it has recently been suggested that covert and overt attentional systems may serve different purposes in social communication. While covert social attention may primarily function to gather social information from the environment without revealing the focus of an agent's attention to others, overt social attention may aid in the communication of social cues to other agents during social interactions (Gobel, Kim, & Richardson, 2015; Risko et al., 2016). As such, while it is possible that differential dissociated operations between covert and overt systems may not be unique to social attention, future studies are needed to determine the individual contribution of covert and overt attentional systems to social and general attentional behaviors across different test situation complexities (e.g., Hayward et al., 2017).

To address alternate explanations for our pattern of results, it may be possible that the face-house cue image used in this study were perceptually equated to such an extent to result in a loss of information that is critical for distinguishing between face and non-face stimuli. If so, these low-level feature differences would then appear to be necessary for social attentional biasing rather than the overall presence of the face cues alone. It may also be possible that subtle differences in the task and stimulus parameters utilized here as compared to past work may have also contributed to the reduction of the social attentional bias. However, when compared to the original Bindemann and colleagues (2007) study, these task changes were minimal. The changes included presenting three instead of two types of cues, six instead of two targets, and responses that required target identification instead of target localization. If the processes behind social attention were as spontaneous and robust as originally thought, then these minor alterations to the task and stimulus should not have such a dramatic effect on the measured effects. It was also suggested to us that participants may have spread their attention in an object-based manner such that either the face or the house was prioritized for responding. If so, we would have expected to find an overall global effect for the face, along with no specific effects for the eyes or mouth locations; however, our results did not reveal any evidence of facilitative responses for targets occurring at the previous location of the face overall but did demonstrate an oculomotor bias towards the eyes over the mouth. It is possible that participants may have also strategically responded to targets irrespective of the cues; however if so, this would still support our main finding indicating that social cue identity did not influence target detection.

Finally, it is important to discuss that a potential reason for why we may not have observed social attentional biasing for faces and/or facial features in this study could reflect an insensitivity of the dot-probe task to detect these effects. Although plausible, there are three reasons for why we believe this is not a likely explanation for our data. One, the dot-probe task (MacLeod et al., 1986), along with the cuing task (Posner, 1980), has been one of the most utilized attentional paradigms, and a go-to task for examining attentional biases to emotional and rewarding stimuli (Frewen, Dozois, Joanisse, & Neufeld, 2008). This popularity reflects the task's ability to elicit attentional effects on a trial-to-trial basis and to measure their behavioral modulations across different parts of the visual field (Cooper & Langton; Frewen et al., 2008;

Klein & MacInnes, 1999; MacLeod et al., 1986; Navon & Margalit, 1983; but see Schmukle, 2005, for issues with non-clinical samples). Two, existing studies that have measured and reported preferential attentional biasing by faces have often done so using the dot-probe task. For example, both Bindemann and colleagues (2007) original study and the replication reported in the current paper showed stable attentional allocation to faces using this paradigm. Three, even though we did not find reliable differences between responses to targets preceded by faces and those preceded by houses, our data indicated that participants performed the task as instructed – they exhibited high accuracy in responses and performed the task with the expected level of temporal alertness, as demonstrated by the robust main effects of cue-target interval, which is commonly understood to reflect response preparation processes (Bertelson, 1967). Furthermore, preferential selection of faces was found when compared to control scrambled stimuli, indicating that social information was preferentially attended over and above neutral information but not over and above other stimuli of relevance. This suggests that while our procedure was able to measure differences in target processing, it did not yield theoretically predicted performance differences between targets occurring at the location of the face and house images. Although it is unlikely that our results reflect an inability of the dot-probe paradigm to reveal preferential attentional biasing by social cues, future work should address the sensitivity of this task in assessing more subtle processing differences between social and non-social cues using more temporally precise methodologies such as electroencephalography.

To conclude, in this study we provide one of the first pieces of evidence showing the fragility of spontaneous social attentional biasing within a standard laboratory task. This finding challenges the prevailing notion that faces and facial features bias human attention spontaneously and preferentially, and highlights the need for future studies to delineate the specific contributions of stimulus, task, and situational factors to social attention.

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Social attention is biased by perceived facial attractiveness but not overall luminance or featural configuration differences

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Abstract

Humans spontaneously attend to faces and eyes. However, recent findings suggest that social attention biasing is affected by the stimulus content and visual context within which faces are presented. Here, we investigated whether social attentional biasing is modulated by stimulus content. Across six experiments, participants completed a dot-probe task, in which a face, a house, and two neutral images were followed by the presentation of a target at one of those locations. Each experiment examined manual responses when eye movements were restricted (version a) and manual and oculomotor responses when eye movements were not restricted (version b). Experiment 1 assessed social attentional biasing when the face had higher overall global luminance. Experiment 2 examined social attentional biasing when the face retained the typical canonical configuration of internal features but the house did not. Experiment 3 examined social attentional biasing when the face cue was perceived as more attractive than the house cue. When eye movements were restricted, manual responses across all experiments did not reveal any preferential attentional biasing for faces. When eye movements were not restricted, the most important result emerged in Experiment 3b, indicating a specific oculomotor bias towards the eyes of attractive upright faces. Together, these results show that perceived attractiveness plays an important role in social attentional biasing.

Keywords: social attention; attentional biasing; faces; stimulus content; attractiveness

Introduction

Faces and facial features convey a great deal of information, with humans prioritizing this source of information from early on in development (e.g., faces; Farroni, Csibra, Simion, & Johnson, 2002; Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Simion & Giorgio, 2015; Valenza, Simion, Cassia, & Umilta, 1996; gaze; Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998). It is widely known that humans also possess a distributed and specialized network of brain regions, including the temporal, occipital, and frontal lobes, as well as subcortical structures like the amygdala, that are specifically dedicated for processing faces and their features (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Gauthier et al., 2000; Haxby et al., 1994; Kanwisher & Yovel, 2006; Nummenmaa & Calder, 2008; Perrett, Hietanen, Oram, Benson, & Rolls, 1992; Perrett et al., 1985; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Yovel, Levy, Grabowecky, & Paller, 2003).

Consistent with this overall importance, a large volume of research shows that faces and their features, especially eyes, bias attention in both covert (i.e., attentional shifts independent of eye movements; Jonides, 1981) and overt (i.e., attentional shifts accompanied by eye movements; Posner, 1980) responses. Covertly, attentional biasing is indexed by manual response time and/or accuracy in response to targets that appear following social (e.g., a face) compared to non-social (e.g., a house) cues. Bindemann and colleagues (2007) were among the first to demonstrate such attentional biasing by presenting participants with an image of a face and an image of an object simultaneously and asking them to respond to a target that appeared with equal probability at either of these two cue locations. The data indicated faster responses for targets that appeared at the location of the face relative to the comparison cue. This result is interpreted as indicating that faces attract attention preferentially even when they are irrelevant for the task. Subsequent work has replicated this general finding using other paradigms, including the go/no-go task (Bindemann, Burton, Hooge, Jenkins, & DeHaan, 2005), RSVP task (Ariga & Arihara, 2017), visual search (Lavie, Ro, & Russell, 2003), change detection (Ro, Russell, & Lavie, 2001), and inattentional blindness procedures (Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009).

Faces also attract overt attention, as indicated by greater number of fixations and/or shorter latency of eye movements elicited towards faces relative to comparison non-social stimuli. Yarbus' seminal work (1967) provided one of the first demonstrations of preferential overt social attentional biasing, whereby he recorded participants' eye movements while they viewed images of real world scenes, and found that participants preferentially looked at faces and facial features, including eyes, relative to other non-social objects. This general result has also been replicated on numerous occasions using a variety of other paradigms, including free-viewing naturalistic tasks (Birmingham, Bischof, & Kingstone, 2008a, 2008b; Cerf, Frady, & Koch, 2009; Laidlaw, Risko, & Kingstone, 2012), saccadic choice tasks (Crouzet, Kirchner, & Thorpe, 2010), cuing tasks (Theeuwes & Van der Stigchel, 2006), and oculomotor capture tasks (Devue, Belopolsky, & Theeuwes, 2012).

Although these findings show that social attentional biasing occurs both in manual and oculomotor responses, two recent studies have demonstrated that this effect may not be due to the social content of the face, but may instead be driven by extraneous stimulus and task factors. In the first study, Pereira, Birmingham, and Ristic (2019a) used a dot-probe task and presented participants with images of a face, house, and comparison neutral cues (i.e., scrambled face and house images). Participants were asked to respond to targets occurring equiprobably at one of these possible locations. Critically, and unlike past studies, the authors controlled the task for stimulus content, visual context, and task settings. To match stimulus content, the face and the house cues were equal in size, placed equidistantly from the central fixation, had similar global luminance, matching configuration of internal features (i.e., the spatial arrangement of two eyes and a mouth for the face mapped on to the spatial arrangement of two windows and a door for the house), and equivalent perceived attractiveness. To control visual context, the background information around the face and house cues was removed and all stimuli were presented against a uniform background. To control task settings, the identical task was used to measure social attentional biasing in manual and oculomotor measures, neither cue was spatially or semantically informative about the target, and the response keys and response types were not confounded with the cue position, target position, or target type. Across three experiments, the data revealed no evidence of spontaneous attentional biasing towards faces in manual data; however, there was a numerically small, but statistically reliable, oculomotor bias towards the eye region of the face.

The second study from the same authors (Pereira, Birmingham, & Ristic, 2019b) followed up on this finding and examined whether the removal of typical visual context played a key role in this result. Here, the authors re-introduced hair and body information for the face cue, along with a typical context in which the person was depicted sitting in a room and the house was presented within a picture hanging on a wall in a room. As before, the face and house cues were matched on all other stimulus content and task factors. Using the same dot-probe procedure and manual and oculomotor measures, the data once again indicated no reliable evidence of spontaneous attentional biasing towards faces or facial features in manual responses and an infrequent but reliable eye movement bias towards the eyes of the face. Taken together, the results from these two studies show that robust social attentional biasing effects may reflect the contribution of various stimulus and task factors rather than the social information contained within faces.

In the present study, we examined whether stimulus content factors, namely global luminance, internal configuration of features, and perceived attractiveness, play a role in social attentional biasing. Each of these factors have been documented to attract attention, and more so when stimuli include faces (Cerf, Harel, Einhäuser, & Koch, 2008; Eastwood, Smilek, & Merikle, 2001; Hedger, Garner, & Adams, 2019; Itier, Latinus, & Taylor, 2006; Rousselet, Ince, van Rijsbergen, & Schyns, 2014), thus strongly suggesting that one or more of these factors may play an important role in social attention.

Six experiments were run. In each, separate groups of participants completed a dot-probe task in which the presentation of the face, house, and comparison neutral (scrambled face and house) images were followed by the presentation of a response target appearing at one of the previous location of the eyes, mouth, the top of the house, the bottom of the house, or one of the two neutral locations. While holding visual context and task factors constant, each experiment examined social attentional biasing when only one stimulus content factor was manipulated. That is, in Experiment 1, overall global luminance was higher for the face relative to other cues; in Experiment 2, the face cue displayed typical configuration of internal features while the comparison house cue did not; and in Experiment 3, the face cue was perceived as more attractive than the house cue. In Experiments 1a, 2a, and 3a, we measured manual responses by instructing participants to withhold their eye movements. In Experiments 1b, 2b, and 3b, we additionally measured participants' oculomotor responses while they performed the task by not providing any specific instructions about eye movements. If either of these stimulus factors played a role in social attentional biasing, we expected to find reliable attentional biasing effects towards faces and/or eyes when that factor was specifically manipulated.

General Methodology

Participants

Each experiment included data from separate groups of thirty naïve volunteers (total N = 180), reporting normal or corrected-to-normal vision. This sample size reflects an a priori power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) based on the estimated magnitude of attention biasing for faces from past research (Bindemann & Burton, 2008; Bindemann et al., 2007; Langton, Law, Burton, & Schweinberger, 2008; Ro et al., 2001). This analysis indicated that data from 6–38 participants were needed to detect a medium-to-large effect ranging from .41–1.36 (as estimated from Cohen's f) with corresponding power values from .95–.97. Informed written consent was obtained from all participants and they received course credits upon study completion. The study was conducted in accordance with the Declaration of Helsinki, and all protocol and procedures were approved by the University research ethics board.

Apparatus

All stimuli were presented on a 16" CRT monitor at an approximate viewing distance of 60cm, with the stimulus presentation sequence controlled by MATLAB's Psychophysics toolbox (Brainard, 1997).

In experiments measuring oculomotor responses (Experiments 1b, 2b, and 3b), eye movements were tracked using a remote EyeLink 1000 eye tracker (SR Research; Mississauga, ON) recording with a sampling rate of 500Hz and a spatial resolution of .05°. Although viewing was binocular, only the right eye was tracked, with saccades defined as eye movements with an amplitude of at least .5°, an acceleration threshold of 9,500°/s^2, and a velocity threshold of 30°/s. Prior to the start of the experiment, a nine-point calibration procedure was performed, and spatial error was rechecked before every trial using a single-point calibration dot. Average spatial error was no greater than .5°, with maximum error not exceeding 1°.

Stimuli

Figure 3.1 illustrates the cues used in each experiment. All stimuli were set against a uniform 60% gray background. The fixation screen included a white fixation cross measuring 1° x 1° of visual angle, which was positioned at the center of the screen. The cue screen consisted of the fixation cross and grey-scale photographs of *(i)* a female face looking straight ahead with a neutral expression and the hairline removed, *(ii)* a house with no contextual background, and *(iii)* a neutral image consisting of a fused overlay of the face and house photographs scrambled using 22-pixel blocks. Cue images were sourced from the Glasgow Unfamiliar Face Database (Burton, White, & McNeill, 2010) and other online resources. Cues were equated for size and distance from fixation, as each image measured 4.2º x 6º and was positioned 6.3º away from the fixation cross. Luminance information, i.e., image intensity or brightness based on local or global contrast were computed using the MATLAB SHINE toolbox (Willenbockel et al., 2010). The target screen consisted of the fixation cross and a single target (yellow circle or square measuring 0.3º x 0.3º each) positioned 7.2º away from the fixation cross. Thus, the cue size, distance from fixation, target size, target position, and common uniform background were equated and controlled across experiments.

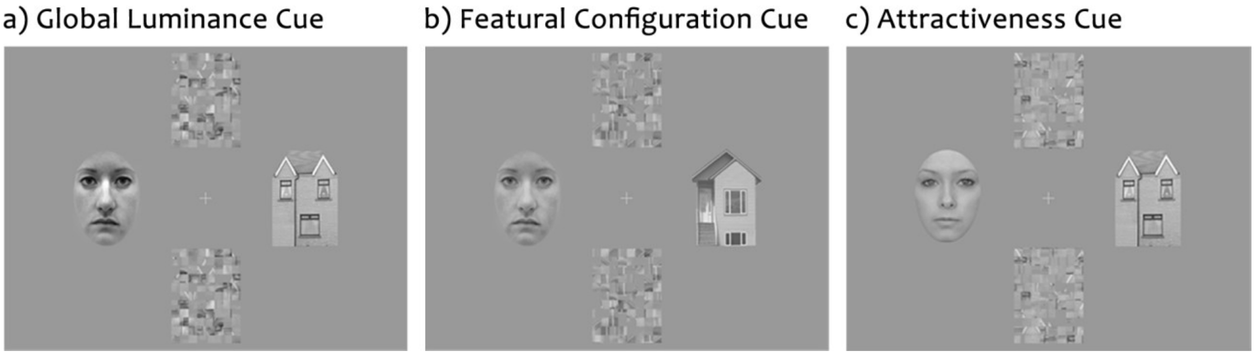

Figure 3.1 Illustration of cues for (a) Experiment 1, where the face cue contained greater global luminance than the house cue, (b) Experiment 2, where the internal featural configuration of the face cue did not match the internal featural configuration of the house cue, and (c) Experiment 3, where the face cue had a higher rating of perceived attractiveness than the house cue.

Stimulus manipulations. Stimulus content factors of global luminance, featural configuration, and perceived attractiveness were individually manipulated in Experiments 1, 2, and 3 respectively.

To manipulate global luminance, in Experiment 1 (Figure 3.1a), we used luminance-uncorrected images for the face and house cue, such that the average gray scale luminance (ranging from 0-1) was numerically higher for the face than the house cue (Face = 0.63, House = 0.58). In Experiments 2 and 3, the average gray scale luminance was equated across the face and house cues (Experiment 2 Face = 0.60, House = 0.61; Experiment 3 Face = 0.60, House = 0.58).

To manipulate featural configuration, in Experiment 2 (Figure 3.1b), the consistent first-order relationship in the spatial placement of internal features of the house cue, i.e., the placement of the windows and door, did not match the internal canonical configuration of the face cue, i.e., the spatial arrangement of the eyes and mouth, as shown in Figure 1b. In Experiments 1 and 3, the face and house cues had a consistent placement of internal configuration of features.

To manipulate perceived attractiveness, in Experiment 3 (Figure 3.1c), we used a face cue that was perceived as more attractive than the house cue. Perceived attractiveness was based on data from an additional twenty-eight naïve participants who were presented with 64 different face and house photographs. Participants were asked to rate each image on perceived attractiveness using a Likert scale ranging from 1- *Very Unattractive* to 6- *Very Attractive*. The face cue used in Experiment 3 received the highest attractiveness rating, while the house cue received an average rating and was the same used in Experiment 1 (Face M=5.71, SD=.71; House M=2.96, SD=.96; $t(27)=11.24$, $p<.001$, $d_z=2.12$). The face and house cue images used in Experiments 1 and 2 received equivalent average attractiveness ratings (E1: Face M=2.89, SD=1.68; House M=2.96, SD=.96; $t(27)=.17$, $p=.87$, $d_z=.03$; E2: Face M=2.93, SD=.77; House M=3.11, SD=1.47; $t(27)=.57$, $p=.57$, $d_z=.11$).

Aside from overall luminance in Experiment 1, placement of internal features in Experiment 2, and perceived attractiveness in Experiment 3, all other stimulus content, visual context, and task parameters (i.e., stimulus size, distance from fixation, background information, as well as task and response properties) remained equated.

Design

The dot-probe target discrimination task was a repeated measures design with five equiprobable factors: *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house, upper neutral, lower neutral), *Target identity* (circle, square), and *Cue-target interval* (250, 360, 560, 1000ms).

Cue orientation varied between upright and inverted cue images. Given the general processing and behavioral preferences for upright faces (Frank, Vul, & Johnson, 2009; Simion &

Giorgio, 2015; Yin, 1969), this factor was manipulated to ensure that any effects of social attentional biasing were specific to faces in an upright orientation. *Face position* varied between the left and right visual fields, with the house image always placed in the opposite visual field. This factor was manipulated to examine any advantageous processing effects of lateralized social information processing in the right hemisphere of the human brain (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; Puce et al., 1998; Rossion, Joyce, Cottrell, & Tarr, 2003; Yovel et al., 2003). *Target location* varied between the previous spatial location occupied by the eyes, the mouth, the top of the house, the bottom of the house, or the center of the upper or lower neutral image. This key manipulation was included to capture any performance differences for targets occurring at the previous location of the face and its facial features relative to the comparison stimuli. *Target identity* varied between a yellow circle and a yellow square in order to collect both response time and response accuracy. *Cue-target interval* varied between 250, 360, 560, and 1000ms and was manipulated in order to assess any differences in the time course of social attentional biasing (Bindemann et al., 2007; Pereira et al., 2019a, 2019b).

All factor combinations were presented equally often throughout the task sequence. The cues were spatially uninformative about the target location and its identity, as each target was equally likely to occur at any of the possible target locations. Conditions were intermixed and presented in a randomized order, so participants had no incentive induced by the task to attend to any particular cue.

Procedure

After the presentation of the fixation display for 600ms, participants were presented with a cue display for 250ms. After 0, 110, 310, or 750ms (constituting 250, 360, 560, and 1000ms cue-target intervals, respectively), a single target was shown at the previous location of the eyes, mouth, top house, bottom house, upper neutral, or lower neutral image. The target remained visible until response or until 1500ms had elapsed. Participants were instructed to identify the target quickly and accurately by pressing the ‘b’ or ‘h’ keys on the keyboard. Target identity-key response assignment was counterbalanced between participants.

Participants were informed about the task sequence, that the target was equally likely to be a circle or a square, that the target could appear in any of the possible locations, and that there was no spatial relationship between the cue content, cue orientation, cue placement, target location, or target identity. In the experiments that measured manual responses only (1a, 2a, and 3a), participants were instructed to maintain central fixation. In the experiments that measured both manual and oculomotor responses (1b, 2b, and 3b), participants were not given any specific instructions about restricting or initiating eye movements, which additionally allowed us to examine their natural oculomotor behaviour during the task. Each experiment consisted of 960 trials divided equally across five testing blocks. Ten practice trials were run at the start.

Data Analyses

Manual Response Time (RT). Any trials with response anticipations (RTs < 100ms), timeouts (RTs > 1000ms), and incorrect key presses (key press other than ‘b’ or ‘h’) counted as errors and were removed from analyses. Based on our previous findings (Pereira et al., 2019a, 2019b) repeatedly indicating no reliable overall social attentional biasing effects or meaningful interactions with attentional biasing, we first examined the data in each experiment using an a priori analysis, which tested for the presence of an overall social attentional bias effect. To do so, we compared mean correct RTs using one-way repeated measures ANOVAs across Face, House, and Neutral target locations separately for Upright and Inverted cues. If any significant social attentional biasing effect was found, i.e., the data indicated faster RTs for targets occurring at the location of the Face relative to targets occurring at the House, we then proceeded to examine the contribution of all factors by running a repeated measures ANOVA with *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house, upper neutral, lower neutral), and *Cue-target interval* (250, 360, 560, 1000ms).

Eye movements. In Experiments 1b, 2b, and 3b, along with manual RTs, we also examined the pattern of eye movements for trials in which saccades were launched from the central fixation cross towards one of the cues during the cue presentation time. To do so, we defined regions of interest (ROIs) around the cues (i.e., eyes, mouth, top house, bottom house, upper neutral, and lower neutral locations), with each ROI spanning an average of 43° radial window. Then, for each participant, the number of saccades that were launched towards each of those ROIs was determined by examining the direction of the first saccade that launched from the central fixation cross towards one of the ROIs upon cue onset. Proportion of saccades towards each ROI for each participant was calculated by tallying the number of saccades towards each ROI across the entire experiment and then dividing this number by the total number of first saccades that occurred during the cue period.

As with manual RT analyses, proportion of saccades were first examined for the overall presence of an attentional biasing effect across Face, House, and Neutral ROIs using one-way repeated measures ANOVAs run separately for Upright and Inverted conditions. If significant attentional biasing towards Faces were found, we then examined the contribution of all factors using a repeated measures ANOVA with *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house, upper neutral, lower neutral).

For all analyses, Greenhouse-Geiser corrections were applied for any violations of sphericity. Paired two-tailed t-tests were used for post-hoc comparisons, with multiple comparisons corrected using the Holm-Bonferroni procedure to control for Type I error (Holm, 1979). All comparisons are shown with corresponding adjusted *p*-values (α_{FW} = .05; Ludbrook, 2000).

Experiment 1

Experiment 1 examined the role of global facial luminance in social attentional biasing in manual responses when participants were instructed to maintain central fixation (1a), and in manual and oculomotor responses when no instruction about controlling eye movements was given (1b).

Luminance is one of the most salient attentional cues (Johannes, Münte, Heinze, & Mangun, 1995; Smith, 1998; Turatto & Galfano, 2000). For social information in particular, eye movements are often biased towards luminant regions of the face (Doherty, McIntyre, & Langton, 2015; Lewis & Edmonds, 2003). Furthermore, studies have also demonstrated that detection of facial features like eye gaze may involve luminance properties of the iris and sclera of the pupil (Ando, 2002, 2004), with the increasing exposure of the scleral field leading to enhanced attentional biasing towards faces and eyes (Lee, Susskind, & Anderson, 2013).

In order to examine whether controlling for global luminance across the face and comparison house stimuli affected past studies on social attentional biasing (Pereira et al., 2019a, 2019b), in Experiment 1, we did not match the cues for overall luminance information. As illustrated in Figure 3.1a, this resulted in the face cue having a higher global luminance than the house cue. To ensure that any effects of social biasing were due to this manipulation alone, we kept the stimuli equated across all other stimulus content, visual context, and task factors, i.e., size, distance from fixation, configuration of internal features, perceived attractiveness, uniform background, as well as task and response settings. Therefore, if global luminance differences between the cues facilitated social attentional biasing towards the face, we expected to find faster responses for targets occurring at the previous location of the face relative to the house and neutral cues.

Results

Experiment 1a: Eye movements controlled. Thirty volunteers (25 females, M_{age} = 20.2 years, SD_{age} = 1.1 years) participated.

Manual RT. Overall, response accuracy was high at 92% with 0.1% of data accounting for anticipations, 3.0% for timeouts, and 0.1% for incorrect key presses. As shown in Figure 3.2, which plots mean correct RTs as a function of target position for Upright (3.2a) and Inverted (3.2b) cues, no overall social attentional biasing effects were found. The analyses indicated a main effect of Target location for both Upright [Mauchly's test of sphericity, $\chi^2(2)=12.14, p=.002$; $F(1.48,42.91)=157.34, p<.001, \eta_p{}^2=.84$] and Inverted cues [$F(2,58)=83.32$, $p<.001, \eta_p{}^2=.74$], reflecting overall slower responses to targets occurring at the location of the Neutral cues relative to targets occurring at the Face or House cues [Upright, $ts>12.67, ps<.001$, $d_z s>2.31$; Inverted $ts>9.99, ps<.001, d_z s>1.82$]. No significant differences were found for targets occurring at the previous location of the Face versus House [Upright, $t(29)=.82, p=.42, d_z=.15$; Inverted, $t(29)=.93, p=.36, d_z=.17$].

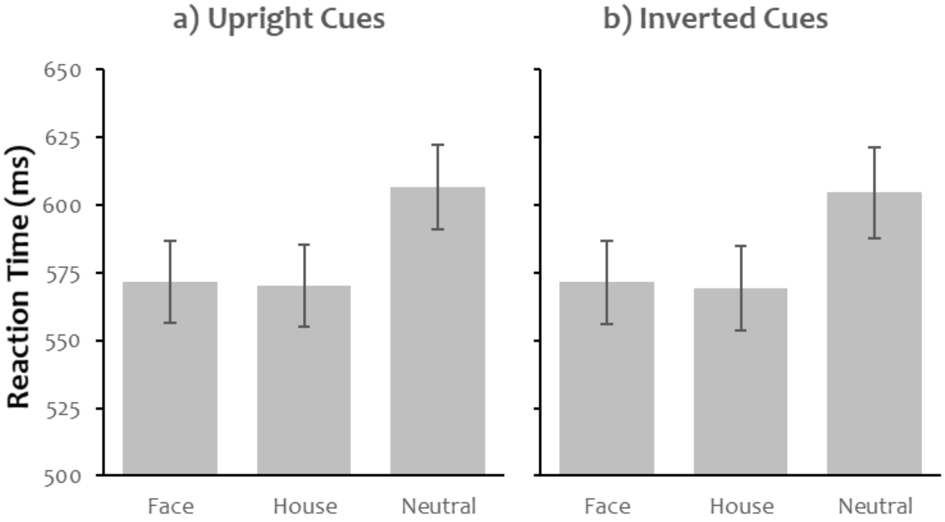

Figure 3.2 Experiment 1a manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Experiment 1b: Eye movements allowed. Thirty additional volunteers (24 females, M_{age} = 20.9 years, SD_{age} = 1.6 years) participated.

Manual RT. Overall response accuracy was 96%, with 0.03% trials accounting for anticipations, 2.0% accounting for timeouts, and 0.03% accounting for incorrect key presses removed from analyses. Similar to Experiment 1a, manual RT data, shown in Figures 3.3a and 3.3b, showed slower overall RTs for targets occurring at the location of the Neutral cues relative to the targets occurring at the Face or House cues for both Upright [$F(2,58)=78.60$, $p<.001$, $\eta_p^2=.73$; ts>9.47, ps<.001, d_zs>1.73] and Inverted conditions [$F(2,58)=91.49$, $p<.001$, $\eta_p^2=.76$; ts>10.10, ps<.001, d_zs>1.84]. Once again, no significant differences were found for targets occurring at the previous location of the Face versus House [Upright, $t(29)=1.49$, $p=.15$, $d_z=.27$; Inverted, $t(29)=.87$, $p=.39$, $d_z=.16$].

