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Perceptual bias, more than age, impacts on eye movements during face processing

Louise R. Williams *, Madeleine A. Grealy, Steve W. Kelly, Iona Henderson, Stephen H. Butler

School of Psychological Sciences and Health, University of Strathclyde, 40 George Street, Glasgow G1 1QE, UK

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ABSTRACT

Consistent with the right hemispheric dominance for face processing, a left perceptual bias (LPB) is typically demonstrated by younger adults viewing faces and a left eye movement bias has also been revealed. Hemispheric asymmetry is predicted to reduce with age and older adults have demonstrated a weaker LPB, particularly when viewing time is restricted. What is currently unclear is whether age also weakens the left eye movement bias. Additionally, a right perceptual bias (RPB) for facial judgments has less frequently been demonstrated, but whether this is accompanied by a right eye movement bias has not been investigated. To address these issues older and younger adults' eye movements and gender judgments of chimeric faces were recorded in two time conditions. Age did not significantly weaken the LPB or eye movement bias; both groups looked initially to the left side of the face and made more fixations when the gender judgment was based on the left side. A positive association was found between LPB and initial saccades in the freeview condition and with all eye movements (initial saccades, number and duration of fixations) when time was restricted. The accompanying eye movement bias revealed by LPB participants contrasted with RPB participants who demonstrated no eye movement bias in either time condition. Consequently, increased age is not clearly associated with weakened perceptual and eye movement biases. Instead an eye movement bias accompanies an LPB (particularly under restricted viewing time conditions) but not an RPB.

1. Introduction

In general, faces appear approximately symmetrical along the vertical axis with the left and right sides typically revealing no discernible differences. However, research has consistently demonstrated that judgments of similarity, gender, age, attractiveness and emotional expression are based on facial cues seen to the viewer's left (Bourne, 2011; Burt & Perrett, 1997; Gilbert & Bakan, 1973). For example, when asked to judge the gender of a chimeric face – a constructed image where the left and right sides differ with regard to the gender shown – judgments are typically based on information presented in the left visual field, even when faces are inverted (Parente & Tommasi, 2008). The predisposition to base decisions on the left side is known as the left perceptual bias (LPB) and some research using eye tracking has shown an association between the LPB and a left eye movement bias. The left eye movement bias is the tendency to generate initial saccades to the left side, which has been described as a reflex response when faces are viewed (Leonards & Scott-Samuel, 2005), and for fixations to be more frequent and last for longer to the left side. This may be due to right hemispheric superiority for face processing (Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997), or could reflect more domain general processing as a left eye movement bias has also been noted using non-face stimuli such as photographs of indoor and outdoor scenes (Foulsham, Gray, Nasiopoulos, & Kingstone, 2013; Nuthmann & Matthias, 2014). Alternatively it may, in part, be an artifact of the habituated left–right scanning direction practiced in the West for reading, writing and music, as this bias reduces in cultures where a right-left scanning is the norm (Megreya & Havard, 2011; Vaid & Singh, 1989).

Research investigating the link between biases of perception and attention during face processing is in its infancy. Some studies indicate that eye movements and the LPB appear to be associated when viewing faces. For example, it has been noted that when eye movements are not possible, due to viewing time being restricted, only 55% of gender judgments were based on the left side of the face (Butler & Harvey, 2006); however, when no limits to eye movements were imposed in a freeview condition 63% are based on the left side (Butler et al., 2005) which indicates that eye movements act to enhance the strength of the LPB. As the LPB is associated with greater activity and volume in RH structures (Kanwisher et al., 1997; McCarthy et al., 1997), and the LPB appears to be strengthened by eye movements, these findings potentially indicate that left lateral biases of attention and perception use the same neural circuits. However, the link between perceptual and eye movement biases during face processing is not conclusive. In a recent study

* Corresponding author at: School of Psychological Sciences and Health, University of Strathclyde, 40 George St, Glasgow, G1 1QE, Scotland, UK.
E-mail address: louise.williams@strath.ac.uk (L.R. Williams).

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chimeric and whole faces were presented individually at the top, bottom, left or right of screen, rather than in the centre as with Butler's various experiments (Samson, Fiori-Duharcourt, Doré-Mazars, Lemoine, & Vergilino-Perez, 2014). When one saccade was permitted an LPB was only apparent for the face presented at the top of the screen and analysis of eye gaze revealed a right bias for the face presented on the left and a left bias for the face on the right. Consequently, gaze was biased to the side of the face closest to the centre of the screen and no direct link between perception and eye movements was established. As with Butler et al. (2005), Samson and colleagues investigated eye movements when the decision was based on the left and right side. A similar number of saccades were made to each side irrespective of the side used for a decision and as such their results demonstrate no consistent association between lateral biases of perception and attention.

