THE UPPER-HEMIFIELD ADVANTAGE FOR MASKED FACE-PROCESSING:

NOT JUST AN ATTENTIONAL BIAS*

Genevieve L. Quek[a,b,c] & Matthew Finkbeiner[a,b,c]

[a] Department of Cognitive Science, Macquarie University
[b] ARC Centre of Excellence in Cognition and its Disorders (CCD)
[c] Perception and Action Research Centre (PARC), Macquarie University
Level 3, Australian Hearing Hub, 16 University Avenue
North Ryde, NSW, 2109
Sydney, Australia

*Correspondence should be directed to:

Genevieve Quek[1]

genevieve.lauren.quek@gmail.com

[1] Present address:
Université catholique de Louvain (UCL)
10, Place du Cardinal Mercier
1348 Louvain-La-Neuve, Belgium
Phone: +32(0)493113662

1.   Abstract

Recent evidence suggests that face-processing may be more robust in the upper visual field (UVF) than in the lower visual field (LVF; see Quek & Finkbeiner, 2014). We asked whether this UVF advantage is due to an upward bias in participants' visuospatial attention. Participants classified the sex of a UVF or LVF target face that was preceded by a congruent or incongruent masked prime face. We manipulated spatial attention within subjects by varying the predictability of target location across sessions (UVF:LVF ratio of 50:50 on Day 1 and 20:80 on Day 2). When target location was unpredictable, priming emerged earlier in the UVF (~165ms) than the LVF (~195ms). This UVF advantage was reversed when targets were more likely to be presented in the LVF. Here priming arose earlier for LVF targets (~53ms) than UVF targets (~165ms). Critically, however, UVF primes were processed to the same degree regardless of whether spatial attention was diffuse (Day 1) or deployed elsewhere (Day 2). We conclude that, while voluntarily directed spatial attention is sufficient to modulate the processing of masked faces in the LVF, it is not sufficient to explain the UVF advantage for masked face processing.

Keywords: Attention, faces, vertical asymmetry, upper visual field, lower visual field

2. Introduction

Human visual perception is not uniform across the retinal field, but, rather, is characterised by perceptual asymmetries arising from the brain's preferential response to particular stimulus types at different retinal locations. Investigations of *vertical asymmetry* in visual perception have historically favoured the lower visual hemifield relative to the upper visual hemifield. For example, spatial resolution (Talgar & Carrasco, 2002) and contrast sensitivity (Carrasco, Penpeci-Talgar, & Cameron, 2001; Skrandies, 1987) are enhanced in the lower visual field (LVF) compared to the upper visual field (UVF), with this asymmetry being most pronounced at the vertical meridian (Carrasco et al., 2001; Talgar & Carrasco, 2002). Performance is also typically better in the LVF on tasks of hue discrimination (Levine & McAnany, 2005), perception of illusory contours (Rubin, Nakayama, & Shapley, 1996), motion processing (Amenedo, Pazo-Alvarez, & Cadaveira, 2007; Edwards & Badcock, 1993; Levine & McAnany, 2005), global processing (Christman, 1993), and perception of coordinate spatial relationships (Niebauer & Christman, 1998). There are select tasks which exhibit a UVF advantage, however, including visual search (Chaiken, Corbin, & Volkmann, 1962; Fecteau, Enns, & Kingstone, 2000; Previc & Blume, 1993; Previc & Naegele, 2001; Yund, Efron, & Nichols, 1990), local processing of hierarchical stimuli (Christman, 1993), perception of apparent distance (Levine & McAnany, 2005), and categorical judgements of position (Niebauer & Christman, 1998).

While vertical visual asymmetries are well-documented for a range of low-level perceptual stimulus types, it is only recently that researchers have extended this line of enquiry to include higher-level visual representation. Kravitz, Kriegeskorte, and Baker (2010) used fMRI to show that object representation in several object selective regions is constrained by vertical position. Critically for the present case, they observed an UVF bias for object representation in the left and right posterior fusiform areas, in that split half correlations

(Haxby et al. 2001) for these regions were strongest for object line drawings presented in the upper hemifield. Consistent with this report, there is now a burgeoning body of work which suggests the processing of faces – arguably one of the most important types of object we encounter in the visual world - may enjoy an *upper-hemifield advantage*. For example, Felisberti and McDermott (2013) have reported that participants are able to recognise previously seen faces better when those faces are initially encoded in the upper-hemifield rather than the lower-hemifield. Within the neurophysiological literature, Liu and Ioannides (2010) have shown that magnetoencephalography (MEG) peaks elicited by emotional faces in regions such as the medial prefrontal cortex (MPFC), left fusiform face area (FFA), and left occipital face area (OFA) arise earlier for faces presented in the UVF compared to the LVF. Most recently, we used masked priming to show that that the UVF exhibits a clear behavioural advantage for face-sex categorisation (Quek & Finkbeiner, 2014). Participants in our study categorised the sex of a target face by reaching to either the left or right edge of a computer monitor. The target face could appear in either the upper or lower visual field and was preceded by a nonconscious masked prime face of either the same or opposite sex (i.e., congruent or incongruent). Despite being outside participants' conscious awareness, these masked prime faces nevertheless exerted a strong influence on participants' classification of the target faces, in that the participants reached towards the correct response panel *faster* when the prime and target were associated with the same sex-categorisation response (i.e., the congruent condition). Importantly, we found that this index of nonconscious face-processing (termed the masked congruence effect, or MCE) arose earlier in time when the prime and target faces appeared in the UVF compared to the LVF. Moreover, we observed a differential benefit of attentional cueing between the vertical hemifields. Where the MCE elicited by faces in the lower-hemifield depended on a valid spatial cue (i.e., no priming without spatial attention), the emergence of the MCE in the upper-hemifield was unaffected by spatial

cueing, suggesting that masked prime faces presented above-fixation were processed irrespective of spatial attention's locus (see Finkbeiner & Palermo, 2009 for a similar finding with masked UVF primes).

Although not all studies of face-perception across the visual field have observed stable biases across individuals (Afraz, Pashkam, & Cavanagh, 2010), on balance the evidence suggests that the visual system is able to process face information *more efficiently* at locations above-fixation compared to below. What is not yet established, however, is why this might be the case. A possible explanation that we explore in the present paper is that the upper-hemifield advantage in face-processing arises due to an upward bias in voluntarily directed spatial attention. We are not the first to appeal to the tendency to divide attention unevenly across the visual field as a potential explanation for vertical asymmetry in visual perception. Rezec and Dobkins (2004) proposed that an "attentional weighting" favouring the *lower hemifield* might explain the LVF advantage they observed in motion and orientation discrimination. Interestingly, however, there is some suggestion that biases in spatial attention may depend on stimulus type. For example, studies involving vertical line bisection (Bradshaw, Nettleton, Nathan, & Wilson, 1985; Drain & Reuter-Lorenz, 1996; van Vugt, Fransen, Creten, & Paquier, 2000), object matching (Chambers, McBeath, Schiano, & Metz, 1999), and mental scene representation (Drummond & Tlauka, 2012) suggest an *upward* bias in spatial attention. Importantly for the present case, there are good reasons to think participants may be particularly prone to favouring the UVF in the context of face-perception, as this region of space often carries important face information during real world interactions. We tend to encounter human faces more frequently in the UVF, as this region corresponds to extrapersonal space (Previc, 1999). Eye gaze, a potent source of social information which guides adaptive behaviour (Hood, Willen, & Driver, 1998; Langton, Watt, & Bruce, 2000), is also typically contained within the top half of our visual field. Thus, it is reasonable to think

that participants in our previous study might have voluntarily attended to the upper hemifield even while maintaining central fixation, resulting in both the earlier emergence of priming in the (attended) UVF, and the lack of an exogenous cueing effect in this region (Quek & Finkbeiner, 2014).

If an upward bias in voluntarily directed spatial attention does indeed explain the UVF face-processing advantage, then manipulating participants' endogenously oriented spatial attention *away* from the UVF (i.e., towards the LVF) should attenuate the UVF advantage evident in the timecourse of the MCE for faces. To test this hypothesis, we adapted our previous design known to yield both robust masked priming effects and a clear UVF advantage for face-sex categorisation (Quek & Finkbeiner, 2014). We manipulated participants' endogenous attention to the vertical hemifields by varying the probability of UVF and LVF targets across days. On Day 1, the ratio of UVF targets to LVF targets was 50:50, such that target location was entirely unpredictable for participants. In contrast, on Day 2, targets appeared in the LVF on 80% of trials (20:80 UVF to LVF ratio). We reasoned that participants would be sensitive to this increased probability of LVF targets and would consequently direct their spatial attention towards the lower-hemifield after a period of learning. Our predictions were as follows. For Day 1 (50:50 target location ratio), we expected the MCE would be superior for UVF prime–target pairs than for LVF prime–target pairs, replicating the UVF advantage for face-sex categorisation we have shown previously (Quek & Finkbeiner, 2014). For Day 2 (20:80 target location ratio), we predicted that masked face-processing below-fixation would be facilitated by participants voluntarily directing spatial attention towards this hemifield. That is, we expected the priming effect for the LVF would be equivalent to, or perhaps even superior to, the UVF priming effect from the same day. The question of critical interest was what impact our manipulation of endogenous attention on Day 2 would have on the priming effect for the *UVF*. If the documented UVF

advantage for subliminal face-processing should be attributed to an upward bias in participants' spatial attention, then the MCE elicited by UVF faces should suffer when participants direct their spatial attention to a different location. That is, in the measure to which the UVF advantage is due to focused spatial attention, then the redeployment of that focused spatial attention to the LVF should yield both increased performance in the LVF and a cost to the priming effect in the UVF.

Before undertaking this planned design, however, we wanted to first take account of the fact that our manipulation of target location probability across days would not allow us to counterbalance the order of conditions across participants. All participants would need to complete the conditions in a fixed order (50:50 on Day 1, 20:80 on Day 2), to ensure that the location probability learned during the 20:80 condition would not carry over and influence participants' approach to the 50:50 version of the task. Consequently, we are faced with the possibility of an artefact in this design: namely, participants would be highly practiced during the 20:80 condition on Day 2, and less so during the 50:50 condition on Day 1. Thus, if we were to observe the predicted enhancement of the priming effect in the 20:80 condition on Day 2, one could argue that this was due to participants' performance simply improving over time as opposed to the redeployment of spatial attention. To rule out this possible explanation of our predicted results, before embarking on the experiment proper we ran an initial control experiment in which the target location probability was held constant at 50:50 across both testing days. If the properties of the masked congruence priming in the LVF are sensitive to the effects of practice, then we would expect to see differences in either the magnitude or onset of the MCE (or both) across days. To anticipate our results of this initial control experiment, the MCE did not vary across days in either hemifield, suggesting this index of face-processing to be robust to the effects of practice.

3. Experiment 1

Our goal in Experiment 1 was to determine whether the masked congruence priming effect (particularly in the LVF), would improve as a function of exposure to the task. Participants attended two testing sessions within a three day period (i.e., the second session occurred either one or two days after the first). The task on each day was identical: classify the sex of the target face by reaching out to touch a response panel at the left or right edge of the screen. We used a fully crossed factorial design with the factors Visual Field (UVF vs. LVF) and Prime Type (congruent vs. incongruent). Importantly, this design was identical to the one planned for Experiment 2 (e.g. same number of trials, etc.), save that the predictability of the target's location did not vary across days. That is, the ratio of UVF to LVF targets was 50:50 on both Day 1 and Day 2. If the MCE is indeed sensitive to the effects of practice, then we should observe a stronger priming effect on Day 2 compared to Day 1.