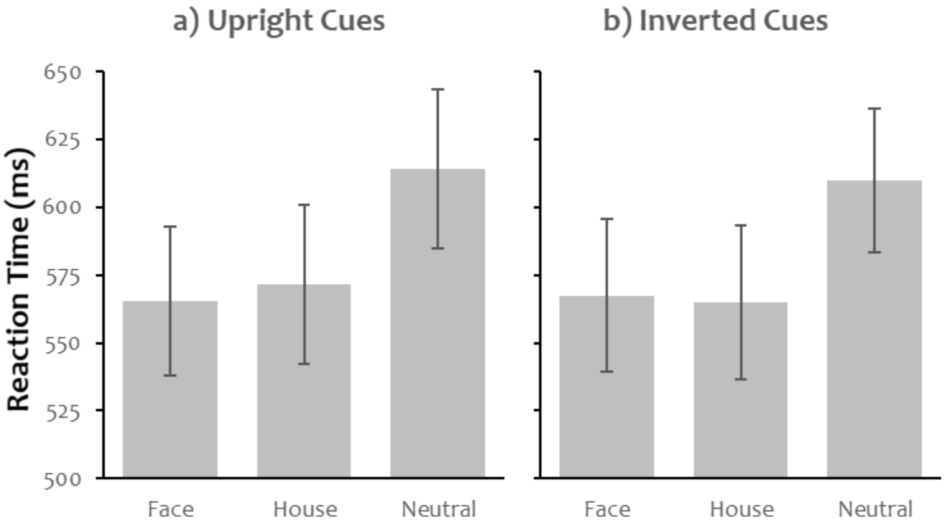

Figure 3.3 Experiment 1b manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Eye Movement Data. Participants on average saccaded away from the fixation cross rarely, on 6% of trials. In these fixation breakaway trials, saccades were launched towards an ROI 97% of the time. Mean overall proportion of saccades is illustrated in Figure 3.4 as a function of ROI. The ANOVA indicated main effects of ROI for both Upright [$F(2,58)=7.65$, $p=.001$, $\eta_p^2=.21$] and Inverted cues [$F(2,58)=6.97$, $p=.002$, $\eta_p^2=.19$]. For Upright cues, a greater proportion of saccades were directed towards the Face cue relative to both House and Neutral cues [$ts>2.51$, $ps<.036$, d_zs>.46; all other $p=.12$, $d_z=.29$]. For Inverted cues, this effect indicated an overall higher proportion of saccades directed to both Face and House cues relative to Neutral cues [$ts>3.18$, $ps<.007$, d_zs>.58; all other $p=.82$, $d_z=.04$].

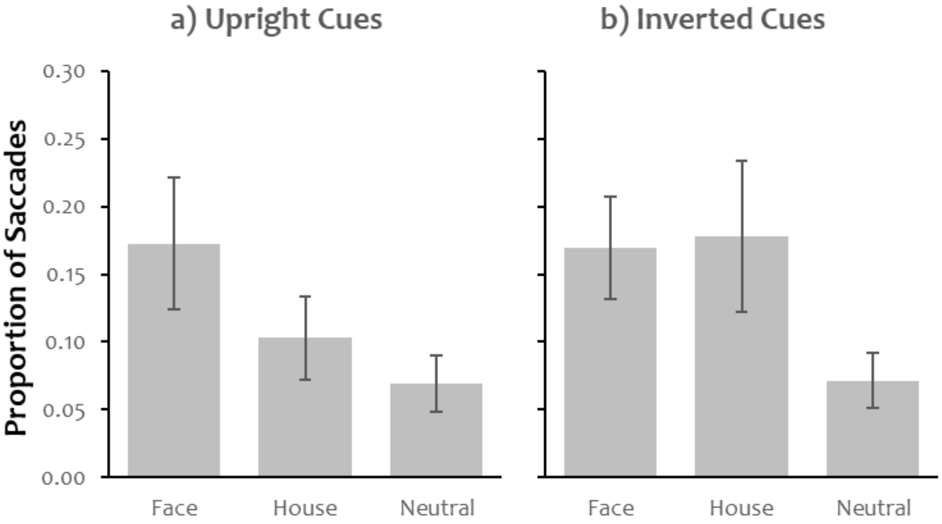

Figure 3.4 Experiment 1b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of overall ROI for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Since the data indicated an overall oculomotor bias towards faces, we next examined how proportion of breakaway saccades varied as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house, upper neutral, lower neutral). Figure 3.5 illustrates the mean proportion of saccades as a function of all ROIs.

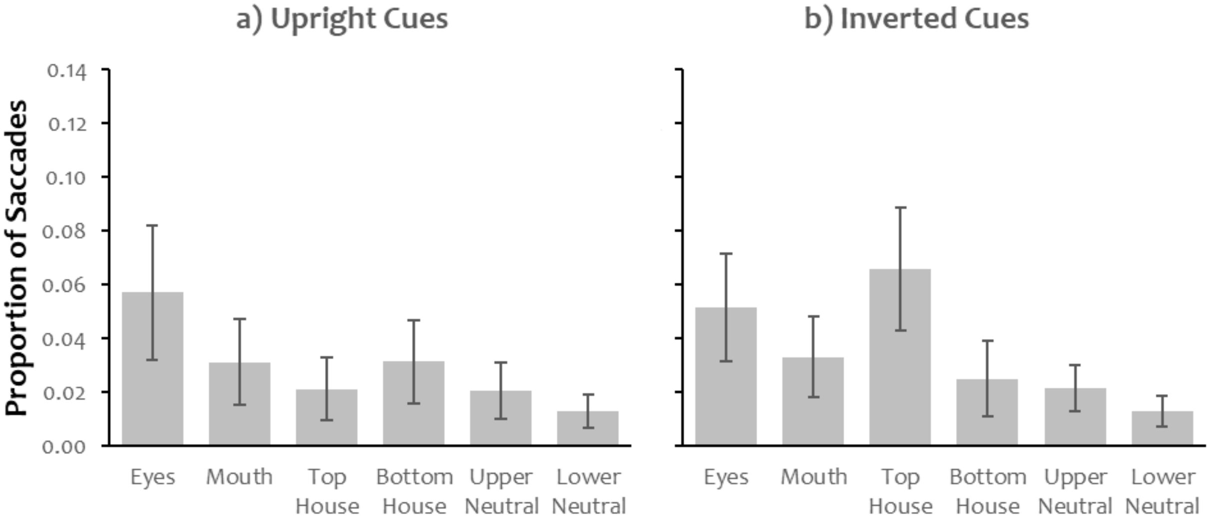

Figure 3.5 Experiment 1b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of all ROIs for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

There was main effect of *ROI* [Mauchly's test of sphericity, $\chi^2(14)=40.80$, $p<.001$; $F(2.95,79.56)=6.56$, $p=.001$, $\eta_p^2=.20$], with an overall lower proportion of saccades directed towards the Lower Neutral cue than the Eyes, Mouth, Top House, and Bottom House regions [ts>3.18, ps<.045, d_zs>.58]. No overall significant differences in the proportion of saccades directed towards the Eyes, Mouth, Top House, and Bottom House cues emerged [ts<2.60, ps>.14, d_zs<.47].

Two interactions were significant. The first was between *ROI* and *Cue orientation* [Mauchly's test of sphericity, $\chi^2(14)=71.67$, $p<.001$; $F(2.53,68.36)=3.27$, $p=.033$, $\eta_p^2=.11$]. A greater proportion of saccades were directed towards the Eyes versus the Lower Neutral cue for both Upright [$t(27)=3.33$, $p=.038$, $d_z=.61$; all other ps>.09, d_zs<.54] and Inverted conditions [$t(27)=3.73$, $p=.013$, $d_z=.68$]. Further, when the cues were Inverted, a greater proportion of saccades were directed towards the Top House cue compared to the Bottom House, Upper Neutral, and Lower Neutral cues [ts>3.36, ps<.028, d_zs>.61; all other ps>.14, d_zs<.49]. However, no differences were found in proportion of saccades towards the Eyes, Mouth, Top House, and Bottom House [*t*s<2.37, *p*s>.24, d_zs<.43].

The second interaction was between *ROI* and *Face position* [Mauchly's test of sphericity, $\chi^2(14)=72.13$, $p<.001$; $F(2.46,66.44)=3.41$, $p=.03$, $\eta_p^2=.11$], which revealed that a greater proportion of saccades were launched towards the Eyes versus the Lower Neutral cue when the face was presented in the left visual field [$t(27)=3.26$, $p=.046$, $d_z=.59$; all other *p*s>.07, d_zs<.56]. When the face was presented in the right visual field, a lower proportion of saccades were launched towards the Lower Neutral cue compared to both Top and Bottom House cues [*t*s>3.65, *p*s<.016, d_zs<.67; all other *p*s>.08, d_zs<.54]. Similar to the previous interaction, no differences were found in proportion of saccades towards the Eyes, Mouth, Top House, and Bottom House cues [*t*s<2.68, *p*s>.14, d_zs<.49]. No other effects or interactions were significant [*F*s<3.90, *p*s>.06, $\eta_p^2<.13$].

Thus, when participants’ natural eye movements were tracked while they performed the dot-probe task and global luminance was greater for the face than the house cue, there was once again no evidence of social attentional biasing in manual data and some evidence for social attentional biasing in oculomotor data. Specifically, while the overall analysis indicated greater overall number of oculomotor breakaways towards the Face relative to the House cue, the follow-up ANOVA indicated that this effect was not specific to Upright cues and may have been driven by overall larger number of saccade breakaways for the Eye region relative to the Neutral cue when the face was shown in the left visual field.

Discussion

Experiment 1 examined whether social attention biasing occurred when overall luminance within the face cue was higher than overall luminance within the comparison house cue. Regardless of whether participants were instructed to maintain central fixation, we found no evidence for social attentional biasing in manual responses. When eye movements were not controlled, some evidence for social attentional biasing was found for targets occurring at the previous location of the face in oculomotor responses. More specifically, eye movement data indicated that although participants rarely disengaged from central fixation to look at one of the cues (i.e., on only 6% of all trials), when eye movements did occur, they were directed more frequently towards the face. However, this effect was not specific to differences across the face and house cues and was also not specific to upright faces, and as such likely reflects overall difference in low level visual features in the stimuli rather than any specific bias towards the facial region (Turatto & Galfano, 2000). Therefore, it appears that increased global luminance within the face does not lead to the typical re-instantiation of social attentional biasing when other stimulus content and visual context factors are held constant, but it does lead to general oculomotor biasing towards the more luminant region of the display.

Next, we examined whether the presence of social attention biasing may depend on the configuration of the comparison stimulus.

Experiment 2

Experiment 2 examined whether the absence of social attentional biasing in previous studies (Pereira et al., 2019a, 2019b) reflected overall similar internal organization of features between the face and comparison house cues. Once again, we examined this question in manual responses when participants were instructed to maintain central fixation (2a) and in manual and oculomotor responses when no instruction about eye movements were given (2b).

Studies have demonstrated that face perception strongly depends on the canonical representation of internal features, with two eyes on the top, nose in the center and mouth at the bottom. As such, upright faces are easier to perceive and identify than individual facial features or inverted faces (Frank et al., 2009; Hochberg & Galper, 1967; Simion & Giorgio, 2015; Yin, 1969), with additional studies demonstrating preferential oculomotor biasing toward faces with more consistent internal configuration (Johnson et al., 1991; Mondloch et al., 1999). Typically, houses are used as comparison stimuli to faces as they display similar canonical configural structure but lack social content (Bruce & Young, 1986; Farah, Wilson, Drain, & Tanaka, 1998; Kanwisher & Yovel, 2006; O'Craven, Downing, & Kanwisher, 1999; Tanaka & Farah, 1993). However, keeping the internal configuration between face and houses on par (Pereira et al., 2019a, 2019b) may have resulted in house cues appearing face-like, thus biasing the results towards no difference between targets appearing at the previous location of these two types of cues.

To examine this possibility, in Experiment 2, the house cue had a different configuration of internal features relative to the face cue. As illustrated in Figure 3.1b, the house cue contained one door that was placed off to the side and only one central window. As before, the images were equated on all other factors, namely size, distance from fixation, average global luminance, perceived attractiveness, uniform background, and task and response settings. Therefore, if the previous absence of social attentional biasing effects (Pereira et al., 2019a, 2019b) was driven by the overall similarity between face and house cues in their featural configuration, we expected to find typical social attentional biasing effects indicating faster responses for targets occurring at the previous location of the face and eyes relative to the comparison house cues.

Results

Experiment 2a: Eye movements controlled. Thirty new volunteers participated (24 females, M_{age} = 20.3 years, SD_{age} = 1.3 years).

Manual RT. Overall response accuracy was 92%, with 0.3% of trials accounting for anticipations, 3.6% for timeouts, and 0.3% for incorrect key presses. As illustrated in Figure 3.6, which shows mean correct RTs for Upright (3.6a) and Inverted (3.6b) cues, there was once again no overall response advantage for targets occurring at the location of the face relative to targets occurring at the location of the house cue. The ANOVA confirmed these observations, showing overall slower RTs for targets occurring at the location of the Neutral cues relative to the targets occurring at the Face or House cues [Upright, Mauchly's test of sphericity, $\chi^2(2)=9.46$, $p=.009$; $F(1.55,45.08)=75.82$, $p<.001$, $\eta_p^2=.72$; ts>9.02, ps<.001, d_zs>1.65; Inverted, $F(2,58)=84.48$, $p<.001$, $\eta_p^2=.74$; ts>10.07, ps<.001, d_zs>1.84], with no significant differences for targets occurring at the previous location of the Face relative to the House [Upright, $t(29)=.28$, $p=.78$, $d_z=.05$; Inverted, $t(29)=1.34$, $p=.19$, $d_z=.24$].

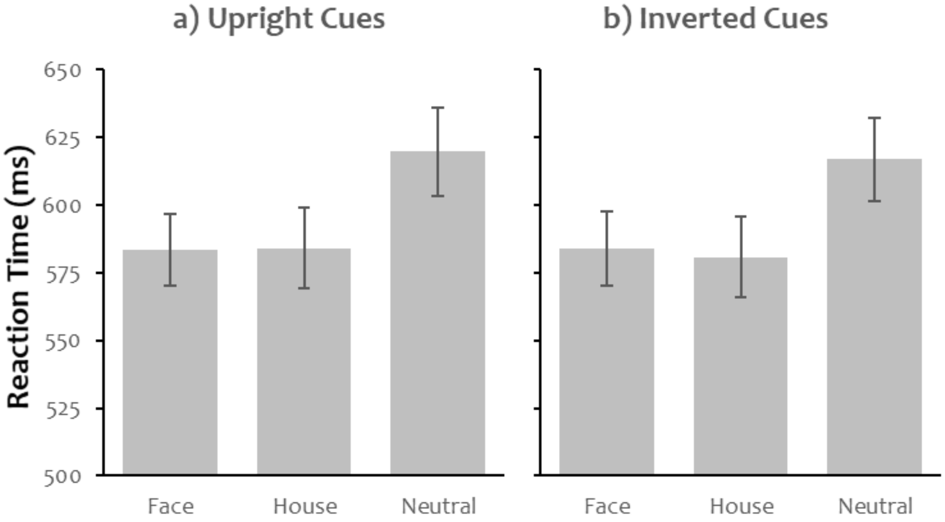

Figure 3.6 Experiment 2a manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Experiment 2b: Eye movements allowed. Thirty new volunteers (25 females, M_{age} = 20.4 years, SD_{age} = 1.5 years) participated.

Manual RT. Overall response accuracy was 96%, with anticipations (0.02%), timeouts (1.2%), and incorrect key presses (0.01%) removed from RT data. Once again, and as depicted in Figures 3.7a and 3.7b, no reliable social attentional biases were found. Significant main effects for Upright [$F(2,58)=63.57$, $p<.001$, $\eta_p^2=.69$] and Inverted cues [$F(2,58)=72.81$, $p<.001$, $\eta_p^2=.72$] indicated overall slower RTs for targets occurring at the previous location of the Neutral cues relative to the previous location of the Face and House cues [Upright, *t*s>9.89, *p*s<.001, d_zs>1.81; Inverted, *t*s>10.39, *p*s<.001, d_zs>1.90], with no significant differences for targets occurring at the previous location of the Face relative to the House [Upright, $t(29)=1.26$, $p=.22$, $d_z=.23$; Inverted, $t(29)=.40$, $p=.70$, $d_z=.07$].

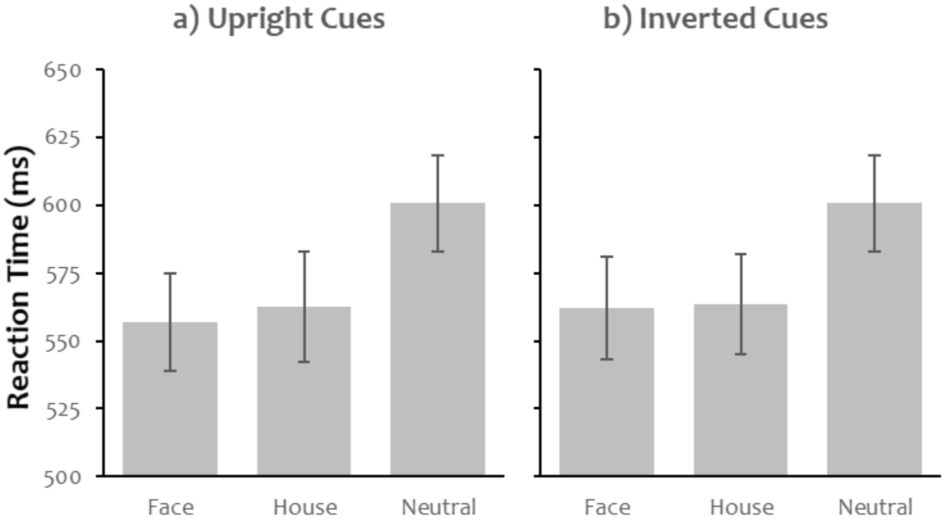

Figure 3.7 Experiment 2b manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Eye Movement Data. Participants on average saccaded away from the fixation cross on 9% of trials. On these trials, saccades were launched towards an ROI 96% of the time. Mean proportion of saccades away from the fixation cross is illustrated in Figure 3.8 as a function of ROI for Upright (3.8a) and Inverted (3.8b) cues.

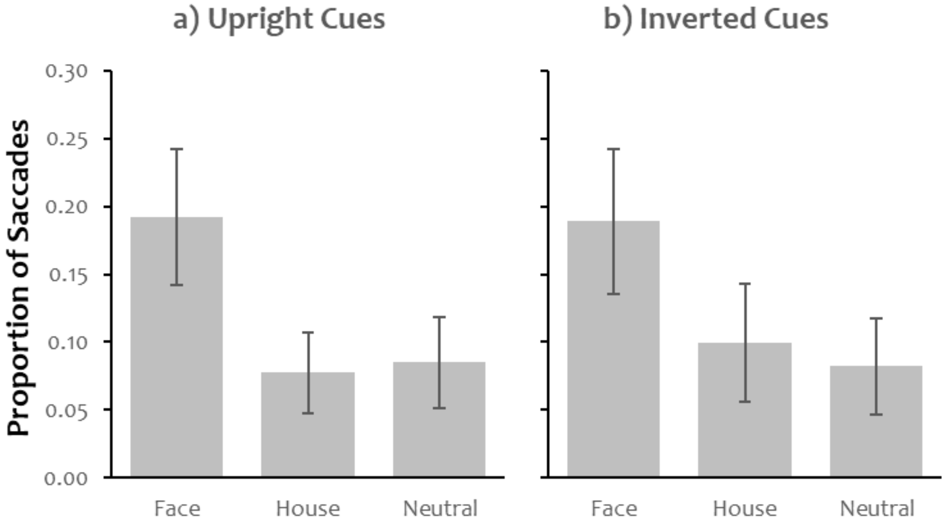

Figure 3.8 Experiment 2b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of overall ROI for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

A main effect of ROI was significant for Upright [Mauchly's test of sphericity, $\chi^2(2)=7.93$, $p=.019$; $F(1.60,46.52)=9.84$, $p=.001$, $\eta_p^2=.25$] and Inverted cues [$F(1.88,54.56)=5.35$, $p=.009$, $\eta_p^2=.16$], denoting a greater proportion of saccades directed towards the Face relative to both House and Neutral cues [Upright, $ts>3.04$, $ps<.01$, d_zs>.55; all other $p=.76$, $d_z=.06$; Inverted, $ts>2.48$, $ps<.039$, d_zs>.45; all other $p=.58$, $d_z=.10$].

Since the data indicated increased frequency of eye movements towards the Face region, we carried out an ANOVA to examine the proportion of breakaway saccades as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house, upper neutral, lower neutral). These data are illustrated in Figure 3.9.

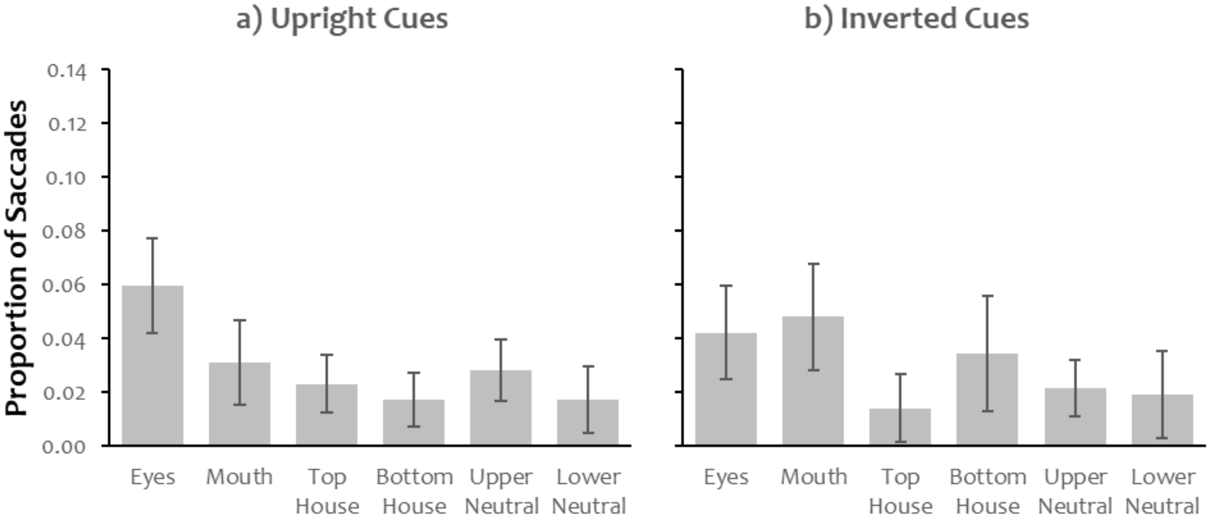

Figure 3.9 Experiment 2b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of all ROIs for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

The analysis indicated a main effect of *ROI* [$F(5,135)=4.77$, $p<.001$, $\eta_p^2=.15$], showing an overall greater proportion of saccades directed towards the Eyes relative to Top House and Upper Neutral regions [ts>3.20, ps<.049, d_zs>.58; all other ps>.09, d_zs<.54].

There was also a reliable interaction between *ROI* and *Face position* [Mauchly's test of sphericity, $\chi^2(14)=33.47$, $p=.003$; $F(3.35,90.52)=2.74$, $p=.042$, $\eta_p^2=.09$]. When the face was presented in the left visual field, a greater proportion of saccades were launched towards the Eyes compared to the Top House, Bottom House, Upper Neutral and Lower Neutral cues [ts>3.43, ps<.023, d_zs>.63]. Furthermore, there were also a greater proportion of saccades directed towards the Mouth compared to the Lower Neutral cue [$t(27)=3.21$, $p=.037$, $d_z=.59$; all other ps>.05, d_zs<.56]. No such relationship was found when the face was presented in the right visual field [all ps>.10, d_zs<.31]. However, this oculomotor biasing effect did not appear to be specific to Upright faces, as no interactions involving *Cue Orientation* were found [*ROI* x *Cue Orientation;* $F(5,135)=2.08$, $p=.07$, $\eta_p^2=.07$; *ROI x Face Position x Cue Orientation*, Mauchly's test of sphericity, $\chi^2(14)=24.89$, $p=.036$; $F(3.74,101.04)=.48$, $p=.74$, $\eta_p^2=.02$]. No other effects reached significance [Fs<.83, ps>.37, $\eta_p^2<.03$].

Thus similar to Experiment 2a, the results from Experiment 2b also found no robust evidence of social attentional biasing in manual data. Oculomotor data indicated increased frequency of saccadic breakaways towards the Eye region of the Face relative to the House and Neutral cues. However, this effect was not specific to Upright faces, and as such could reflect overall differences in low-level visual properties of the stimuli rather than any specific social biasing by face cues.

Discussion

In Experiment 2, we examined how equating the face and house stimuli on internal configuration of features impacted the resulting social attention bias. We hypothesized that if this variable was a key driving factor in social attentional biasing, there should be reliable attentional effects towards faces. The data did not support this hypothesis, and instead indicated that internal featural configuration does not appear to account for reliable effects of social attentional biasing. Similar to Experiment 1, we found no evidence of spontaneous social attentional biasing in manual responses. Although oculomotor breakaway data indicated a greater proportion of saccades directed towards the Eyes of faces, similar to Experiment 1b, this effect was not specific to Upright faces. Thus, the results from Experiment 2 once again did not lend strong support to the hypothesis that the lack of social attentional biasing in previous data (Pereira et al., 2019a, 2019b) was due to the choice of comparison stimuli that exhibit a similar internal configuration of features like faces. The final Experiment 3 examined the role of perceived attractiveness in social attentional biasing.

Experiment 3

Experiment 3 examined whether perceived attractiveness of the face influenced social attentional biasing in manual responses when participants were instructed to maintain central fixation (3a) and in manual and oculomotor responses when no instruction about eye movement was given (3b).

Facial attractiveness is a powerful attentional cue. As it is processed rapidly (Locher, Unger, Sociedade, & Wahl, 1993; Olson & Marshuetz, 2005), attractiveness may play a significant role in social attentional biasing. Indeed, past work shows that eye movements are more strongly biased towards attractive relative to unattractive faces (Aharon et al., 2001; Maner, Gailliot, Rouby, & Miller, 2007), while attentional work shows that attractive faces bias manual responses in a cuing task even when they are manipulated as task-irrelevant (Sui & Liu, 2009).

In order to examine the effect of perceived facial attractiveness on social attentional biasing, in Experiment 3, we used a face cue that was rated as more attractive than the house cue, as illustrated in Figure 3.1c. Specifically, we used a face cue that received the highest attractiveness rating and a house cue that received an average attractiveness rating. As before, all other stimulus content, visual context, and task factors remained equated. If perceived attractiveness was responsible for social attentional biasing, we expected to find faster responses and/or increased oculomotor breakaways for targets occurring at the previous location of the face.

Results

Experiment 3a: Eye movements controlled. Thirty new volunteers participated (26 females, M_{age} = 21.0 years, SD_{age} = 2.2 years).

Manual RT. Overall response accuracy was 92%, with anticipations (0.4%), timeouts (2.9%), and incorrect key presses (0.4%) removed from analyses. Mean correct RTs are illustrated in Figure 3.10 for Upright (3.10a) and Inverted (3.10b) cues, showing once again slowest RTs for targets occurring at the Neutral cue locations [Upright, $F(2,58)=53.54$, $p<.001$, $\eta_p^2=.65$; ts>7.95, ps<.001, d_zs>.1.45; Inverted, $F(2,58)=63.46$, $p<.001$, $\eta_p^2=.69$; ts>9.90, ps<.001, d_zs>1.81], and no difference in overall RTs for targets occurring at the locations of the Face or House cues [Upright, all other $p=.25$, $d_z=.22$; Inverted, all other $p=.61$, $d_z=.09$].

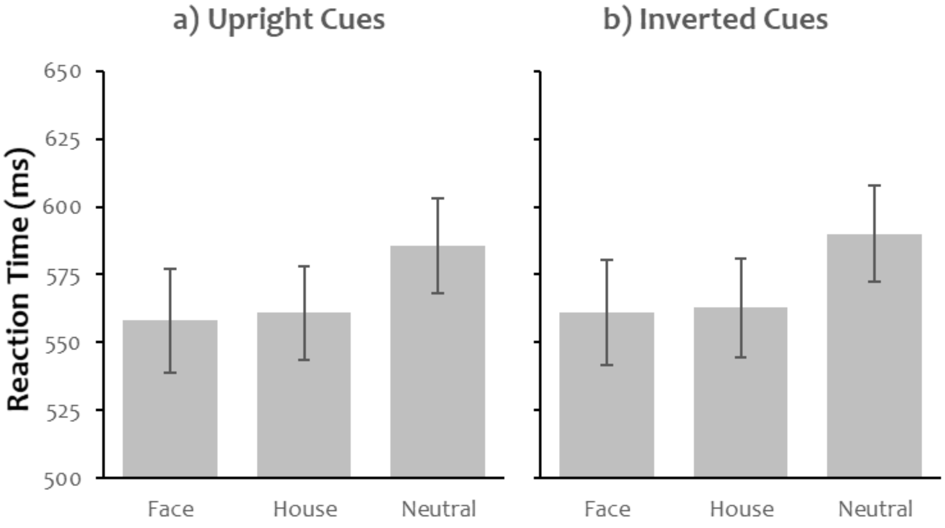

Figure 3.10 Experiment 3a manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Experiment 3b: Eye movements allowed. Thirty new volunteers participated (24 females, M_{age} = 20.6 years, SD_{age} = 1.7 years).

Manual RT. Overall response accuracy was 97%, with anticipations (0.2%), timeouts (1.2%), and incorrect key presses (0.2%) removed from RT analyses. Figures 3.11a and 3.11b show these data. As before, there were significant main effects of Target position for Upright [$F(2,58)=96.44, p<.001, \eta_p^2=.77$] and Inverted cues [$F(2,58)=131.19, p<.001, \eta_p^2=.82$], reflecting slower overall responses for targets occurring at the previous location of the Neutral cues versus the Face and House cues [Upright, ts>10.49, ps<.001, d_zs>1.92; Inverted, ts>12.65, ps<.001, d_zs>2.31]. Additionally, targets occurring at the previous location of the Face cue were responded to faster relative to targets occurring at the previous location of the House cue for both Upright [$t(29)=2.52, p=.018, d_z=.46$] and Inverted cues [$t(29)=2.28, p=.03, d_z=.42$].

