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Bilingualism shapes the other race effect

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Abstract

It has recently been suggested that the other race effect, where people recognise faces of their own race better than those of other races, is abolished by bilingualism. Bilingualism, however, is not a categorical variable, but can vary dramatically with an individual's proficiency across the two languages. We therefore hypothesised that increasing bilingual proficiency should be associated with a diminishing other race effect. To test this hypothesis, we asked a group of ethnic Chinese individuals who spoke English and Chinese to complete the Chinese and Caucasian Cambridge Face Memory Tests. In contrast to recent work, our bilingual participants did as a group exhibit the other race effect, however, the magnitude of this effect decreased as reported cross-language proficiency increased. This effect seemed driven by Chinese, rather than English, listening ability. Face memory performance on all of the tests was not, however, associated with any language proficiency scores. In a second experiment, we confirmed that holistic perception of other race faces, English listening proficiency and Chinese listening proficiency all have distinct influences on the other race effect. Increasing bilingualism must therefore diminish the perceptual narrowing of faces. Our results have serious implications for how we can interpret prior research investigating the other race effect, and possibly other aspects of visual perception, due to the confounding influence of bilingualism. Similarly, the influence of bilingualism on the other race effect should be taken into account when considering eye witness testimonies in the legal system.

Keywords: language, eyewitness, culture, memory, perceptual narrowing.

1. Introduction

Evidence that cultural experience can alter visual perception has been in existence for over 100 years (Rivers, 1905), with recent research particularly focusing on differences between Western and Asian cultures (Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Chua, Boland, & Nisbett, 2005; Hong, Morris, Chiu, & Benet-Martinez, 2000; Nisbett & Masuda, 2003; Sanchez-Burks et al., 2003). For example, when Chinese participants view a scene, they cast their eyes across the scene's background, in contrast to Caucasian participants who focus more strongly on items in the foreground (Chua et al., 2005). Similar differences have been found between how Chinese and Caucasians view faces too, with Chinese preferring to fixate more on the nose area of a face in contrast to Caucasians who prefer to look more broadly across a face's features. These studies are typically interpreted as evidence for how different cultures can distinctly shape visual perception. However, careful inspection of their participant samples reveals an alternative interpretation of their findings, one not where the authors are comparing differences between Chinese and Caucasian cultures per se, but contrasting behaviours of monolinguals (Caucasians) versus bilinguals (Chinese). For example, in the Chua et al. (2005) study their Caucasian participants were Americans who were, one might presume, to be predominantly monolingual English speakers. By contrast, their Chinese participants were studying in an American university and could therefore be expected to be bilingual in their native language Chinese and their second language English. Similar assumptions can be made about the Asian and Caucasian participants who were tested in a study carried out in the UK (Blais et al., 2008). It is therefore possible that differences between visual perception in Asian and Caucasian participants were at least in part due to the confounding effects of bilingual proficiency, rather than purely culture itself.

Understanding more than one language has long been recognised as conferring a wealth of cognitive benefits. For example, bilinguals have been shown to exhibit superior performance in tasks engaging memory (Kormi-Nouri, Moniri, & Nilsson, 2003; Morales, Calvo, & Bialystok, 2013) and attention (Bialystok, 1992). It is not difficult to imagine how the complexities of learning multiple languages can lead to improvements in the aforementioned cognitive functions; listening and speaking in more than one language obviously places unique demands upon remembering, recognising and producing auditory information in the appropriate context. Bilingualism, however, does not only change the perception of linguistic information, but can also lead to surprising alterations in visual perception. Prior work has found that bilinguals display reduced hemispheric lateralisation in the visual processing of words (Lam & Hsiao, 2014) and faces (Hausmann, Durmusoglu, Yazgan, & Güntürkün, 2004) in contrast to monolinguals. Similarly, it has been suggested that the other race effect (ORE; Golby, Gabrieli, Chiao, & Eberhardt, 2001; Kelly et al., 2007) may also be altered by the presence of a second language. Whereas monolinguals exhibited a classic ORE by more accurately identifying faces from their own race over other races, bilinguals did not (Kandel et al., 2016). This finding, however, is not equivocal, with a number of other studies having found examples of presumably bilingual Chinese individuals, who are studying at universities in English speaking countries, still exhibiting an ORE (Blais et al., 2008; Hancock & Rhodes, 2008; McKone et al., 2012; Rhodes et al., 2009) albeit possibly one smaller in magnitude (Herzmann, Willenbockel, Tanaka, & Curran, 2011). The lack of clarity between these findings may therefore be due to the confounding effects of varying bilingual proficiency between the participant samples.