3.1. Experiment 1 Methods

3.1.1. Participants

A group of 14 individuals (seven males) gave informed consent to participate in Experiment 1 for financial compensation. All participants had normal or corrected-to-normal vision, and were identified as strong right handers using the Edinburgh Handedness Inventory (Oldfield, 1971). The mean age was 26.5 years.

3.1.2. Stimuli & Apparatus

Targets were five neutral faces of each sex drawn from the Psychological Image Collection at Stirling database (PICS, http://pics.psych.stir.ac.uk/), cropped to exclude the facial contour. No face contained obvious sex indicators (e.g. facial hair). Distractors were 10 animal images presented within a similar cropped oval, one of which was selected at random on each trial. We used the SHINE toolbox written for Matlab to adjust the 10 target and 10

distractor items so that their mean luminance and contrast values were comparable (Willenbockel, Sadr, Fiset, Horne, Hosselin, & Tanaka, 2010). We then used the same procedure to prepare an additional two faces (one male, one female) and two additional animal images to serve as masked primes and masked foils respectively. These stimuli were considered "novel", in that they never appeared under unmasked conditions. The backward mask on each trial was randomly selected from a group of 10 possible scrambled face images of the same mean luminance and contrast. All stimuli were 75×100 pixels and subtended 3.44×4.58 degrees of visual angle from a viewing distance of 65cm. Response panels marked "M" and "F" remained at the left and right edge of the screen throughout the trial; we counterbalanced the order of these positions across participants. We recorded each participant's reaching trajectories by fitting the their right hand with two light emitting diode (LED) markers and sampling the position of these markers every 5ms with an OptotrakCertus® motion capture system.

3.1.3. Procedure & Design

Participants completed the two separate testing sessions within a three day time period. The testing procedure was identical on both days. The participant sat in a dark room before a table with a touchscreen monitor fixed 50cm from the front edge. Figure 1 presents the visual trial structure. Each trial frame consisted of two 75×100 pixel panels, vertically displaced around a central fixation dot. We instructed participants to maintain their fixation on this central dot throughout the trial and reminded them of this between each block of trials. The trial commenced when the participant used their right index finger to depress a "start button" aligned with the body midline at the front of the table. The first frame contained identical chequerboard forward masks in each panel. After a variable duration, the prime face then appeared in either the upper or lower panel, accompanied by an animal foil in the opposite location. After 50ms, the target face replaced the prime face at the same location

and was accompanied by a randomly selected animal distractor in the opposite panel. After 100ms, identical randomly selected backward masks onset in both panels and remained onscreen until the participant completed their classification by touching one of the two response panels located at the left and right edge of the screen. These conditions – namely the short prime duration and immediate masking by the target face – effectively mask the prime face so that its identity is typically not available for conscious report (Quek & Finkbeiner, 2013, 2014). For the manipulation of vertical hemifield presentation, on each trial the prime–target pair could appear in either the UVF or LVF with equal probability (50:50 UVF to LVF target location ratio). The prime was either the same sex or opposite sex as the target (i.e., congruent or incongruent), with the degree to which the prime's sex modulated the sex-categorisation response to the target face serving as our index of nonconscious face-perception. On Day 1, participants completed two practice blocks (80 trials total) followed by six experimental blocks (240 trials total). On Day 2, they completed one practice block (40 trials total) followed by 15 experimental blocks (600 trials total). All practice trials were discarded from later analyses.
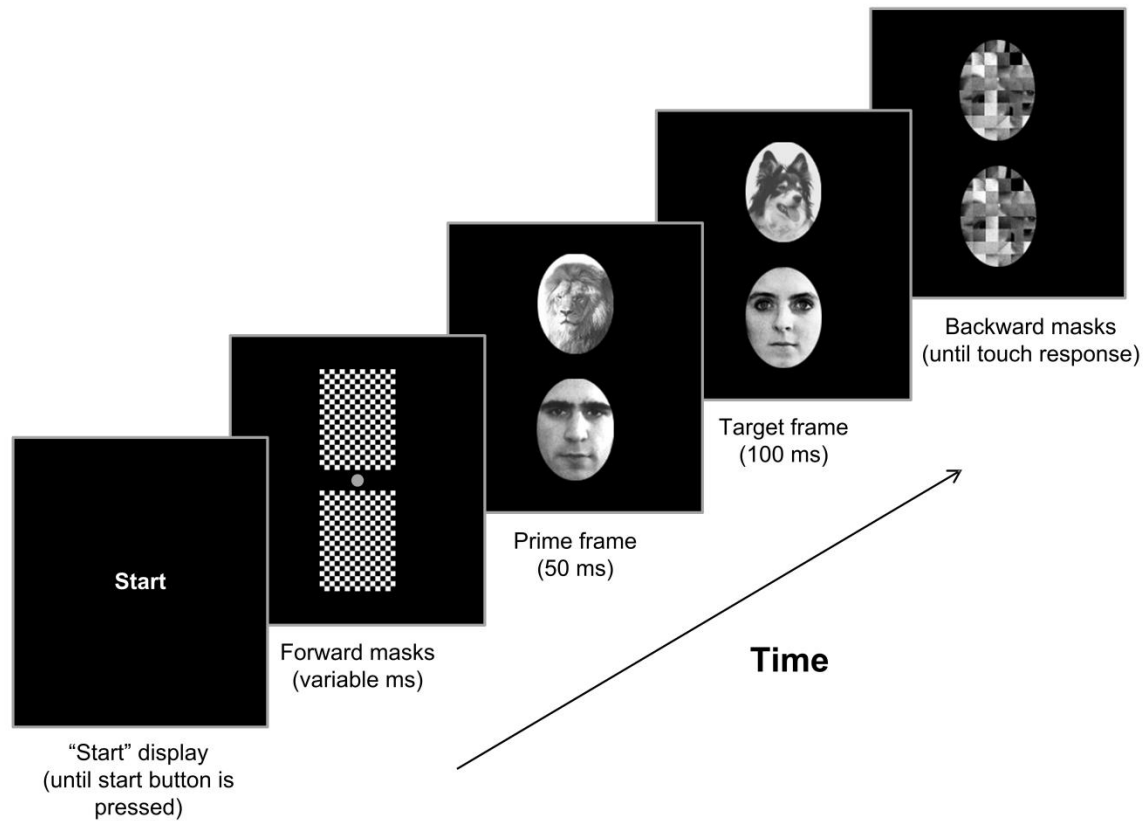
Figure 1. Visual trial structure for Experiments 1 & 2. Each trial frame consisted of two 75×100 pixel vertically displaced panels. The trial began when the participant depressed a start button aligned with the body midline at the front edge of the testing table. Participants saw an initial fixation frame containing two identical chequerboard masks and a central dot they were required to fixate on. After a variable duration, the prime face appeared in either the top or bottom panel for 50ms, accompanied by an opposite animal foil. The subsequent frame contained the to-be-categorised target face in the same location as where the prime had appeared, with another animal distractor in the opposite panel. After 100ms, backward masks onset in both panels and remained onscreen until the participant completed their classification response.

On each trial, the participant had over three seconds to freely adjust their reaching trajectory and finalise their classification of the target by touching either the left or right response panel. However, although participants could *complete* the reaching movement in their own time, we imposed strict parameters regarding when they should *initiate* the movement. We required participants to begin reaching in response to an auditory go-signal on each trial - the third tone in a series of three ascending beeps (see Finkbeiner, Coltheart, & Coltheart, 2014; Quek & Finkbeiner, 2014). The position of this go-signal varied in time with respect to target onset, such that on any trial the third beep could occur at one of five randomly selected durations following target onset (0ms, 75ms, 150ms, 225ms, or 300ms). We defined Movement Initiation Time (MIT Latency) as the time in milliseconds from target onset until the finger's velocity reached 10cm/second. We allowed MIT latencies up to 100ms before and 200ms after the beep signal. If the participant began their reaching movement outside this critical window, they received negative auditory (a loud buzz) and visual feedback (e.g. "Too Early!"), and the trial was aborted and cached for re-presentation at the end of the block. Trials with response-window failures during the re-presentation stage were removed from all subsequent analyses (11.37% of all trials).

As in our previous study, we assessed the visibility of the masked prime items using a two alternative forced-choice (2AFC) prime detection task (conducted at the conclusion of the Day 2 testing session). This prime-visibility test included 160 trials which were identical to those used in the experiment proper, save that after reaching out to classify the target face, participants saw two faces (the real prime and a lure) and had to indicate which of them had been the prime on that trial. This prime-identification response was untimed, and position of the real prime and lure was counterbalanced across trials. Importantly, we instructed participants to maintain the same strategy for these prime-identification trials as they used in the experiment proper.

3.1.4. Analysis Methods

Data preparation. To prepare the reaching trajectories for analysis, we selected the 450 *xyz* samples between the points corresponding to 100ms *before* movement onset, and 2150ms after movement onset[2]. At each sample within this epoch, we calculated <u>*x*-velocity</u> – a signed value which reflects the finger's velocity along the *x*-axis. Because participants indicate their sex-categorisation decision along this left-right dimension (e.g. left for male; right for female), *x*-velocity at any given sample represents the finger's velocity *in the correct direction.* Positive *x*-velocity values indicate the finger is moving towards the correct response panel, and negative *x*-velocity values indicate that the finger is heading *away* from the correct response panel (i.e., in the incorrect direction). We smoothed the *x*-velocity profiles using a modified version of the Orthogonal Polynomial Trend Analysis (OPTA) procedure (Karayanidis, Provost, Brown, Paton, & Heathcote, 2011; Woestenburg, Verbaten, & Slangen, 1983), the details of which have been extensively reported elsewhere (Finkbeiner, Coltheart, & Coltheart, 2014; Quek & Finkbeiner, 2013; 2014). As a final step, we averaged across the initial 300ms of the reaching movement to produce a single representative value for each trial termed <u>initial *x*-velocity</u>. We limited our dependent measure to the initial segment of the trajectory because this initial portion best reveals the motor plan that participants had formulated just prior to movement initiation. This is important since we are interested in comparing the way in which participants' responses develop with stimulus-viewing time across different experimental manipulations. In the present case, the masked congruence effect (MCE) is reflected in higher initial *x*-velocities on congruent trials than

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[2]   We included the 100ms leading up to movement onset to ensure that we considered the very start of the reaching movement on each trial. For instances in which the participant's reaching movement concluded sooner than 2150ms after movement onset, we repeated the *xyz* coordinates from the final sample to make up the full number of samples for that trial.

incongruent trials. This pattern is analogous to the MCE reflected in RT data (e.g. Finkbeiner & Palermo, 2009; Naccache, Blandin, & Dehaene, 2002), in that just as participants in button-press priming studies tend to press the correct button faster on congruent trials than incongruent, here participants move in the correct direction faster when the prime and target are associated with the same classification response.