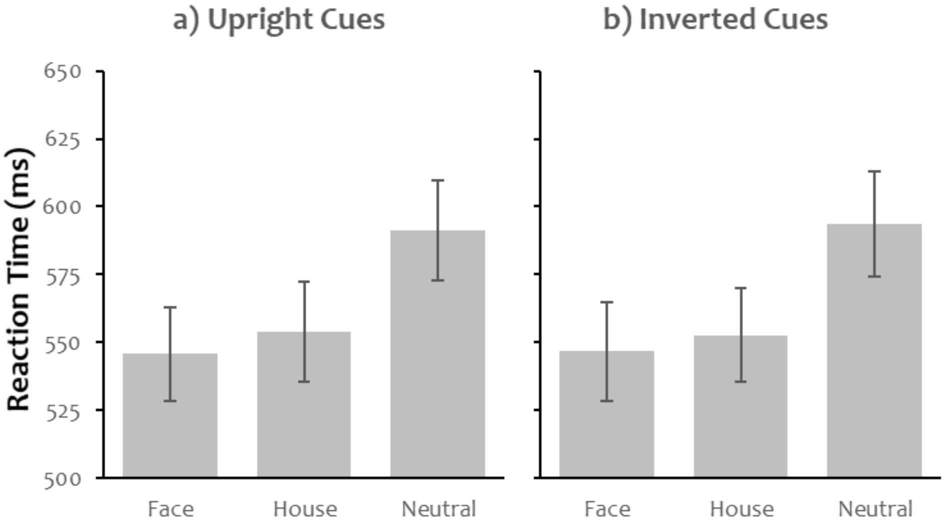

Figure 3.11 Experiment 3b manual RT results. Mean correct RTs as a function of overall Target position for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

Thus, when participants were not provided with any instruction to maintain central fixation, presenting an attractive face resulted in faster overall responses for targets occurring at the location of the Face relative to the targets occurring at the location of the House and Neutral cues. To probe into this effect further, we subjected mean correct RTs to a repeated measures ANOVA with *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house, upper neutral, lower neutral), and *Cue-target interval* (250, 360, 560, 1000ms).

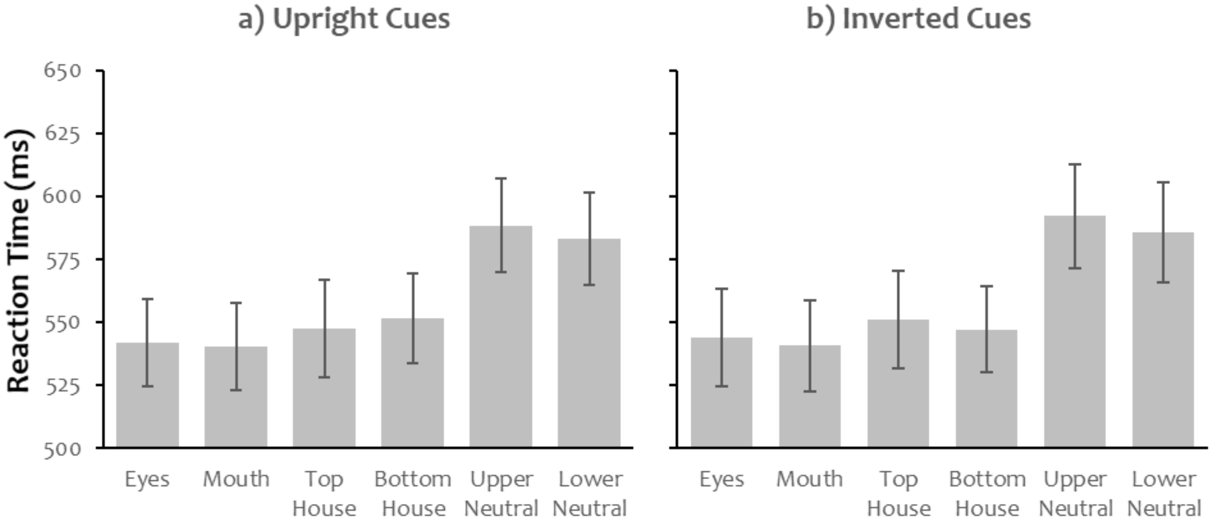

Figure 3.12 Experiment 3b manual RT results. Mean correct RTs as a function of all Target positions for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

This analysis indicated a significant main effect of *Cue-target interval* [$F(3,81)=36.94$, $p<.001$, $\eta_p^2=.58$], reflecting overall slower RTs for shorter versus longer cue-target intervals [250ms vs. all, ts>6.36, ps<.001, d_zs>1.16; all other ps>.39, d_zs<.29]. This finding demonstrates the typical foreperiod effect found within attentional dot-probe tasks (Bertelson, 1967; Hayward & Ristic, 2013) and reflects an increased response preparation with a lengthening of the time between the cue and the target.

There was also a significant main effect of *Target location* [Mauchly's test of sphericity, $\chi^2(14)=35.25$, $p=.001$; $F(3.51,94.78)=62.34$, $p<.001$, $\eta_p^2=.70$], reflecting overall slower RTs for targets occurring at the previous location of the Neutral cues versus all other cues [ts>8.94, ps<.001, d_zs>1.63]. However, unlike the overall analysis, the ANOVA returned no reliable facilitation for targets occurring at the location of the Eyes or Mouth relative to those occurring at the location of the Top or Bottom House [ts<2.63, ps>.09, d_zs<.48]. No other effects were reliable [Fs<1.10, ps>.36, $\eta_p^2<.04$].

Therefore, even though manual RTs suggested a presence of a general attentional bias for Faces relative to House and Neutral target locations, this effect did not persist for specific target locations. Furthermore, no effects were specific to upright faces as no effects or interactions involving Cue orientation reached significance [*Cue orientation* x *Target location*, *F*=.64, *p*=.67, η_p^2=.02; *Cue orientation* x *Face position* x *Target location*, *F*=1.08, *p*=.37, η_p^2=.04; *Cue orientation* x *Cue-target interval* x *Target location*, *F*=.98, *p*=.48, η_p^2=.04; *Cue orientation* x *Face position* x *Cue-target interval* x *Target location*, *F*=.66, *p*=.82, η_p^2=.02].

Eye Movement Data. Similar to previous experiments, few trials contained oculomotor breakaways, with participants saccading away from central fixation on 9% of all trials, of which saccades were launched towards an ROI on 95% of trials. Mean proportion of saccades are illustrated in Figure 3.13 as a function of ROIs for Upright (3.13a) and Inverted (3.13b) cues.

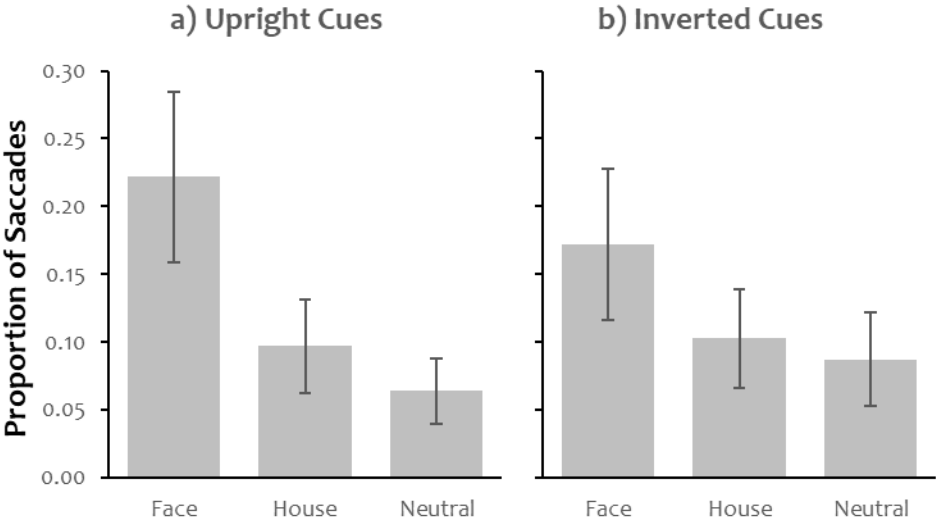

Figure 3.13 Experiment 3b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of overall ROI for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

There were reliable main effect of ROI for both Upright [Mauchly's test of sphericity, $\chi^2(2)$=14.86, *p*<.001; *F*(1.42,41.08)=12.21, *p*<.001, η_p^2=.30] and Inverted conditions

[$F(2,58)=3.65$, $p=.032$, $\eta_p^2=.11$], indicating a greater proportion of saccades directed towards the Face versus the House and Neutral cues for Upright [ts>3.00, ps<.011, d_zs>.55; all other $t(29)=1.52$, $p=.14$, $d_z=.28$] but not Inverted cues [ts<2.18, ps>.11, d_zs<.40].

Thus, a follow-up ANOVA examined the proportion of breakaway saccades as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house, upper neutral, lower neutral). The means are illustrated in Figure 3.14.

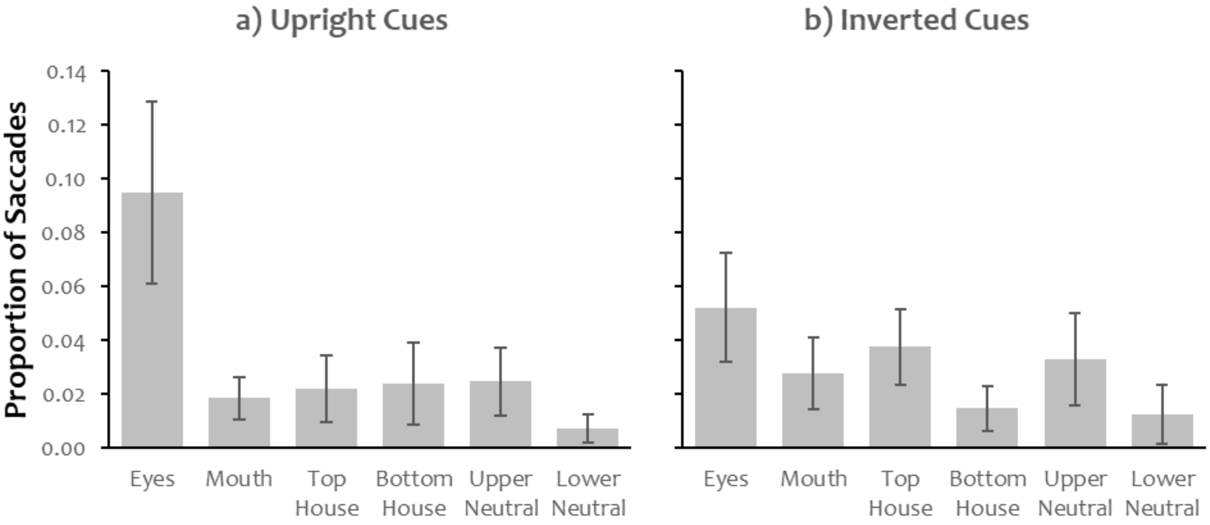

Figure 3.14 Experiment 3b oculomotor results. Mean proportion of breakaway saccades during the cue presentation period as a function of all ROIs for (a) Upright and (b) Inverted cues. Error bars represent 95% CIs.

There was a main effect of *ROI* [Mauchly's test of sphericity, $\chi^2(14)=69.64$, $p<.001$; $F(2.24,60.60)=13.14$, $p<.001$, $\eta_p^2=.33$] with an overall greater proportion of saccades directed towards the Eyes versus all other regions [ts>3.31, ps<.026, d_zs>.60] and an overall greater proportion of saccades directed towards the Top House versus Lower Neutral cue [$t(27)=3.75$, $p=.01$, $d_z=.68$; all other ps>.08, d_zs<.52].

This main effect was qualified by an interaction between *ROI* and *Cue orientation* [Mauchly's test of sphericity, $\chi^2(14)=28.10$, $p=.014$; $F(3.38,91.28)=3.98$, $p=.008$, $\eta_p^2=.13$]. When cues were Upright, a greater proportion of saccades were directed towards the Eyes compared to all other regions [ts>3.44, ps<.021, d_zs>.63; all other ps>.07, d_zs<.53]. When cues were Inverted, greater proportion of saccades were directed towards the Eyes versus Bottom House and Lower Neutral cues [ts>3.46, ps<.023, d_zs>.63] and towards the Top House versus Bottom House cue [$t(27)=3.70$, $p=.015$, $d_z=.68$; all other ps>.09, d_zs<.53].

An interaction between *ROI* and *Face position* was also significant [Mauchly's test of sphericity, $\chi^2(14)=55.92$, $p<.001$; $F(2.83,76.37)=2.46$, $p=.037$, $\eta_p^2=.08$]. It further revealed overall greater proportion of saccades launched towards the Eyes versus all other regions [ts>3.53, ps<.017, d_zs>.64] and a greater proportion of saccades towards the Mouth versus the Lower Neutral cue [$t(27)=3.32$, $p=.026$, $d_z=.61$; all other ps>.27, d_zs<.42] when the face was presented in the left visual field. When the face was presented in the right visual field, a greater proportion of saccades were launched towards the Eyes compared to the Mouth and Lower Neutral cues [ts>3.54, ps<.021, d_zs>.65], as well as a greater proportion of saccades were launched towards the Top House versus Lower Neutral cue [$t(27)=3.21$, $p=.045$, $d_z=.59$; all other ps>.11, d_zs<.51]. No other effects were found [Fs<.67, ps>.55, $\eta_p^2<.02$].

Thus, when participants' eye movements were not restricted, more evidence for social attentional biasing in oculomotor data was found. That is, there were more spontaneous saccades launched towards the Eye region of the face, particularly when the face was presented in an upright orientation and when it was positioned in the left visual field.

Discussion

The final Experiment 3 examined whether social attentional biasing could be reinstated by presenting a face cue that had higher perceived attractiveness than the comparison house cue. When participants were instructed to maintain central fixation and execute manual responses in Experiment 3a, no overall social attentional bias was found. When the same task was run but participants' eye movements were not restricted in Experiment 3b, we found an overall social attentional bias in manual responses, such that targets occurring at the previous location of the Face were responded to faster than the targets occurring at the location of the House and Neutral cues. However as revealed further by follow-up comparisons across individual target locations, this effect was not specific to upright faces or individual target locations.

More specific social attentional biasing effects were found in oculomotor data. When we examined spontaneous saccades launched towards the cues, we found an increased proportion of saccades were launched towards the Eye region of the face, and particularly when faces were presented in an upright orientation and in the left visual field. Therefore, even though oculomotor biasing occurred on a small subset of all trials (i.e., 9%), a reliable number of saccades were preferentially launched towards the Eyes of an attractive face. Together, the results from Experiment 3 identify perceived facial attractiveness as one of the potentially key driving factors of social attention biasing.

General Discussion

The present series of experiments examined whether independent manipulations of face stimulus content, namely global luminance, featural configuration, and perceived attractiveness, were able to re-instantiate spontaneous social attentional biasing previously widely reported in the literature in both manual (Ariga & Arihara, 2017; Bindemann et al., 2005; Bindemann et al., 2007; Lavie et al., 2003; Ro et al., 2001; Sato & Kawahara, 2015) and oculomotor measures (Birmingham et al., 2008a, 2008b; Laidlaw et al., 2012; Langton et al., 2008; Theeuwes & Van der Stigchel, 2006; Yarbus, 1967). Using the dot-probe paradigm, in a series of six experiments, we presented participants with face, house, and neutral cues, and measured the speed and accuracy of target discrimination responses for targets that were presented at the previous location of the face (eyes, mouth), house (top, bottom), or neutral (upper, lower) cues. We manipulated stimulus content information between the face and house stimuli by assessing if differences in global luminance (Experiment 1), imbalance of featural configuration (Experiment 2), and higher attractiveness (Experiment 3) affected the resulting social attentional bias. When measuring manual RT under instruction to maintain eye fixation, we found no evidence of attentional biasing towards faces across all studies. However, when measuring oculomotor biasing in conditions when eye movements were not restricted, Experiment 3 provided the only reliable indication of a social attention bias that was specific to upright faces and specific to the eyes. Taken together, the results of these experiments show that global luminance and internal configuration of features likely contribute little to social attentional biasing, but that perceived attractiveness potentially plays a critical role in oculomotor social attentional biasing. These results raise at least three points for further discussion.

First, when examining the effect of perceived facial attractiveness when eye movements were not restricted in Experiment 3b, we found some evidence for social attentional biasing in both manual and oculomotor data. In manual effects, there was an overall bias to detect targets occurring at the location of the face that was not specific to upright faces or any facial feature. It is possible that this finding may indicate a nonspecific manual bias for targets occurring at the location of the face, as recent data has shown that attractiveness may survive face inversion and potentially even enhance it due to the loss of distinctive facial characteristics with inversion effects (Leder, Goller, Forster, Schlageter, & Paul, 2017), however more studies are needed to investigate whether this nonspecific effect reflects social attentional biasing. In oculomotor data, our findings indicated a saccadic bias towards the eyes of the face, which was specific to upright faces and when faces were presented in the left visual field. These results dovetail with a number of past studies showing a general preference for upright faces and a processing advantage for faces presented in the left visual field due to right hemisphere specializations for face perception (Frank et al., 2009; Kanwisher et al., 1997; Kanwisher & Yovel, 2006; Puce et al., 1998; Rossion et al., 2003; Simion & Giorgio, 2015; Yin, 1969; Yovel et al., 2003). As such, these findings from Experiment 3b stand out as they provide evidence for social attentional biasing that may be reflected across both manual and oculomotor data.

Thus, perceived attractiveness may be an important factor that influences social attention over and above stimulus luminance and featural configuration factors. This notion is supported by behavioural studies that suggest that assessing facial attractiveness occurs automatically (Olson & Marshuetz, 2005; Willis & Todorov, 2006) and is difficult to inhibit (Sui & Liu, 2009). Our findings dovetail with this result, as oculomotor effects occurred even though saccadic breakaways from fixation occurred rarely (i.e., on 9% of trials). This would suggest that even with a low proportion of eye movements, perceived attractiveness led to robust oculomotor biasing towards the eyes of the face, which also appeared to be sustained when manually responding to targets that occurred in the overall region of the face. Furthermore, our findings also show that the attractive face used in the current study and the controlled face used in previous work (Pereira et al., 2019a) both resulted in similar percentage of trials with saccadic breakaways, but that the attractive face resulted in numerically greater proportion of saccades directed towards the eyes (i.e., 3.4% in the current study versus 1.9% in Pereira et al., 2019a). Although these comparisons only represent a numerical difference and should be taken with caution, they suggest that perceived attractiveness may regulate the degree of oculomotor social biasing effects for faces and eyes rather than acting to enhance the number of overall eye movements. As such, these results suggest that past studies that have shown robust social attentional biasing in oculomotor measures (Birmingham et al., 2008a, 2008b; Laidlaw et al., 2012; Langton et al., 2008; Theeuwes & Van der Stigchel, 2006; Yarbus, 1967) could have also reflected the underlying influence of perceived facial attractiveness due to its ability to quickly engage social attention.

Second, and in contrast to oculomotor data, our manipulations of stimulus content factors did not result in reliable social attentional biases in manual responses when participants' eye movements were restricted. This finding is consistent with our previous research showing that controlling stimulus content, visual context, and task settings abolishes social attentional biasing in manual performance (Pereira et al., 2019a, 2019b). Our data further extend this line of work by demonstrating that spontaneous social attentional biasing may likely involve a combination of stimulus content and visual context factors rather than being specific to a single variable. It may also be possible that robust social attention towards faces and eyes may be task dependant, and that social attentional biasing occurs purposefully based on internal and external demands. Some evidence supports this notion. For example, Võ and colleagues (2012) have demonstrated that attentional selection of faces and facial features can be differentially elicited based on established priorities from the task at hand (e.g., see also Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006). More recently, Burra and colleagues (2018) similarly showed that both behavioural and neural measures of social attentional biasing are influenced by task relevancy by showing modulations in gaze processing depending on whether the face was relevant to the task. The present results dovetail with these findings and highlight the need for future investigations geared towards understanding how components of stimulus content, visual context, and task factors lead to robust social attentional biasing.

Finally, the results of the present study continue to highlight dissociations in covert and overt measures of social attention (Gobel, Kim, & Richardson, 2015; Kuhn, Teszka, Tenaw, & Kingstone, 2016; Laidlaw, Badiudeen, Zhu, & Kingstone, 2015; Risko, Richardson, & Kingstone, 2016), as differential results were found when participants were instructed to maintain central fixation (Experiment 3a) relative to when they were free to move their eyes in a natural manner (Experiment 3b). As such, this finding suggests that humans may use covert and overt attentional processes differently in various environments, such as in situations where we need overt attention to explicitly convey our own internal thoughts and emotions to others or when we use covert attention to discreetly gather information around us without revealing our immediate intentions to others. In addition to providing evidence in support of this distinction, the present set of studies also point to factors that may give rise to this dissociation in a spontaneous manner, since facial attractiveness was found to be the only stimulus content factor that resulted in differential effects, such that no manual biases were found when participants were instructed to maintain central fixation, whereas a nonspecific manual bias towards faces and a specific oculomotor bias towards the eyes was found when participants were allowed to freely move their eyes. As such, this factor may provide a particularly illuminating real-world example of the necessity for separately investigating covert and overt responses, further pointing to the utility of reconceptualising attentional control as an integrative system that can be influenced by stimulus factors, task information, internal preferences, and personal experiences

(Awh, Belopolsky, & Theeuwes, 2012; Ristic & Enns, 2015). Given our results showing an overall nonspecific manual bias towards the face in Experiment 3b when eye movements were not controlled, future work should examine to what extent oculomotor behaviour influences manual responses when both are allowed to occur, and how this particular task settings informs potential dissociations of covert and overt social attentional measures.

In summary, the present set of studies investigated how stimulus content factors, namely global luminance, internal configuration of features, and perceived attractiveness influenced social attentional biasing. While the data showed no robust effects of social attentional biasing across any of the stimulus content factors when eye movements were restricted, they indicated that perceived facial attractiveness elicited social attentional biasing when eye movements were freely allowed to occur. As such, these data point to perceived attractiveness as an important factor in social attentional biasing and further highlights the need for future work to delineate the contributions of task, content, and context factors to social attention.

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Contextually-based social attention diverges across covert and overt measures

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Abstract

Humans spontaneously attend to social cues like faces and eyes. However, recent data show that this behavior is significantly weakened when visual content, such as luminance and configuration of internal features, as well as visual context, such as background and facial expression, are controlled. Here, we investigated attentional biasing elicited in response to information presented within appropriate background contexts. Using a dot-probe task, participants were presented with a face-house cue pair, with a person sitting in a room and a house positioned within a picture hanging on a wall. A response target occurred at the previous location of the eyes, mouth, top of the house, or bottom of the house. Experiment 1 measured covert attention by assessing manual responses while participants maintained central fixation. Experiment 2 measured overt attention by assessing eye movements using an eye tracker. The data from both experiments indicated no evidence of spontaneous attentional biasing towards faces or facial features in manual responses; however, an infrequent, though reliable, overt bias towards the eyes of faces emerged. Together, these findings suggest that contextually-based social information does not determine spontaneous social attentional biasing in manual measures, although it may act to facilitate oculomotor behavior.

Keywords: social attention; attentional biasing; faces; context

Introduction

Faces convey a great deal of information. From an evolutionary perspective, researchers have theorized that the hierarchical system of social groups in both human and non-human primates primarily relied on visual information in faces to convey social signals to others (Argyle, 1969; Brüne & Brüne-Cohrs, 2006). As such, systems that processed these signals quickly and efficiently enhanced the ability to accurately predict other's behavior and dispositions (Corballis & Lea, 2000; Whiten & Byrne, 1988). This prioritization of social information is evident developmentally, with a preference for faces and eyes early in life (Farroni, Csibra, Simion, & Johnson, 2002; Goren, Sarty, & Wu, 1975; Hood, Willen, & Driver, 1998; Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Cassia, & Umilta, 1996), as well as neurologically, with a distributed network of specialized brain structures within the temporal and occipital lobe (e.g., fusiform face area, superior temporal sulcus, occipital face area) that are specifically tuned for processing faces, gaze, and other socio-biological signals (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Gauthier et al., 2000; Haxby et al., 1994; Kanwisher & Yovel, 2006; Nummenmaa & Calder, 2008; Perrett, Hietanen, Oram, Benson, & Rolls, 1992; Perrett et al., 1985; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Yovel, Levy, Grabowecky, & Paller, 2003). These findings suggest that information conveyed by faces and facial features like eyes represent a key component of the complex social communication system (Baron-Cohen, 1995; Dunbar & Shultz, 2007; Emery, 2000; Schaller, Park, & Kenrick, 2007).

As such, it is intuitive to expect that faces and facial features would preferentially capture and spontaneously shift attention, a process often called social attentional biasing (Birmingham & Kingstone, 2009; Nummenmaa & Calder, 2008). Consistent with this idea, research has demonstrated quick and spontaneous attentional biasing towards faces and eyes in both covert (attentional shifts independent of eye movements) and overt (attentional shifts accompanied by eye movements) measures. Covertly, attentional biasing is typically indexed by manual performance (i.e., response time and/or accuracy) that is elicited in response to targets that follow social versus non-social cues. Bindemann and colleagues (2007) were among the first to show that attention is preferentially drawn to faces by presenting participants with side-by-side images of a face and a non-social object (e.g., a faucet) followed by targets that appeared equally often at either location. Even though participants had no incentive to shift their attention to either cue, faster responses were found for targets that occurred at the previous location of the face, suggesting that task-irrelevant faces spontaneously biased attention. Subsequently, similar effects have been reported using a wide range of popular behavioral paradigms (i.e., go/no-go tasks, Bindemann, Burton, Hooge, Jenkins, & DeHaan, 2005; rapid serial visual presentation tasks, Ariga & Arihara, 2017; visual search, Lavie, Ro, & Russell, 2003; change detection and inattentional blindness paradigms, Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009; Ro, Russell, & Lavie, 2001).

A spontaneous attentional bias for faces is also found when attention is indexed by the latency and/or pattern of eye movements occurring in response to social relative to non-social stimuli. Yarbus' seminal work (1967) provided one of the first demonstrations of an oculomotor bias for faces. He recorded participants' eye movements while they freely viewed photographs of social scenes and found that they preferentially looked at faces and eyes. This general result has since been replicated by numerous studies, which collectively show that faces and facial features bias eye movements within the first two fixations (Birmingham, Bischof, & Kingstone, 2008a, 2008b; Cerf, Frady, & Koch, 2009; Laidlaw, Risko, & Kingstone, 2012) and elicit earlier saccades compared to other stimuli (Crouzet, Kirchner, & Thorpe, 2010; Devue, Belopolsky, &

Theeuwes, 2012). Similar overt social biasing has also been found in tasks that use controlled laboratory paradigms (Theeuwes & Van der Stigchel, 2006), those that manipulate static and dynamic representations of social behavior (Boggia & Ristic, 2015; Riby & Hancock, 2009; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006; Smith, 2013), as well as during tasks that measure social attention during dynamic real-life social interactions (Hayward, Voorhies, Morris, Capozzi, & Ristic, 2017; Kuhn, Teszka, Tenaw, & Kingstone, 2016; Risko, Richardson, & Kingstone, 2016). Thus, similar to covert attention, overt attention also appears to be spontaneously biased towards faces and eyes.

However, despite the abundance of evidence of an attentional bias towards faces, recent work has revealed that this effect may not be as robust as once thought. Pereira, Birmingham, and Ristic (2019a) noted that previous studies reporting an attentional bias for faces lacked rigorous control over stimulus and task settings, potentially accounting for the previously reported effects. In their study, Pereira and colleagues presented participants with a face, house, and comparison neutral cues, and controlled for stimulus size, distance from the central fixation cross, global luminance, internal configuration of features, attractiveness, background context, and task settings. This is because all of these factors have previously been documented to strongly engage attention, independent of the social nature of faces (size and positioning, Crouzet & Thorpe, 2011; saliency, Cerf, Harel, Einhäuser, & Koch, 2008; low-level internal features, Itier, Latinus, & Taylor, 2006; Kendall, Raffaelli, Kingstone, & Todd, 2016; Rousselet, Ince, van Rijsbergen, & Schyns, 2014; valence and attractiveness, Nakamura & Kawabata, 2014; Silva, Macedo, Albuquerque, & Arantes, 2016; Sui & Liu, 2009; context, Chun & Jiang, 1998; Loftus & Mackworth, 1978; Neider & Zelinsky, 2006). Pereira and colleagues measured *(i)* manual responses by examining reaction time to targets that appeared with equal probability at one of the previous cue locations, and *(ii)* eye movements by examining proportion of saccades towards any of the cue locations. The data revealed no spontaneous attentional biasing towards faces and eyes in manual data and only a small bias in eye movements towards the eyes of the face. Thus, the conclusion from this study was that once stimulus and task factors are tightly controlled, faces and facial features do not spontaneously and robustly bias covert or overt attention.