It is suggested that the ORE arises in the first year of our life. In early infancy, we are able to exhibit signs of remembering not only individual human faces, but monkey faces too (Pascalis, de Haan, & Nelson, 2002). This ability to remember monkey faces, however, disappears at around 9 months of age, with only own race face recognition remaining. Caucasian (Kelly et al., 2007) and Chinese (Kelly et al., 2009) infants exhibit a similar loss of other race face remembering at around 9 months of age, leaving only within race discrimination intact. These findings suggest that while we are born with some neural architecture to help us discriminate the wide variety of potential faces we might encounter, our brains perceptually narrow for the specialised processing of those faces that we are most exposed to, namely those of our own race.

The fusiform gyrus, a region of the brain commonly known as the fusiform face area (FFA) due to its highly specialised function of processing faces (Kanwisher, McDermott, & Chun, 1997), has been shown to exhibit diminished neural responses to other race faces, indicating a possible neural locus for where perceptual narrowing occurs (Golby, Gabrieli, Chiao, & Eberhardt, 2001). How experience with a second language may shift this narrowing is at present unclear, but experience with auditory information has been shown to change the FFA's activity when viewing a face (Ethofer et al., 2006; Wang et al., 2016). This altering of activity is likely due to the auditory signal reaching the FFA via pathways through the amygdala (Ethofer et al., 2006) or voice selective brain regions (Von Kriegstein & Giraud, 2006). The possibility that the FFA, which is typically associated with face recognition (Rotshtein, Henson, Treves, Driver, & Dolan, 2005), is linked to auditory perception is perhaps unsurprising considering that faces are commonly paired with speech. Thus the suggestion that auditory experience with a second language may lead to changes in the FFA, and counteract the perceptual narrowing of faces, is perhaps not so unreasonable. If this were to be the case, then we might expect listening, rather speaking, proficiency in a second language to similarly alter the other race effect.

It should be mentioned that the hypothesis that the FFA is responsible for the ORE is not entirely accepted. Alternative arguments have been made that the ORE may be due to some form of domain general cognitive process that alters the perception of not only between race facial identities, but also the perception of between race speech (Werker & Tees, 1999) and music (Hannon & Trehub, 2005) too (Pascalis et al., 2014). In this perspective, it is not the FFA that is responsible for the cross modality perception of distinct racial information, but the superior temporal sulcus (Pascalis et al., 2014). The STS has been shown to process certain aspects of facial identity (Fox, Moon, Iaria, & Barton, 2009), speech perception (Deen, Koldewyn, Kanwisher, & Saxe, 2015; Démonet, Thierry, & Cardebat, 2005) and is believed to integrate auditory and visual information together (Barraclough, Xiao, Baker, Oram, & Perrett, 2005; Beauchamp, Lee, Argall, & Martin, 2004). When one considers these converging points of evidence, the STS may therefore be a potentially better candidate for bilingualism shaping the ORE.