Statistical Analyses. We analysed all data using custom software written in R (www.r-project.org), implementing linear mixed-effects modelling (LMM, cf. Baayen, Davidson, & Bates, 2008; Bates, 2005) using the lmer4 package (http://lme4.r-forge.r-project.org, Bates, Maechler, & Bolker, 2011). We evaluated the reliability of each effect of interest using an incremental model comparison procedure in which we used goodness-of-fit statistics (AIC, BIC, and Log Likelihood values, see Akaike, 1974; Schwarz, 1978) to determine which of two models fit our data better – a model which included the term under inspection, or the same model without this term. For each comparison, we selected the model which a) minimised AIC and BIC, and b) maximised the Log Likelihood. Below we report the results of this Likelihood ratio test and, where appropriate, also report the coefficients, standard errors (SE), and *t*-values for terms included in the final model selected. Our criterion for significance for individual fixed effects was an absolute *t* ratio of 2.0, as per Kliegl, Masson, and Richter (2010). Although the degrees of freedom are not known exactly in LMM, the very large number of observations in the datasets used here and elsewhere mean that the *t* distribution converges to the normal distribution. Thus, the criterion cutoff of two SEs corresponds well to the .05 significance criterion (see Finkbeiner et al., 2014; Kliegl et al, 2010; Masson & Kliegl, 2013; Quek & Finkbeiner, 2013; 2014).

3.2.   Experiment 1 Results

3.2.1.   Accuracy

The mean classification accuracy for Experiment 1 was 85.5%. LMM analysis confirmed that a model including random slopes between Participant and Prime Type fit the binomial accuracy data better than a model including only random intercepts for Participant, $\chi^2(2) = 155.82$, $p < .001$. We then verified that including the fixed effects of Prime Type, $\chi^2(1) = 18.27$, $p < .001$, Visual Field, $\chi^2(1) = 72.74$, $p < .001$, and <mark>Day</mark>, $\chi^2(1) = 28.80$, $p < .001$ also improved the model's fit. As may be seen in Figure 2a, there was a strong MCE reflected in classification accuracy, in that participants were more likely to classify the target's sex correctly on congruent trials as compared to incongruent trials ($b = -0.74$, $SE = 0.12$, $z = -6.06$, $p < .001$). Target classification was also more likely to be accurate for UVF trials than for LVF trials ($b = -0.43$, $SE = 0.05$, $z = -8.48$, $p < .001$) (see Figure 2b), and on Day 2 compared to Day 1 ($b = 0.31$, $SE = 0.06$, $z = 5.45$, $p < .001$) (see Figure 2c). Importantly, none of the two- or three-way interactions between these three experimental factors improved the model's fit ($p > .05$ in all model comparison cases), indicating the best model of the accuracy data to be an additive one.
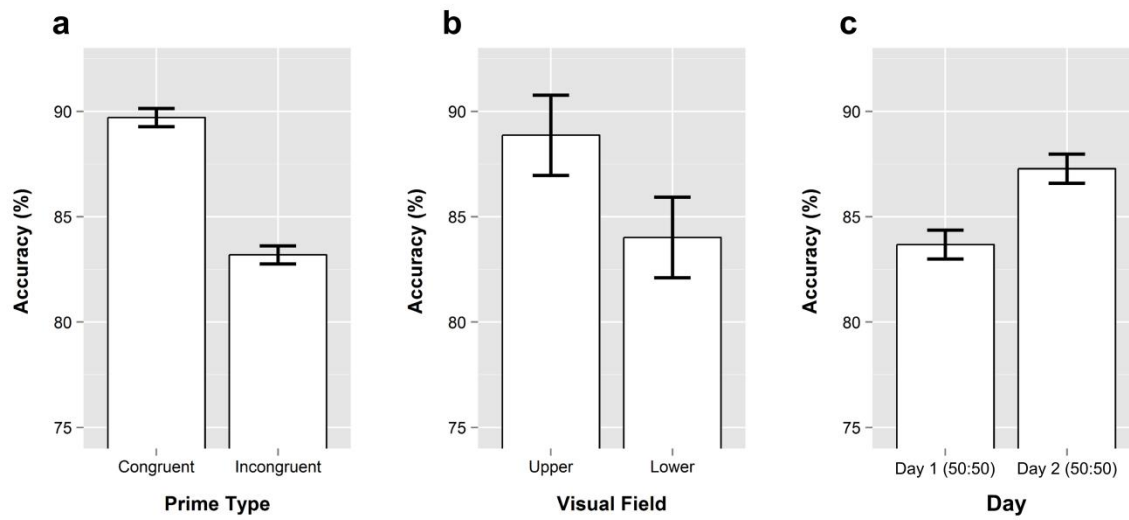
Figure 2. Experiment 1 accuracy rates as a function of a) Prime Type, b) Visual Field, and c) Day. Target classification was significantly more likely to be accurate when primes were congruent compared to incongruent; when the prime–target pair appeared in the UVF compared to the LVF; and on Day 2 compared to Day 1. No interactions between these factors were reliable. Most importantly for our purposes here, our index of nonconscious face-processing – the masked congruence effect (MCE) – did not vary significantly across the testing days. Error bars are within-subjects standard error.

3.2.2. Initial *x*-velocity

The analysis procedure described above yielded 11,940 initial x-velocity values from 14 participants. We used LMM to firstly determine that a model with random slopes between Prime Type and Participant fit the initial x-velocity data better than one with only random intercepts for Participant, $\chi^2(2) = 1544.99$, $p < .001$. Including the fixed effect of Prime Type also significantly improved the model's fit, $\chi^2(1) = 10.13$, $p < .005$. Just as with the accuracy data, there was a strong MCE evident in initial x-velocity, which was higher on average for congruent trials than incongruent trials ($b = -25.09$, $SE = 6.57$ $t = -3.82$). While the fixed effect of Visual Field did not significantly improve the fit of the model, $\chi^2(1) = 0.40$, $p = .527$, we nonetheless retained this term in the model so as to inspect its interaction with other factors. This effect was reliable in the context of the final fitted model, however, with initial x-velocity observed to be higher on UVF trials than on LVF trials ($b = -8.41$, $SE = 1.87$, $t = -4.50$). Including the fixed effect of Day improved the model, $\chi^2(1) = 91.53$, $p < .001$, with the final estimates indicating that initial x-velocity was higher on Day 1 than on Day 2 ($b = -12.13$, $SE = 1.63$ $t = -7.46$). Importantly for our purposes here, the interaction between Prime Type and Day did not improve the fit of the model, $\chi^2(1) = 0.27$, $p = .603$, suggesting that the MCE evident in the initial stages of participants' reaching responses did not change as a function of exposure to the task. In contrast, there was a significant interaction between Prime Type and Visual Field, $\chi^2(1) = 9.60$, $p < .01$. We followed this up by conducting a paired *t*-test between the congruent and incongruent conditions in each Visual Field (*p* values corrected using the False Discovery Rate, FDR). As can be seen in Figure 3, there was a significant MCE in both the upper-hemifield ($t(13) = 3.80$, $p < .005$, *Pearson's r* = .73) and lower-hemifield ($t(13) = 3.10$, $p < .01$, *Pearson's r* = .65). However, as the MCE above-fixation was *larger* than the MCE below-fixation (25.97 mm/second vs. 20.65 mm/second).
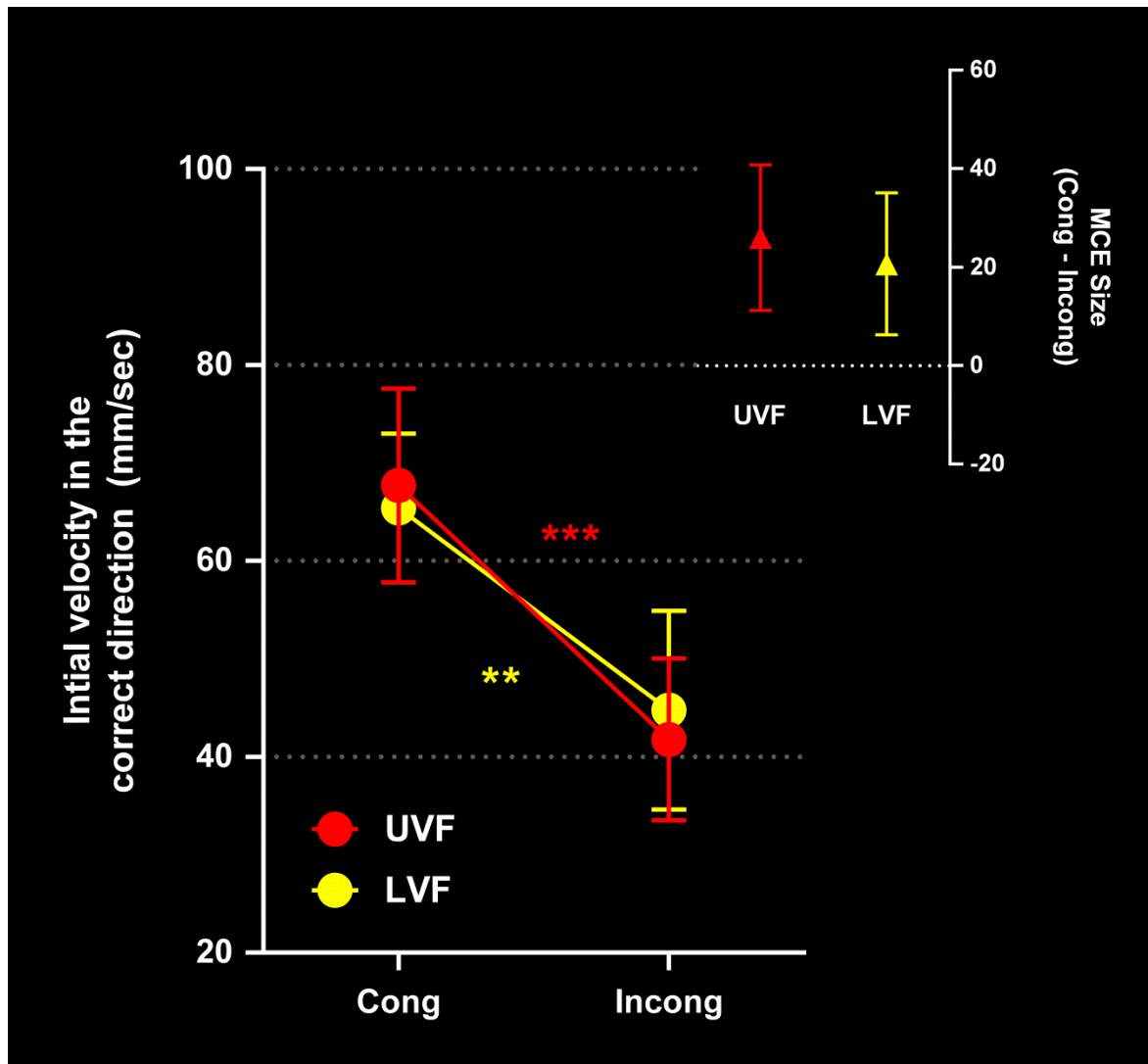
Figure 3. Initial *x*-velocity for Experiment 1 as a function of Prime Type and Visual Field. Initial *x*-velocity reflects the finger's velocity in the correct direction during the initial 300ms of the reaching movement. Although the MCE (evident in the slope of the lines) was reliable in both the UVF and LVF, a significant interaction between Prime Type and Visual Field indicated this priming effect to be larger in the UVF (red points) than in the LVF (yellow points). *$p < .05$; **$p < .01$; ***$p < .005$; ****$p < .001$ (two tailed paired *t*-tests, FDR corrected). Error bars are 95% within-subjects confidence intervals (WSCIs). **Inset:** Since there is no rule-of-eye for interpreting overlap between WSCIs (see Cumming & Finch, 2005), we here depict the 95% WSCI around the mean of the congruent – incongruent difference scores for each of the vertical hemifields. Note that the 95% WSCI for each visual field excludes zero, indicating there was a reliable MCE in both hemifields.