These findings raise new questions about which stimulus and/or task factors are the most relevant for instantiating a reliable bias of attention towards faces and eyes. In the present study, while continuing to control for both visual content information like global luminance, target-background contrast, and attractiveness, as well as task settings like stimulus distance from the central fixation cross and key-response assignment, we tested whether visual context information in the form of an appropriate background would reinstate social attentional biasing. We reasoned that this manipulation may affect social attention as faces in the real world most often do not appear detached from bodies, isolated from their natural backgrounds, and/or cropped of hair. As such, the lack of social orienting in Pereira and colleagues' (2019a) study may have resulted from an artificially high similarity between the comparison face and house cues due to a tight control of these external features across the stimuli. Thus, one possibility is that spontaneous attentional biasing for faces will emerge once a natural background context, likened to how faces are found in the real world, is provided. Past work shows that peripheral situational or background information is important for perceptual and neural processing of faces and objects (Aviezer, Bentin, Dudarev, & Hassin, 2011; Bentin, Sagiv, Mecklinger, Friederici, & von Cramon, 2002; Hassin, Aviezer, & Bentin, 2013). Context is also found to exert strong effects on how social information is prioritized (MacNamara, Ochsner, & Hajcak, 2011; Morel, Beaucousin, Perrin, & George, 2012; Righart & de Gelder, 2006; Wieser et al., 2014), with for example, increased congruency effects in identifying facial emotions when faces are consistent versus inconsistent with background scene contexts (Righart & de Gelder, 2008). However, it remains relatively unexplored how background context influences social attentional biasing.

To address this question, here we used the same task and parameters as Pereira and colleagues (2019a), but embedded the face and house cues within natural contextual backgrounds as illustrated in Figure 1. We measured attentional biasing using a dot-probe task and assessed the speed of manual target discrimination when targets were presented at the previous location of the face versus the house cue. Since it is still unclear whether attentional biasing towards faces are driven by faces as a whole or by any specific facial feature, targets were positioned at either the previous location of the eyes or mouth of the face or the top or bottom of the house to allow for a more detailed examination of attentional biasing at each location. Experiment 1 measured covert attention while participants maintained central fixation, whereas Experiment 2 measured natural eye movements using an eye tracker. If contextually-based social information resulted in robust social attentional biasing, we expected to find a reliable social attentional bias in both covert and overt measures, with faster responses in manual measures for targets occurring at the previous location of the face, and in particular the eyes, and greater proportion of saccades directed towards the face and eye cues.

Experiment 1

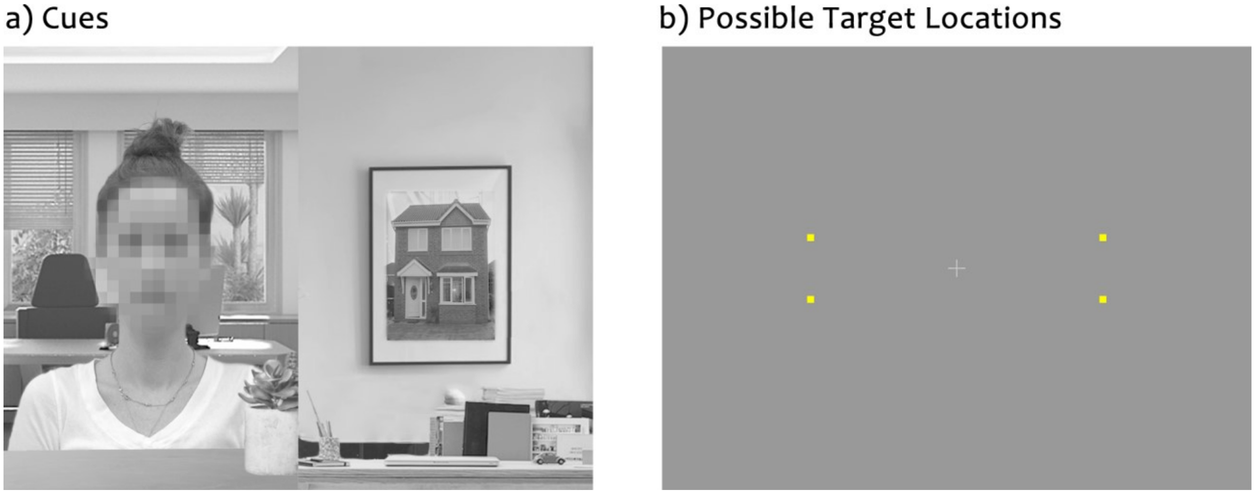
Materials and Methods

Participants. Thirty volunteers, with normal or corrected-to-normal vision, participated (25 females, M_{age} = 21 years, SD_{age} = 3 years). They were remunerated with course credits. This sample size falls within the range reflected by an a priori power analysis (G*Power, Faul, Erdfelder, Lang, & Buchner, 2007) that was based on the estimated magnitude of face selection effects from past research (Bindemann & Burton, 2008; Bindemann et al., 2007; Langton, Law, Burton, & Schweinberger, 2008; Ro et al., 2001). The analysis indicated that data from 6–38 participants were needed to detect medium-to-large effects ranging from .41–1.36 (as estimated from Cohen's f) with corresponding power values from .95–.97. Informed consent was obtained from all participants before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and all protocol and procedures were approved by the University Research Ethics board (protocol number 81-0909).

Stimuli and Apparatus. All stimuli were presented on a 16" Cathode Ray Tube (CRT) monitor at an approximate viewing distance of 60cm. Stimulus presentation sequence was controlled by MATLAB's Psychophysics toolbox (Brainard, 1997).

The fixation screen consisted of a fixation cross (1° x 1° of visual angle), positioned at the center of the screen and set against a uniform 60% gray background. The cue stimuli, illustrated in Figure 4.1, consisted of grey-scale photographs of a female face and a house. The face and house parts of each cue measured 4.2º x 6º, and were positioned 6.3º away from the central fixation cross. A house image was selected as the comparison stimulus due to both faces and houses being canonical stimuli (i.e., those that maintain a consistent internal configuration), with faces containing two eyes and a mouth, and houses typically containing windows and a door. This choice of stimuli maintains consistency with past attentional work (Bruce & Young, 1986; Farah, Wilson, Drain, & Tanaka, 1998; Kanwisher & Yovel, 2006; O'Craven, Downing, & Kanwisher, 1999; Tanaka & Farah, 1993).

Along with size and distance from the fixation cross, the face and house cues were matched for average luminance (computed using the MATLAB SHINE toolbox, Willenbockel et al., 2010)[6], and perceived attractiveness (measured via independent raters)[7]. Background context was added to the face and house cues using a photo editing software (Adobe Photoshop CS5), such that the face belonged to a person who was depicted sitting in a room, while the house was depicted as a picture that was hanging on a wall. The target screen consisted of a yellow circle or square (0.3º x 0.3º each), positioned 7.2º away from the fixation cross and set against a uniform 60% gray background.


a) Cues

b) Possible Target Locations

Figure 4.1 a) The cue screen depicting upright cues with the face in the left visual field. The face has been blurred to preserve the privacy of the actor. b) The target screen depicting all possible target locations for square targets.

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[6] Average gray scale luminance (ranging from 0-1) was equated across cues overall (face = .60, house = .56) as well as between the upper and lower halves of each cue (eyes = .60, mouth = .60, top house = .58, bottom house = .55). Michelson contrasts across each of these regions were also equivalent, though some variance existed across the lower half of each cue (eyes = .64, mouth = .56, top house = .65, bottom house = .72). Although we did not use a linearized monitor, all luminance and contrast measures reflecting image pixel values were verified to accurately reflect screen measures using a DataColor Spyder3Pro colorimeter.

[7] Thirty-five additional naïve participants were asked to independently rate images of faces and images of comparison house and object stimuli using a Likert scale ranging from 1- *Very Unattractive* to 10- *Very Attractive*. The cue images used here received equivalent attractiveness ratings, $t(34)=1.40$, $p=.17$, $d_z=.24$.

Design. The target discrimination task was a repeated measures design with five factors: *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), *Target identity* (circle, square), and *Cue-target interval* (denoting the time between the onset of the cue and the onset of the target; 250, 360, 560, 1000ms).

Cue orientation varied between upright and inverted cue images to control for baseline visual differences across the cue stimuli (Frank, Vul, & Johnson, 2009; Simion & Giorgio, 2015; Yin, 1969). *Face position* varied between the left and right visual fields, with the house image always occurring in the opposite visual field. This manipulation was included as previous work has found that social processing of faces is facilitated when they are presented in the left visual field (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; Pereira et al., 2019; Puce et al., 1998; Rossion, Joyce, Cottrell, & Tarr, 2003; Yovel et al., 2003). *Target location* was varied to occur at either the previous location of the eyes, mouth, top of the house, or bottom of the house. This critical manipulation was included to capture performance differences between targets occurring at the location of the face and its specific facial features relative to the comparison stimuli. *Target identity* was varied between a yellow circle and a yellow square in order to collect both response time (RT) and response accuracy. *Cue-target interval* varied between 250, 360, 560, and 1000ms in order to assess the time course of attentional biasing and to maintain consistency with past work (Bindemann et al., 2007; Pereira et al., 2019a).

All factor combinations were equiprobable and presented equally often throughout the task sequence. The cues were spatially uninformative about the target location and its identity, as each target was equally likely to occur at any of the possible target locations. Conditions were intermixed and presented in a randomized order. Thus, participants had no incentive to attend to any particular cue.

Procedure. As before (Bindemann et al., 2007; Pereira et al., 2019a), we used the dot-probe task (MacLeod, Mathews, & Tata, 1986). Figure 4.2 depicts the typical sequence of events. After the fixation display of 600ms, a cue display was shown for 250ms. After 0, 110, 310, or 750ms (constituting 250, 360, 560, and 1000ms cue-target intervals, respectively), a single target was presented at the previous location of the eyes, mouth, top house, or bottom house, and remained visible until participants responded or 1500ms had elapsed. Participants were instructed to withhold their eye movements and to identify the target by pressing the ‘b’ or ‘h’ keys on the keyboard quickly and accurately (target identity-key response was counterbalanced). They were informed about the progression of the task sequence, that the target was equally likely to be a circle or a square, that the target could appear in any of the possible locations, and that there was no spatial relationship between the cue content, cue orientation, cue placement, target location, or target shape. Participants completed 960 trials divided equally across five testing blocks, with ten practice trials run at the start. Responses were measured from target onset.

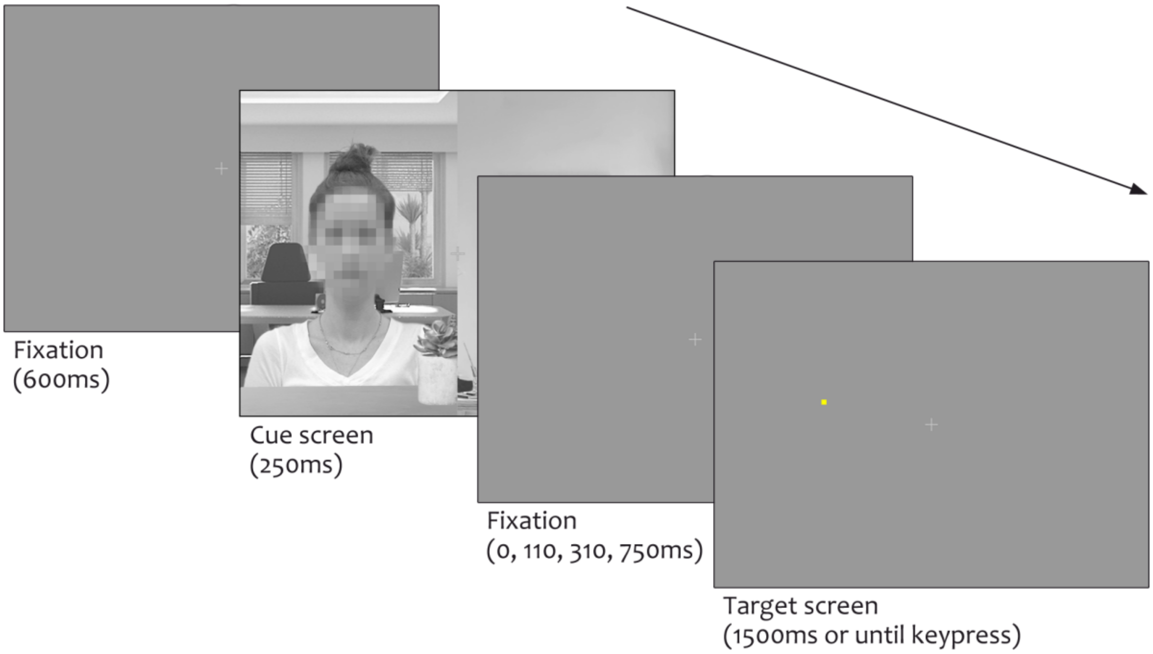

Figure 4.2 Example trial sequence. Trials began with the presentation of the fixation screen for 600ms. The cue screen was then presented for 250ms. After 0, 110, 310, or 750ms, a target (circle or square) demanding a discrimination response appeared in one of four possible locations. The target remained on screen for 1500ms or until a key press was made.

Results

Response anticipations (RTs < 100ms; 0.3% of all trials), timeouts (RTs > 1000ms; 2.9%), and incorrect key presses (key press other than ‘b’ or ‘h’; 1.9%) accounted for 5.1% of data and were removed from all analyses. Overall, accuracy was at ceiling at 94% and was not analyzed further.

Manual RT. In order to probe the extent of attentional biasing towards both overall faces and specific facial features (i.e., eyes and mouth), we conducted three sets of analyses. Using null hypothesis significance testing (NHST), we examined mean correct RTs for *(1)* target responses for the overall face (averaged across target locations of eyes and mouth) compared to the overall house (averaged across target locations of top and bottom house), and *(2)* target responses for each target location of the eyes, mouth, top house, and bottom house. NHST were performed using repeated measures Analyses of Variance (ANOVA) with Greenhouse-Geiser corrections applied for any violations of sphericity. Paired two-tailed t-tests were used for post-hoc comparisons where applicable, with multiple comparisons corrected using the Holm-Bonferroni procedure to control for Type I error (Holm, 1979). All comparisons are shown with corresponding adjusted *p*-values ($\alpha_{FW} = .05$, Ludbrook, 2000). If background context facilitated social attentional biasing, we expected to find faster responses for targets occurring at the previous location of the face (both overall and/or at the eyes) relative to targets occurring at the previous location of the house.

Furthermore, any null effects were examined using Bayesian analyses to assess *(3)* the relative strength of evidence for preferential attentional biasing towards faces versus houses by quantifying the evidence for the alternative hypothesis over the null hypothesis (Dienes, 2011). Bayesian analyses were performed using an online Bayes factor calculator[8] based on previously reported social attentional biasing effects when using similar paradigms. A Bayes factor that is less than .33 provides substantial evidence for the null hypothesis, whereas a Bayes factor greater than 3.00 indicates evidence for the alternative hypothesis (values between .33 and 3.00 suggest the need for more evidence).

Overall face vs. house comparisons. Mean correct interparticipant RTs were analyzed using an omnibus repeated measures ANOVA, run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (face, house), and *Cue-target interval* (250, 360, 560, 1000ms). There was a main effect of *Cue-target interval* [$F(3,87)=62.31$, $p<.001$, $\eta_p^2=.68$], indicating overall faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, $ts>9.80$, $ps<.001$, $d_zs>1.79$; 360ms vs. all, $ts>3.20$, $ps<.008$,

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[8] http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/bayes_factor.swf

d_zs>.58; all other p=.36, d_z=.17]. This finding demonstrates the typical foreperiod effect (Bertelson, 1967; Hayward & Ristic, 2013), reflecting increased preparation to respond with a lengthening of the time between the cue and target. As such, this finding shows that participants performed the task with an expected degree of preparation and alertness to the target. Importantly though, no effects of *Target location* were found [$F(1,29)=3.73$, p=.06, η_p^2=.11].

Two interactions with Target location reached significance. A two-way interaction between *Target location* and *Cue-target interval* [$F(3,87)=3.25$, p=.026, η_p^2=.10] indicated slower RTs for targets that occurred at the previous location of the face vs. house cue at a cue-target interval of 560ms [$t(29)=3.11$, p=.017, d_z=.57; all other ps>.13, d_zs<.39]. A three-way interaction between *Face position*, *Target location*, and *Cue-target interval* [$F(3,87)=4.96$, p=.003, η_p^2=.15] was reliable as well. When separated by Face position, significant main effects of *Cue-target interval* were found when the face was presented in both the left and right visual fields [$F(3,87)=36.85$, p<.001, η_p^2=.56; $F(3,87)=57.87$, p<.001, η_p^2=.67, respectively], showing faster RTs for longer relative to shorter cue-target intervals [left visual field, 250ms vs. all, ts>6.90, ps<.001, d_zs>1.26; 360ms vs. 1000ms, $t(29)=3.05$, p=.014, d_z=.56; all other ps>.07, d_zs<.40; right visual field, 250ms and 360ms vs. all, ts>2.43, ps<.043, d_zs>.44; all other p=.94, d_z=.01]. When faces were presented in the left visual field, an interaction between *Target location* and *Cue-target interval* [$F(3,87)=8.18$, p<.001, η_p^2=.22] further indicated slower RTs for targets occurring at the previous location of the face vs. house cue at 560ms [$t(29)=3.13$, p=.016, d_z=.57; all other ps>.12, d_zs<.39]. No other significant main effects or interactions were found [Fs<3.94, ps>.06, η_p^2<.12].

Specific facial features vs. house comparisons. Mean correct interparticipant RTs were analyzed using an omnibus repeated measures ANOVA, run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), and *Cue-target interval* (250, 360, 560, 1000ms). Figure 4.3 illustrates mean RTs for each participant as a function of target position for Upright (4.3a) and Inverted (4.3b) cues.

Figure 4.3 Experiment 1 results. Stripcharts depicting mean correct RTs for each participant as a function of Target position for Upright (a) and Inverted (b) cues. Horizontal lines mark the deciles, with the thicker darker line representing the median. Note that the reported pattern of results does not vary even if the outlier is removed from analyses.

The results revealed main effects of *Cue-target interval* [$F(3,87)=62.09$, $p<.001$, $\eta_p^2=.68$] and *Target location* [$F(3,87)=2.96$, $p=.037$, $\eta_p^2=.09$]. The first indicated overall faster RTs for longer relative to shorter cue-target intervals [250ms vs. all, ts>9.70, ps<.001, d_zs>1.77; 360ms vs. all, ts>3.17, ps<.007, d_zs>.58; all other $p=.36$, $d_z=.17$], demonstrating the typical foreperiod effect (Bertelson, 1967; Hayward & Ristic, 2013). The second main effect indicated overall slower RTs for targets that occurred at the previous location of the mouth vs. top house cues [$t(29)=3.01$, $p=.032$, $d_z=.55$; all other $ts<1.67$, $ps>0.53$, d_zs<.31], with no facilitative effects for the eyes in comparison to the house cues [$ts<1.39$, $ps>0.53$, d_zs<.25]. A two-way interaction between *Cue orientation* and *Target location* [$F(3,87)=3.20$, $p=.027$, $\eta_p^2=.10$] further showed that this finding held only for upright cues [$t(29)=3.61$, $p=.007$, $d_z=.66$; all other ps>.05, d_zs<.50; inverted cues, all ps>.19, d_zs<.41].

A three-way interaction between *Face position*, *Target location*, and *Cue-target interval* was reliable as well [Mauchly's test of sphericity, $\chi^2(44)=63.56$, $p=.03$; $F(6.41,185.89)=2.33$, $p=.031$, $\eta_p^2=.07$]. When run separately by Face position, significant main effects of *Cue-target interval* for both the left and right visual field were found [$F(3,87)=37.32$, $p<.001$, $\eta_p^2=.56$; $F(3,87)=57.52$, $p<.001$, $\eta_p^2=.67$, respectively], with faster RTs for longer relative to shorter cue-target intervals [left visual field, 250ms vs. all, ts>6.98, ps<.001, d_zs>1.27; 360ms vs. 1000ms, $t(29)=3.04$, $p=.015$, $d_z=.55$; all other ps>.07, d_zs<.40; right visual field, 250ms and 360ms vs. all, ts>2.42, ps<.044, d_zs>.44; all other $p=.92$, $d_z=.02$]. Furthermore, a significant interaction between *Target location* and *Cue-target interval* [Mauchly's test of sphericity, $\chi^2(44)=62.23$, $p=.04$; $F(6.15,178.25)=3.08$, $p=.006$, $\eta_p^2=.10$] was found when faces were presented in the left visual field, indicating slower RTs for targets occurring at the previous location of the eyes vs. top house cue at 560ms only [$t(29)=3.22$, $p=.019$, $d_z=.59$; all other ps>.13, d_zs<.43]. No other effects were reliable [Fs<2.09, ps>.10, η_p^2<.07].

Bayesian analyses. To further examine the plausibility of no attentional differences between the cues, we performed Bayesian analyses using a two-tailed Gaussian distribution centered around a mean of 17.67ms and SD of 7.55ms, which reflected the previously-reported manual RT advantage for faces vs. objects (Bindemann et al., 2007; Experiments 1a & 1b). A Bayes factor of .08 was found for upright face vs. house contrasts, thus supporting the findings from the NHST and providing evidence in favour of the null hypothesis of no difference in reaction times between the face and house cues.

Discussion

If contextually-based social information resulted in spontaneous covert social attentional biasing, we expected to find faster responses for targets occurring at the previous location of the face overall and/or the eyes specifically. Our data did not support this hypothesis, indicating no attentional effects for targets occurring at the location of the face or the eyes. If anything, there was a short-lived effect at 560ms cue-target interval only, suggesting slower RTs for overall faces relative to houses, as well as specifically for eyes relative to top house, when faces were presented in the left visual field; however, since this finding was not specific to upright faces, it may have reflected differences in the stimulus properties of the contextualized cues (Frank et al., 2009; Simion & Giorgio, 2015; Yin, 1969). Similar contextualized differences may have been responsible for slower RTs for the mouth relative to top house targets, both overall and when cues were presented in an upright orientation, particularly since this effect was not specific to when faces were presented in the left visual field. Additionally, Bayes analyses supported the null hypothesis of no differences between face and house cues.

Experiment 1 then suggests that when the face and house stimuli are presented within appropriate background context, there are no reliable effects to indicate preferential covert attentional biasing towards the face or the eyes. These results are consistent with our recent work (Pereira et al., 2019), and further suggest that covert social attention is not determined by contextual factors alone. In Experiment 2, we examined whether these results held when we measured overt attention.

Experiment 2

In the Pereira and colleagues (2019a) study, when participants were allowed to make eye movements during the dot-probe task, they broke central fixation on 11% of all trials. Of these 11% of trials, when examining where saccades were directed, it was found that participants looked towards the eyes of the face 17% of the time. This reliable, albeit modest, bias to look at the eyes reflects a potential dissociation between covert and overt orienting towards social stimuli. In the present experiment, we examined whether similar oculomotor biasing also occurred when cues were presented within contextual backgrounds. To do so, we did not provide participants with any instructions to maintain central fixation, but measured their spontaneous eye movements while they performed the same dot probe task as in Experiment 1.

Materials and Methods

Participants, Apparatus, Stimuli, Design, and Procedure. Thirty new volunteers (23 females, M_{age} = 21 years, SD_{age} = 3 years) participated. None took part in the previous experiment and all reported normal or corrected-to-normal vision. All stimuli, design, and procedures were identical to Experiment 1, except that: *(i)* Participants' eye movements were tracked using a remote EyeLink 1000 eye tracker (SR Research; Mississauga, ON) recording with a sampling rate of 500Hz and a spatial resolution of .05°. Although viewing was binocular, only the right eye was tracked; *(ii)* Prior to the start of the experiment, a nine-point calibration was performed, and spatial error was rechecked before every trial using a single-point calibration dot. Average spatial error was no greater than .5°, with maximum error not exceeding 1°; and *(iii)* Participants were not given any instructions regarding maintaining central fixation in order to preserve their natural eye movements during the task.

Results

Anticipations (0.1%), timeouts (2.2%), and incorrect key presses (0.1%) were removed from manual data analyses. Overall response accuracy was 96%. Manual RTs were analyzed as before using the same three sets of analyses.

Overall face vs. house comparisons. Mean correct RTs were analyzed using an omnibus ANOVA, run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (face, house), and *Cue-target interval* (250, 360, 560, 1000ms). A significant main effect of *Cue-target interval* [Mauchly's test of sphericity, $\chi^2(5)=14.72$, $p=.012$; $F(2.22,64.50)=62.95$, $p<.001$, $\eta_p^2=.69$] emerged, with overall slower RTs for short vs. longer cue-target intervals [250ms vs. all, ts>8.18, ps<.001, d_zs>1.49; all other ps>.34, d_zs<.30]. However, similar to the overall comparisons for Experiment 1, no effects of *Target location* were found [$F(1,29)=.81$, $p=.38$, $\eta_p^2=.03$].

A significant two-way interaction between *Cue orientation* and *Target location* [$F(1,29)=6.73$, $p=.015$, $\eta_p^2=.19$] indicated a numerical pattern of slower RTs for inverted vs. upright houses, though post-hoc comparisons did not reach significance [all ps>.06, d_zs<.42]. Additionally, a three way interaction between *Cue orientation*, *Target location*, and *Cue-target interval* [$F(3,87)=3.08$, $p=.032$, $\eta_p^2=.10$] emerged once again. When separated by Cue orientation, there was a significant main effect of *Cue-target interval* for both upright and inverted cues [Mauchly's test of sphericity, $\chi^2(5)=12.79$, $p=.026$; $F(2.37,68.82)=40.60$, $p<.001$, $\eta_p^2=.58$; and $F(3,87)=47.54$, $p<.001$, $\eta_p^2=.62$, respectively], with overall slower RTs for short vs. longer cue-target intervals [upright, 250ms vs. all, ts>6.90, ps<.001, d_zs>1.26; all other ps>.62, d_zs<.24; inverted, 250ms vs. all, ts>7.53, ps<.001, d_zs>1.37; all other ps>.23, d_zs<.34]. Furthermore, a significant main effect for *Target location* [$F(1,29)=5.17$, $p=.031$, $\eta_p^2=.15$] was found for inverted cues, with slower RTs for overall faces vs. houses. An interaction between *Target location* and *Cue-target interval* [$F(3,87)=2.92$, $p=.039$, $\eta_p^2=.09$] was found for upright cues, indicating a numerical pattern of faster RTs for faces vs. houses at 250ms only, though post-hoc comparisons did not reach significance [all ps>.06, d_zs<.47]. No other significant main effects or interactions were found [Fs<1.64, ps>.19, η_p^2<.05].

Specific facial features vs. house comparisons. An omnibus ANOVA with *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target position* (eyes, mouth, top house, bottom house), and *Cue-target interval* (250, 360, 560, 1000ms) was run. Mean RTs for each participant are illustrated in Figure 4.4 for Upright (4.4a) and Inverted (4.4b) cues.

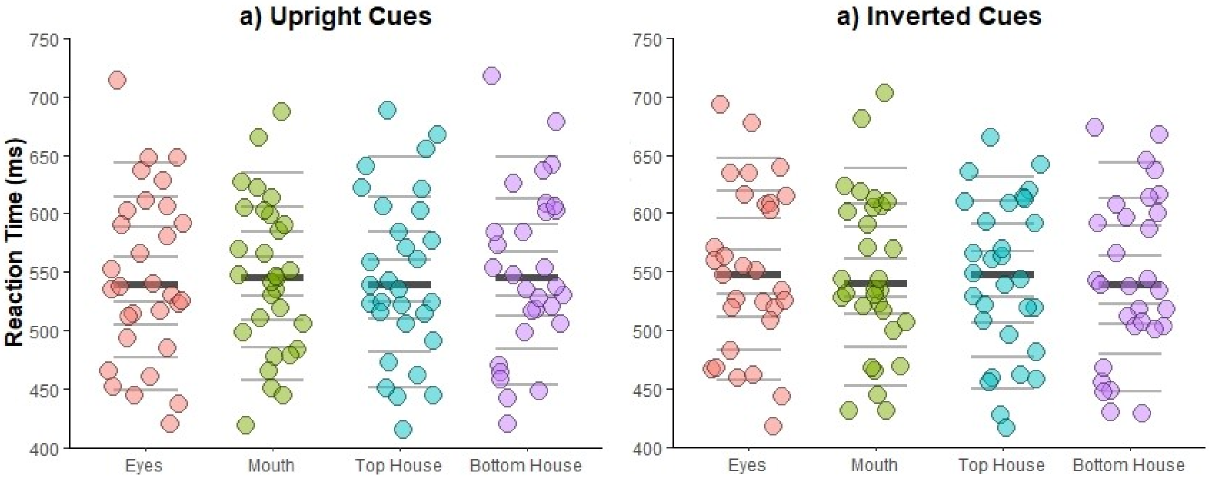

Figure 4.4 Experiment 2 manual results. Stripcharts depicting mean correct RTs for each participant as a function of Target position for Upright (a) and Inverted (b) cues. Horizontal lines mark the deciles, with the thicker darker line representing the median.

