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Natural, but not artificial, facial movements elicit the left visual field bias in infant face scanning

Naiqi G. Xiao [a], Paul C. Quinn [b], Andrea Wheeler [a], Olivier Pascalis [c], Kang Lee [a,*]

[a] University of Toronto, 45 Walmer Road, Toronto, Ontario, Canada M5R 2X2
[b] University of Delaware, Newark, DE 19716, United States
[c] LPNC – Université Grenoble Alpes, CNRS, Grenoble 38400, France

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ABSTRACT

A left visual field (LVF) bias has been consistently reported in eye movement patterns when adults look at face stimuli, which reflects hemispheric lateralization of face processing and eye movements. However, the emergence of the LVF attentional bias in infancy is less clear. The present study investigated the emergence and development of the LVF attentional bias in infants from 3 to 9 months of age with moving face stimuli. We specifically examined the naturalness of facial movements in infants' LVF attentional bias by comparing eye movement patterns in naturally and artificially moving faces. Results showed that 3- to 5-month-olds exhibited the LVF attentional bias only in the lower half of naturally moving faces, but not in artificially moving faces. Six- to 9-month-olds showed the LVF attentional bias in both the lower and upper face halves only in naturally moving, but not in artificially moving faces. These results suggest that the LVF attentional bias for face processing may emerge around 3 months of age and is driven by natural facial movements. The LVF attentional bias reflects the role of natural face experience in real life situations that may drive the development of hemispheric lateralization of face processing in infancy.

1. Introduction

Faces are likely the most frequently encountered visual stimuli in our everyday experience. One common characteristic that faces share is that they are nearly symmetrical along the horizontal axis: the eyes are on either side of the face with the nose and mouth in the middle. However, the way we process faces has long been found to be asymmetrical. We tend to rely on the left side of the face (from the perceiver's perspective) more than the right side in face processing. This left visual field (LVF) bias has been consistently found in the literature with children and adults and has been linked to the hemispheric lateralization of face processing (Gilbert & Baken, 1973; Yovel, Tambini, & Brandman, 2008). However, little research has examined the emergence and development of the LVF face bias in infancy. To address this important gap in the literature, the present study, using eye tracking, investigated (1) whether infants as young as 3 months of age already display a LVF bias, and (2) how this bias emerges and develops with increased age in the first year of life.

Investigations of the left visual field bias in face processing were inspired by the observations of Wolff (1933). In his study, Wolff (1933) reported that the left and right face halves were different in their emotional expression resemblance to the whole face. Participants consistently judged emotion on the left face half (from the observer's view) as closer to the whole face's emotion than that on the right face half. In addition to face emotionality, this *LVF perceptual bias*, which biases perception to the face half in the left visual field, has been consistently observed in terms of face recognition, emotion categorization, and age judgment (Aljuhanay, Milne, Burt, & Pascalis, 2010; Burt & Perrett, 1997; Butler & Harvey, 2008; Chiang, Ballantyne, & Trauner, 2000; Coolican, Eskes, McMullen, & Lecky, 2008; Dahl, Rasch, Tomonaga, & Adachi, 2013; Gilbert & Bakan, 1973; Levine & Koch-Weser, 1982; Levine, Banich, & Koch-Weser, 1984, 1988; Levy, Heller, Banich, & Burton, 1983; Levy, Trevarthen, & Sperry, 1972; Luh, Redl, & Levy, 1994; Luh, Rueckert, & Levy, 1991; Sackeim & Gur, 1978; Yovel et al., 2008). Gilbert and Baken (1973) proposed that the LVF perceptual bias is likely due to right hemispheric dominance for face processing. Face information in the left visual field is projected to the contralateral right hemisphere, leading face perception to be disproportionally reliant on the left face half. This proposal has recently been supported by a neural imaging study, which found a positive association between the face selective region activation in

* Corresponding author: Tel.: +1 416 934 4597.
E-mail addresses: naiqi.xiao@mail.utoronto.ca (N.G. Xiao), pquinn@psych.udel.edu (P.C. Quinn), andrea.wheeler@utoronto.ca (A. Wheeler), olivier.pascalis@upmf-grenoble.fr (O. Pascalis), kang.lee@utoronto.ca (K. Lee).

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the right hemisphere and the size of the LVF perceptual bias (Yovel et al., 2008).

Recent studies using eye-tracking technology observed that the LVF perceptual bias was linked to a leftward eye movement pattern in face processing (Butler et al., 2005; Butler & Harvey, 2006; Dundas, Best, Minshew, & Strauss, 2012; Dundas, Gastgeb, & Strauss, 2012; Guo, Smith, Powell, & Nicholls, 2012; Hsiao & Cottrell, 2008, 2009; Mertens, Siegmund, & Grüsser, 1993; Schyns, Bonnar, & Gosselin, 2002). Butler et al. (2005), for example, observed that participants who relied on the left face half for judgment of face gender exhibited significantly longer looking time on the left face half and an initial leftward saccade to the left visual field. By contrast, no such leftward saccade or looking time preference was observed for those who did not show the LVF bias. Butler and Harvey (2006) further suggested the crucial role of eye movements in the LVF perceptual bias by showing a significant decrease in the LVF bias when eye movements were restricted. This leftward eye movement bias was named *the LVF attentional bias*, which stands for the accumulatively longer looking time or initial leftward saccade for the face half in the left visual field. Based on the findings from Butler and co-workers, researchers regarded the LVF attentional bias, similar to the LVF perceptual bias, as rooted in right hemispheric dominance for face processing. The stronger activation in the right hemisphere face network can be transmitted to the frontal eye fields (FEF, BA45, and BA8) in the right hemisphere through the neural connections between the two (Bullier, Schall, & Morel, 1996; Schall, Morel, King, & Bullier, 1995). The FEF is the neural region that mainly controls eye movement to the contralateral side; the activation in the right FEF would lead to eye movement to the left side (Robinson, 1968). Thus, the lateralized activation in the right hemisphere during face processing would result in the LVF attentional bias.