We also observed a significant Visual Field by Day interaction, $\chi^2(1) = 13.40$, $p < .001$. On Day 1, initial x-velocity was numerically higher for the UVF than the LVF. The reverse pattern was true on Day 2, however follow up paired t-tests (FDR corrected) of the Visual Field effect on each Day indicated that neither difference was statistically reliable ($t < 1$ in both cases). Our final model comparison verified that including the 3-way interaction between Prime Type, Visual Field, and Day did *not* improve the model's fit of the initial x-velocity data, $\chi^2(1) = 2.20$, $p = .138$ (see Figure 4). As can clearly be seen in Figure 4C, the magnitude of MCE did not change from Day 1 to Day 2 for either the UVF or LVF. This suggests that participants' ability to extract sex-information from the masked prime faces *did not* improve as a function of exposure to the task (i.e., practice).
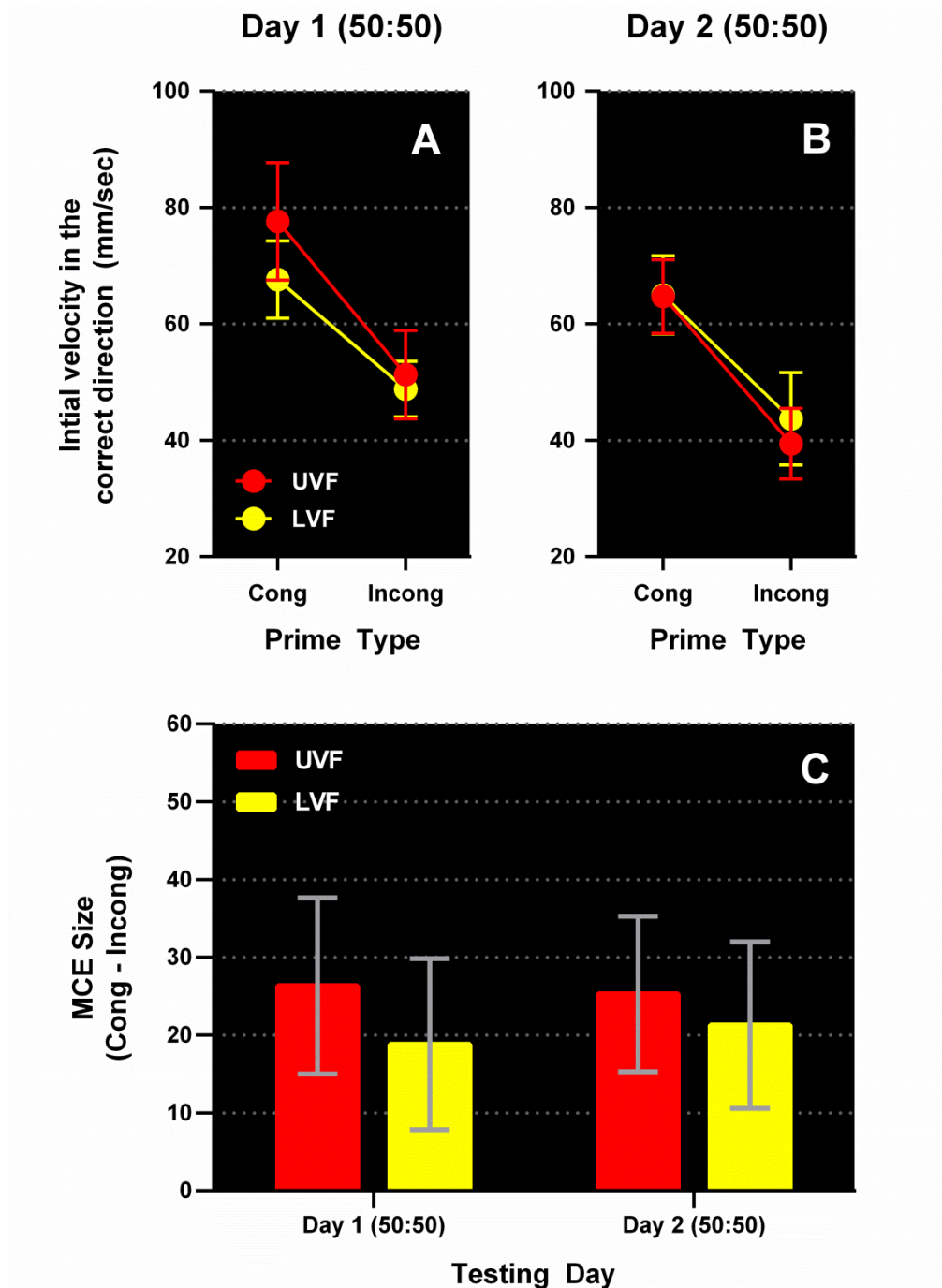
Figure 4. (A & B) Experiment 1 initial x-velocities shown as a function of Prime Type, Visual Field, and Day. The ratio of UVF:LVF targets was 50:50 on both days. The 3-way interaction here was *not* significant, suggesting the priming effect in each Visual Field was similar across days. (C) The size of the MCE (congruent – incongruent) for the UVF and LVF on each testing Day. Note that all 95% WSCIs exclude zero, indicating there was a reliable MCE in all conditions. The magnitude of the MCE in each visual field was constant from Day 1 to Day 2. Error bars are 95% WSCIs, thus inter-bar overlap should not be interpreted by eye (see Cummings & Finch, 2005).

3.2.3. Prime Detection

To assess prime visibility, we used the 2AFC prime detection data to calculate a hit rate, false alarm rate, and *d'* value for each participant. The mean *d'* value was 0.07. A one sample *t*-test confirmed that this was not significantly different from zero ($t(13) = 0.86$, *p* = .404, *Pearson's r* = .23), suggesting participants in Experiment 1 had minimal awareness of the masked prime faces.

3.3. Experiment 1 Discussion

We observed a strong masked congruence effect (MCE) in Experiment 1, in that participant's classification reaching movements were both more accurate and more efficient for targets preceded by congruent primes compared to incongruent primes (i.e., same rather than opposite sex). We also found clear evidence of an upper visual field (UVF) advantage for face-sex classification, in that participants were more accurate in categorising the sex of UVF targets compared to LVF targets. Moreover, although both UVF and LVF prime–target pairs yielded a significant MCE in participants' reaching data, the magnitude of this priming effect was *reliably larger in the UVF*. This suggests participants were able to process the sex information carried by the masked prime more efficiently when the prime appeared in the upper-hemifield compared to the lower-hemifield. Taken together, these results provide strong evidence for the emerging position in the literature that face-processing, and in particular face-sex categorisation, is superior in the upper-hemifield relative to the lower-hemifield (Liu & Ioannides, 2010; Quek & Finkbeiner, 2014). In addition, and importantly for Experiment 2, we also found that the priming effect reflected in both participants' accuracy and initial reaching movements did not differ significantly between testing days for either hemifield. This suggests that participants' ability to extract the task-relevant sex

information from masked faces did not improve as a function of exposure to the task (i.e.,

from the first to the second testing day).

4. Experiment 2

Armed with the knowledge that the MCE in our paradigm was not sensitive to the effects of practice across days, we were free to pursue the principle goal of the present study − to determine how voluntarily directed spatial attention would modulate the effect of vertical hemifield on masked face priming. Experiment 2 used an identical design to Experiment 1, save that here we manipulated target location predictability across days. On Day 1, the ratio of UVF to LVF targets was 50:50, such that target location was unpredictable to participants (just as in Experiment 1). On Day 2, however, we increased the ratio of LVF to UVF targets so that the target appeared below-fixation on 80% of trials. We reasoned that participants would be sensitive to this increased probability of LVF targets and, after a period of learning, would direct their attention to the lower-hemifield as a consequence. We predicted that covertly attending to the LVF would facilitate the priming effect in this hemifield, resulting in a stronger MCE for the LVF on Day 2 than on Day 1. Because we had already confirmed that the MCE in the LVF did not improve with task exposure in Experiment 1, we felt we would be able to attribute any improvement in the MCE in the LVF across testing days to our manipulation of target location probability, rather than simple practice effects. Of critical interest was what impact this manipulation would have on participants' ability to process masked prime faces *above-fixation*. If the UVF advantage we and others have observed for face-processing really is underpinned by an attentional bias towards the upper-hemifield, then a redeployment of spatial attention to the LVF should yield an enhanced MCE in the LVF and a diminished MCE in the UVF.

4.1. Experiment 2 Methods

4.1.1. Participants

We recruited a different group of 16 Macquarie University undergraduate students (seven males) to participate in Experiment 2 for course credit. All participants had normal or corrected-to-normal vision, and were identified as strong right handers using the Edinburgh Handedness Inventory (Oldfield, 1971). The mean age was 18.81 years.

4.1.2. Procedure & Design

We used the same stimuli, apparatus, trial structure, and testing procedure as described for Experiment 1. As before, we required participants to initiate their reaching movement in response to an auditory go-signal (the third beep in a series) which could occur either 0ms, 75ms, 150ms, 225ms, or 300ms after target onset. Participants completed 240 trials on Day 1 in which the prime and target faces appeared with equal probability (50%) in either the upper or lower panel. On Day 2, we included the same number of UVF trials as on Day 1 (i.e., 60 UVF-congruent, 60 UVF-incongruent), and included 480 LVF trials to yield a 20:80 ratio of UVF to LVF trials. There were 80 practice trials excluded from later analyses on Day 1, and 40 on Day 2. We assessed prime visibility at the end of the experiment proper on Day 2 using the same 2AFC task described for Experiment 1, in which we maintained the 20:80 UVF to LVF target ratio.

4.2. Experiment 2 Results

4.2.1. Accuracy

Prior to analysis we removed all trials on which movement error occurred (11.81% of trials). Mean classification accuracy following this was 89.45%. We then used LMM to

verify that a model including random intercepts for each Participant, as well as random slopes between Participant and Prime Type, fit the binomial accuracy data better than a model with only random intercepts for each participant, $\chi^2(2) = 414.38$, $p < .001$. Including the fixed effect of Day significantly improved the model, $\chi^2(1) = 40.96$, $p < .001$, in that there was a greater likelihood of participants classifying the target incorrectly on Day 2 than on Day 1 ($b = -0.35$, $SE = 0.10$, $z = -3.47$, $p < .001$). The inclusion of Prime Type also improved the model, $\chi^2(1) = 27.22$, $p < .001$, with a clear MCE reflected in participants' accuracy scores. Participants were significantly *less likely* to classify the target's sex correctly on incongruent trials ($M_{INCONG} = 86.95\%$) compared to congruent trials ($M_{CONG} = 96.22\%$) ($b = -1.58$, $SE = 0.19$, $z = -8.32$, $p < .001$). As in Experiment 1, the interaction between Prime Type and Day did not improve the model, $\chi^2(1) = 0.07$, $p = .786$, indicating that the effect of Prime Type did not vary from Day 1 to Day 2. Visual Field improved the model, $\chi^2(1) = 107.01$, $p < .001$, however, unlike in Experiment 1, this effect was qualified by testing Day, $\chi^2(1) = 59.78$, $p < .001$. To follow up this two-way interaction we ran FDR corrected paired *t*-tests between the UVF and LVF accuracy rates, separately for Day 1 and Day 2. As can be seen in Figure 5, when target location was unpredictable (i.e., Day 1), participants' classification accuracy was comparable between the upper ($M_{UPPER} = 88.84\%$) and lower visual fields ($M_{LOWER} = 89.43\%$), $t(15) = -0.24$, $p = .814$, *Pearson's r* = .06. In contrast, when participants could reliably expect the target to appear in the LVF (i.e., Day 2), classification accuracy was significantly higher in this region compared to the upper-hemifield ($M_{LOWER} = 94.38\%$ vs. $M_{UPPER} = 85.24\%$), $t(15) = -5.16$, $p < .001$, *Pearson's r* = .80. To verify that the increased accuracy in the LVF on Day 2 did *not* come at a cost to target classification in the UVF, we then broke the interaction down the opposite way. FDR corrected paired *t*-tests of the effect of Day for each Visual Field indicated that accuracy in the UVF was comparable between Day 1 and Day 2, $t(15) = 1.67$, $p = .155$, *Pearson's r* = .40 ($M_{Day1} = 88.84\%$ vs. $M_{Day2} =$