Similar to the pattern of results found for overall faces vs. houses, the ANOVA indicated a main effect of *Cue-target interval* [Mauchly's test of sphericity, $\chi^2(5)=14.04$, $p=.015$; $F(2.24,65.07)=62.30$, $p<.001$, $\eta_p^2=.68$], which was once again driven by overall slower RTs at shorter cue-target times [250ms vs. all, ts>8.10, ps<.001, d_zs>1.48; all other ps>.35, d_zs<.30] and a significant interaction between *Cue orientation* and *Target location* [$F(3,87)=3.02$, $p=.034$, $\eta_p^2=.09$] indicating a numerical pattern of shorter RTs for eyes for upright vs. inverted faces and shorter RTs for bottom house for inverted vs. upright houses, though post-hoc comparisons did not reach significance [all ps>.07, d_zs<.49]. No other effects were found [Fs<1.89, ps>.06, $\eta_p^2<.06$].

Bayesian analyses. Once again, Bayes factor was used to examine the plausibility of these findings using the same parameters as before (i.e., two-tailed Gaussian distribution, M=17.67, SD=7.55; Bindemann et al., 2007; Experiments 1a & 1b). A Bayes factor of .07 was found for upright face vs. house contrasts, which once again provided support for the null over the alternative hypothesis indicating no difference in reaction times between the face and house cues.

Oculomotor data. To assess if participants spontaneously looked at the face cue more frequently, we next examined trials in which saccades were launched from central fixation towards one of the predefined regions of interest (ROI), i.e., Eyes, Mouth, Top House, or Bottom House location, during the 250ms cue period only, as we were specifically interested in examining attentional biasing in response to the cue stimuli. As illustrated in Figure 4.5, each ROI was comprised of its respective cue region and spanned a 30° radial window. Saccades were defined as eye movements with an amplitude of at least .5°, an acceleration threshold of $9{,}500°/s^2$, and a velocity threshold of 30°/s.

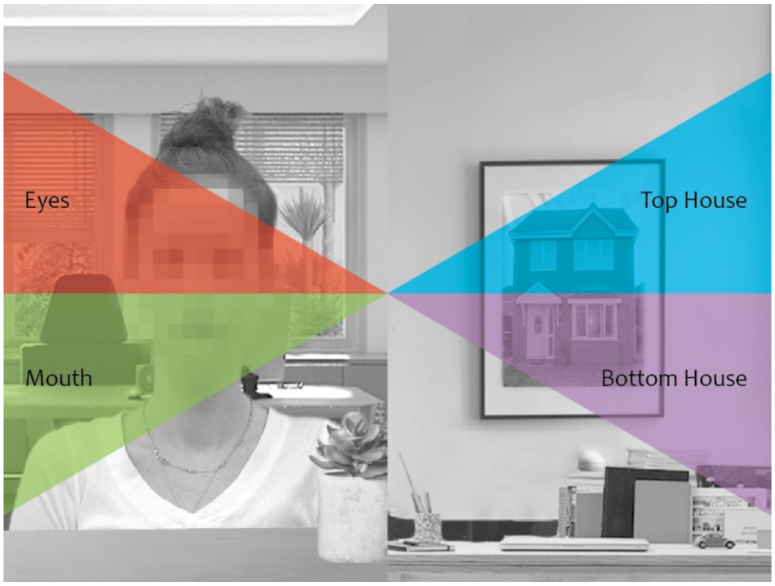

Figure 4.5 Regions of Interest (ROI). ROIs were defined by a radial window that included the area of interest; red = eyes, green = mouth, blue = top house, purple = bottom house.

For each participant, we calculated the proportion of saccades for each ROI by examining the direction of the very first saccade that was launched from central fixation towards one of the ROIs upon cue onset. The number of saccades that were launched towards each ROI were tallied across the entire experiment for each participant and then divided by the total number of first saccades that occurred during the cue period. On average, participants saccaded away from the fixation cross on 11% of all trials, of which saccades were launched towards an ROI on 91% of those trials. As with manual RT, we conducted NHST to analyze the proportion of saccades launched towards *(1)* the overall face versus the house and *(2)* each specific target location (eyes, mouth, top house, bottom house), and we conducted Bayesian analyses to examine any null effects to assess *(3)* the relative strength of evidence for the alternative over the null hypothesis.

Overall face vs. house comparisons. Proportion of saccades were analyzed using a repeated measures ANOVA run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (face, house). Main effects of *Cue* *orientation* [$F(1,29)=13.23$, $p=.001$, $\eta_p^2=.31$] and *Face position* [$F(1,29)=9.90$, $p=.004$, $\eta_p^2=.25$] were reliable, with a greater proportion of saccades occurring when cues were upright and when faces were presented in the left visual field, respectively.

However importantly, there was a significant main effect of *ROI*, [$F(1,29)=51.96$, $p<.001$, $\eta_p^2=.64$], with an overall greater proportion of saccades towards the face compared to the house. This main effect was further qualified by a significant interaction between *Cue orientation* and *ROI* [$F(1,29)=15.84$, $p<.001$, $\eta_p^2=.35$], which demonstrated a larger bias for proportion of saccades towards the face vs. house for upright cues [$t(29)=6.53$, $p<.001$, $d_z=1.19$] as compared to inverted cues [$t(29)=3.68$, $p=.001$, $d_z=.67$]. An interaction between *Face position* and *ROI* [$F(1,29)=6.85$, $p=.014$, $\eta_p^2=.19$] further demonstrated a larger effect for the proportion of saccades towards the face vs. house when the face was presented in the left visual field [$t(29)=5.80$, $p<.001$, $d_z=1.06$] as compared to the right visual field [$t(29)=3.01$, $p=.005$, $d_z=.55$]. No other significant effects were found [Fs<3.43, ps$>.07$, η_p^2s$<.11$].

Specific facial features vs. house comparisons. Proportion of saccades were examined using a repeated measures ANOVA run as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house). Mean proportion of saccades away from the fixation cross are illustrated in Figure 4.6 as a function of ROIs for Upright (4.6a) and Inverted (4.6b) cues.

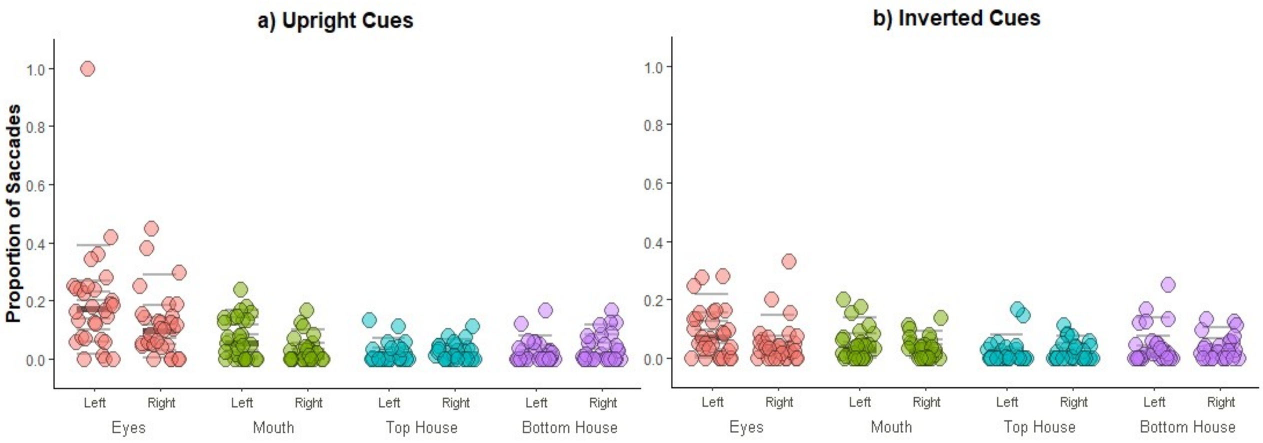

Figure 4.6 Experiment 2 eye movement results. Stripcharts depicting mean proportion of saccades for each participant during the cue presentation period as a function of Face Position and ROI for Upright (a) and Inverted (b) cues. Horizontal lines mark the deciles, with the thicker darker line representing the median. Note that the pattern of results does not change even if the outlier is removed from analyses.

Similar to the overall comparisons, there were main effects of *Cue orientation* [$F(1,29)=13.23$, $p=.001$, $\eta_p^2=.31$] and *Face position* [$F(1,29)=9.90$, $p=.004$, $\eta_p^2=.25$], showing that a greater proportion of saccades occurred when cues were upright and when faces were presented in the left visual field, respectively. Importantly, we also found a main effect of *ROI*, [Mauchly's test of sphericity, $\chi^2(5)=25.89$, $p<.001$; $F(1.92,55.54)=43.53$, $p<.001$, $\eta_p^2=.60$] with an overall greater proportion of saccades towards the Eyes compared to all other ROIs [ts>6.79, ps<.001, d_zs>1.24] and an overall great proportion of saccades towards the Mouth compared to Top house [$t(29)=4.06$, $p=.001$, $d_z=.74$; all other ps>.07, d_zs<.41].

This main effect was further qualified by a significant interaction between *Cue orientation* and *ROI* [Mauchly's test of sphericity, $\chi^2(5)=35.91$, $p<.001$; $F(1.67,48.54)=8.49$, $p=.001$, $\eta_p^2=.23$]. When cues were upright, a greater proportion of saccades were directed towards the Eyes compared to all other regions [ts>4.72, ps<.001, d_zs>.87], along with greater proportion of saccades towards the Mouth compared to Top house [$t(29)=3.03$, $p=.015$, $d_z=.55$; all other ps>.17, d_zs<.33]. A similar pattern was found when cues were inverted, however this effect was numerically smaller and was specific to the eye region only [eyes vs. all other regions, *t*s>2.72, *p*s<.04, d_zs>.50; all other *p*s>.16, d_zs<.37]. A reliable *Face position* and *ROI* interaction emerged as well [Mauchly's test of sphericity, $\chi^2(5)=59.00$, $p<.001$; $F(1.44,41.81)=4.52$, $p=.027$, $\eta_p^2=.14$], which further suggested that proportion of saccades towards the Eyes and Mouth was greater when faces were presented in the left visual field. That is, a greater proportion of saccades were launched towards the Eyes compared to all other regions and the Mouth compared to Top house when the face was presented in the left visual field [*t*s>3.71, *p*s<.003, d_zs>.68; all other *p*s>.05, d_zs<.43], however, this effect was smaller and only specific to the eyes when the face was presented in the right visual field [eyes vs. all other regions, *t*s>3.32, *p*s<.01, d_zs<.61; all other *p*s>.14, d_zs<.38]. No other effects were found [$F<1.12$, *p*s>.30, $\eta_p^2<.04$].

Thus, when participants' natural eye movements were measured, spontaneous saccades were launched more frequently towards the face overall as well as the eyes specifically, particularly when the face was presented in an upright orientation and when it was positioned in the left visual field.

Discussion

In Experiment 2, we examined whether participants' overt attention was spontaneously directed toward faces or their specific features. Without any specific instructions about eye movements, we once again found no manual advantages for targets occurring at the location of the face and Bayesian analyses provided evidence for the null hypothesis of no RT differences between targets occurring at the previous location of the face and house cues. However, when we examined spontaneous eye movements, we found that participants broke fixation and looked at the cue stimuli on 11% of all trials, which is numerically consistent with the percentage of saccades found in the Pereira and colleagues (2019a) study. However here, saccades were launched towards the eye region on 48% (versus 17% in the previous study) of trials that broke fixation. This finding was also qualified by an increase in the proportion of saccades towards faces overall, and eyes specifically, when faces were upright and when they were presented in the left visual field. Therefore, even though oculomotor biasing occurred on a small subset of all trials, it appears that faces presented within consistent contextual backgrounds exert differential effects across manual and overt responses.

General Discussion

The present study examined whether social information presented in context influenced spontaneous social attention biasing. Using the dot-probe paradigm, we presented participants with face and house cues embedded within appropriate contextual backgrounds and measured their speed of target discrimination when targets were presented at the previous location of the face (eyes, mouth) versus the house (top, bottom). While controlling for stimulus information across size, distance from the fixation cross, overall luminance, and attractiveness between the face and house stimuli (as in Pereira and colleagues' (2019a) study), we measured covert attention by instructing participants to maintain central fixation in Experiment 1 and spontaneous eye movements by using an eye tracker in Experiment 2.

No evidence of attentional biasing towards faces or facial features was found in manual responses in either experiment. This replicates and extends our previous work demonstrating that covert social attentional biasing is fragile in nature and affected by stimulus content factors (Pereira et al., 2019a) even when the stimuli are embedded in appropriate background contexts. Thus, visual context alone appears to be insufficient in engaging social attention biasing in covert measures. However, when we measured participants' eye movements, we found that their overt attention was biased towards the eyes of faces when they were presented in an upright orientation and in the left visual field. Although this biasing towards the eye region occurred in only 48% of trials in which participants broke fixation during the cue display (i.e., only 5.3% of all trials), the magnitude of this effect was numerically larger than in Pereira and colleagues (2019a) study, where they observed biasing towards the eye region on only 17% of trials in which participants broke fixation (i.e., 1.9% of all trials). This suggests that it may be quicker and less effortful to extract social information from faces when they are presented in the appropriate context. However, since these observations are based on between-study comparisons, future investigations are needed in which background context is directly manipulated using a within-participants design to arrive at a more precise estimation of the effects of context on the magnitude of social attention biasing. Taken together, the results of the present study show that contextually-embedded social information does not result in spontaneous social attentional biasing in covert measures but does appear to modulate the magnitude of attentional biasing in overt measures.

These findings raise three main discussion points. One, they suggest that past work that has reported robust effects of social attention biasing in manual and oculomotor measures when using more uncontrolled stimuli (Bindemann et al., 2005; Bindemann et al., 2007; Birmingham et al., 2008a; Devue et al., 2012; Langton et al., 2008; Ro et al., 2001; Theeuwes & Van der Stigchel, 2006; Yarbus, 1967) likely did not reflect the contribution of visual context alone. Instead, it is more plausible that these effects were due to some combination of visual context, stimulus content, and task factors. Content factors such as luminance, internal configuration of features, and emotional valence have each been documented to engage attention irrespective of any biases elicited by the social nature of faces (Cerf et al., 2008; Eastwood, Smilek, & Merikle, 2001; Hedger, Garner, & Adams, 2019; Itier et al., 2006; Rousselet et al., 2014). Additional factors, like geometrical shape, that are specific to faces but not tied to any inherent social importance that faces contain may also play a role in attentional biasing towards these social stimuli (Larson, Aronoff, & Stearns, 2007). Furthermore, task settings, like the predictability of the cues and the setting of the attentional paradigms have also been found to modulate the magnitude of social attentional effects (Hayward & Ristic, 2013, 2015). For example, Burra, Framorando, and Pegna (2018) investigated the electrophysiological correlates of eye gaze processing and found that perceiving eye gaze was highly dependent on whether the faces were relevant to the task. Similarly, Hessels and colleagues (2018) engaged participants in face-to-face communication and found that gaze allocation was affected by task instructions (i.e., speaking versus listening) and the social context of the communication (i.e., direct conversation versus pre-recorded video). Dovetailing with these data, the present results point to the underlying influence of both stimulus and task settings in spontaneous attentional biasing towards faces and eyes, and highlight the need for future investigations geared towards manipulating and isolating the contribution of visual context, stimulus content, and task factors.

Two, while overt measures demonstrated infrequent effects, they were nevertheless statistically reliable. This is consistent with recent work by Hayward and colleagues (2017) who compared social biasing occurring within a typical cuing task with social biasing occurring during a live social interaction. One difference that emerged in the comparison of these methods was the relative scarcity of gaze following observed during real-world interaction. Subsequently, Blair, Capozzi, and Ristic (2017) found similarly infrequent though reliable effects when examining overall social orienting during gaze cuing tasks. Together, these data demonstrate that gaze following and social orienting may in actuality occur relatively infrequently, which further suggests that these behaviors may be contextually and situationally mediated, such that appropriate attentional responses only need to occur occasionally in order to affect behavior reliably. Our eye movement measures support these findings showing that orienting may be reflective of an infrequent bias towards key parts of social cues.

Finally, while social attention biasing was observed in overt measures, no effects emerged in covert measures. This result adds to the growing body of evidence demonstrating dissociations between covert and overt measures of social attention, in that the two modes of orienting appear to serve different purposes in real-world social environments – covert attention is hypothesized to serve as a mechanism that surreptitiously gathers information from the environment, while overt attention is hypothesized to serve as an active signalling mechanism in order to communicate with others (Gobel, Kim, & Richardson, 2015; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Latinus et al., 2015; Risko et al., 2016; Scott, Batten, & Kuhn, 2018). These dissociations have only just begun to be probed on an experimental level (Bonmassar, Pavani, & van Zoest, 2019; Kuhn & Teszka, 2018; Kuhn et al., 2016; Laidlaw & Kingstone, 2017; Laidlaw, Rothwell, & Kingstone, 2016), with the present study along with Pereira and colleagues' (2019a) study providing direct evidence in support of this distinction. Future studies in which covert and overt attention are systematically manipulated and measured are needed to understand the nature of this dissociation.

In sum, the present investigation shows that spontaneous social attention biasing may diverge across covert and overt measures. This underscores the fragility of spontaneous attentional biasing towards social information and points to the need for systematic investigations of the specific contributions of stimulus content and visual context factors in covert and overt social attention.

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Infrequent novel faces bias social attention in manual and oculomotor measures

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Abstract

Although attention is thought to be spontaneously biased by social cues like faces and eyes, recent data have demonstrated that when stimulus content, visual context, and task factors are controlled, this attentional bias is abolished in manual responses while still occurring infrequently in oculomotor measures. Here, we investigated how social attentional biasing is affected by stimulus novelty by measuring responses to frequently presented face identities (i.e., those with lower novelty) and infrequently presented face identities (i.e., those with higher novelty). Using a dot-probe task, participants were presented with either the same face-house cue pair that was frequently presented on half of the trials or sixteen different face-house cue pairs that were infrequently presented on the other half of the trials. A response target occurred at the previous location of the eyes or mouth of the face or the top or bottom of the house. Experiment 1 measured manual responses to the target while participants maintained central fixation. Experiment 2 additionally measured natural oculomotor behaviour using an eye tracker when eye movements were not restricted. Similar to previous work, no evidence of social attentional biasing was found in manual responses when central fixation was maintained, although there was overall higher alertness to infrequently presented faces. When eye movements were not restricted, there was a short-lived social attentional bias in manual data that was not specific to upright faces and a reliable oculomotor bias towards the eyes of infrequently presented upright faces. Together, these findings suggest that face novelty impacts manual attention measures in a general manner, while facilitating spontaneous oculomotor biasing towards the eyes of upright infrequently presented faces more specifically.

Keywords: social attention; attentional biasing; faces; novelty

Introduction

Research has long-since determined that faces are functionally important within our daily lives (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Farroni, Csibra, Simion, & Johnson, 2002; Yovel, Levy, Grabowecky, & Paller, 2003). Although a large number of studies have demonstrated this importance through findings of preferential and spontaneous attentional biasing towards faces and facial features like eyes (Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007; Birmingham, Bischof, & Kingstone, 2008; Cerf, Frady, & Koch, 2009; Ro, Russell, & Lavie, 2001), recent studies have called the robustness of these social attentional biasing effects into question.

Specifically, multiple studies have now demonstrated that extraneous factors within the stimuli and the task may have played a key role in the aforementioned social biasing effect. Pereira and colleagues (2019a) were among the first to demonstrate the fragility of the social attention biasing. Using the dot-probe task, the authors presented participants with a face, house, and comparison neutral cues, followed by a target that appeared with equal probability at one of these cue locations. Importantly, stimulus content, visual context, and task factors were tightly controlled. To control stimulus content, the face and house cues were equated in size, distance from central fixation, overall luminance, featural configuration, and perceived attractiveness, while the response target appeared against a uniform gray background to control for possible local contrast between the target and the cue images. To control visual context, a single face and house identity cue pair was used that was always presented without extraneous information, such as the hair and body information for the face and scene setting information for the house. Finally, to control for task factors, the cue and target were never spatially or semantically related, the response keys and response type were orthogonal to one another, and the same task was used for both covert and overt measures of attentional biasing, which measured reaction time to targets when eye movements were restricted and proportion of saccades towards any of the cue locations when eye movements were not restricted, respectively. Surprisingly, the results revealed no evidence of spontaneous attentional biasing towards targets pre-cued by faces in manual responses, and a numerically small but statistically reliable attentional bias towards the eyes of the face in oculomotor responses. Follow-up studies from the same group have found that this lack of social attentional bias was not due to the loss of stimulus content factors from equated luminance or similar featural configuration between the face and house stimuli (Pereira, Birmingham, & Ristic, 2019c). However, the authors did find that attentional biasing was increased when faces were perceived as highly attractive (Pereira et al., 2019c) and when visual context factors provided typical contextual background information for face stimuli (Pereira, Birmingham, & Ristic, 2019b). In the current study, we examined whether stimulus novelty plays a similar role in modulating social attentional biases.

To date, a majority of research that has examined the effects of face novelty on social information processing has shown differences between faces that are familiar (i.e., faces that are famous, well-known, or personally-familiar) and novel (i.e., faces that are unfamiliar or have never been seen before). Although both familiar and novel faces exhibit similar underlying processing signatures (Yin, 1969; Young, Hellawell, & Hay, 1987), familiar and novel facial identities have distinct representations within the cognitive system. This is reflected by studies demonstrating that familiar faces are perceptually dissociated from novel faces (Malone, Morris, Kay, & Levin, 1982; Young, Flude, Hay, & Ellis, 1993) in that familiar faces activate distributed networks of brain regions involved in person perception and emotion recognition (Gobbini & Haxby, 2007). This facilitation for familiar faces also extends into the attentional domain, which has shown that familiar faces are preferentially attended relative to novel faces (Bruce & Young, 1986; Chapman, Hawkins-Elder, & Susilo, 2018; Ellis, Shepherd, & Davies, 1979). In addition, eye movements are biased towards familiar faces, with faster saccades (Visconti di Oleggio Castello & Gobbini, 2015) and more reliable fixations towards the internal features (i.e., the eyes, nose, and mouth region) of familiar compared to novel faces (Althoff & Cohen, 1999; Heisz & Shore, 2008; Stacey, Walker, & Underwood, 2005). In contrast, the processing of novel faces appears to rely on differential processing strategies, suggesting that they may be processed in a generalized manner that is similar to non-social stimuli (Megreya & Burton, 2006).

These findings are consistent with the lack of social attentional biasing found in Pereira and colleagues' work (2019a, 2019b, 2019c), wherein the authors used a single novel face-house cue pair throughout the task and found no typical attentional biasing effects towards face cues. However, this finding raises questions for why past work that has utilized multiple novel face-object cue pairs found robust social attentional biasing effects (Bindemann, Burton, Hooge, Jenkins, & DeHaan, 2005; Bindemann et al., 2007; Birmingham et al., 2008; Devue, Belopolsky, & Theeuwes, 2012; Lavie, Ro, & Russell, 2003; Ro et al., 2001). One possibility is that perception of face novelty is modulated by stimulus repetition, i.e., how frequently a single face identity is repeated throughout the task. Indeed, research has shown that processing advantages are found for novel faces that are repeated infrequently throughout the task (Bruce & Young, 1986; Chapman et al., 2018; Ellis et al., 1979; Heisz, Watter, & Shedden, 2006; Winston, Henson, Fine-Goulden, & Dolan, 2004; Yi, Kelley, Marois, & Chun, 2006). Therefore, it is possible that lower repetition rates for facial identity may have contributed to the robustness of social attentional biasing effects in previous work (Bindemann et al., 2007; Birmingham et al., 2008), whereas higher repetition rates for a single face identity may have contributed to a decreased magnitude of social attention biasing in Pereira and colleagues' (2019a, 2019b, 2019c) work.

Here, we tested this possibility by contrasting attentional responses to infrequently and frequently presented novel faces. To do so, we used the same task as Pereira and colleagues (2019a, 2019b, 2019c), in which the presentation of a face-house cue pair was followed by the presentation of a target appearing at one of the previous locations of the eyes or mouth of the face or the top or bottom of the house. However importantly, a single face-house pair acted as a frequent cue stimulus and was presented on half of all trials, while multiple different face-house pairs acted as infrequent cue stimuli and were presented on the other half of trials. We continued to control for stimulus content (i.e., size, distance from central fixation, global luminance, and perceived attractiveness) and visual context factors (i.e., contextual information, background).

Experiment 1 measured manual responses while participants maintained central fixation, whereas Experiment 2 additionally measured participants' natural oculomotor behaviour using a high-speed eye tracker when eye movements were not restricted. If increased frequency of novel face presentation was responsible for social attentional biasing in previous work (Bindemann et al., 2007; Birmingham et al., 2008), we expected to find attentional biasing effects for infrequently presented face cues but not for frequently presented ones.

Experiment 1

Materials and Methods

Participants. Thirty volunteers with normal or corrected-to-normal vision participated. They were compensated with course credits. This sample size was determined by an a priori power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007), which was based on previously estimated magnitudes of the face biasing effect (Bindemann & Burton, 2008; Bindemann et al., 2007; Langton, Law, Burton, & Schweinberger, 2008; Ro et al., 2001). Informed consent was obtained from all participants. All procedures were approved by the University Research Ethics board.

Stimuli and Apparatus. Stimuli were presented on a 16” CRT monitor at a viewing distance of 60cm. Stimulus presentation was controlled by MATLAB’s Psychophysics toolbox (Brainard, 1997).

The fixation screen consisted of a fixation cross (1° x 1° of visual angle), positioned at the center of the screen and set against a uniform 60% gray background. The cue stimuli, as illustrated in Figure 5.1a and 5.1b, consisted of grey-scale photographs of *(i)* male and female faces looking straight ahead with neutral expressions and the hairline removed, and *(ii)* houses with no contextual background. For the Frequent cue (Figure 5.1a), a single female face identity was paired with a single house image identity. For the Infrequent cues (Figure 5.1b), 8 male and 8 female face identities were individually paired with 16 different house images identities, resulting in 16 unique face-house cue combinations.

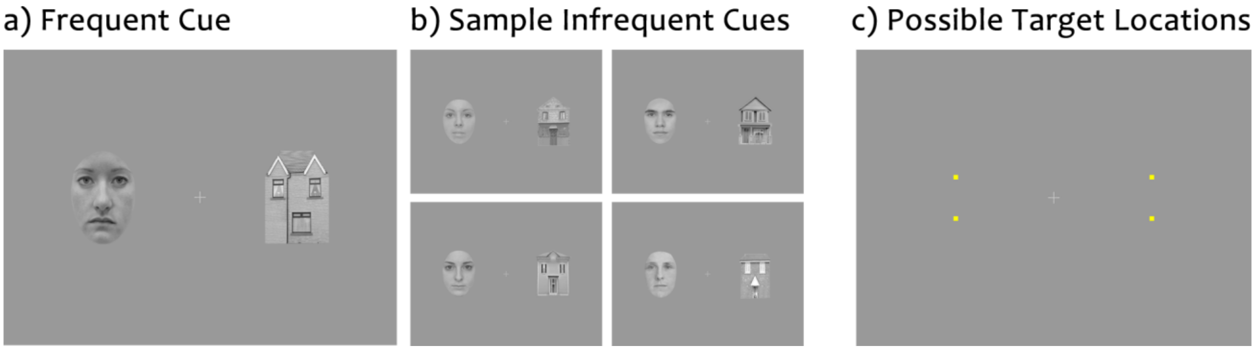

Figure 5.1 The cue screen depicting upright cues with the face in the left visual field for (a) Frequent and (b) Infrequent cue conditions. (c) The target screen depicting all possible target locations for square targets.

Each face-house pair was equated for size (4.2º x 6º) and distance from central fixation (6.3º). To match images for global luminance, average gray scale luminance (ranging from 0-1) was computed using the MATLAB SHINE toolbox (Willenbockel et al., 2010) and equated within each face-house cue pair. Any remaining luminance differences within each face-house cue pair (calculated as the average luminance of the face minus the average luminance of the house) did not differ from 0 [one-sample t-test, $t(15)=1.45$, $p=.17$, $d=.36$]. To match for perceived attractiveness, thirty-five new naïve participants were independently asked to rate all images of face and house cues using a Likert scale ranging from 1- *Very Unattractive* to 10- *Very Attractive*. The face and house cue images used for each pair received equivalent attractiveness ratings [all ps>.21, d_zs<.37], with differences within the pairs (calculated as the average attractiveness of the face minus the average attractiveness of the house) not differing from 0 [one-sample t-test, $t(15)=.17$, $p=.87$, $d=.04$]. The stimuli, except for the frequent face image, was sourced from the Glasgow Unfamiliar Face Database (Burton, White, & McNeill, 2010) and from online resources. The target screen consisted of a yellow circle or square (0.3º x 0.3º each), positioned 7.2º away from the fixation cross (Figure 5.1c).

Design. The target discrimination task was a repeated measures design with six factors: *Cue frequency* (frequent, infrequent), *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), *Target identity* (circle, square), and *Cue-target interval* (i.e., the time between the onset of the cue and the onset of the target; 250, 360, 560, 1000ms). All factor combinations were intermixed, equiprobable, and presented equally often throughout the task.

Cue frequency varied between frequent and infrequent face-house pairs. For the Frequent cue pair, as shown in Figure 5.1a, the same face identity was paired with the same image of a house and this cue pair was presented on half of all trials (i.e., 384 times). For the Infrequent cue pairs, illustrated in Figure 5.1b, 16 different face images (8 male and 8 female) were paired with 16 different house images, resulting in 16 unique face-house pairs that were presented on the other 384 trials (i.e., 24 times each). The number of repetitions for the Infrequent face-house cue pairs was on par with past work. For example, there were 15 repetitions for each face cue in Langton and colleagues (2008) study, 16 repetitions for each face cue in Theeuwes and colleagues' (2006) study, 24 repetitions for each face cue in Ro and colleagues' (2001) study, and 45 repetitions for each face cue in Devue and colleagues' (2012) study.