Bilingualism is not a categorical variable, but can vary along a continuum of proficiency across both languages. Face perception has been shown to vary in tandem with a host of other continuous variables, such as levels of autism (Luo, Burns, & Xu, 2017) and alexithymia (Cook, Brewer, Shah, & Bird, 2013). We therefore hypothesise that if bilingualism leads to alterations in the ORE, then it is likely that such changes are indexed by quantitatively varying levels of bilingual proficiency, rather than a qualitative all or nothing shift in the ORE from monolingualism to bilingualism. We tested this hypothesis by asking a group of English-Chinese speaking ethnic Chinese bilinguals ranging in various levels of cross language proficiency to complete the Asian (McKone et al., 2012) and two Caucasian Cambridge Face Memory Tests (Original - Duchaine & Nakayama, 2006; Australian - McKone et al., 2012). These tests have been widely used to test both neurotypical (Arnell & Dube, 2015; Palermo et al., 2016) and neuropsychological (Bate et al., 2014; Burns et al., in press; Burns, Martin, Chan, & Xu, submitted; Burns, Tree, & Weidemann, 2014; Kirchner, Hatri, Heekeren, & Dziobek, 2011; O'Hearn, Schroer, Minshew, & Luna, 2010) populations' face memory abilities, and are particularly useful as they can reveal subtle differences in performance that other tests fail to yield (Duchaine & Nakayama, 2006). We anticipate that increasing bilingual proficiency will lead to a diminishing ORE, with listening proficiency in particular being more strongly linked than speaking proficiency due to the fact that auditory signals modulate activity in the FFA (Ethofer et al., 2006; Wang et al., 2016) and STS (Deen, Koldewyn, Kanwisher, & Saxe, 2015; Démonet, Thierry, & Cardebat, 2005).

Experiment 1

2.1. Methods

2.1.1. Participants

Thirty participants (10 male) of Chinese ethnicity gave their informed consent to take part in this experiment at Nanyang Technological University. The ages ranged from 19-22 years (mean age 20.5 years). All participants had grown up in Singapore, never lived abroad and were studying at the same university at undergraduate level. This suggests that our participants were a fairly homogenous group who had been exposed to a similar ethnic culture, and had experienced formally taught English and Chinese while at school as per Singapore's educational policy. All participants had normal or corrected to normal vision, and reported no history of head injury.

The study was approved by the Institutional Review Board at Nanyang Technological University, Singapore and conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). As developmental prosopagnosia is associated with qualitative changes in the neural sensitivity to facial information (Zhang et al., 2015), participants had to report no regular difficulties in recognising faces to be a participant in this study.

2.1.2 Stimuli and procedure

The original Cambridge Face Memory Test (Duchaine & Nakayama, 2006) requires participants to learn 6 grayscale American Caucasian face images presented across three different viewpoints. In the initial stage, participants only have to identify one of these faces from two distractors. In a second stage, the participants are required to learn 6 faces presented in portrait view onscreen together, and must subsequently identify each of them from various viewpoints amongst two distractors. The final stage repeats the last stage, but this time the faces are presented in noise to make face recognition much more challenging. The Asian and Australian versions of the tests use exactly the same format except Chinese and Australian faces replace the faces found in the original test (McKone et al., 2012). Full details of all of the methods for the tests can be found in the respective literature.

Participants were also required to report their perceived Chinese and English listening and speaking proficiencies on a 7 point scale. Numerous studies have shown that self-reported language ratings by bilinguals are associated with performance on objective language tasks (Jia, Aaronson, & Wu, 2002; Shi, 2011, 2013; Von Hapsburg & Bahng, 2006; Weiss & Dempsey, 2008). Self-reported language proficiencies can therefore be used as a valid index of bilingual language functioning in our participants. On a separate day from reporting language proficiency, all participants completed each of the faces memory tests in a counterbalanced order. All analyses were performed using JASP (JASP Team).