85.24%). In contrast, there was a significant improvement in accuracy for the LVF from Day

1 to Day 2, $t(15) = -2.68$, $p = .017$, *Pearson's r* $= .57$ ($M_{Day1} = 89.43\%$ vs. $M_{Day2} = 94.38\%$).
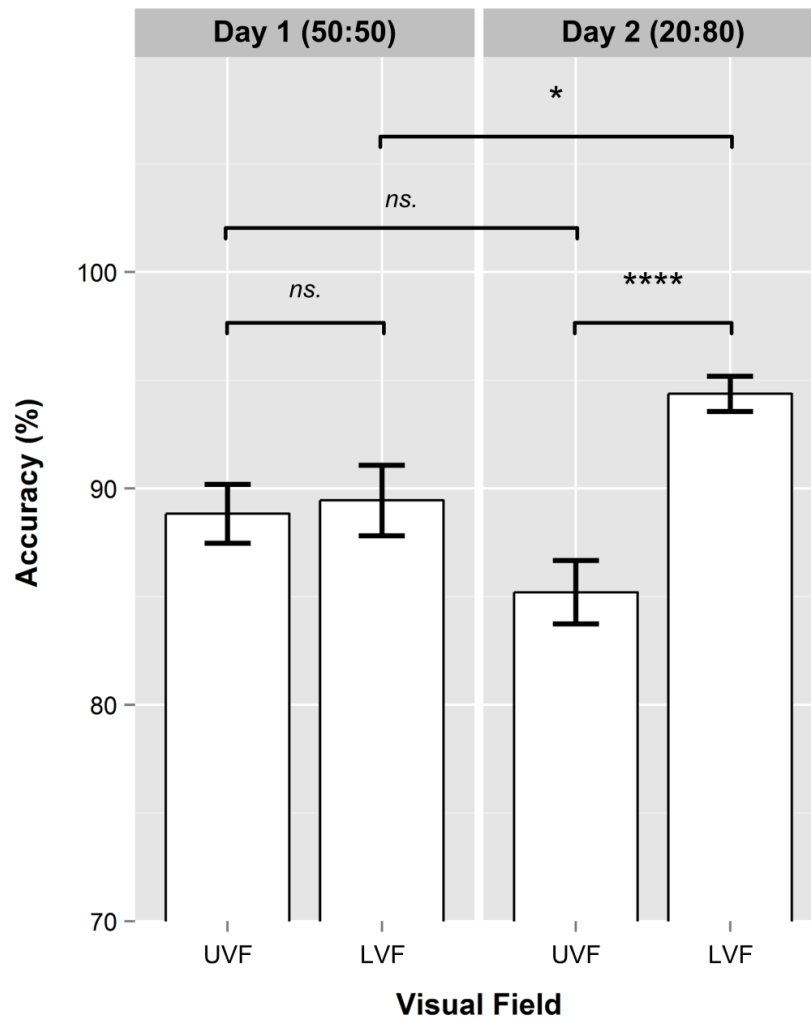

Figure 5. Mean accuracy rates for Experiment 2 as a function of Visual Field and Day. When

the ratio of UVF to LVF targets was 50:50 (Day 1), accuracy rates were comparable between the upper

and lower-hemifields. In contrast, when the UVF to LVF location ratio was 20:80 (Day 2), accuracy was

significantly higher in the LVF than in the UVF. This suggests our target location predictability

manipulation was successful in encouraging participants to voluntarily direct spatial attention to the LVF

on Day 2. Error bars are within-subjects standard error. *$p < .05$; **$p < .01$; ***$p < .005$; ****$p < .001$ (two

tailed paired *t-* tests, FDR corrected).

4.2.2. Initial x-velocity

As in Experiment 1, we calculated <u>initial *x*-velocity</u> by averaging the first 300ms of each smoothed *x*-velocity profile. Below we subject these initial x-velocities to statistical analysis, both a) averaged across target viewing time and then b) as a function of target-viewing time.

Analyses averaging across target-viewing time. To model initial x-velocity collapsing across target viewing times, we firstly verified that a model including both random intercepts for Participant and random slopes between Participant and Prime Type fit the data better than a model with only random intercepts $\chi^2(2) = 2354.22$, $p < .001$. There was a significant fixed effect of Prime Type, $\chi^2(1) = 13.97$, $p < .001$, in that initial *x*-velocity was higher for congruent trials compared to incongruent trials ($b = -27.82$, $SE = 7.33$, $t = -3.80$). The fixed effects of Visual Field, $\chi^2(1) = 83.00$, $p < .001$, and Day, $\chi^2(1) = 243.48$, $p < .001$, also improved the model's fit, with initial *x*-velocity being higher on average for UVF trials compared to LVF trials ($b = -3.05$, $SE = 2.08$, $t = -1.46$), and on Day 2 compared to Day 1 ($b = 14.67$, $SE = 2.10$, $t = 7.00$). Regarding 2-way interactions, including the Prime Type × Visual Field interaction did not improve the model's fit, $\chi^2(1) = 1.82$, $p = .177$, however both the Prime Type × Day and Visual Field × Day interactions did, $\chi^2(1) = 42.29$, $p < .001$ and $\chi^2(1) = 5.81$, $p < .05$ respectively. Critically, and in contrast to Experiment 1, including the 3-way interaction between Prime Type, Visual Field, and Day also significantly improved the model of Experiment 2 initial *x*-velocities.

We followed up the nature of this significant 3-way interaction (presented in Figure 6) by modelling the data separately for the upper- and lower-hemifields. The model for the UVF was characterised by a significant fixed effect of Prime Type, $\chi^2(1) = 7.51$, $p < .01$, in which initial *x*-velocity was higher on congruent compared to incongruent trials ($b = -27.67$, $SE =$

10.51, $t = -2.63$). There was also a significant fixed effect of Day, $\chi^2(1) = 69.01$, $p < .001$, in that initial x-velocity for the UVF was higher on Day 2 than on Day 1 ($b = 15.58$, $SE = 1.96$, $t = 7.81$). Importantly, including the interaction between Prime Type and Day also significantly improved our model of the initial x-velocity data for the UVF, $\chi^2(1) = 5.83$, $p < .05$. As can be seen in Figure 6C (red bars), although the MCE for the UVF was reliable on both Day 1 and Day 2 (as indicated by FDR corrected paired t-tests: $t(15) = 2.85$, $p < .05$, *Pearson's r* = .59 and $t(15) = 2.56$, $p < .05$, *Pearson's r* = .55 respectively), this effect was larger on Day 2 (34mm/second) than on Day 1 (28mm/second). The model for LVF initial x-velocities was similarly characterised by significant main effects of Prime Type, $\chi^2(1)$ 15.70, $p < .001$, and Day, $\chi^2(1) = 198.83$, $p < .001$. Initial x-velocity was higher on congruent trials compared to incongruent trials ($b = -19.64$, $SE = 6.86$, $t = -2.87$) and on Day 2 compared to Day 1 ($b = 24.45$, $SE = 1.61$, $t = 15.17$). The interaction between these factors also improved the model, $\chi^2(1)$ 48.83, $p < .001$. As can be seen in Figure 6C (yellow bars), while the MCE in the LVF was reliable on both Day 1 and Day 2 (indicated by FDR corrected paired t-tests: $t(15) = 3.21$, $p < .05$, *Pearson's r* = .64 and $t(15) = 4.97$, $p < .001$, *Pearson's r* = .79 respectively), the magnitude of the effect was much larger on Day 2 (36 mm/second) than on Day 1 (20 mm/second).

For interest's sake, we also examined another aspect of the 3-way interaction between Prime Type, Visual Field, and Day by modelling the data separately for Day 1 (50:50) and Day 2 (20:80). To summarise these analyses briefly, when target location was unpredictable (i.e., Day 1), there was a significant interaction between Prime Type and Visual Field which indicated the MCE to be larger in the UVF than the LVF (28 mm/second vs. 20 mm/second), $\chi^2(1) = 7.91$, $p < .005$. In contrast, on Day 2 this interaction was not reliable, $\chi^2(1) = 1.52$, $p = .218$, indicating that the magnitude of the MCE did not differ significantly between the

hemifields on Day 2 when participants could expect the target to appear more frequently in

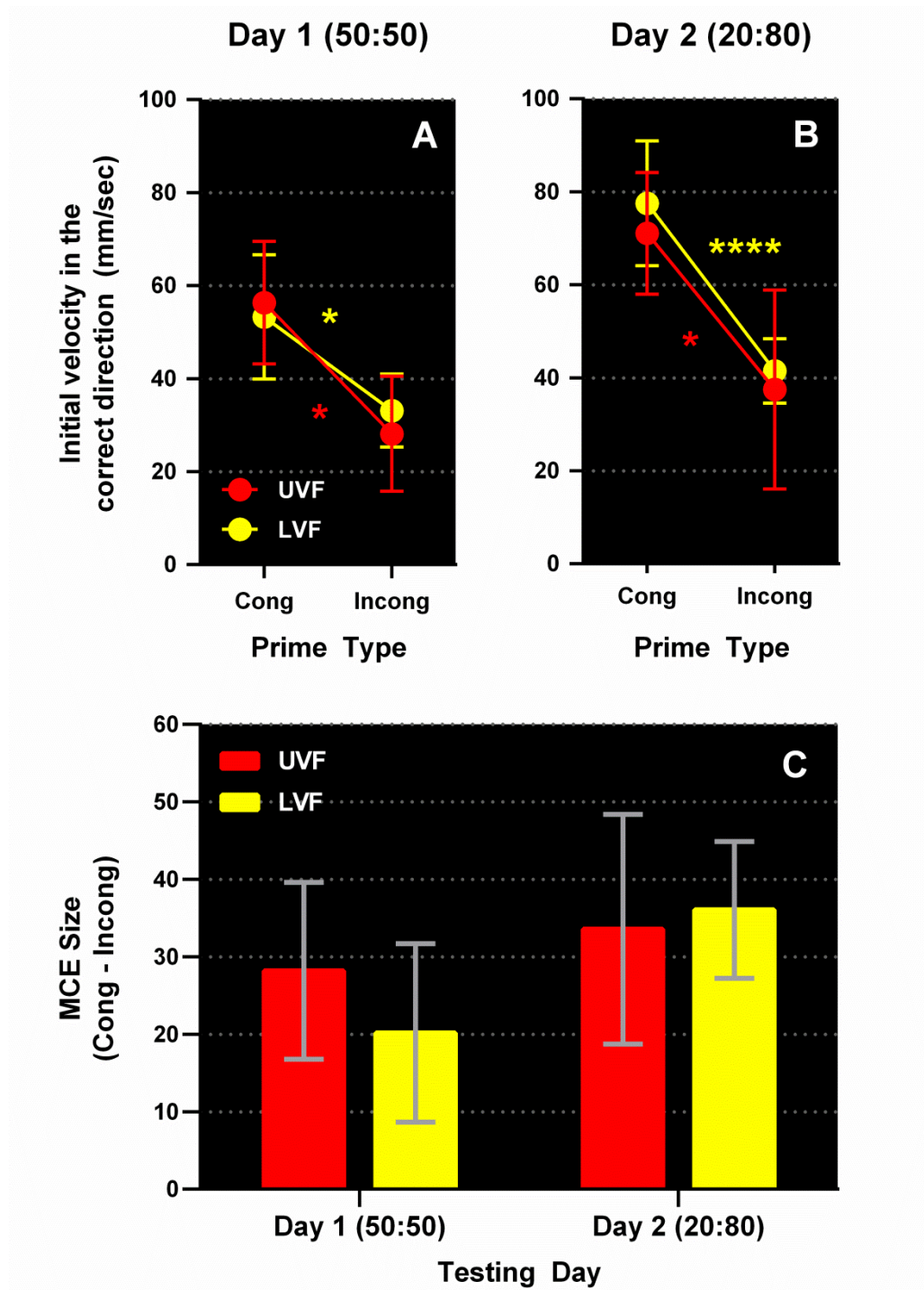the LVF (34mm/second in the UVF vs. 36mm/second in the LVF).