Cue orientation varied between upright and inverted cue images to examine any unique facilitative processing effects when faces are presented in an upright orientation (Frank, Vul, & Johnson, 2009; Simion & Giorgio, 2015; Yin, 1969).

Face position varied between the left and right visual fields, with the house image occurring in the opposite visual field, to examine facilitative effects of social processing when faces are presented in the left visual field (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; Pereira et al., 2019a; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Rossion, Joyce, Cottrell, & Tarr, 2003; Yovel et al., 2003).

Target location varied the location of the target, which could occur at either the previous location of the eyes or mouth of the face or the top or bottom of the house, as illustrated in Figure 5.1c. This manipulation captured performance differences between targets occurring at the location of the face and house overall as well as at specific features of the face and the house locations.

Target identity varied between a yellow circle and a yellow square in order to measure both response time and response accuracy.

Finally, *Cue-target interval* varied between 250, 360, 560, and 1000ms in order to assess the time course of attentional biasing (Bindemann et al., 2007; Pereira et al., 2019a, 2019b, 2019c).

Cue frequency and location of presentation was spatially uninformative about target location and target identity as each target was equally likely to occur at any of the possible target locations following any possible cue. Conditions were presented in a randomized order, therefore participants had no incentive from the task to attend to any particular cue.

Procedure. We used the dot-probe task (MacLeod, Mathews, & Tata, 1986), which closely mirrored past work (Bindemann et al., 2007; Pereira et al., 2019a, 2019b, 2019c). After an initial fixation display of 600ms, either a frequent or infrequent face-house cue pair was shown for 250ms. After 0, 110, 310, or 750ms (constituting 250, 360, 560, and 1000ms cue-target intervals, respectively), a target was presented at the previous location of the eyes, mouth, top house, or bottom house, and remained visible until participants responded or 1500ms had elapsed. Participants were instructed to withhold their eye movements and to identify the target by pressing the ‘b’ or ‘h’ keys on the keyboard quickly and accurately. Target identity-key response was counterbalanced between participants.

Prior to the start of the task, participants were informed about the task sequence, that the target was equally likely to be a circle or a square, that the target could appear in any of the possible target locations, and that there was no spatial relationship between the cue content, cue orientation, cue placement, target location, or target shape. Participants completed a total of 768 trials divided equally across four testing blocks, with ten practice trials run at the start. Manual Response Time (RT) was measured from target onset until a response had been made.

Results

Overall, accuracy was high at 93%, with 0.2% of data accounting for response anticipations (RTs < 100ms), 2.4% for response timeouts (RTs > 1000ms), and 0.2% for incorrect key presses (key press other than ‘b’ or ‘h’). These trials were removed from further analyses. Mean correct RTs were examined using an omnibus repeated measures ANOVA with *Cue frequency* (frequent, infrequent), *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), and *Cue-target interval* (250, 360, 560, 1000ms). Any violations of sphericity were adjusted using Greenhouse-Geiser corrections. Post-hoc comparisons were conducted using paired two-tailed t-tests, with multiple comparisons corrected using the Holm-Bonferroni procedure (Holm, 1979). All comparisons are shown with corresponding adjusted *p*-values ($\alpha_{FW} = .05$; Ludbrook, 2000).

If the novelty of face identity played a significant role in the reduced social attentional biasing as reported by Pereira and colleagues (2019a, 2019b, 2019c), we expected to replicate this finding with frequently presented cues due to the reduction in face novelty for this condition. The opposite result was expected for infrequently presented face-house cue pairs. As depicted in Figure 5.2, illustrating mean correct RTs as a function of target location and cue orientation for Infrequent (5.2a) and Frequent (5.2b) cues, social attention biasing was not reliable for either frequently or infrequently presented face-house cue pairs.

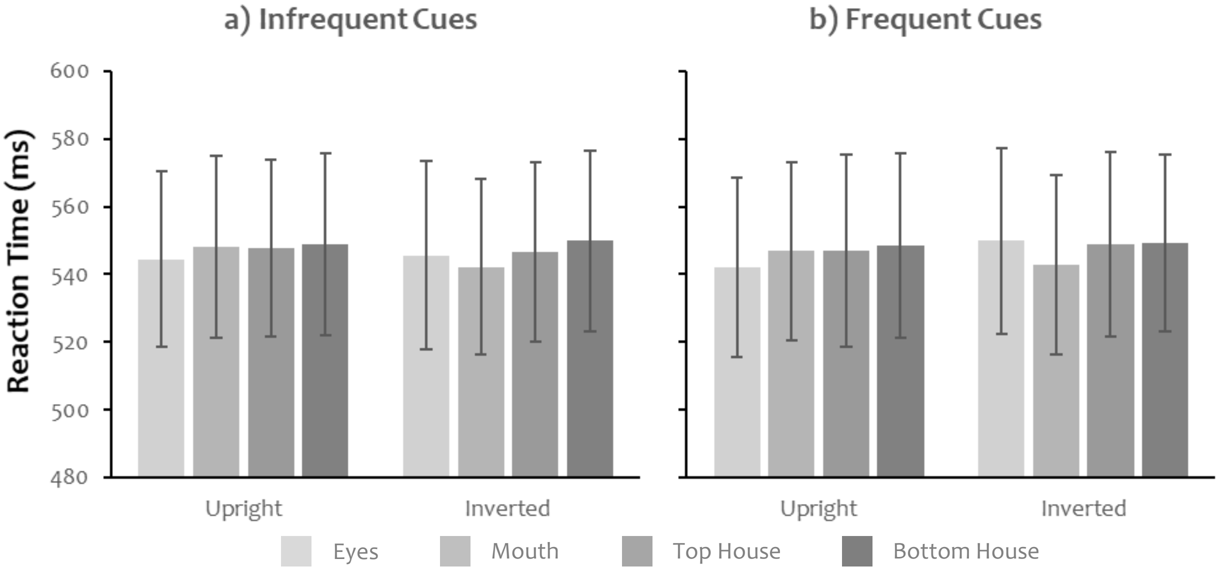

Figure 5.2 Experiment 1 results. Mean correct RTs in ms as a function of Cue orientation and Target position for (a) Infrequent and (b) Frequent cues. Error bars represent 95% CIs.

The only significant effect involving the key factor of Cue frequency was a three-way interaction between *Cue frequency*, *Face position*, and *Cue-target interval* [$F(3,87)=3.21$, $p=.027$, $\eta_p^2=.10$] indicating a larger foreperiod effect for infrequently relative to frequently presented cues. To follow-up on this analysis, repeated measures ANOVAs were carried out for Infrequent and Frequent cues separately, each run as a function of *Face position* and *Cue-target interval*.

For Infrequent cues, there was a significant main effect of *Cue-target interval* [$F(3,87)=92.25$, $p<.001$, $\eta_p^2=.76$], which reflects the foreperiod effect, a consistent finding across previous studies utilizing the dot-probe task (Pereira et al., 2019a, 2019b, 2019c), showing increased response preparation with a lengthening of the time between the cue and the target (Bertelson, 1967; Hayward & Ristic, 2013). Overall slower RTs were found for shorter versus longer cue-target intervals [250ms vs. all, ts>10.83, ps<.001, d_zs>1.98; all other ps>.58, d_zs<.24]. There was also an interaction between *Face Position* and *Cue-target interval* [$F(3,87)=3.69$,

p=.015, η_p^2=.11], which demonstrated a greater foreperiod effect when faces were presented in the left visual field [250ms vs. all, ts>12.07, ps<.001, d_zs>2.20; all other ps>.09, d_zs<.41] compared to the right visual field [250ms vs. all, ts>7.10, ps<.001, d_zs>1.30; all other ps>.64, d_zs<.23]. No other effects were reliable [all other F=.48, p=.50, η_p^2=.02].

For Frequent cues, there was only a significant main effect of *Cue-target interval* [F(3,87)=41.97, p<.001, η_p^2=.59], with slower overall RTs for shorter versus longer cue-target intervals [250ms vs. all, ts>7.33, ps<.001, d_zs>1.34; all other ps>.57, d_zs<.24]. No other effects were significant [all other Fs<2.59, ps>.06, η_p^2s<.08].

The omnibus ANOVA also indicated a main effect of *Cue-target interval* [Mauchly's test of sphericity, χ^2(5)=21.50, p=.001; F(2.21,63.97)=94.72, p<.001, η_p^2=.77; 250ms vs. all, ts>10.42, ps<.001, d_zs>1.90; all other ps>.72, d_zs<.22], and a *Face position* and *Cue-target interval* interaction [Mauchly's test of sphericity, χ^2(5)=13.03, p=.023; F(2.46,71.23)=2.95, p=.049, η_p^2=.09; faces in the left visual field, 250ms vs. all, ts>11.13, ps<.001, d_zs>2.03; all other ps>.91, d_zs<.19; faces in the right visual field, 250ms vs. all, ts>8.20, ps<.001, d_zs>1.50; all other ps>.99, d_zs<.18]. No other main effects or interactions were reliable [all other Fs<2.53, ps>.06, η_p^2<.08].

Discussion

If the previous lack of social attentional biasing effects (Pereira et al., 2019a, 2019b, 2019c) were due to decreased face novelty brought about by the frequent presentation of a single face identity, we expected to find similar lack of social attention biasing for frequently presented cues. Conversely, if previously robust social attentional biasing effects (Bindemann et al., 2007; Birmingham et al., 2008; Cerf et al., 2009; Ro et al., 2001) were due to increased face novelty brought about by infrequent presentation of multiple face identities, we expected to find social biasing results for infrequently presented cues. The results showed no attentional biasing effects for targets occurring either at the location of the infrequently or frequently presented face cues. The data however indicated that infrequently presented face-house cue pairs, irrespective of cue orientation, were associated with larger preparatory responses, which is consistent with the notion that infrequently presented novel cues may be overall more alerting than frequently presented ones (Turatto & Pascucci, 2016). As such, these results are consistent with recent work showing no reliable attentional biasing by face cues (Pereira et al., 2019a, 2019b, 2019c), and further suggests that novelty does not preferentially bias covert attention towards faces and eyes but that it may modulate overall alertness to novel stimuli. In Experiment 2, we examined whether these results held when we additionally measured participants' natural eye movements while they performed the same task.

Experiment 2

Our previous work (Pereira et al., 2019a, 2019b, 2019c) showed that when participants were allowed to make eye movements during the dot-probe task, there was a reliable bias to overtly look at the eyes of the face during the cue presentation period. Here, we examined whether this oculomotor bias was modulated by cue novelty. To do so, we kept the same procedure as in Experiment 1, but we did not provide participants with any instructions to maintain central fixation. A high-speed remote eye tracker was used to measure eye movements during the task. Both manual RT for target responses and oculomotor responses were measured.

Materials and Methods

Participants, Apparatus, Stimuli, Design, and Procedure. Thirty new volunteers participated. None took part in the previous experiment and all reported normal or corrected-to-normal vision. All stimuli, design, and procedures were identical to Experiment 1, except that: *(a)* Participants' eye movements were tracked using a remote EyeLink 1000 eye tracker (SR Research; Mississauga, ON) recording with a sampling rate of 500Hz and a spatial resolution of .05°. Although viewing was binocular, only the right eye was tracked; *(b)* Prior to the start of the experiment, a nine-point calibration was performed, and spatial error was rechecked before every trial using a single-point calibration dot. Average spatial error was no greater than .5°, with maximum error not exceeding 1°; and *(c)* Participants were not given any instructions regarding maintaining central fixation in order to preserve their natural eye movements during the task.

Results

Manual RT. Overall response accuracy was 96%, with anticipations (0.1%), timeouts (0.6%), and incorrect key presses (0.1%) removed from manual data analyses.

As in Experiment 1, mean correct RTs were examined using an omnibus repeated measures ANOVA with *Cue frequency* (frequent, infrequent), *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), and *Cue-target interval* (250, 360, 560, 1000ms), and the same correction procedures for multiple comparisons. Once again, we found no attentional biasing towards either frequent or infrequent cues. Figure 5.3 shows this result, illustrating mean correct RTs as a function of target location and cue orientation for Infrequent (5.3a) and Frequent (5.3b) cues.

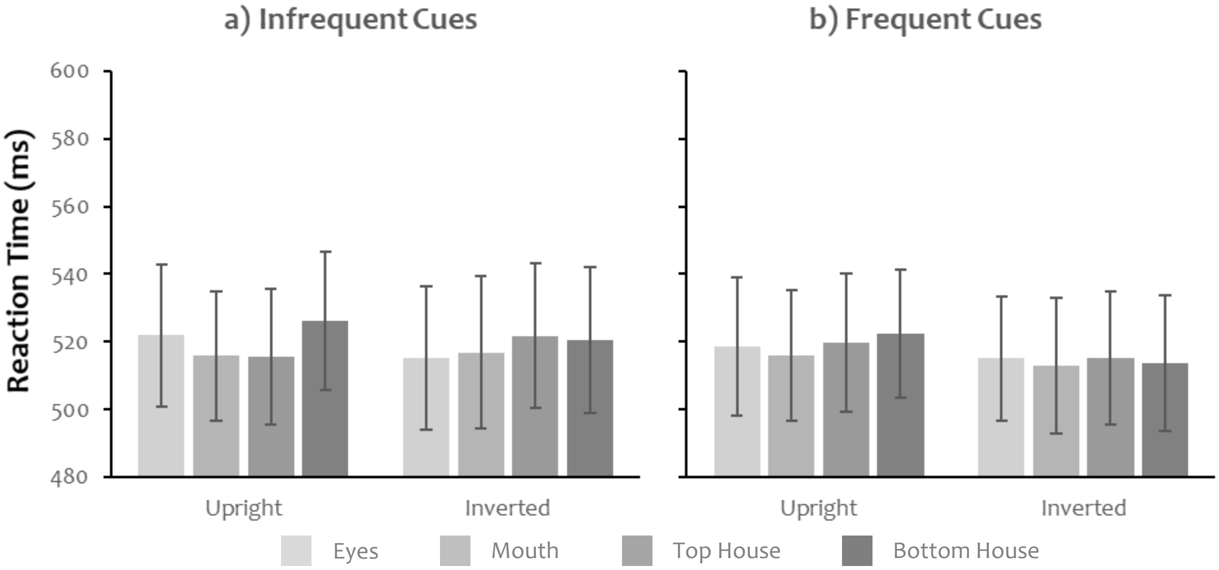

Figure 3. Experiment 2 manual results. Mean correct RTs in ms as a function of Cue orientation and Target position for (a) Infrequent and (b) Frequent cues. Error bars represent 95% CIs.

The highest level interaction involving Cue frequency that reached significance was a three way interaction between *Cue frequency*, *Target location*, and *Cue-target interval* [$F(9,261)=2.27$, $p=.019$, $\eta_p^2=.07$]. To follow this up, two separate repeated measures ANOVAs for each Cue frequency level, i.e., Infrequent and Frequent cues, were run as a function of *Target location* and *Cue-target interval*.

For Infrequent cues, there was a significant main effect of *Cue-target interval* [$F(3,87)=40.58$, $p<.001$, $\eta_p^2=.58$] reflecting an overall foreperiod effect [250ms vs. all, ts>8.34, ps<.001, d_zs>1.52; all other ps>.99, d_zs<.11], and an interaction between *Target location* and *Cue-target interval* [Mauchly's test of sphericity, $\chi^2(44)=63.92$, $p=.029$; $F(6.31,182.94)=2.17$, $p=.045$, $\eta_p^2=.07$]. This interaction indicated that at the shortest cue-target interval of 250ms, targets occurring at the previous location of the Eyes and Mouth were responded to faster than targets occurring at the previous location of the House Bottom [ts>2.87, ps<.038, d_zs>.52; all other ps>.10, d_zs<.43]. No differences were found at any other cue-target interval [all ps>.20,

d_zs<.41] and no other effects were found [all other F=2.08, p=.11, η_p^2=.07]. For Frequent cues, only a main effect of *Cue-target interval* was reliable [F(3,87)=36.66, p<.001, η_p^2=.56; 250ms vs. all, ts>8.29, ps<.001, d_zs>1.51; all other ps>.99, d_zs<.14].

The omnibus ANOVA also indicated a significant main effect for *Face position* [F(1,29)=4.25, p=.048, η_p^2=.13], with faster overall RTs when faces were presented in the left versus right visual field, and for *Cue-target interval* [F(3,87)=56.63, p<.001, η_p^2=.66; 250ms vs. all, ts>10.44, ps<.001, d_zs>1.91; all other ps>.99, d_zs<.15]. No other effects were found [Fs<1.56, ps>.13, η_p^2<.05].

Thus, the results from manual data indicated a short-lived attentional bias to respond to targets appearing at the previous location of the Eyes and the Mouth of infrequent faces at the shortest cue-target time of 250ms only; however, this effect was not specific to upright faces. No reliable attentional biasing effects were found for frequently presented face-house pairs.

Eye Movements. To assess if participants' eye movements were preferentially biased towards frequently or infrequently presented face-house cue pairs, we examined trials in which saccades were launched from the central fixation cross towards one of the cues during the 250ms presentation of the cue screen. To analyze those trials, we first defined regions of interest (ROIs) around the cue display (i.e., eyes, mouth, top house, and bottom house), with each ROI spanning a 30° radial window. Then, for each participant, the number of saccades, defined as eye movements with an amplitude of at least .5°, an acceleration threshold of 9,500°/s^2, and a velocity threshold of 30°/s, that were launched towards each ROI was determined by examining the direction of the first saccade that launched from the central fixation cross towards one of the ROIs upon cue onset. Proportion of saccades towards each ROI for each participant was calculated by tallying the number of saccades towards each ROI across all trials and then dividing this number by the total number of first saccades that occurred during the cue period.

On average, participants saccaded away from the fixation cross on 12% of all trials, of which saccades were launched towards an ROI on 96% of trials. Mirroring previous analyses, the proportion of breakaway saccades was examined using an omnibus repeated measures ANOVA with *Cue frequency* (frequent, infrequent), *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *ROI* (eyes, mouth, top house, bottom house). Figure 5.4 illustrates mean correct RTs as a function of ROI and cue orientation for Infrequent (5.4a) and Frequent (5.4b) cues. Unlike manual responses, here the data indicated significant oculomotor biasing towards the eyes of infrequently presented upright faces.

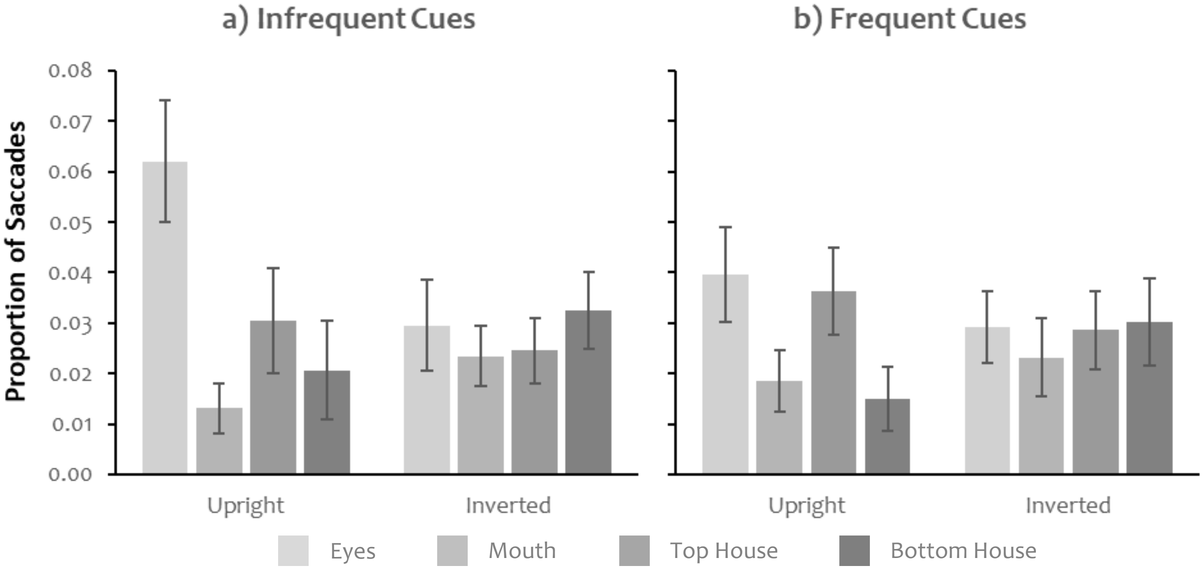

Figure 5.4 Experiment 2 eye movement results. Mean proportion of breakaway saccades as a function of Cue orientation and ROI for (a) Infrequent and (b) Frequent cues. Error bars represent 95% CIs.

The highest order significant interaction involving Cue frequency was a three-way interaction between *Cue frequency*, *ROI*, and *Cue orientation* [$F(3,87)=3.97$, $p=.011$, $\eta_p^2=.12$] showing more oculomotor biasing towards the eyes of upright infrequent face cues, as depicted in Figure 5.5. We followed-up this interaction with repeated measures ANOVAs run separately for each Cue Frequency level, i.e., Infrequent and Frequent, as a function of *ROI* and *Cue orientation*.

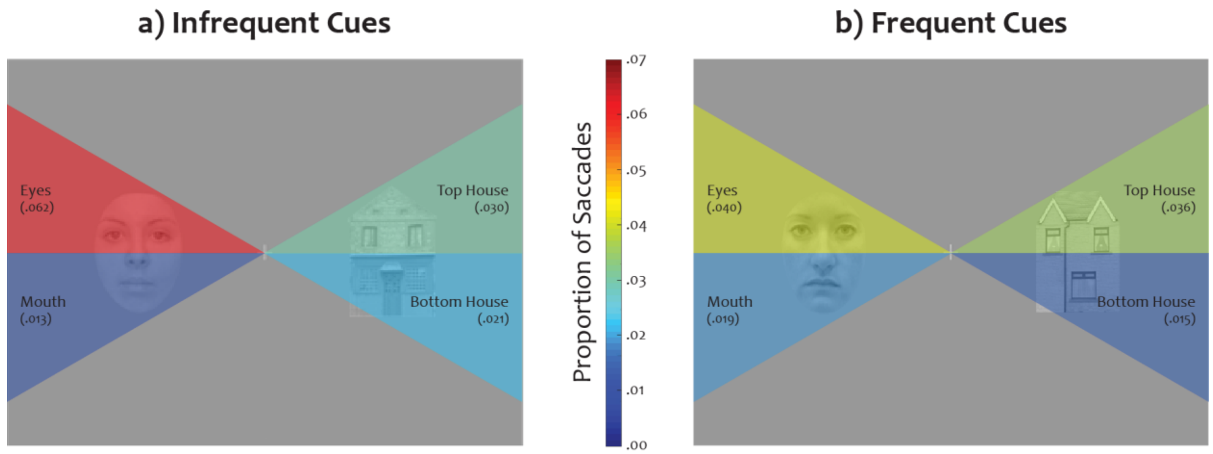

Figure 5.5 Experiment 2 eye movement results. Mean proportion of breakaway saccades for Upright cues depicted within respective ROIs for (a) Infrequent and (b) Frequent cues.

For Infrequent cues, there was a significant main effect of *ROI* [Mauchly's test of sphericity, $\chi^2(5)=14.55$, $p=.013$; $F(2.17,62.99)=12.28$, $p<.001$, $\eta_p^2=.30$], which indicated that a greater overall proportion of saccades were directed towards the Eyes compared to all other ROIs [ts>2.98, ps<.023, d_zs>.54; all other ps>.10, d_zs<.41]. There was also an interaction between *ROI* and *Cue orientation* [Mauchly's test of sphericity, $\chi^2(5)=27.16$, $p<.001$; $F(2.00,58.04)=10.62$, $p<.001$, $\eta_p^2=.27$], showing a greater proportion of saccades directed towards the Eyes versus all other ROIs [ts>3.51, ps<.006, d_zs>.64] and greater proportion of saccades directed towards the Top House versus the Mouth [$t(29)=2.85$, $p=.024$, $d_z=.52$; all other ps>.34, d_zs<.26] for Upright cues. No effects were found for Inverted cues [all ps>.14, d_zs<.44]. No other effects were found [all other $F=3.05$, $p=.09$, $\eta_p^2=.10$].

For Frequent cues, a significant main effect of *ROI* [$F(3,87)=8.68$, $p<.001$, $\eta_p^2=.23$] indicated a general oculomotor bias towards the upper regions of the cues. That is, a greater proportion of saccades were directed towards the Eyes versus the Mouth and Bottom House [*t*s>3.41, *p*s<.008, d_zs>.62] and towards the Top House versus the Mouth and Bottom House [*t*s>3.17, *p*s<.011, d_zs>.58]. No differences were found in proportion of saccades directed towards the Eyes versus the Top House [*t*(29)=.51, *p*=.99, d_z=.09] or towards the Mouth versus the Bottom House [*t*(29)=.50, *p*=.99, d_z=.09]. There was also an interaction between *ROI* and *Cue orientation* [Mauchly's test of sphericity, $\chi^2(5)=16.07$, *p*=.007; *F*(2.27,65.75)=3.25, *p*=.039, $\eta_p^2=.10$], showing that this general bias was specific to Upright cues. When cues were Upright, a greater proportion of saccades were directed towards the Eyes versus the Mouth and Bottom House [*t*s>3.53, *p*s<.006, d_zs>.64] and towards the Top House versus the Mouth and Bottom House [*t*s>3.00, *p*s<.016, d_zs>.55], with no differences between the Eyes versus Top House [*t*(29)=.54, *p*=.60, d_z=.10] and between the Mouth versus Bottom House [*t*(29)=1.06, *p*=.60, d_z=.19]. No reliable effects emerged for Inverted cues [all *p*s>.99, d_zs<.24]. No other effects were reliable [all other *F*=.03, *p*=.87, $\eta_p^2=.001$].

Additionally, the omnibus ANOVA indicated a main effect of *ROI* [Mauchly's test of sphericity, $\chi^2(5)=15.45$, *p*=.009; *F*(2.18,63.06)=12.45, *p*<.001, $\eta_p^2=.30$], showing that an overall greater proportion of saccades were directed towards the Eyes compared to the Mouth and Bottom House [*t*s>3.81, *p*s<.003, d_zs>.70] and an overall greater proportion of saccades were directed towards the Top House compared to the Mouth [*t*(29)=2.87, *p*=.03, d_z=.52; all other *p*s>.08, d_zs<.42]. Two-way interactions between *ROI* and *Cue frequency* [*F*(3,87)=6.87, *p*<.001, $\eta_p^2=.19$] and *ROI* and *Cue orientation* [Mauchly's test of sphericity, $\chi^2(5)=29.41$, *p*<.001; *F*(1.91,55.32)=7.65, *p*=.001, $\eta_p^2=.21$] were also reliable, and reflected consistent effects with the three-way interaction. That is, for the *ROI* and *Cue frequency* interaction, greater overall proportion of saccades were directed towards the Eyes for Infrequent cues [Eyes vs. all regions, *t*s>2.98, *p*s<.023, d_zs>.54; all other *p*s>.10, d_zs<.41] and towards the upper cue regions for Frequent cues [Eyes and Top House vs. Mouth and Bottom House, *t*s>3.17, *p*s<.011, d_zs>.58; all other *p*s>.99, d_zs<.09], and for the *ROI* and *Cue orientation* interaction, an overall greater proportion of saccades were directed towards the Eyes and Top House versus all other regions when cues were Upright [*t*s>2.61, *p*s<.04, d_zs>.48; all other *p*=.60, d_z=.10; Inverted, all *p*s>.33, d_zs<.36]. All other effects were non-significant [*F*s<3.69, *p*s>.05, η_p^2<.11].

Discussion

In Experiment 2, we examined whether the frequency of novel face-house cue presentation influenced manual and oculomotor social attentional biasing when eye movements were not restricted. Our data indicated a manual response advantage for targets occurring at a short cue-target interval at the location of the eyes and mouth for infrequently presented faces; however, these effects were not specific to cues in an upright orientation.

The oculomotor data indicated a greater proportion of saccades directed towards infrequently presented face cues, such that the eyes of infrequent faces were saccaded to more than other regions. The effect for frequently presented faces was less specific, such that more saccades were launched towards the upper region of both face and house cues, with the eyes and top house regions having greater proportions of saccades as compared to the mouth and bottom house regions, with no differences found between the eyes and top house regions or between the mouth and bottom house regions. As such, the data from Experiment 2 show that infrequently presented novel face identities bias attention in manual and oculomotor responses when eye movements are not restricted.