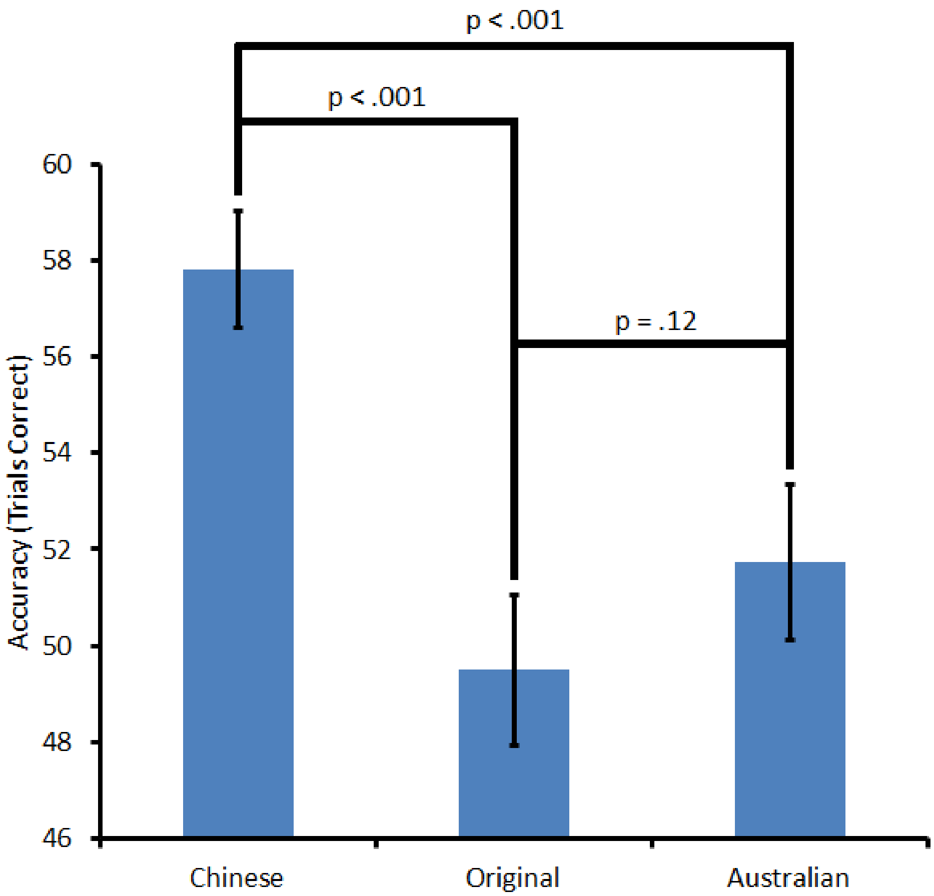


Figure 1. Accuracy rates on the three face memory tasks. The Chinese CFMT examines memory for Chinese faces, whereas the original and Australian CFMTs index memory for Caucasian faces. Error bars indicate ±SEM and comparisons are Bonferroni corrected.

2.2. Results

Figure 1 shows the accuracy scores across the three tests, with our Chinese participants unsurprisingly recognising Chinese faces better than the two sets of Caucasian faces. Prior work has suggested that bilingualism abolishes the ORE (Kandel et al., 2016). To examine whether this was the case in our bilingual sample, we performed an ANOVA on accuracy rates across the three face memory tests to reveal significant differences between the tasks [$F(2,58) = 33.23$, MSE = 553, $p < .001$, $\eta^2 = .53$]. Subsidiary Bonferroni corrected comparisons revealed that our participants did indeed recognise the Chinese faces better than the Australian ($p < .001$) and