Figure 6. (A & B) The significant 3-way interaction in initial x-velocity between Prime Type, Visual Field, and Day (*p < .05; **p < .01; ***p < .005; ****p < .001, FDR corrected), plotted also as (C) the MCE difference score (congruent – incongruent) for the UVF and LVF on each testing Day. As in Experiment 1, there was a reliable effect of prime type in all conditions. However, in the LVF (yellow bars), the MCE was clearly stronger on Day 2 than on Day 1, suggesting that prime-processing in the LVF was improved by participants attending to this region of space. Critically, the magnitude of the MCE in the UVF did not decrease from Day 1 to Day 2, indicating that attending *away* from this region did not impair prime-processing in the UVF in any way. Error bars are 95% WSCIs; inter-bar overlap should not be interpreted by eye (see Cummings & Finch, 2005).

Analyses taking target-viewing time into account. In addition to comparing the magnitude of the MCE across experimental conditions, in Experiment 2 we wanted to examine whether the *timecourse* of this effect varied as a function of vertical hemifield or target location probability. To do so, we took advantage of the fact that our auditory go-signal manipulation ensured that participants' reaching trajectories would be initiated across a very wide range of MIT latencies (from -100ms before to 500ms after target onset). Since MIT latency reflects the amount of time the participant has to process the critical stimuli prior to commencing their classification response, examining initial x-velocity as a function of MIT latency enables us to observe the MCE as it unfolds in stimulus-processing time (i.e., at less than 500ms from target onset). The OPTA procedure we implemented to smooth our data enabled us to take account of this relationship between initial x-velocity and target-viewing time, depicted in Figure 7. Here we have used MIT to group the x-velocity profiles into 20 bins of equal proportion (i.e., semi-deciles, see Figure 7a) and calculated an average x-velocity profile for each of these MIT Quantiles (see Figure 7b). The effect of target-viewing time on the unfolding of the trajectory response is plain in this figure – the longer participants wait to *begin* their reaching response, the faster their finger moves in the correct direction.

That is, the more time participants have to process the stimuli before initiating their movement, the more efficient the initial stages of their classification response is.
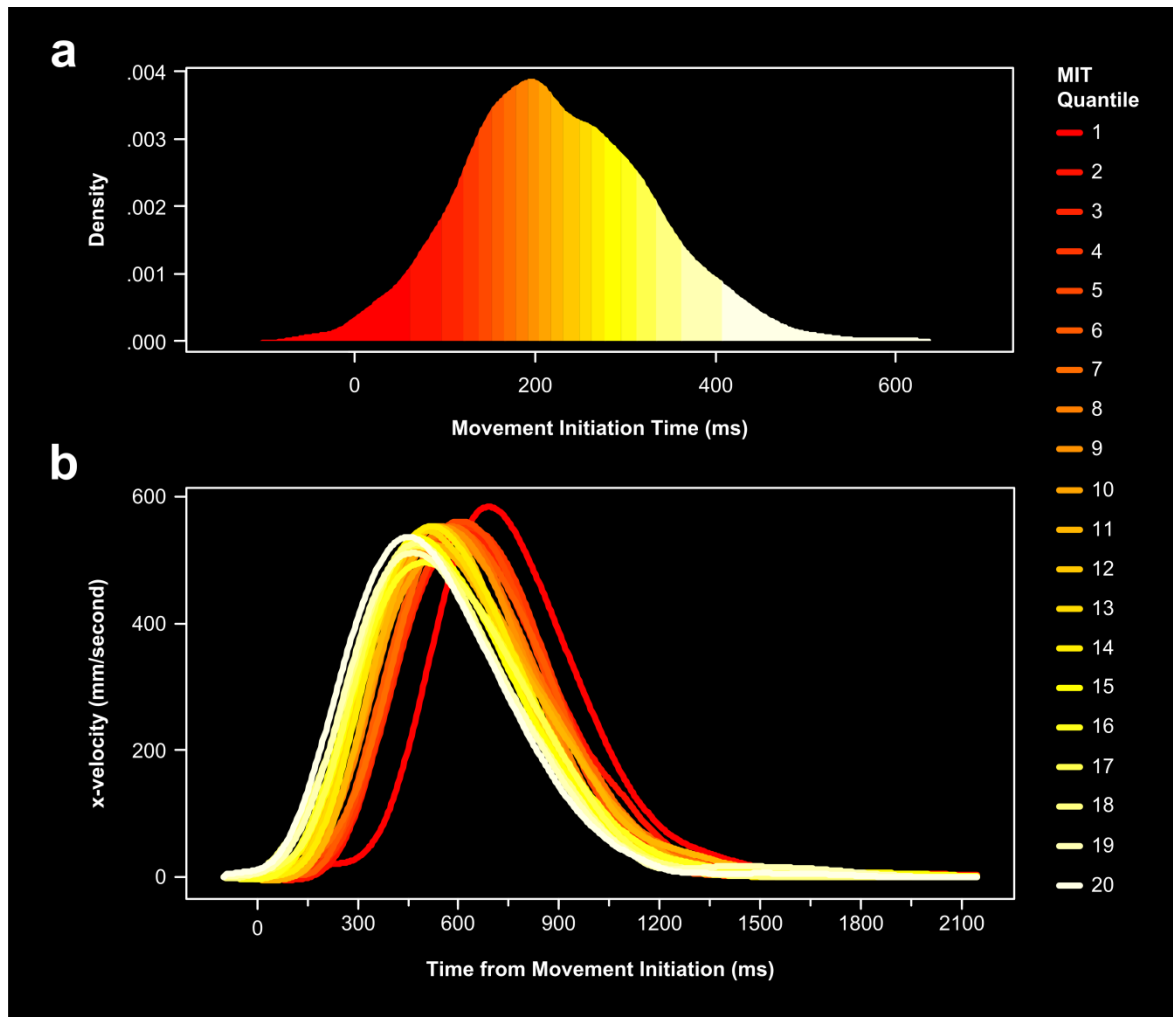

Figure 7. Examining *x*-velocity as a function of target-viewing time. (a) The distribution of MIT Latencies from target onset (i.e., a distribution of target-viewing-times). We used Orthogonal Polynomial Trend Analysis (OPTA) to smooth the *x*-velocity profiles and grouped these into 20 bins (quantiles) ranked by MIT latency. (b) Mean *x*-velocity profiles by MIT Quantile. Darker colours indicate trials with short MIT Latencies (beginning at the 1st Quantile); lighter colours correspond to the longest MIT Latencies (20th Quantile). Note the clear effect of MIT Latency: the longer participants wait to begin moving, the faster the finger moves in the correct direction during the reaching response itself.

To understand the timecourse of the MCE reflected in participants' reaching trajectories, we examined initial *x*-velocity as a function of target-viewing time by including MIT Quantile as a factor in our LMM analyses. First, we verified that a model including random slopes between participant and Prime Type fit the initial *x*-velocity data better than a model with only random intercepts for each subject, $\chi^2(2) = 10737.41$, $p < .001$. Including the fixed effect of MIT Quantile further improved the model's fit, $\chi^2(1) = 24.37$, $p < .001$. As is clear in Figure 8, conditional mean initial *x*-velocity values increase dramatically as a function of target-viewing time (i.e., MIT latency, $b = 4.75$, $SE = 0.80$, $t = 5.94$). This indicates that the longer participants viewed the target prior to commencing their classification response, the faster their finger moved in the correct direction during the initial portion of the reaching movement. We then confirmed the presence of a strong MCE, evident in the significant fixed effect of Prime Type, $\chi^2(1) = 3815.40$, $p < .001$. Initial *x*-velocity was significantly higher on average for congruent trials compared to incongruent trials ($b = -20.55$, $SE = 0.94$, $t = -21.84$) (see Figure 8). Including the fixed effect of Day also improved the model, $\chi^2(1) = 726.82$, $p < .001$, as did the fixed effect of Visual Field, $\chi^2(1) = 222.98$, $p < .001$. Initial *x*-velocity was reliably higher on UVF trials compared to LVF trials ($b = -2.51$, $SE = 1.12$, $t = -2.24$). To elucidate the *timecourse* over which these experimental effects emerged, we examined their interactions with MIT Quantile. We observed a significant Prime Type × MIT Quantile interaction, $\chi^2(1) = 199.64$, $p < .001$, indicating that the magnitude of the MCE depended on target-viewing time. As may be seen in Figure 8, the longer participants have to process the prime–target pair prior to initiating their classification response, the larger the MCE evident in the initial stages of the reaching movement. In other words, the ability of the prime to influence the initial stages of the classification response grew as a function of target-viewing time.
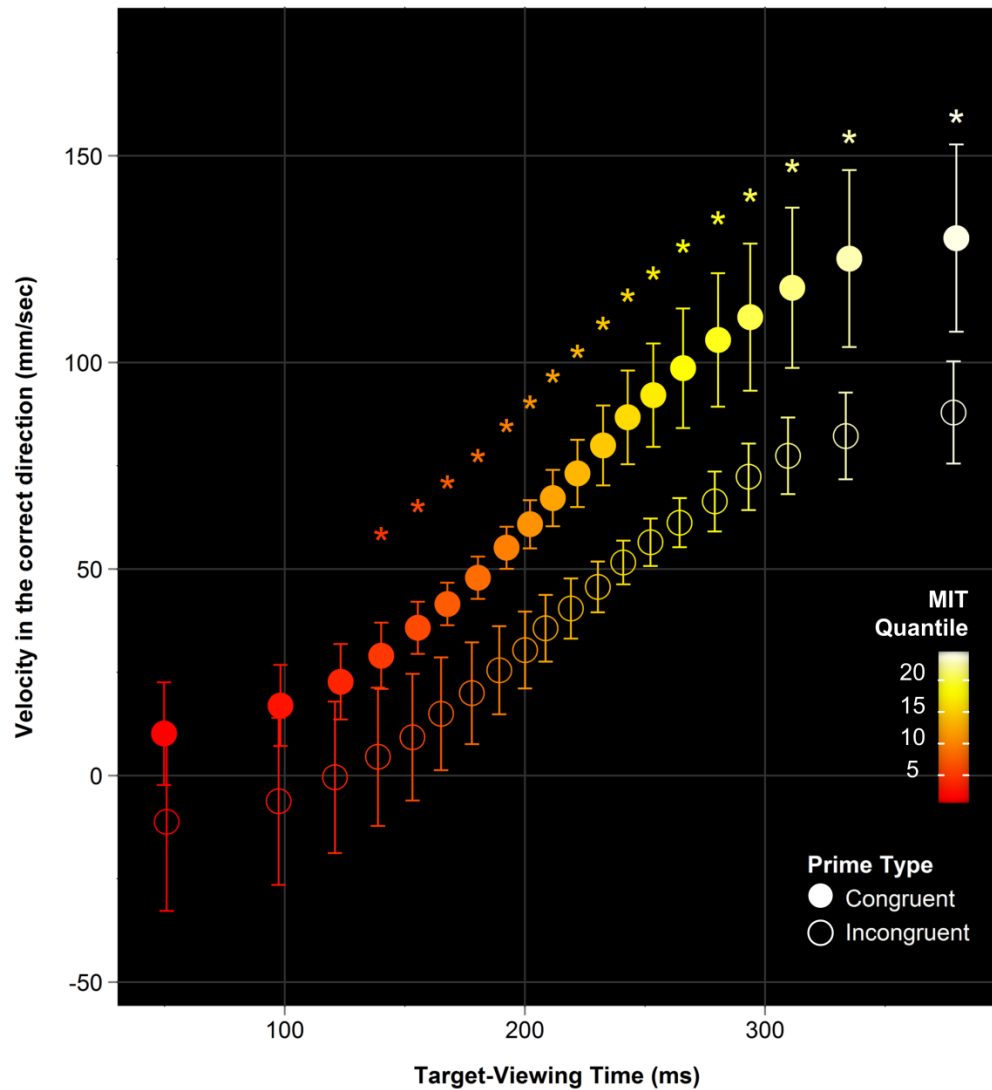
Figure 8. Initial *x*-velocities as a function of MIT Quantile and Prime Type. Initial *x*-velocity reflects the finger's velocity in the correct direction averaged across the first 300ms of the classification response. There was a strong effect of target-viewing time (i.e., MIT Quantile), in that the longer participants processed the prime–target pair before initiating their reaching response, the faster they moved in correct direction during its initial stages. There was also a clear MCE, with congruent trials (filled circles) producing higher initial *x*-velocity values than incongruent trials (open circles). As is clear in the figure above, the prime's ability to influence the response to the target appeared to grow as a function of target-viewing time. Asterisks denote .05 significant contrasts between congruent and incongruent values at each MIT Quantile (FDR corrected). Error bars are 95% WSCIs; inter-bar overlap should not be interpreted by eye (see Cummings & Finch, 2005).