Although the association between perceptual and eye movement biases appears somewhat equivocal, the LPB is a robust phenomenon considered to reflect right hemisphere superiority for face processing (Kanwisher et al., 1997; McCarthy et al., 1997) and support for this view is found from studies of patients who have sustained right hemispheric trauma. These patients consistently reveal deficits in face processing which are not detected in left hemisphere damaged patients (Bava, Ballantyne, May, & Trauner, 2005; Kolb, Milner, & Taylor, 1983). However, it has been argued by Cabeza (2002) and Park and Reuter-Lorenz (2009), that ageing impacts on lateralized hemispheric specialties such as face processing. Cabeza et al. (1997) noted that in functional neuroimaging studies of participants conducting verbal recall tasks – a task typically dominated by the right hemisphere – the prefrontal cortex was more bilaterally activated in older adults. The interpretation offered by Cabeza et al. is that this indicates functional compensation in later life and this forms the basis of the Hemispheric Asymmetry Reduction in OLDer adults (HAROLD) model (Cabeza, 2002). Cabeza also argues that the HAROLD model could be extended to include temporal and parietal regions because face matching (Grady, McIntosh, Horwitz, & Rapoport, 2000) and face recognition (Grady, Bernstein, Beig, & Siegenthaler, 2002) studies reveal greater bilateral activity in these areas in older compared to younger adults. The Scaffolding Theory of Ageing and Cognition (STAC) proposed by Park and Reuter-Lorenz (2009) similarly predicts that a wider, more generalised processing network across both hemispheres acts to scaffold or support specialist processing regions in an adaptive brain. Consequently, as these two models are aligned in predicting greater symmetrical processing across both hemispheres in healthy older adults, such adults may also demonstrate more symmetrical eye movement patterns and perceptual judgments than young adults when completing face processing tasks, particularly if these two processes rely on the same neural circuits.

To date no studies have assessed the impact of ageing on lateral eye movement biases, and the few studies that have examined the effect of ageing on perceptual biases have produced somewhat mixed evidence. For example, when Levine and Levy (1986) and Moreno, Borod, Welkowitz, and Alpert (1990) asked older and younger participants to judge the emotional intensity of happy/neutral chimeric faces, no significant age differences in LPB were revealed. All age groups demonstrated a bias to the left. Similarly, it has been found (Coolican, Eskes, McMullen, & Lecky, 2008) that both younger and older adults demonstrated an LPB to happy/neutral chimeric images with no significant difference in the strength of bias between the groups. However, in contrast when participants aged 20 to 70 years judged the emotional intensity of happy/neutral chimerics, it was the oldest adults who demonstrated the weakest LPB, although non-significantly so (Cherry, Hellige, & McDowd, 1995). This trend was more recently echoed in Failla, Sheppard, and Bradshaw's (2003) study. They found that from a group of participants aged 5–70 years, only those in the oldest group did not demonstrate an LPB. The same effect has also been revealed with older (mean age 72) and younger participants (mean age 22) in a study employing gender chimerics, particularly when task difficulty was increased through limiting the viewing time (Butler & Harvey, 2008).

Additionally, the strength of LPB appears to vary across the general population as up to 45% of gender judgments have been noted to be based on the right side (Butler & Harvey, 2006). Similarly, the leftward bias for eye movements is not revealed in all participants as some researchers have found approximately 34% of initial saccades are made to the right when faces are viewed (Guo, Smith, Powell, & Nicolls, 2012). Indeed Leonards and Scott-Samuel (2005) found that approximately 40% of their participants made initial saccades to the right when viewing faces. Some researchers report an association between leftward facial judgments and leftward eye movements (Butler et al., 2005) while others do not (Samson et al., 2014) and no exploration of right perceptual bias (RPB) and eye movements during facial analysis has been documented.

We sought to shed light on these inconsistencies by using eye-tracking to provide a more detailed analysis of face processing differences in older and younger adults and to investigate whether people demonstrating a RPB also demonstrate a right eye movement bias. Using chimeric faces, we asked participants to judge each image's gender either in a limited or unlimited time condition. In addition to analysing participants' perceptual biases, we measured the direction of their initial saccade and the proportion and duration of fixations to each face side. Using faces presented centrally on screen, we predicted that an association between the LPB and left eye movement bias would be revealed, such that people who based their gender judgment on the left side of the chimeric face would also generate initial saccades, proportionally more fixations and fixations of greater duration to the left side too. Due to age-related reductions in hemispheric asymmetries, we also predicted that age would weaken the LPB, the overall number of leftward eye movements and the length of time spent looking to the left face side. Additionally, based on Butler and Harvey's (2008) findings, we anticipated that the greater demand imposed by limiting the viewing time would have a bigger impact on the older group, as speed of processing reduces in later life (Habekost et al., 2013). Consequently, when viewing time was limited, we anticipated that older adults would reveal a further weakening of their left perceptual and eye movement biases compared with younger adults. A final goal was to determine whether the associations between perception and eye movements for participants demonstrating a RPB mirrored the relationships shown by those with LPB.

2. Method

2.1. Participants

To minimise the effects of fatigue and learning, separate cohorts were recruited for each of the time conditions.

2.1.1. Freeview condition

Sixty three right handed adults participated in this condition, 31 older adults (7 males) with a mean age of 65.10 ($SD = 4.28$, range 60–84 years) and 32 younger adults (9 males) with a mean age of 19.47 ($SD = 2.30$, range 18–28 years). Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed group differences with older adults demonstrating higher right laterality ($M = 93.45$, $SD = 10.27$) than younger adults ($M = 86.63$, $SD = 13.33$, $t(61) = -2.27$, $p = .027$). National Adult Reading Test (NART; Nelson, 1982) results also indicated group differences with older adults scoring higher ($M = 37.87$, $SD = 8.90$) than younger adults ($M = 26.88$, $SD = 5.60$, $t(50.25) = -5.85$, $p < .001$), although no group differences were revealed for years spent in full time education for older ($M = 15.26$, $SD = 3.47$) or younger adults ($M = 14.22$, $SD = 1.64$, $t(42.45) = -1.51$, $p = .138$).

2.1.2. Time limited condition

Fifty two participants were initially recruited for this viewing condition; however, data from three older adults were removed due to