General Discussion

In the present study, we examined whether the frequency of face identity information modulated social attentional biases towards face cues. Using the dot-probe paradigm, we presented participants with frequently repeating (i.e., the cue appeared often throughout the study) and infrequently repeating (i.e., different cues appeared seldom throughout the study) face-house cue pairs, which were followed by a target that was presented at the previous location of the eyes or mouth of the face or the top or bottom of the house. Based on past work, frequent presentation of a single face identity has been associated with lower facial novelty (Heisz et al., 2006; Winston et al., 2004; Yi et al., 2006) while infrequent presentation of multiple face identities served to maintain face novelty. As in previous work (Pereira et al., 2019a, 2019b, 2019c), other stimulus content (i.e., size, distance from central fixation, overall luminance, and perceived attractiveness), visual context (i.e., background information), and task factors (i.e., target predictability, response key counterbalancing) were controlled. In Experiment 1, we measured manual responses by examining the speed of target discrimination while instructing participants to maintain central fixation, whereas in Experiment 2, we additionally assessed spontaneous saccades during the cue period when eye movements were not restricted.

When eye movements were controlled in Experiment 1, we found no reliable evidence for social attentional biasing towards infrequently or frequently presented face identities. Our data indicated that infrequently presented face-house cue pairs resulted in larger overall foreperiod effects than the frequently presented cue for both upright and inverted stimuli. This is consistent with previous research showing strong attentional biases for novel stimuli (Burack & Enns, 1997; Fagan Iii & Haiken-Vasen, 1997; Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990) and away from frequently repeated stimuli (Colombo & Mitchell, 1990), with more recent work demonstrating that frequent presentations of stimuli can lead to both short-term and long-term attentional effects when eye movements are restricted (Turatto & Pascucci, 2016). As such, infrequently presented cues may be perceived as more alerting than frequently presented ones, engaging the attentional system quickly. However, despite this overall benefit, there were no differences in the speed of responses for targets occurring at the location of the infrequent or frequent face cue as compared to the house cue. Thus, changing the perception of face novelty via the frequency of stimulus presentation did not reinstate typical social attentional biasing. That is, stimulus novelty, regardless of the frequency of presentation, does not appear to influence social attentional biasing in manual data. These results are once again at odds with past work that has utilized similar presentations of several different novel faces and demonstrated robust social attention biasing towards faces (Ariga & Arihara, 2017; Bindemann et al., 2005; Bindemann et al., 2007; Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009; Lavie et al., 2003; Ro et al., 2001; Sato & Kawahara, 2015), suggesting once again that these past results may have been influenced by extraneous stimulus content, visual context, and/or task factors.

In contrast, when eye movements were not restricted in Experiment 2, there was evidence for social attentional biasing in both manual and oculomotor data. In manual measures, targets occurring at the previous location of infrequently presented faces were overall facilitated compared to the bottom house location at the shortest cue-target interval of 250ms. This suggests that novelty effects may reflect an early nonspecific bias for infrequently presented faces, independent of facial orientation and any particular facial feature. This dovetails with previous work showing that novel faces are resistant to inversion effects in matching and recognition tasks (Megreya & Burton, 2006), and that processing for novel faces is strongly linked to more general facial information, such as the overall shape and jawline of the face, rather than any individual facial feature (Clutterbuck & Johnston, 2002; Fletcher, Butavicius, & Lee, 2008; Osborne & Stevenage, 2008; Visconti di Oleggio Castello, Wheeler, Cipolli, & Gobbini, 2017).

Oculomotor data additionally indicated that saccades were consistently biased towards the eyes of infrequently presented upright faces. This result replicates past work showing a general oculomotor preference for faces in an upright orientation (Rossion et al., 2003; Yin, 1969), and further demonstrates that overt social attention towards novel faces can be modulated by the frequency of cue presentation, with eye movements being biased towards infrequently presented face identities (i.e., those with more novelty) more than frequently presented ones (i.e. those with less novelty). It is important to note here that oculomotor effects for infrequently presented faces occurred even though the displays used in the current study contained both novel faces and novel houses. Thus, despite the fact that both cues were novel within each cue pairing, eye movements were still spontaneously biased towards faces and eyes rather than the house cue. This suggests that there is a unique aspect of novelty within faces that drives the attentional system to overtly focus on novel faces and eyes over other novel comparison stimuli. Together, these findings demonstrate that novelty influences overt social attentional biasing.

An important aspect of these results concerns the relationship between manual and oculomotor data. That is, in Experiment 1, there were no social attentional biasing effects and some alerting effects towards infrequent cues in manual RTs when participants were instructed to maintain central fixation. However, in Experiment 2, when participants performed the same task without any instruction to maintain fixation, there was evidence of reliable manual RT and oculomotor effects towards infrequent novel faces and eyes. This dissociation raises two points of discussion.

One, it suggests that facial novelty may have a strong biasing influence on attentional processes given that our studies have rarely found evidence of attentional effects towards the eyes in both manual and oculomotor measures (Pereira et al., 2019a, 2019b, 2019c). As such, it is possible that the ability to make eye movements during tasks may be an important factor in revealing social attentional biasing by novelty. More research is needed to examine whether face novelty can result in both short-term and long-term manual performance effects that are unique to upright faces, and the degree to which these effects are temporally dependent on concurrent oculomotor biasing towards the internal features of the face.

Two, the differential results across Experiments 1 and 2 have the potential to lend further insight into how manual and oculomotor measures link with covert and overt social attention, as recent results have repeatedly found that social attentional measures dissociate depending on whether eye movements are restricted or allowed, i.e., across covert and overt measures, respectively (Bonmassar, Pavani, & van Zoest, 2019; Gobel, Kim, & Richardson, 2015; Kuhn & Teszka, 2018; Kuhn, Teszka, Tenaw, & Kingstone, 2016; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Laidlaw & Kingstone, 2017; Laidlaw, Rothwell, & Kingstone, 2016; Latinus et al., 2015; Risko, Richardson, & Kingstone, 2016; Scott, Batten, & Kuhn, 2018). It is important to note here though that the present manipulation does not fully overlap with typical definitions of covert and overt attention. Specifically, Experiment 1 did not provide a pure measure of covert attention since participants were verbally instructed to maintain fixation without fixation monitoring. Similarly, Experiment 2 did not provide a typical measure of overt attention because eye movements were not task-relevant, as seen in typical free-viewing oculomotor tasks. Despite these differences, the present manipulations indicated clear dissociations in manual and oculomotor social attention biasing under the same task and set of parameters. Further work investigating the links between manual and oculomotor measures of social attention and their links with covert and overt modes of attentional engagement will be beneficial in uncovering the role and functionality of social attention both in laboratory and real world settings.

In sum, the current study demonstrates that infrequent presentation of face identity does not impact manual measures of social attention when eye movements are restricted, but that it does enhance oculomotor social attentional biasing towards specific facial features when eye movements occur. As such these results indicate that face novelty plays a role in social attentional biasing and highlights the need for comprehensive studies on the factors that determine the co-occurrence of social attentional biasing in manual and oculomotor measures.

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General Discussion

The overarching goal of the work presented in this dissertation was to re-examine the prevailing notion that faces and facial features spontaneously bias human attention (Bindemann et al., 2007; Birmingham et al., 2008a; Crouzet et al., 2010; Langton et al., 2008; Sato & Kawahara, 2015; Theeuwes & Van der Stigchel, 2006). To do so, we studied the contributing influences of stimulus content, visual context, and task settings. Across four chapters and 14 experimental studies, we employed the dot-probe task and measured participants' manual response times towards targets, as well as their oculomotor responses towards faces relative to comparison non-social objects when eye movements were restricted and when they were not restricted. The main result that emerged from these investigations is that previously reported robust spontaneous attentional biasing towards faces and facial features (Bindemann et al., 2007; Birmingham et al., 2008a; Crouzet et al., 2010; Langton et al., 2008; Sato & Kawahara, 2015; Theeuwes & Van der Stigchel, 2006) disappeared and became fragile once these systematic experimental controls were applied.

In Chapter 2, we controlled the task for *stimulus content* – physical size, distance from central fixation, global luminance, featural configuration, perceived attractiveness – *visual context* – background information, novelty – and *task settings factors* – predictability of the task, method of response, use of comparison conditions. The data indicated no preferential manual performance effects towards targets occurring at the location of the face when eye movements were restricted. However, there was an infrequent but statistically reliable oculomotor bias towards the face cue and specifically towards the eyes of the face when eye movements were not restricted. These results show that once stimulus content, visual context, and task setting factors are systematically controlled, the oft-reported social attentional bias is absent in manual responses and relatively weak in oculomotor data.

Chapter 3 investigated whether one of the stimulus content factors was responsible for the loss of typical social attentional biasing effects. To do so, we varied stimulus content by using a face cue that displayed higher global luminance (Experiments 1a and b), different featural configuration (Experiments 2a and b), and higher attractiveness (Experiments 3a and b) than the comparison non-social cue. All remaining stimulus content, visual context, and task settings factors were controlled. When eye movements were restricted, none of the stimulus content manipulations resulted in reliable social attentional biasing in manual performance. When eye movements were not restricted, face attractiveness was the only manipulation that resulted in both manual performance benefits for targets occurring at the location of the face as well as an infrequent oculomotor bias towards the eyes of the face. Thus, global luminance and featural configuration do not appear to influence social attentional biasing in manual or oculomotor measures, whereas perceived facial attractiveness seems to play an important role in social attentional biasing, resulting in both manual facilitation for faces and oculomotor biasing towards the eyes.

Chapter 4 examined whether the visual context factor of background information was responsible for the loss of typical social attentional biasing effects. To investigate this issue, face and house cues were presented within typical and semantically consistent contextual backgrounds. That is, the face cue displayed a person, including their upper body and hair, sitting in a room and the house cue presented an image of the house within a picture hanging on a wall. Once again, when eye movements were restricted, there was no preferential attentional biasing in manual performance for targets at the previous location of the face. When eye movements were not restricted however, there was an infrequent oculomotor bias towards the eyes of the face. These results show that background context does not contribute much to social attentional biasing in manual measures, but it may facilitate oculomotor effects.

The final experimental Chapter 5 investigated whether the visual context factor of novelty was responsible for the loss of typical social attentional biasing effects. To do so, we examined performance in response to novel face and house identities that were either presented frequently (thereby decreasing novelty) or infrequently (thereby maintaining novelty) during the task. When eye movements were restricted, no preferential attentional biasing was found in manual measures for either frequent or infrequent stimuli. When eye movements were not restricted, manual responses were facilitated for targets occurring at the location of infrequently presented novel faces, while oculomotor biases occurred towards the eyes of infrequently presented novel faces. As such, these data show that face novelty does not influence social attentional biasing in manual performance. However, increasing the novelty of the face by decreasing the frequency of each facial identity presentation may facilitate both manual and oculomotor responses when eye movements can occur.

Thus, when all extraneous factors were controlled, there was no evidence of spontaneous attentional biasing in manual measures when eye movements were restricted and only a small oculomotor effect towards the eyes of the face when eye movements were not restricted. Neither individual stimulus content nor visual context factor alone was able to recover spontaneous attentional biasing in manual measures when eye movements were restricted. However, when eye movements were not restricted, face attractiveness enhanced social attentional biasing in both manual and oculomotor measures, contextual background information enhanced oculomotor measures for faces presented within consistent contextual backgrounds, and face novelty enhanced both manual and oculomotor measures.

As such, these results highlight the critical role that stimulus content and visual context factors play in the spontaneous biasing of social attention, irrespective of information contained within the face. They additionally suggest that social attention operates differently when participants' eye movements are restricted versus not restricted during the task. As such, while faces may be a unique visual stimulus, it appears that when devoid of extraneous stimulus, contextual, and task factors, they do not elicit robust spontaneous attentional effects.

The implications of these results are discussed in the four sections that follow. Section I discusses how these findings fit within the existing knowledge on social attention, with an emphasis on relating the current work to previous literature on social attention biasing. Section II expands on this discussion to examine the functionality of social attention and the underlying reasons as to why social attentional effects diverged when eye movements were restricted versus not. Section III examines how the present set of results informs the literature on general mechanisms of human attention, and specifically how modes of attentional control relate to the current data on social attention. Finally, Section IV discusses the main methodology, i.e., the dot-probe task, and outlines other possible methodological avenues for future work.

Section I: Conceptualizing the current findings within social attentional literature

The present work demonstrated that spontaneous biasing of social attention, as reported in prior literature (Bindemann et al., 2007; Birmingham et al., 2008a; Crouzet et al., 2010; Langton et al., 2008; Sato & Kawahara, 2015; Theeuwes & Van der Stigchel, 2006), has likely been driven by a combination of stimulus content, visual context, and task settings rather than the information contained within faces alone. If faces biased attention spontaneously, irrespective of extraneous factors, we expected to find typical social attentional biasing effects across all our manipulations in both manual and oculomotor measures.

The findings in the current set of studies did not support this basic hypothesis. On the contrary, they stand in stark contrast to a large body of existing knowledge that has repeatedly demonstrated attentional biasing toward faces in manual measures when eye movements are restricted (Bindemann et al., 2005; Bindemann et al., 2007; Devue et al., 2009; Langton et al., 2008; Ro et al., 2001; Sato & Kawahara, 2015) and oculomotor effects towards faces and eyes when eye movements are not restricted (Birmingham et al., 2008a; Cerf et al., 2009; Crouzet et al., 2010; Theeuwes & Van der Stigchel, 2006). Furthermore, it is important to note that our inability to uncover robust social attentional biasing effects were not due to a lack of power in detecting these effects, as a priori analyses determined that our sample size per experiment had sufficient power to detect medium-to-large effect sizes (as estimated from Bindemann & Burton, 2008; Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2001).

Thus, the following paragraphs present and discuss three possible ways to account for the discrepancy between the present work and past data in order to integrate the current findings within the existing knowledge of social attention: *(i)* faces used in the current set of studies were too well equated with non-social cue comparisons, *(ii)* faces may drive attention only when they are coupled with stimulus content, visual context, and/or task factors, or *(iii)* faces may not be special.

Faces were too equated with non-social stimuli. The first possibility for why the current data showed little-to-no typical social attentional biasing may be due to the current manipulations, such that there could have potentially been too much experimental control over extraneous factors. In doing so, we may have equated the information contained in the social face and non-social house stimuli across multiple different levels, consequently stripping faces of their typical cognitive and perceptual uniqueness, importance, and/or relevance. For example, equating stimuli for overall luminance, matching across configuration of internal features, and removing contextual background information alters how faces are typically perceived within the environment. Similarly, controlling for perceived attractiveness and novelty may have deflated the typical attentional priority assigned to faces. Previous work supports this notion as processing of faces has been found to rely on computations of luminance contours (Dakin & Watt, 2009; Goffaux & Dakin, 2010; Pachai, Sekuler, & Bennett, 2013b) and spatial frequencies (Boutet, Collin, & Faubert, 2003; Gaspar, Sekuler, & Bennett, 2008; Gold, Bennett, & Sekuler, 1999), as well as on strategic fixations made on specific facial regions such as the eyes or the central region of the face (Hsiao & Liu, 2012; Or, Peterson, & Eckstein, 2015; M. F. Peterson & Eckstein, 2012; Vinette, Gosselin, & Schyns, 2004).

However, our data suggest that this is an unlikely explanation for two reasons. First, across all studies, when eye movements were not restricted, there was reliable evidence of oculomotor biasing towards the eyes of the face, indicating that participants processed perceptual differences between the face and house cues. Second, the visual context manipulation used for studies in Chapter 4, in which the face and house stimuli included full contextual information, would have made it perceptually easier for participants to distinguish between the face and house cues (Chun, 2005; Oliva, 2005; Underwood, Foulsham, van Loon, & Underwood, 2005). Despite this, when eye movements were restricted, the data continued to show no evidence of spontaneous social attentional biasing towards faces and facial features.

Thus, although the present manipulations included tight control over many important variables that are necessary for social attentional studies, there is evidence within the data showing that participants were able to differentiate between face and house cues. As such, the high degree of experimental control over the stimuli and task likely did not render the face and house cues too similar and was not a primary reason for why the data from our studies do not show typical social attentional biases.

Faces are attentionally enhanced by extraneous factors. The second possibility for why the data do not dovetail with existing literature is that faces may potentially bias attention only when they are coupled with specific stimulus content, visual context, and/or task setting information, i.e., their social value may be bootstrapped from non-social visual information. This would suggest that one or more of the external factors that were controlled within the current set of studies enhanced or heightened the stimulus' social relevance or importance. There is some evidence in support of this idea. For example, research shows that some extraneous factors amplify both face and scene perception for social stimuli specifically. That is, attention to faces has been shown to be heighted when faces are considered more attractive (Nakamura & Kawabata, 2014; Silva, Macedo, Albuquerque, & Arantes, 2016; Sui & Liu, 2009), presented within consistent contextual backgrounds (Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Wu, Bischof, & Kingstone, 2013), and novel within their environment (Haxby, Hoffman, & Gobbini, 2002; E. A. Hoffman & Haxby, 2000). Attention to faces and facial features like the eyes or mouth has also been shown to be strongly affected by task instruction (Birmingham et al., 2008a, 2008b; Koval, Thomas, & Everling, 2005; Võ et al., 2012; Yarbus, 1967). Similarly, past work has also demonstrated that broader social factors also impact the magnitude of social attentional effects. For example, Beyan and colleagues (Beyan, Capozzi, Becchio, & Murino, 2018; Beyan et al., 2016) examined attentional behaviours during real-life group interactions and found that individuals perceived as higher in social status (e.g., leaders) attract more attention than individuals who are perceived as lower in social status. Furthermore, this biasing of attentional measures can even be induced when the social status of a person is manipulated via professional prestige by presenting high versus low-profile CVs (Dalmaso, Galfano, Coricelli, & Castelli, 2014; Dalmaso, Pavan, Castelli, & Galfano, 2012).

Together with the current data, this research suggests that social attention may not depend on a direct one-to-one relationship between facial cues and attentional processes, but that it may also require additional stimulus content, visual context, and/or task setting information in order to be modulated and enhanced by interpretive and evaluative processes (Capozzi & Ristic, 2018). More work is needed to determine which external factors and/or combination of factors play a particularly important role in enhancing the social value of face cues.

Faces are not special. A final possibility discussed here is that faces may not hold a special or privileged status within the attentional system. Although there is a large literature pointing to the uniqueness of face processing within cognitive and perceptual systems, as demonstrated across evolutionary, primate, physiological, neurological, and developmental domains (Bentin et al., 1996; Corballis & Lea, 2000; Hood et al., 1998; Perrett et al., 1985; Yin, 1969), there is also work showing that faces may not be a *special* kind of stimulus, but instead an instance of an overlearned visual stimulus.

Much of the work supporting this notion stems from the debate on whether faces are processed in a domain-specific or domain-general manner. Proponents of the domain-specific view theorize that faces represent a special stimulus that necessitates specialized visual processing (Allison, Puce, & McCarthy, 2000; Perrett et al., 1992; Perrett et al., 1988; Tsao, Freiwald, Tootell, & Livingstone, 2006) and affords specific behavioural advantages (Farah et al., 1998; Frank et al., 2009; Simion & Giorgio, 2015; Tanaka & Simonyi, 2016; Yin, 1969). For example, Kanwisher and colleagues (Grill-Spector, Knouf, & Kanwisher, 2004; Kanwisher et al., 1997; Kanwisher, Stanley, & Harris, 1999; Kanwisher & Yovel, 2006) examined the fusiform face area of the brain and found this region to be consistently and purposefully activated when viewing faces compared to other objects. In opposition to this, proponents of the domain-general view suggest that faces are not a special stimulus but an example of a stimulus category for which humans have gained high visual expertise through continuous exposure. For instance, work by Gauthier and colleagues (Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier, Tarr, et al., 2000; Tarr & Gauthier, 2000) has demonstrated that the fusiform face area is more akin to a flexible fusiform area that can be preferentially activated when viewing objects for which individuals hold considerable perceptual expertise (e.g., cars, birds, or faces).

Within this context, the data presented here conceptually support a domain-general view of social attention, such that faces do not hold a special status within attentional processes and bias attention because of extraneous factors, which carry their own ability to bias attentional mechanisms irrespective of information contained within faces. Those factors include attractiveness (Kirk, 2008; Nodine, Mello-Thoms, Krupinski, & Locher, 2007), contextual information (Chun, 2005; Oliva, 2005), novelty (Q. Wang, Cavanagh, & Green, 1994; Wolfe, 2001) and task settings (Watanabe et al., 1998). An important point to note here is that although the present set of studies did not find typical social attentional biasing effects, they did indicate the workings of specialized perceptual systems. That is, the present results consistently indicated that reliable social attentional effects mostly occurred for upright faces and when faces were presented in the left visual field. These data reflect a general processing preference for upright faces and a processing advantage for faces due to right hemisphere specializations for face perception (Frank et al., 2009; Kanwisher et al., 1997; Kanwisher & Yovel, 2006; Puce et al., 1998; Rossion, Joyce, Cottrell, & Tarr, 2003; Simion & Giorgio, 2015; Yin, 1969; Yovel et al., 2003).

Given these results, it is thus possible that while specialized visual processing systems responsible for face perception are engaged by faces and facial features, their specific connections with attentional systems may be more nuanced. Some evidence of this can be found when examining the different neural networks that are involved in attentional orienting. For example, when outlining the functional and anatomical correlates of attentional control, Corbetta and Shulman (2002) showed that the right ventrolateral frontoparietal network, which primarily consists of the right temporoparietal junction (TPJ) and the ventral frontal cortex, is activated when attention is engaged in a spontaneous manner. The TPJ is of particular interest here as this region is known to be important for attentionally orienting towards behaviourally relevant stimuli (Geng & Vossel, 2013; Joseph, Fricker, & Keehn, 2014; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Ristic & Giesbrecht, 2009; Serences et al., 2005) and for higher level socio-cognitive processing, such as theory of mind (Corbetta, Patel, & Shulman, 2008; Decety & Lamm, 2007; Mars, Sallet, Neubert, & Rushworth, 2013). Recent work from Capozzi and Ristic (2018) has proposed that connections between the TPJ and adjacent face processing regions may be critical in understanding how attentional systems are linked with visual processing hubs for social information at a neural level. Although more research is needed to determine the specific gating mechanisms between social attention and face perception, the current set of studies suggest that these links may be modulated by additional extraneous factors.

Future directions. Future work is needed to address and resolve some of these possibilities. One way of testing the nature of social attention biasing would be to capitalize on neuroimaging methodologies such as electroencephalography (EEG), which offer the ability to examine temporal properties of perceptual and attentional processing, and combine these methods with the present stimulus and task parameters. Such experiments would be beneficial in examining face-specific neural effects and determining the degree to which they may be linked with face-specific attentional effects.

For example, previous research has documented that processes underlying face perception have been strongly associated with a distinct negative ERP component localizable in the temporal region of the brain (i.e., the N170; Amihai et al., 2011; Bentin et al., 1996; Eimer, 2000a; Itier & Taylor, 2004; Rousselet, Macé, & Fabre-Thorpe, 2004). Similarly, markers of attentional selection have also been captured via target-related ERP components that produce early (i.e., 80-130ms after target onset) contralateral effects (i.e., the P1 wave; Hillyard & Anllo-Vento, 1998; Hillyard, Vogel, & Luck, 1998; Zhang & Luck, 2009) and mid-latency (i.e., 150-300ms after target onset) posterior-contralateral responses (i.e., the N2pc wave; Eimer, 1996; Luck & Hillyard, 1994). Capitalizing on these EEG markers, future work could utilize a similar dot-probe behavioural task while systematically manipulating stimulus content, visual context, and task setting factors to examine the amplitude and/or latency of face perception (i.e., the N170 waveform) and subsequent markers of attentional selection (i.e., the P1 and/or N2pc). If there were reliable markers of both face perception and attentional selection, it would imply that the manipulated extraneous factor engaged both face perception and attentional mechanisms. Alternatively, if there were reliable markers of face perception without subsequent target selection, it would imply that the manipulated factor did not abolish face perception but that it did not elicit attentional biasing.

Additionally, to examine the contribution of the TPJ in face processing and subsequent attentional biasing, future work could modulate functioning within this region using methodologies like transcranial magnetic stimulation (TMS) in order to better elucidate the links between social perceptual and attentional systems (Bardi, Six, & Brass, 2017; Porciello, Crostella, Liuzza, Valentini, & Aglioti, 2014; H. Wang, Callaghan, Gooding-Williams, McAllister, & Kessler, 2016). Such an integrated and multidimensional research approach would be highly beneficial in assessing whether external factors play an essential, additive, or deterministic role in social attention.

Section II: Implications for the functionality of social attention

One of the key results that was consistent across all studies relates to the dissociation in data when eye movements were restricted and when they were not restricted. That is, typical social attentional biasing was never observed in manual data when eye movements were restricted, but it emerged in manual data in Chapters 3 and 5 and in oculomotor data in most experiments when eye movements were not restricted. This dissociation highlights a key theoretical question about how manual and oculomotor measures relate to the functionality of social attention, as well as how they relate more broadly to the theoretical constructs of covert and overt attention.

Before delving into this discussion, it is important to note that the design of the present work does not fully map onto the methods that have been used in past studies to evoke covert and overt attentional biasing. Covert attention is typically measured using manual response tasks, but this is usually done in conjunction with eye movement monitoring in order to verify that eye movements did not occur. In the present experiments when eye movements were restricted, apart from Chapter 2 wherein an eye tracker was used to ensure that no eye movements occurred, we verbally instructed participants to maintain central fixation without using fixation monitoring. The oculomotor measures relate to typical overt attentional measures in a more complex manner. Typically, in overt attention tasks, oculomotor responses like eye movement fixations or speeded saccades are task-relevant such that participants are instructed to respond by looking at the stimuli and/or target. In the present experiments when eye movements were not restricted, oculomotor responses were never response relevant, as the experiments were intended to capture spontaneous eye movements that occurred during cue presentation.

Although the present design did not adhere to the strict methodological protocols of covert and overt attentional biasing, there is some evidence within the data to suggest that both covert and overt attentional processes were captured. Confirming covert attentional engagement, in Chapter 2, we conducted two separate experiments, one in which we gave participants verbal instructions to maintain central fixation and another in which, in addition to verbal instructions, we ensured that they maintained central fixation by employing eye monitoring. The pattern of manual performance across the two experiments did not differ, suggesting that the absence of manual effects likely did not reflect non-compliance with task instructions, and that verbally instructing participants to maintain central fixation was sufficient to engage typical covert processes. Demonstration of overt attentional engagement has likely been captured by measures of spontaneous saccadic breakaways from central fixation, as this behaviour occurred in response to the cue and within 250ms of cue presentation before any manual responses were executed.

The paragraphs that follow discuss the observed dissociations between covert and overt social attention biasing by first summarizing the existing literature on the relationship between these two types of attentional engagement, and then turning to a discussion of how dissociations in covert and overt social attention may benefit social behaviour and broad social functioning.

Covert and overt attention. The existing literature on the relationship between covert and overt attention shows that in contrast to early work, which theorized that eye movement preparation drives subsequent covert attentional shifts (Klein, 2004; Rizzolatti et al., 1987; Shepherd et al., 1986), the two processes relate in the opposite direction of influence, with covert attentional shifts driving subsequent overt eye movement responses (Bundesen, 1990; Deubel & Schneider, 1996). This research has characterized covert and overt attentional systems as being strongly linked but dissociable systems, which often move together but can diverge and operate independently (Hunt et al., 2019; D. T. Smith & Schenk, 2012).

Numerous studies using non-social stimuli, such as luminance transients and geometric shapes, have demonstrated instances where both covert and overt attentional systems are either engaged together or independently depending on task factors (Casteau & Smith, 2019, 2020; de Haan et al., 2008; Hunt & Kingstone, 2003a, 2003b; Land, Mennie, & Rusted, 1999; MacInnes, Jóhannesson, Chetverikov, & Kristjánsson, 2020; Nobre et al., 2000; M. S. Peterson et al., 2004). However, when social stimuli are used to engage attention, mounting evidence suggests that the two systems are engaged together or independently based on their functional purpose within our daily lives – that is, based on their utility within social interactions (Kuhn et al., 2016; Laidlaw et al., 2011; Risko et al., 2016). In one of the first demonstrations of covert and overt divergence in social attention, Kuhn and colleagues (2016) used a magic trick to examine whether participants could detect whether a playing card changes colour. Results revealed that instructing participants to keep their eyes on the playing card versus not instructing them at all could modulate overt fixations on the magician's face, but it had no impact on participants' ability to covertly detect the change in playing card. That is, changes in overt attention did not impact covert measures. Similarly, Laidlaw and colleagues (2011) examined differential modulations of social attention by measuring participants' covert and overt attention when they were sitting in a waiting room either with a live actor or with a video recording of the actor. Overt and covert attention to the actor was measured by examining fixations on the actor and head turns in the direction of the actor without direct fixations, respectively. The results indicated that participants were more likely to overtly look at the actor when they were shown on video as compared to when they were physically present, and were more likely to covertly attend to the actor when they were physically present. Thus, these findings illustrate that covert and overt social attentional behaviours can be engaged differentially depending on the presence of or opportunity for social interaction.

The functionality of covert and overt social attention. This work implies that social information may impact covert and overt attentional processes differently. Rationale for this divergent functionality is outlined in the dual function of gaze theory (Gobel, Kim, & Richardson, 2015; Grossmann, 2017; Nasiopoulos, Risko, & Kingstone, 2015), which theorizes that in human behaviour, eyes are used to both communicate social information to others and to gather social information available in the world. In this view, it is evolutionarily advantageous to have an overt attentional system in which eye gaze and associated social cues are observable, as well as a covert system in which eye gaze would be fixed in order for attentional systems to gather social information surreptitiously. As such, covert social attention could be conceptualized as a process that enables discrete gathering of social information from the environment without outwardly illustrating the present focus of attention, which would be beneficial in situations which warrant the concealment of the current locus of attention. In contrast, overt social attention could be conceptualized as a process that explicitly collects social information from the environment and communicates that information to others (Bonmassar, Pavani, & van Zoest, 2019; Gobel et al., 2015; Kuhn & Teszka, 2018; Kuhn et al., 2016; Laidlaw et al., 2011; Laidlaw & Kingstone, 2017; Laidlaw, Rothwell, & Kingstone, 2016; Latinus et al., 2015; Risko et al., 2016; Scott, Batten, & Kuhn, 2018).