Next, we verified that the effect of target-viewing time on priming was further qualified by vertical hemifield (i.e., significant Prime Type × MIT Quantile × Visual Field interaction, $\chi^2(2) = 133.09$, $p < .001$). Lastly, we determined that the modulation of the MCE's timecourse by vertical hemifield depended on the ratio of UVF to LVF targets (i.e., significant Prime Type × MIT Quantile × Visual Field × Location Predictability interaction, $\chi^2(4) = 400.96$, $p < .001$). We followed up the nature of this four-way interaction (presented in Figure 9) by modelling initial x-velocity separately for each testing day.

LMM analysis for Day 1 indicated significant fixed effects of MIT Quantile and Prime Type ($p < .001$ in both cases), but not Visual Field, $\chi^2(1) = 0.58$, $p = .448$. We nevertheless retained this factor in the model so as to inspect its interaction with other factors. Next, we verified the inclusion of the two-way interaction between Prime Type and MIT Quantile and determined that this was further qualified by Visual Field ($p < .001$ in both cases). Because we obtained the critical Prime Type × Quantile × Visual Field interaction, we were able to conduct a paired t-test between the congruent and incongruent conditions at each MIT Quantile, separately for the upper and lower-hemifields. In the UVF (see Figure 9A), the FDR-corrected p-values were significant from the 6th to the 20th MIT Quantile – indicating that participant's initial reaching movements reflected a significant MCE from 165ms of target-viewing time onwards. In contrast, primes presented in the LVF did not elicit a reliable MCE until the 8th MIT Quantile; at around 195ms of target-viewing time (see Figure 9C). Thus, on Day 1, when target location was unpredictable for participants, we observed a clear UVF advantage for masked face processing, with the MCE emerging some 30ms earlier in stimulus-processing time for UVF face stimuli than for LVF face stimuli.

LMM analysis for Day 2 confirmed the same fixed effects and interactions as observed for Day 1 ($p < .001$ in all model comparison cases). Most importantly, the

significant three-way interaction indicated that emergence of the MCE across MIT Quantile

depended on Visual Field. As for Day 1, we further examined this interaction by conducting a

paired *t*-test comparison of the congruent and incongruent conditions at each MIT Quantile,

separately for each hemifield. As can be seen in Figure 9B, the MCE in the UVF was reliable

from the 6th to the 20th MIT Quantile, or from approximately 165ms of target-viewing time

onwards. In contrast, the MCE elicited by prime–target pairs presented in the LVF was

reliable at all MIT Quantiles, from around 53ms of target-viewing time onwards (see Figure

9D). Thus, on Day 2, in which participants could reliably anticipate the target's location and

direct their attention appropriately in response, we observed an LVF advantage for masked

face-processing. Here primes presented in the LVF elicited a priming effect at an earlier stage

of stimulus processing than primes presented in the UVF – the opposite pattern to that

observed on Day 1, when target location was unpredictable. Of critical importance for present

purposes is the comparison between Day 1 and Day 2 for the UVF. Looking across Figures

9A and 9B, it is clear that face-processing efficiency in the UVF did *not* suffer when

participants covertly attended to the LVF. That is, the MCE in the UVF emerged at the same

stage of stimulus-processing on both Day 1 and Day 2 (i.e., around 165ms of target-

processing time), suggesting that directing participants' covert attention *away* from the upper-

hemifield did not interfere with participants' ability to process masked faces in this region.
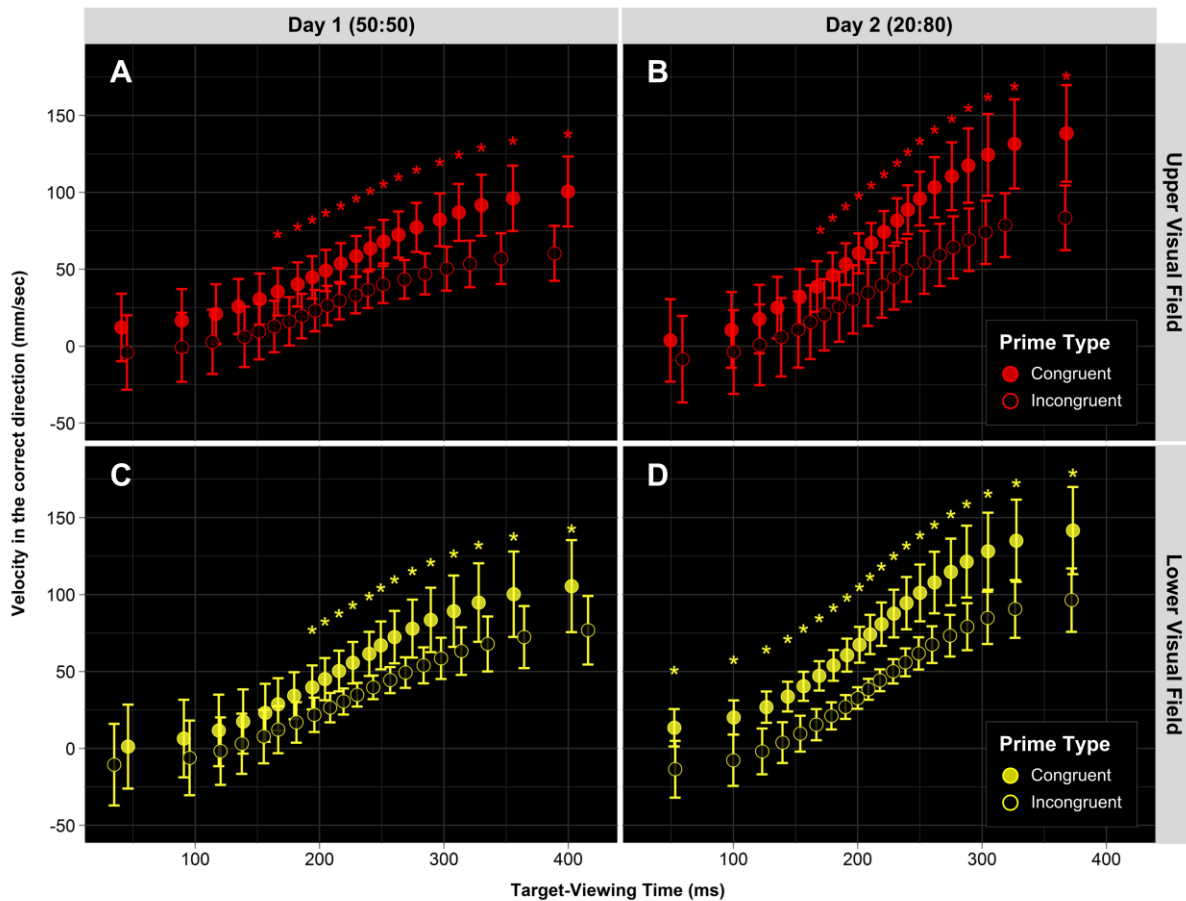
Figure 9. Initial *x*-velocity as a function of Prime Type, MIT Quantile, Visual Field, & Day. (A) On Day 1 (50:50 target location ratio), the MCE in the UVF was significant from ~165ms of target-viewing time onwards, whereas (C) LVF primes did not elicit a reliable MCE until ~195ms of target-viewing time. The reverse was true on Day 2, in which participants could reliably expect the target to appear in the LVF more often than the UVF (80:20 ratio). Here the MCE was significant from ~53ms onwards in the LVF (D) and from ~165ms onwards in the UVF (B). A comparison of panels B) and D) suggests that directing spatial attention *away* from the UVF did not impair participants' ability to process masked faces presented in this region. Asterisks denote .05 significant contrasts between congruent and incongruent values at each MIT Quantile (FDR corrected). Error bars are 95% WSCIs; inter-bar overlap should not be interpreted by eye (see Cummings & Finch, 2005).

4.2.3. Prime Detection

As in Experiment 1, to assess prime visibility we calculated *d'* from each participant's 2AFC prime detection data. Here the mean *d'* value was 0.11 (*SD* = 0.13), which a one sample *t*-test determined was significantly greater than zero (*t*(15) = 3.37, *p* < .01, *Pearson's r* = .66). <mark>This suggests that the participants in Experiment 2 may have had some partial awareness of the masked prime items</mark>, likely owing to our manipulation of target location predictability. That is, because participants voluntarily attended to the lower-hemifield in response to the increased probability of targets in this region, masked primes presented in the LVF were likely to have been subject to focused spatial attention.

4.3. Experiment 2 Discussion

Just as in Experiment 1, we observed a strong MCE in both participants' accuracy and initial reaching movements. We also replicated the UVF advantage for face-sex categorisation, in that when participants could not reliably predict the target's location (i.e., on Day 1), the magnitude of the MCE reflected in the initial stages of their reaching movement was reliably larger for UVF prime–target pairs than for LVF pairs. Moreover, the analysis that took target-viewing time into account revealed that the MCE under unpredictable target location conditions emerged *earlier* during stimulus-processing time when the face stimuli appeared in the UVF compared to the LVF (~165ms vs. ~195ms of stimulus-processing time). That masked prime items influenced the target classification response at an earlier stage of stimulus-processing when presented above- compared to below-fixation would suggest that face-sex categorisation is *more efficient* in the UVF than the LVF.