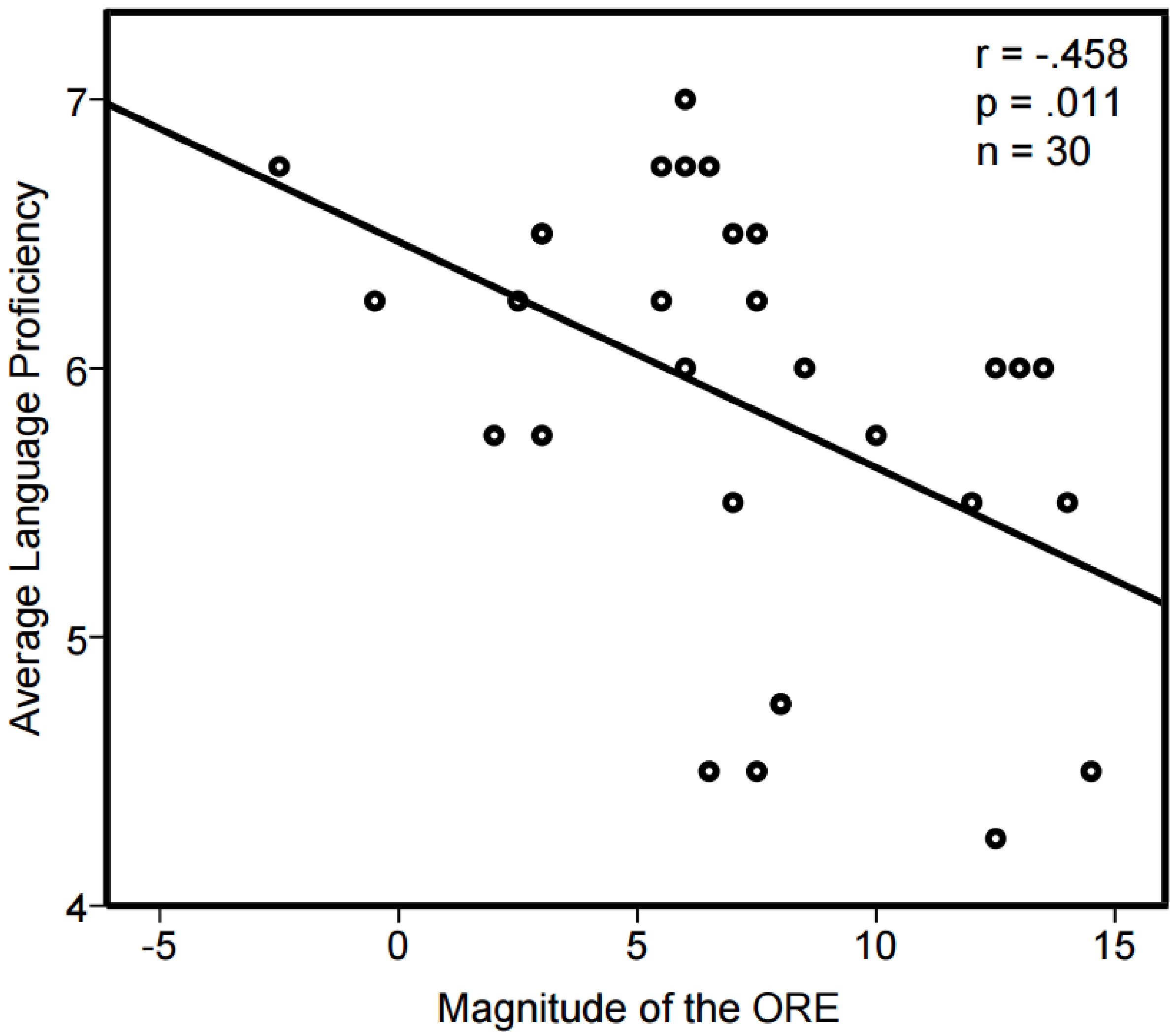


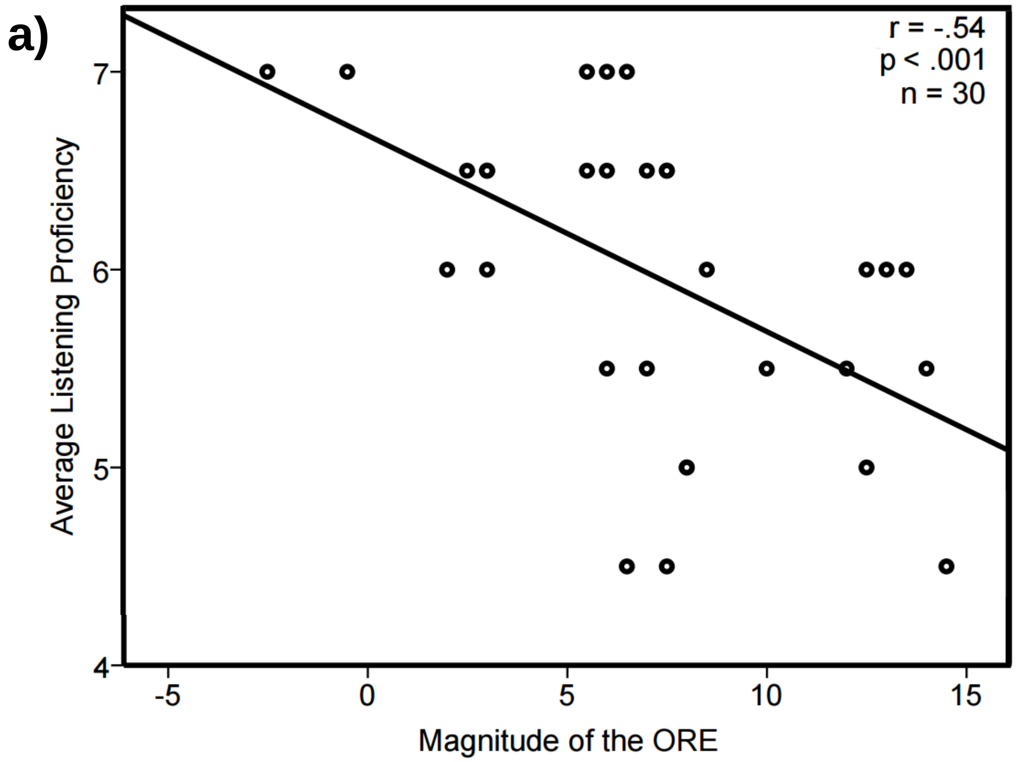
Figure 2. Association between average language proficiency and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison to the Chinese faces.

Original ($p < .001$) Caucasian face sets, with no differences found between the latter two ($p = .12$). It would seem that bilingualism does not completely abolish the ORE in our ethnic Chinese population.

Bilingualism is not a categorical variable, but one that can range continuously through varying levels of cross language proficiency. We had hypothesised that increasing bilingual proficiency would be associated with a diminishing ORE. As there were no differences in performance on the two Caucasian tests, we averaged their accuracy scores together, and subtracted these values from the Asian CFMT accuracy rates to give us an index of the ORE. Figure 2 shows these values plotted against the mean cross language proficiency ratings, which comprise the mean of our participants' self-reported listening and speaking abilities in both English and Chinese. A correlational analysis revealed that as levels of bilingual proficiency increased, then so too did the ORE diminish (r = -.458, p = .011).

We were curious as to whether the average listening or the average speaking proficiency measures were driving this association. As earlier mentioned, the FFA or the STS seems to be responsible for the perceptual narrowing observed during the ORE, and auditory signals seem capable of altering neural activity in both (Ethofer et al., 2006; Wang et al., 2016). We therefore hypothesised that listening proficiency might be better associated with the ORE than speaking proficiency. The average listening proficiency scores of both English and Chinese averaged together (Figure 3a) and the average speaking proficiency scores (Figure 3b) were plotted against the ORE. Correlational analyses showed that listening (r = -.54, p < .001), but not speaking (r = -.34, p = .064), abilities were negatively correlated with the ORE; the better you reported cross-language listening proficiency, the smaller your ORE.

We further examined whether English or Chinese listening proficiency was linked to the ORE. If increasing English listening proficiency were to be associated with a diminishing ORE, then it may crudely index such participants' greater exposure to Western media heavy with the presence of Caucasian faces; this would therefore explain their diminished ORE due to greater exposure to such faces. All of our participants, however, reported themselves as being highly proficient at listening to English, with no participant rating themselves less than 5 out of 7. The