Several lines of research have supported the proposed involvement of the right hemisphere in the LVF attentional bias. The first focused on the specificity of the leftward eye movement pattern for face processing. Leonards and Scott-Samuel (2005) reported an initial saccade to the left visual field in adult participants only for upright face stimuli but not for inverted faces, landscapes, or patterns. In line with this finding (Guo, Meints, Hall, Hall, & Mills, 2009) observed such face specificity in terms of longer looking time on the left face half in adults. These studies reflect the underlying role of the right hemispheric lateralized face selective neural network, which is shaped by long-term face experience (Birmingham et al. 2012). The second line of studies for the LVF attentional bias mainly compared the face-scanning pattern in a typically developing population to that in individuals with autism spectrum disorder (ASD). Individuals with ASD have been found to have difficulties in processing face stimuli, which is probably due to their lack of right hemisphere lateralization for face processing (Ashwin, Wheelwright, & Baron-Cohen, 2005). One would expect lack of lateralization to restrict eye movements to the left visual field. Consistent with this proposal, Dundas and Best (2012) found that typically developed adults and adolescents exhibited longer looking time to the left side of the face, while no such LVF attentional bias was observed in observers with ASD. In sum, both behavioral and neuropsychological studies have supported the association between the LVF attentional bias and the right hemisphere lateralized face processing neural network in children, adolescents, and adults.

In contrast to the consistent LVF attentional bias found in children, adolescents, and adults, little is known about the emergence and development of the LVF attentional bias in the first year of life. Dundas and Gastgeb (2012) observed that 11-month-olds looked longer on the left than the right side of face, while no such bias was revealed in 6-month-olds or in infants with high ASD risk. This study suggested that the LVF attentional bias in face processing might emerge between 6 and 11 months of age. Another study reported the LVF attentional bias in 6-month-olds (Guo et al., 2009). The LVF attentional bias found in this study was not face specific. It was found with not only upright human faces, but also inverted human faces, upright and inverted monkey faces, and objects. When considering all these findings, it seems the face specific LVF attentional bias emerges at around 11 months of age, although a more general LVF attentional bias can be revealed as early as 6 months.

However, it should be noted that this developmental trajectory of the LVF attentional bias is inconsistent with findings that the specialization of the right hemisphere for face processing emerges around 4 months after birth (Deruelle & de Schonen, 1998; de Schonen & Mathivet, 1990). The findings consistent with an earlier emergence have been further supported by recent neural imaging studies using event-related potential (ERP) and functional near infrared spectroscopy (fNIRS) technology (Honda et al. 2010; Ichikawa, Kanazawa, Yamaguchi, & Kakigi, 2010; Nakato et al. 2009; Otsuka et al. 2007; Scott, 2006). Considering the association between the LVF attentional bias and the lateralized face processing neural network, the LVF attentional bias would be expected to emerge even earlier in infancy. But to the best of our knowledge, few studies have reported a LVF attentional bias under 6 months of age.

It is notable that most of the studies investigating infants' LVF attentional bias used static face pictures as stimuli. However, in real life situations, most faces that young infants see are moving ones: they smile, talk, chew, and change viewpoints. The richness of facial movement information has been found to lead to more right hemispheric activity than static faces (Ichikawa et al., 2010; Pitcher, Dilks, Saxe, Triantafyllou, & Kanwisher, 2011; Schultz, Brockhaus, Bülthoff, & Pilz, 2013). Ichikawa et al. (2010), for example, used fNIRS to examine 7- to 8-month-olds' neural response to abstract point-light moving face stimuli. Relative to a static point-light display, facial movement induced more neural activity in the right temporal region. If moving faces activate stronger right hemispheric neural activity than static faces in infants, we would expect to observe the associated leftward eye movement in early infancy, which may not be observed with static faces as stimuli. Consistent with this proposal, a recent study found a LVF attentional bias in 4- to 9-months-olds (Liu et al., 2011). It used more natural dynamic faces as stimuli and presented 4- to 9-month-olds with frontal-view silent videos that depicted a woman counting. The results demonstrated that infants looked marginally longer at the face half to the left of the vertical midline than at the face half to the right of the midline. Compared to those studies that used static face pictures as stimuli (Dundas et al. 2012b; Guo et al., 2009), the Liu et al. (2011) results suggest that the introduction of facial movement might facilitate leftward eye movement. Based on these previous studies, the present study examined the role of facial movement in the emergence and development of the LVF attentional bias for face processing in infants between 3 and 9 months of age.

Although previous studies have shown that facial movements can activate a right lateralized neural response, it should be noted that the findings were derived from the contrast between moving and static faces. We do not know to what extent the right hemispheric activation reflects the role of facial movement as opposed to other motion-related attributes. Facial movement would directly lead to changes in the spatial relations among facial features (e.g., eyes, nose, and mouth), which is referred to as configural information (Maurer, Le Grand, & Mondloch, 2002). Earlier studies have shown that the processing of facial configural information was also dominant in the right hemisphere in infancy (Deruelle & de Schonen, 1998; Scott, 2006). These findings suggest that the link between facial movement and the LVF attentional