The effect of vertical hemifield on masked-face processing was very different, however, when participants could reliably expect the target to appear in the lower half of the display and could direct their spatial attention appropriately in response (i.e., on Day 2). Here accuracy was better for LVF targets than for UVF targets. Moreover, the magnitude of the MCE in the LVF was significantly larger on Day 2 than on Day 1. This suggests that voluntarily directing their spatial attention towards the LVF improved participants' ability to process masked prime faces presented in this region. This interpretation is further supported by the finding that LVF primes influenced the initial stages of target classification at a much earlier point during stimulus-processing when participants voluntarily attended to the lower-hemifield (i.e., on Day 2 compared to Day 1). By itself, this result is perhaps not altogether surprising – indeed, there is good reason to expect that attending to the prime's location should facilitate processing and increase its ability to the response to the target (see Quek & Finkbeiner, 2013). What *is* surprising, however, is that the increase in performance for LVF faces was not coupled with a commensurate decrease in performance for UVF faces. Target classification accuracy for UVF targets was comparable across testing days, and the MCE in the UVF was neither diminished nor delayed on Day 2 compared to Day 1, emerging at the same time during stimulus processing on both testing days (~165ms). Taken together, these results suggest that while directing covert spatial attention to the lower-hemifield clearly confers a benefit on the processing of LVF faces, face-processing in the UVF appears to be unaffected by participants' deployment of spatial attention to the opposite hemifield.

5. General Discussion

This paper establishes three important findings. First, we have demonstrated that under unpredictable target location conditions, face-sex categorisation exhibits a clear upper

visual field (UVF) advantage. We observed this robust advantage in two separate groups of participants in both the magnitude and the timecourse of the masked congruence effect (MCE). Participants in Exp 1 also showed this effect in sex-categorisation accuracy. These results replicate an earlier study (Quek & Finkbeiner, 2014) and they are also highly consistent with findings from the neurophysiological literature showing that faces presented above-fixation activate regions such as the left fusiform face area (FFA), left occipital face area (OFA), and medial prefrontal cortex (mPFC) earlier than faces presented below-fixation (Liu & Ioannides, 2010). Taken together, these findings strongly suggest that the visual system processes faces more efficiently in the upper-hemifield than in the lower-hemifield.

Second, we have shown that voluntarily directed spatial attention reliably modulates the ability of masked faces to influence the overt response to the target face. Masked primes in our study influenced the target classification response to a greater extent, and at an earlier stage of stimulus-processing, when participants could *predict* the likely location of the upcoming target and direct their attention to this location. This finding represents an important contribution to the masked priming literature, in that as far as we are aware, it is the first demonstration that *endogenously directed* spatial attention modulates the masked priming effect for faces. The finding also echoes and complements our previous demonstrations that *exogenously oriented* spatial attention facilitates the processing of masked face primes (Quek & Finkbeiner, 2013; 2014).

Third, and most importantly, the present paper dispels the possibility that the UVF advantage for face-processing is underpinned by an upward bias in voluntarily directed spatial attention. If this *were* the case, then masked face-processing in the UVF would have been negatively affected when participants voluntarily attended to the opposite hemifield, as they did on Day 2 of our second experiment. Instead, we found that participants' ability to

extract the task-relevant sex information from masked faces in the upper-hemifield did not vary as a function of our manipulation of voluntarily directed spatial attention. This key finding strongly undermines the possibility that the UVF advantage for face-sex processing we report here and elsewhere (Quek & Finkbeiner, 2014) is driven by an upward bias in spatial attentional orienting (see Bradshaw et al., 1985; Drain & Reuter-Lorenz, 1996; van Vugt et al., 2000). The implications of these findings for the masked priming, face-perception, and broader object recognition literatures are discussed below.

5.1. The upper-hemifield advantage for face-processing: Not a product of attentional bias

Although vertical asymmetry in face-perception has received far less attention than the well-documented laterality effects for faces, there is nonetheless increasing evidence to suggest that face-processing may be superior in the upper-hemifield relative to the lower-hemifield (Coolican, Eskes, McMullen, & Lecky, 2008; Kessler & Tipper, 2004; Liu & Ioannides, 2010). In a recent study, we provided what might be considered the strongest evidence to date for a UVF advantage in face-perception, demonstrating that masked faces affect the sex-categorisation of a target face at an *earlier* stage of stimulus-processing when presented in the UVF compared to the LVF (Quek & Finkbeiner, 2014). In the present study, we have replicated this finding in two separate groups of individuals, providing strong support for the existence of an upper-hemifield advantage in face-sex processing. The discovery has significant implications for the face-perception literature, as where researchers have long tried to take account of laterality artefacts in their designs, thus far there appears to have been little consideration given to the impact of vertical anisotropy in face-perception tasks. The finding also qualifies the characterisation of sex-categorisation as highly robust instance of object-recognition (Bruce & Young, 1998; Wild et al., 2000). While this process is unquestionably efficient, we have highlighted that this aspect of face-perception is

nevertheless still subject to modulation by factors such as spatial location and spatial attention. A natural extension of this finding, and one that is already hinted at in the literature, would be to examine whether other aspects of face-perception, such as identity or emotion recognition, exhibit a similar upper-hemifield advantage (Felisberti & McDermott, 2013; Kessler & Tipper, 2004; Liu & Ioannides, 2010). Given that some have suggested that visual field biases for face-processing are distinct to individual participants (Afraz et al., 2010), another intriguing line of future enquiry is how individual differences in visual field shape (Fortenbaugh, Silver, & Robertson, 2015) might influence the UVF advantage for faces we have documented here.

Importantly, although the mechanism underlying this vertical asymmetry for faces remains unclear, we have provided strong evidence here to discredit the possibility that the upper-hemifield advantage for face-processing is driven by an *upward bias in voluntarily directed spatial attention*. When participants' directed their spatial attention away from the upper-hemifield, as they did when targets appeared in the lower visual field on 80% of the trials, their ability to process faces presented in the UVF was unaffected. It is worth noting, however, that voluntarily directed spatial attention is not the only top-down process capable of modulating basic perceptual processing. Where endogenously directed spatial attention prioritises stimulus processing on the basis of task demands, *expectation* can constrain visual interpretation on the basis of prior knowledge (Summerfield & Egner, 2009) by sharpening sensory representations (Kok, Jehee, & de Lange, 2012). It is well established, for example, that object detection is facilitated by a congruent context (e.g. a coffee cup in a kitchen scene will be found faster than the same cup in a beach scene) (Davenport, 2007; Fize, Cauchoix, & Fabre-Thorpe, 2011). Moreover, Biederman has singled out both probability and spatial position as important relations which affect object recognition in scenes (Biederman, Mezzanotte, & Rabinowitz, 1982). Thus, it is reasonable to think that our wealth of

experience encountering faces in extrapersonal space could well have engendered in us a very strong expectation that face stimuli are more likely to appear above-fixation than below. Just as expectation of object category is known to increase the efficiency with which category exemplars are processed (Puri & Wojciulik, 2008), presumably a perceptual 'prior' which also encompasses spatial location might be expected to facilitate exemplar processing in an anisotropic manner. Importantly, while attention and expectation are often intertwined, it could be the case a perceptual prior for faces is overlearned and thus relatively less flexible. On this possibility, the probabilistic manipulation of target location used in our second experiment might have effectively guided participants' voluntarily directed spatial attention, while simultaneously having no effect on their pre-existing *expectation*. The possibility of a relatively inflexible prior expectation about face location could explain the UVF advantage observed when participants have no cause to preferentially direct their spatial attention to either hemifield (i.e., when target location is unpredictable). This possibility could also explain why face processing remains unaffected in the UVF in experimental contexts in which participants voluntarily direct their attention to the lower visual field. That is, whereas spatial attention can be flexibly controlled and directed to facilitate stimulus processing in predicted target regions, perhaps the well-learned perceptual prior regarding faces remains unchanged, allowing face-processing in the expected region to proceed similarly with or without spatial attention. Intriguingly, there is already some indication that the strength of face and body representations in different parts of the visual field appears to be modulated by the frequency with which the stimuli occur in those locations (Chan, Kravitz, Tryuong, Arizpe, & Baker, 2010).

Alternatively, it may be that a structural account is best equipped to explain why face-processing exhibits a UVF advantage. As others have already alluded to (Kravitz et al., 2010; Kravitz, Saleem, Baker, Ungerleider, & Miskin, 2013), since the representation of the upper

hemifield in early visual cortex is predominantly contained below the calcarine sulcus (Sereno et al., 1995; Zeki, 1969), it may be that presenting faces in the UVF enables more efficient transfer of information to the ventral object recognition systems contained in the temporal lobe, such as the posterior fusiform (Ishai, Ungerleider, Martin, Schouten, & Haxby, 1999; Kravitz et al., 2010; Martin, Wiggs, Ungerleider, & Haxby, 1996). Conversely, transfer to these ventral regions may take slightly longer from the dorsal regions of striate and extrastriate cortex, where information presented to the LVF is initially projected. We note, however, that at present this account of the UVF advantage in face-perception remains speculative - it is clear that there are still important steps to be taken in furthering our understanding of vertical asymmetries in object-recognition. Perhaps the foremost question of interest is whether the UVF advantage is *specific* to face-processing, or whether it may in fact extend to other forms of object recognition, as early reports suggest it could (see Quek & Finkbeiner, 2014b).

5.2. Endogenous attention modulates masked face-processing

Where the modulatory effects of voluntarily directed spatial attention on the *neural response* to face stimuli are well-described in the neurophysiological literature (Holmes, Kiss, & Eimer, 2006; Holmes, Vuilleumier, & Eimer, 2003; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Vuilleumier, Armony, Driver, & Dolan, 2001; Wojciulik, Kanwisher, & Driver, 1998), behavioural investigations to date have often failed to observe an impairment in task performance resulting from directing spatial attention away from a face's location. For example, Reddy and colleagues showed that neither face identification nor face-sex classification of peripheral masked faces suffer when spatial attention is engaged centrally by a demanding discrimination task (Reddy, Reddy, & Koch, 2006; Reddy, Wilken, & Koch, 2004). At first glance, it may appear that our findings do not support the conclusions of Reddy and colleagues. This is because we have shown that face-perception does indeed

benefit from endogenously directed spatial attention, just as it does from exogenously captured attention (Quek & Finkbeiner, 2013). But we suggest, in fact, that our results are consistent with those of Reddy and colleagues. Just as participants in their studies were able to reliably identify both identity and sex even when attention was directed elsewhere, participants in our study remained perfectly able to extract the sex-information from masked face primes in the UVF when attention was directed the LVF.

5.3. Conclusion

There is increasing evidence to suggest that face-perception is supported better at above-fixation locations than at below-fixation locations. The present study further establishes this finding by showing that face-sex categorisation is more efficient in the upper visual field (UVF) than the lower visual field (LVF). It has been suggested that the UVF advantage might be due to participants possessing a strong upward attentional bias in categorisation tasks. The purpose of this study was to test this possibility. Our primary conclusion is that the UVF advantage is *not* due to an upward bias in voluntarily directed spatial attention. Specifically, masked faces presented in the upper-hemifield engaged cognitive processes to the same degree even when spatial attention had been successfully deployed elsewhere.

6. Acknowledgements

7.   References

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