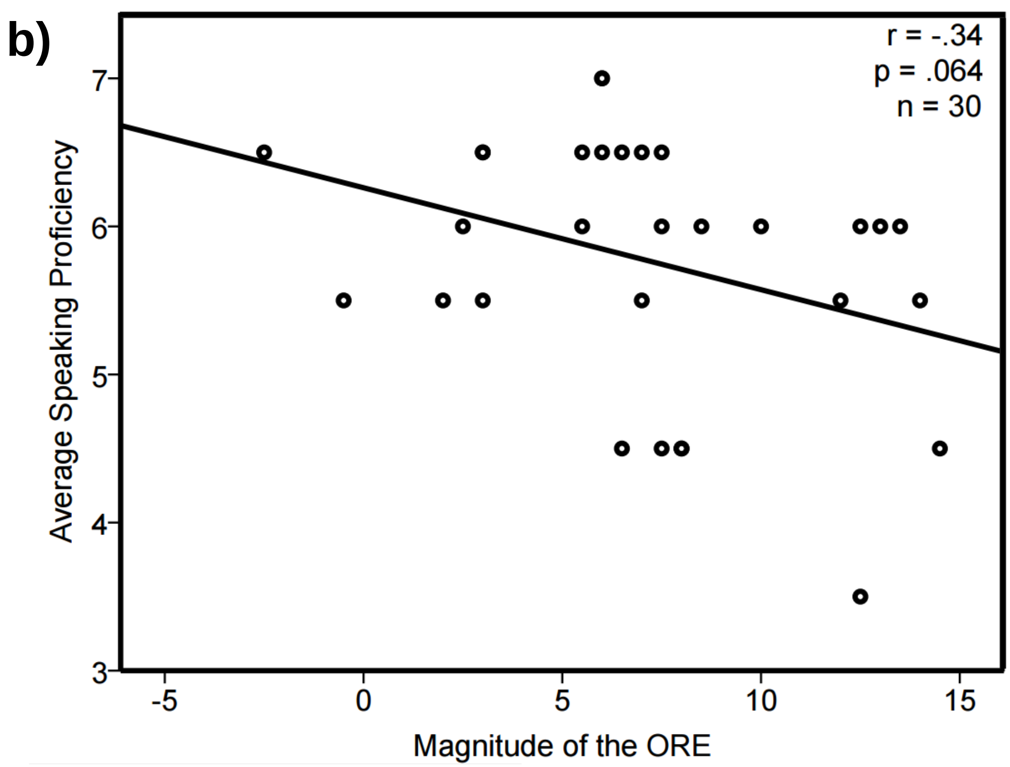


Figure 3. Associations between a) average listening and b) speaking proficiencies and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison to the Chinese faces.

correlation between English proficiency and the ORE therefore failed to reach significance (Figure 4a, r = -.35, *p* =.059). Our participants did, however, report a broad range of proficiencies in Chinese listening. When we analysed these values against the ORE we found a significant correlation (Figure 4b), with diminishing Chinese listening proficiency associated with a larger ORE (r = -.48, *p* = .017). It thus seems that overall levels of bilingual listening proficiency drives the magnitude of the ORE, rather than some level of exposure to Caucasian faces as indexed by English listening proficiency alone.

Developmental prosopagnosia cases who exhibit severe deficits in face recognition also suffer from impairments in auditory perception (Corrow et al., 2016). We were therefore curious as to whether any language proficiency scores were also linked to face memory performance in our neurotypical population. It may be the case that those who have superior auditory perception of Chinese also have superior face memory due to some global, domain general cognitive abilities linking the two processes. However, we found no significant correlations between any of the individual language measures and face memory for Asian or averaged Caucasian CFMT scores (all *ps* > .091). These results indicate that language proficiency is not in any way associated with face memory itself, but merely the distance between accuracy rates across races.

2.3. Discussion

While recent work has suggested that bilinguals do not exhibit an ORE (Kandel et al., 2016), earlier work has indicated that they do (e.g., Blais et al., 2008; McKone et al., 2012). We have shown here that while bilinguals do exhibit an ORE, the magnitude of this effect is modulated by their linguistic proficiency across the two languages. Inspection of Figure 2 shows that many of our participants who reported extremely high cross language proficiencies were still exhibiting