The present results provide experimental evidence for the dissociation between covert and overt social attention since covert and overt measures dissociated across the majority of experiments, showing no effects in manual responses when eye movements were restricted and some oculomotor biasing and manual response effects when eye movements were not restricted. However, the results did not provide an unambiguous characterization of the role that external factors played in these dissociations.

For covert effects, the data did not indicate a single factor that was responsible for driving covert biasing. In contrast, for overt effects, oculomotor behaviour was biased towards faces across most manipulations. These eye movement breakaways occurred at approximately the same rate across all studies, on 9-11% of all trials during cue presentation. Of the trials that contained breakaway saccades, participants looked towards the eyes of the face 17% of the time when all stimulus content and visual context factors were controlled in Chapter 2, 46% of the time when attractiveness was varied in Chapter 3, 48% when contextual information was added in Chapter 4, and 41% when novelty was manipulated in Chapter 5. Furthermore, when attractive or infrequently presented novel faces were employed in Chapters 3 and 5, respectively, there was evidence of oculomotor biasing towards the eyes of the face along with additional manual performance benefits for targets occurring at the location of the face.

As such, these data raise four relevant points of interest. One, spontaneous covert social biasing depends on the presence of external factors. Two, spontaneous overt social biasing does not appear to depend on external factors or on the execution of a large number of eye movements. Three, manipulations of individual stimulus content and visual context appear to exert enhancing effects on overt social biasing, in that they amplify the magnitude of overt effects that occur in the absence of any external factors. Four, facial attractiveness and novelty may be more effective in eliciting overt attentional biasing than manipulations like background context, as attentional biasing towards the eyes of attractive or novel faces were sustained when participants subsequently manually responded to targets that appeared in overtly attended regions.

Future directions. Although these data indicated that no individual factor resulted in typical covert or overt social attentional biasing, it is possible that the contribution of multiple external factors may be required in order to promote robust covert and overt exploration of social information within the environment. Future studies are needed to systematically examine which combination of factors can yield these effects. One means of testing this question would be to examine whether combining the factors that have resulted in significant biasing effects in the present studies – perceived attractiveness, background context, and novelty – result in covert social attentional biasing or can increase the magnitude of overt social attentional effects.

Another important question for future studies concerns how and when covert and overt social attentional processes dissociate. The current work offers evidence that external factors enhance the engagement of overt social attention without biasing covert measures. This may imply that separate from external factors of stimulus content, visual context, and task settings, internal factors such as personal significance, emotional valence, or motivational influences may also be a necessary element for covert social attentional biasing. Support for this notion can be found in studies that show that internally-driven factors, such as agency (S. G. Edwards & Bayliss, 2019; D. A. Hayward et al., 2017) and social relevance (Burra, Framorando, & Pegna, 2018; Hessels, Holleman, Kingstone, Hooge, & Kemner, 2018), can modulate covert social attentional effects. Thus, future studies could examine whether the degree of external versus internal factors may impact the likelihood that covert and/or overt social attention are deployed together or in isolation. Additionally, it would be also beneficial to examine the time course of covert and overt attentional processes both in isolation and in conjunction when using behavioural measures together with independent measures like eye tracking and/or EEG, which would help to determine whether covert and overt attentional biasing is engaged in a temporally different manner for social and non-social information (Dimigen, Sommer, Hohlfeld, Jacobs, & Kliegl, 2011; Kamienkowski, Ison, Quiroga, & Sigman, 2012; Makin, Poliakoff, Ackerley, & El-Deredy, 2012).

Section III: Implications for attentional mechanisms

One of the broader implications of the current work concerns how these findings influence the understanding of basic mechanisms of attention, namely the two modes of attentional control – spontaneous and voluntary attentional processes. As outlined in the General Introduction, *spontaneous attention* is typically driven by a fast-acting processes that respond to salient or relevant information in the environment (Jonides, 1981), whereas *voluntary attention* is driven by a slower-acting controlled processes that use prior knowledge and expectations to guide attentional resources (Folk et al., 1992). The current dissertation was focused on examining how faces and their features biased attention spontaneously. However, across all studies, there was little evidence of attentional biasing towards faces and facial features, which may suggest that social attention does not engage spontaneous attentional processes.

Section I of the General Discussion proposes that spontaneous social attention may have been eliminated or dampened when tight control of extraneous factors was applied because of too stringent experimental controls, the amplifying role of extraneous factors, or the necessity of extraneous factors. Here, the possibility that social attention may be guided by other modes of attentional control, namely through voluntary or other distinctive mechanisms is discussed.

Evidence for voluntary control. One possibility for why there was no spontaneous attentional biasing towards faces is that social attention may require some degree of voluntary attentional control. As briefly discussed in Section II of the General Discussion, past studies have demonstrated that social attention can be under a degree of voluntary control. For example, both manual and oculomotor measures are known to be impacted by task factors, such as when utilizing visual search (Lavie et al., 2003), change detection (Ro et al., 2001), and inattentional blindness (Devue et al., 2009), and may be adjusted depending on situational settings, such as when comparing lab-based and naturalistic settings (Foulsham, Walker, & Kingstone, 2011; Laidlaw et al., 2011). These findings suggest that voluntary processes, which control how attention is deployed and engaged, may also be responsible for controlling social attention. Chanon and Hopfinger (2011) lend support for this notion by showing that social and voluntary attention may share similar mechanisms. In their study, the researchers utilized EEG in order to contrast attentional effects elicited by voluntary, spontaneous, and social cues using a modified version of the cuing task. Participants were presented with a central face followed by a target that could appear in either the left or right visual field. They were also given one of three cues prior to the target: *(i)* a voluntary cue, wherein a central cross changed colour to indicate the spatial location of the target with 80% accuracy, *(ii)* a spontaneous cue, wherein a white ring could appear either in the left or right visual field, predicting the target location at chance (i.e., 50% accuracy), or *(iii)* a social cue, whereby the eye gaze of the face could look either left or right, predicting the target location also at chance (i.e., 50% accuracy). Participants were informed of all three contingencies and could thus alter their attentional behaviour to respond faster to the target. When comparing effects across all three conditions, the results showed that social cues affected target processing in a manner that was highly similar to voluntary cues, suggesting that social and voluntary attention may share similar processing mechanisms.

In this manner, it is possible that prior literature on social attentional biasing, which rarely controlled for stimulus content, visual context, and task settings (Bindemann et al., 2007; Birmingham et al., 2008a; Crouzet et al., 2010; Langton et al., 2008; Sato & Kawahara, 2015; Theeuwes & Van der Stigchel, 2006), may have unknowingly engaged voluntary factors to imbue the face cues with task relevance. For example, not equating faces and non-social stimuli for attractiveness may engage voluntary attentional processes towards faces and facial features like eyes due to attractive faces having deliberate reward values across a wide variety of situations (e.g., infant biology, Slater et al., 1998; personality characteristics, Dion, Berscheid, & Walster, 1972; Thornhill & Gangestad, 1999; neural representations, Cloutier, Heatherton, Whalen, & Kelley, 2008; Liang, Zebrowitz, & Zhang, 2010). Since the present results showed muted social attentional effects once these extraneous factors were controlled, these findings may present indirect evidence that prior literature on social attention may have been at least partly driven or influenced by voluntary processes created by stimulus and/or task relevancy.

An important point to note however is that although the engagement of voluntary mechanisms is one possible explanation for the lack of social attentional biasing observed in the present studies, when eye movements were not restricted, there was evidence of oculomotor biasing towards the eyes of the face within 250ms of cue presentation. This finding is inconsistent with the literature on voluntary attentional control, as voluntary attention is known to emerge slowly, typically only by 300 to 500ms after cue presentation (Folk et al., 1992; Theeuwes, 1991). Instead, the present results are consistent with the engagement of spontaneous attention, as spontaneous effects typically emerge quickly about 100ms after presentation of the cue (Jonides, 1981; Posner, 1980). As such, it is not clear whether the engagement of voluntary attentional mechanisms alone can account for both the lack of social attentional effects observed in manual performance and the social attentional biasing effects observed in oculomotor measures.

This dissociation in results presents a difficulty in situating the present findings within the current model of spontaneous and voluntary attentional control. Interestingly however, this work is not the first to find attentional effects that cannot be explained by this classic theoretical dichotomy. For example, stimuli with selection history (Belopolsky & Theeuwes, 2009; Ristic & Kingstone, 2012; Ristic, Landry, & Kingstone, 2012) or those with rewarded associations (B. A. Anderson, Laurent, & Yantis, 2011; Chelazzi et al., 2014; M. H. MacLean, Diaz, & Giesbrecht, 2016; M. H. MacLean & Giesbrecht, 2015) have also been shown to produce attentional effects that do not fit within either spontaneous or voluntary attentional control. Reward-driven attentional effects are of significant note here because these effects have also been examined in relation to social information. Anderson (2016) was one of the first to study this question by utilizing a training and a test phase within an attentional capture task. During the training phase, participants were presented with six circles surrounding a central fixation point and were asked to respond to the orientation of a bar within a red or green circle. Importantly, responses to one of these colours were associated with the appearance of a happy face, whereas responses to the other colour were associated with the appearance of a neutral face. Then, during the test phase, participants were presented with six shapes of different colours and were asked to identify the orientation of a bar within the unique shape (e.g., a diamond amongst circles). Even though participants were explicitly informed to ignore the colour of the shapes, results demonstrated that colours previously paired with happy faces elicited greater attentional effects. Hayward and colleagues (2018) extended these findings to show that real-life social exchanges can imbue neutral non-social cues (i.e., color patches) with social meaning. In their experiment, participants first interacted with the experimenter in a positive manner, and in a subsequent task, they were given an opportunity to win points for the experimenter. The researchers found that only cues that were associated with points won for the experimenter, i.e., cues that carried implied social reward, elicited attentional benefits a full day after the point rewards were removed.

Together, these studies show that the control of social attention can be engaged in a manner that is not strictly explained by either spontaneous or voluntary processes (Awh, Belopolsky, & Theeuwes, 2012), suggesting that social attention may rely on a distinctive mode of attentional control.

Evidence for a distinctive mechanism. Support for the notion that social attention may engage attentional mechanisms in a distinctive manner has been derived from early studies that investigated how social information impacts attentional processing (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). These studies typically used gaze cuing tasks, wherein participants are first presented with a central social cue (e.g., schematic or photographed face) that gazes at either the left or right visual field. Participants are asked to respond to targets that then appear at either the gazed-at or not gazed-at location. Importantly, the direction of eye gaze is irrelevant to the task, and participants are informed that targets are equally likely to occur at either possible target location. Results of these studies indicated that even though eye gaze direction was task-irrelevant, participants were faster and more accurate to respond to targets occurring at the gazed-at location. Critically though, social attentional effects emerged quickly 100ms after presentation of the cue and persisted well into 700 to 1000ms after cue presentation, showing that social attentional effects may exhibit evidence of both fast-acting spontaneous and slower-developing voluntary processes.

Subsequent work has shown that the effects of social attention can be dissociated from both spontaneous and voluntary attentional control. Friesen & Kingstone (2003) dissociated the effects of spontaneous and social attention by utilizing a schematic face as both a spontaneous and social cue within the same task. In their task, participants were presented with four circles, out of which, the face could appear in one of these circles, either looking straight ahead (i.e., a sudden onset spontaneous cue) or looking at one of the other three circles (i.e., a directional social cue). Then, one of the four circles would disappear, and participants' task was to detect this offset. Critically, researchers compared responses for targets occurring at the locations of the sudden onset cue and the gazed-at location by the directional social cues. Typical effects were found for both targets, with no interference, showing that spontaneous attentional processes were occurring independently from social attentional processes.

Similarly, Hayward and Ristic (2013; see also Friesen, Ristic, & Kingstone, 2004) demonstrated dissociable effects between social and voluntary attention. The researchers used a gaze cuing task in which participants saw a central face looking either left, right, top, or bottom, which was followed by a target that could appear in one of these spatial regions. Here, the cue was counter-predictive of the target's location. That is, the target appeared with 76% accuracy in the opposite direction of the gazed-at location, engaging voluntary attention, and with 8% accuracy in the gazed-at location, engaging social attention. To investigate the dissociation between social and voluntary effects, the researchers combined this gaze cuing task with a working memory load, as high levels of cognitive load have been found to interfere with voluntary attention (Jonides, 1981; Lavie & De Fockert, 2005). The results indicated that social attention was unaffected by working memory load while voluntary attention was supressed, suggesting an independence between social and voluntary processes.

Neuroimaging data also offers additional support for the unique functionality of social attention. Studies have examined attentional effects for both social and non-social information both within the general population (E. J. Edwards, Edwards, & Lyvers, 2015; Greene & Zaidel, 2011; Marotta, Lupiáñez, & Casagrande, 2012) and in split-brain patients whose cerebral hemispheres were disconnected via surgical resection of the corpus callosum (Kingstone, Friesen, & Gazzaniga, 2000; Ristic, Friesen, & Kingstone, 2002). Results of both types of investigation show that neural mechanisms underlying social and non-social attention diverge, such that non-social attention is processed in both the left and right hemispheres, whereas social attention is localized to the right hemisphere, i.e., the hemisphere that is highly specialized for face processing. Studies have also demonstrated that social attention, over and above non-social attention, is additionally supported by differential areas of the brain, such as the superior temporal sulcus (Harries & Perrett, 1991; Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006; Kingstone, Tipper, Ristic, & Ngan, 2004; Visconti di Oleggio Castello, Guntupalli, Yang, & Gobbini, 2014) and the temporoparietal junction (Engell et al., 2010; Joseph et al., 2014; Ristic & Giesbrecht, 2009).

As such, social attention may be dependent on the engagement of domain-general attentional mechanisms, similar to other forms of non-social attention, while also relying on specific interactions with specialized processing systems for social information that communicate social value processing and/or task maintenance. In this manner, there may exist unique influences from both basic attentional processes (e.g., perceived attractiveness, background information, novelty) and social relevance (e.g., beliefs about other mental states, internal intentions, current desires, future aspirations) that can act in complementary and multiplicative ways to bias and direct attention for faces in a highly distinctive manner.

Future directions. Although the current set of studies illustrated that social biasing effects when using tasks that engage spontaneous attentional processes can be muted by controlling extraneous factors, it is still unknown whether these findings also apply for tasks that engage voluntary attentional processes. As such, future studies could examine the impact of stimulus content, visual context, and task setting factors on social attention when utilizing a task that presents reliable information about the spatial location of the target. For example, participants can be presented with a face and house cue that have been controlled for all extraneous factors, and manual and oculomotor performance can then be compared for tasks when either the face or house cue is highly predictive of the target location. This would allow for a direct examination of how extraneous factors impact voluntary attentional processes in order to compare whether these results are consistent with the muted effects found for spontaneous attentional processes. Additionally, these findings can also contrast whether extraneous factors play a particularly enhancing effect for social rather than non-social information.

Furthermore, to investigate whether social attention is under a distinctive mode of attentional control, future studies can examine attentional effects when substituting the face cues with either previously neutral non-social stimuli (e.g., color patches) that are then imbued with social or non-social significance through social or non-social reward (B. A. Anderson, 2016; D. A. Hayward et al., 2018) or non-social directional comparisons that have been used in previous work, such as arrows (Ristic et al., 2002; Tipples, 2002).

Section IV: Considerations for attentional measurement

Finally, it is important to consider that the lack of social attentional biasing effects that has been observed across the studies comprising the current dissertation may be connected to the choice of experimental task.

The current paradigm. Across all studies within this dissertation, we used the dot-probe task (MacLeod et al., 1986) in order to examine the influence of social information on attentional processing. The typical finding from this task is that individuals respond faster to targets that appear in locations that contain attended cue stimuli versus those that contain unattended cue stimuli. This occurs because attentional capture by the cue results in an alignment of attentional resources with that spatial location, subsequently resulting in faster processing of targets appearing in this region of space. In this way, the dot-probe task allows researchers to manipulate where on the screen attention is allocated using a wide variety of different stimuli and to measure resultant behavioural and neural responses.

As such, the dot-probe task has been well-established in examinations of attentional biasing to functionally significant stimuli, including social, emotional, threatening, or rewarding information (Mathews & Mackintosh, 1998; Mogg & Bradley, 1999), as well as in examinations of attentional dysfunctions in populations with clinical disorders, such as depression, anxiety, or chronic pain (Frewen et al., 2008). Furthermore, numerous studies have also verified findings from the dot-probe task using supporting neural data. For example, a meta-analysis conducted by Bar-Haim and colleagues (2007) demonstrated that attentional biasing found for threat-related images (e.g., angry faces, negatively-valenced words) when using the dot-probe task is mirrored in neuroimaging results (Armony & Dolan, 2002; Murphy, Nimmo-Smith, & Lawrence, 2003; Vuilleumier & Pourtois, 2007). Taken together, these results point to the strength of the dot-probe task in measuring attentional biasing.

However, the dot-probe task has also been scrutinized for its reliability when measuring attentional performance across different stimuli and task parameters. For example, Schmukle (2005) examined the psychometric properties of the task by varying the types of cues (i.e., word versus image cue), and found that attentional biasing was not measured consistently across different versions of the dot-probe task. Similar findings have also been reported with other types of stimuli and task parameters (Amir, Zvielli, & Bernstein, 2016; Chapman, Devue, & Grimshaw, 2019; Rodebaugh et al., 2016; Staugaard, 2009; Zvielli, Bernstein, & Koster, 2015), when comparing against neuroimaging data (Kappenman, Farrens, Luck, & Proudfit, 2014; Kappenman, MacNamara, & Proudfit, 2014; Reutter, Hewig, Wieser, & Osinsky, 2017), and when examining nuanced effects within clinical disorders (Dear, Sharpe, Nicholas, & Refshauge, 2011; MacLeod, Grafton, & Notebaert, 2019; Schäfer et al., 2016; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). Given that the present dot-probe task produced little-to-no reliable effects for face cues, this issue does not appear to influence the current set of results.

On the contrary, the present results show that the dot-probe task as used in the current sent of studies was effective in capturing general engagement of attentional systems.

Specifically, first, all experiments demonstrated typical foreperiod effects for manual performance, showing response preparation effects for the temporal sequence utilized in the dot-probe task. Second, for experiments in Chapters 2 and 3, there was evidence of overall facilitated manual responses for targets that occurred at the previous location of the face and house stimuli over and above targets that occurred at the previous location of the neutral stimuli, indicating that attention in general was engaged by social and non-social cues. Third and finally, typical social attentional biasing effects were replicated in Chapter 2 when using the stimuli and dot-probe task settings utilized by Bindemann and colleagues (2007). Thus, even though the data did not indicate typical social attentional biasing effects in the present work, the dot-probe task appears to have engaged general attentional processing in an expected manner.

Despite this, there is some evidence to suggest that attentional paradigms like the dot-probe task, i.e., tasks that infer attentional biasing based on manual responses (e.g., cuing tasks, visual search tasks, inattentional blindness tasks), function optimally when examining robust overall attentional effects. These arguments stem from the notion that most tasks index attentional effects by averaging participants' responses over a large number of trials, and as such, offer little insight into how attention may be engaged on a trial-by-trial basis. As such, these tasks may not be well suited to capture potentially small and fleeting effects (Driver et al., 1999). This notion was illustrated in a study by Blair, Capozzi, and Ristic (2017) that was motivated by discrepancies in results showing lower frequencies of social attentional behaviours in naturalistic versus lab-based studies. To do so, the researchers investigated the frequency of attentional behaviour in a gaze cuing task by categorizing individual trial responses that fell outside one standard deviation from average performance, such that trials were defined as either showing an attentional benefit (if performance was higher than 1 SD) or an attentional cost (if performance was lower than 1SD). Through this novel method, the researchers found that attentional benefits and costs occurred in less than half of all trials, and on those trials, typical patterns of manual performance benefits for targets occurring at cued locations were found. These findings suggest that attentional behaviour in the lab, previously believed to be highly robust, may also occur on relatively few trials, raising the possibility that if there is a failure to find reliable attentional biasing, it is possible that attentional effects may be occurring infrequently but failing to reach the threshold of statistical significance.

Future approaches. Given these notions, it is clear that the measurement of social attention would benefit from utilizing tasks and paradigms that are able to capture more nuanced aspects of this behaviour. Two new approaches – measuring attention dynamically and assessing it in the real world – appear to be particularly useful in this regard.

Measuring attention dynamically. Capturing attention in a more temporally diverse manner would allow for a more thorough examination of how attentional performance unfolds throughout a task. Although past work has often examined attentional behaviour in aggregate terms, research has long determined that attentional abilities can differ across timescales, fluctuating over the course of a day (Busch & VanRullen, 2010), over the span of an hour (Reichle, Reineberg, & Schooler, 2010; Smallwood, McSpadden, & Schooler, 2008; Terhune, Croucher, Marcusson-Clavertz, & Macdonald, 2017), and even over the span of minutes (Cheyne, Solman, Carriere, & Smilek, 2009). This dynamic fluctuation of attention indicates that unpacking how attentional behaviours manifest across the length of a task can be useful in detecting smaller and more transient effects.

One way of doing so would be to utilize nonlinear analyses to quantify fluctuations in attentional behaviours across the length of the task. This can be done through the use of recurrence quantification analyses (RQA), a statistical tool that has been used for describing large-scale dynamic systems like electrocardiograms (Webber & Zbilut, 2005), postural fluctuation (Pellecchia & Schockley, 2005; Riley & Clark, 2003), and climate data (Marwan & Kurths, 2002). Recurrence analyses make use of data across the entire timeseries in order to quantify the trajectory of behaviour across different possible states. For example, if one wanted to examine the timeseries of oculomotor biasing during the cue period in the present set of data, RQA could map each trial in the timeseries onto four states: eye movements occurring towards *(i)* the social face, *(ii)* the non-social house, *(iii)* other locations, or *(iv)* no eye movements made. From this, one could use temporal patterns to analyze the likelihood that participants will repeatedly or recursively transition from making eye movements towards social or non-social information throughout the task. For instance, one could investigate whether long periods of no eye movements could predict a subsequent eye movement made, and if so whether this eye movement would likely be directed towards the face or house. Additionally, one could also investigate whether eye movements are made earlier versus later in the task, such that there might be a greater reliance on making eye movements towards the face or house at the start of the task and a stronger likelihood of no eye movements made towards the end of the task. In this manner, RQA can provide a quantitative measure of the repetitiveness, strength, and complexity of oculomotor behaviour across the full task.

Recently, recurrence quantification analyses have been used in two important studies on attention. To capture individual attentional behaviour, Anderson and colleagues (2013) had participants perform an eye tracking task where photographs of real-world scenes were viewed either under a natural viewing condition (i.e., participants could see the entire scene during the trial) or a restricted viewing condition (i.e., participants viewed the scenes through a gaze contingent window that only depicted 5º of visual angle). The researchers then used RQA to show that restricted viewing conditions induced greater reliance on fixating novel regions of the scene and more rigidity in eye movement scanning. Second, to characterize joint attentional behaviour, Richardson and Dale (2005) used an interactive task, whereby they first recorded speakers talking about actors they were viewing on a screen and then played this recording for listeners who were also viewing the same actors on the screen. Eye movements were recorded for both groups, and RQA was used to quantify coordination between speakers and listeners. They found that the eye movements of speakers and listeners were closely coupled in time, such that the more closely listeners' eye movements matched with speakers', the greater their success at comprehending inferred verbal information.

As such, these studies highlight that recurrence quantification methods can be applied to both existing and new attentional paradigms to capture the temporal structure of attentional behaviours. Future work could apply RQA methods within the current set of studies to examine whether preferential oculomotor biasing effects occur early, intermittently, or recurrently throughout the task.

Assessing attention in the real world. Capturing attentional performance outside of a lab-based setting would allow researchers to determine how social attentional behaviours occur and change during daily life functions. Although one might expect that attention measured within the lab and within naturalistic settings would strongly overlap, numerous studies have so far demonstrated that ongoing attentional performance can critically depend on immediate and extended contextual influences. Seminal work from Land and colleagues (Land & Furneaux, 1997; Land & Lee, 1994; Land & McLeod, 2000; Land et al., 1999; Land & Tatler, 2009) demonstrated this within oculomotor measures across various tasks and activities. For example, when making tea, eye movements tend to be coupled with ongoing or future actions rather than on immediate salient objects in the environment (Land et al., 1999); when driving, eye movements reliably occur on fixed tangent points on the road that account for potential steering patterns (Land & Lee, 1994); and when playing sports like tennis or cricket, eye movements exhibit specific patterns of fixation that attempt to predict the bounce point of the ball rather than fixating on the ball itself (Land & Furneaux, 1997; Land & McLeod, 2000). These findings show that oculomotor attentional behaviours are reliably modulated through sequencing in naturalistic settings, as compared to the mostly static effects we see within lab-based work. More recent studies have also incorporated measures of covert attentional effects as well to examine whether similar differences exist. For example, Laidlaw, Rothwell, and Kingstone (2016) examined whether participants would overtly fixate on an actor who performed either a private action (i.e., raising their hand and saying hi into a phone) or an equivalent public action (i.e., raising their hand and saying hi in person). The data demonstrated that even though participants were not initially looking at the actor prior to the action, fixations to the actor increased when they performed a public versus private action. This difference was interpreted as indicating that prior to the action, participants may have been covertly attending to the actor, such that participants could then adjust their overt behaviour only when it was deemed socially appropriate.

As detailed in the General Introduction, a majority of studies conducted so far have examined social attention in the lab by presenting participants with static images of faces or individuals either in isolation or within complex scenes. Although this work has greatly contributed to the understanding of social attention and its mechanisms, it does not account for the notion that our environment is rich in social meaning and includes multiple opportunities for social reciprocity (De Jaegher, Di Paolo, & Gallagher, 2010), which can profoundly impact attentional behaviour. For example, Sections II and III of the General Discussion have detailed that naturalistic settings that have potential, implied, or live social interactions can greatly reduce or change how social attentional behaviour manifests when compared to lab-based studies (Foulsham et al., 2011; Gobel, Tufft, & Richardson, 2018; D. A. Hayward et al., 2017; Laidlaw et al., 2011). As such, previous lab-based tasks on social attention may have contributed to the overestimation of how often social information is attended to and fixated on in naturalistic settings (Freeth, Foulsham, & Kingstone, 2013; Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003; Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Schilbach et al., 2013). Together, this divergence of effects necessitates a more thorough examination of how social attentional processes evolve in time and within the context of extended behavioural sequences.

The current need for more diverse studies aimed at capturing attention in a broader manner are timely given the progression of technology and analytical methods that can support more sophisticated methods of measurement. Over the past decade, mobile eye tracking systems have become more functional and easier to use in naturalistic settings, with the benefit of concurrently recording participants' eye movements together with their scene view (Franchak & Adolph, 2010; Land & Tatler, 2009). Similarly, the advent of wireless technologies have allowed researchers to record EEG while participants are moving (Gramann et al., 2011; Sipp, Gwin, Makeig, & Ferris, 2013) and during live interactions (Lachat, Hugeville, Lemarechal, Conty, & George, 2012), with specialized preprocessing pipelines created for identifying and removing artifacts generated from physical movements (Gwin, Gramann, Makeig, & Ferris, 2010). These advances make it possible to monitor and assess different types of attentional biasing and modes of attentional control, while still exerting strong experimental control through task-specific constraints.

Thus, both the need and ability to utilize tasks that examine social attention in the wild would be highly beneficial in advancing our understanding of how attentional behaviours occur when imbued with real world significance and when embedded within real world contexts. To examine attentional behaviours when tied to social meaning, future studies could use the current paradigm and run interactions in pairs, such that participants would meet other participant collaborators prior to the task, and their collaborator's face image, controlled for all extraneous factors, would be used for the dot-probe task. This would be one way to examine attentional effects for faces that carry social weight, while still maintaining the rigorous controls that can independently bias attention. Another option would be to examine attentional behaviours within naturalistic settings. In this way, one could utilize mobile eye tracking systems together with portable EEG devices to test whether individual manipulations of attractiveness and novelty within faces bias both covert and overt attention in the real world.

In sum, current tasks and paradigms have provided highly critical information on how attentional systems function and are engaged, while also offering a benchmark for comparison for future studies. As such, the approaches advocated here – to characterize and examine fluid attentional behaviours in a manner that better represents how they may appear in the real world – aims to capture the full spectrum of attentional behaviours seen across a wide range of tasks and activities.

Conclusion and Summary

Across four experimental chapters, in this dissertation, we demonstrated that social attention is highly affected by extraneous factors of stimulus content, visual context, and task settings. These findings establish that although faces are important stimuli within our daily lives, attentional biasing towards social information is not driven by faces alone, but by their functional importance within tasks, environments, and internal settings. As such, the work presented here makes a significant theoretical contribution in understanding the nature of social attention and its underlying mechanisms.

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