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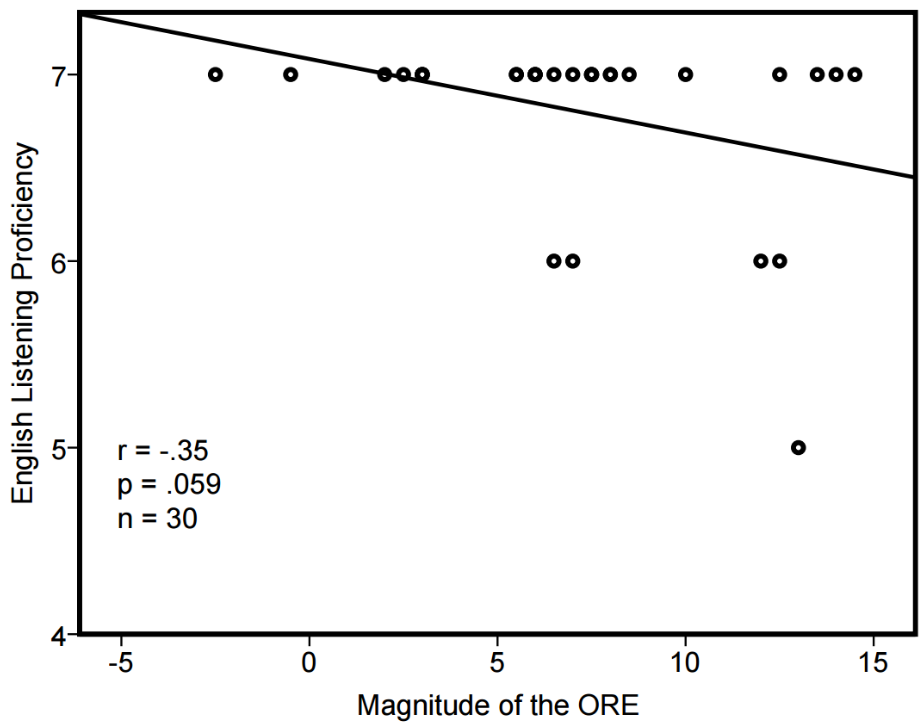

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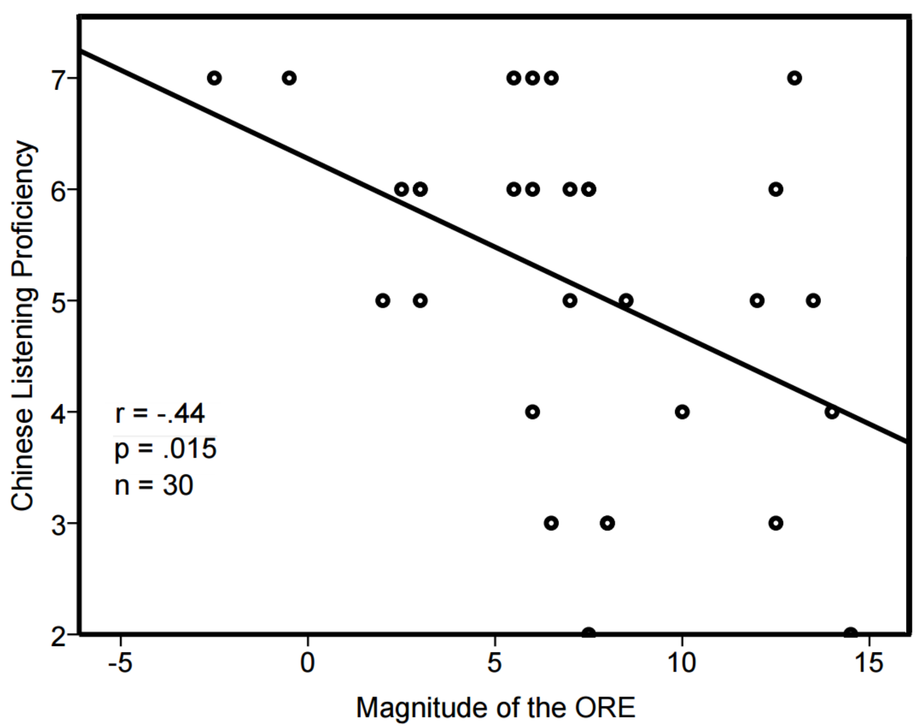

Figure 4. Associations between a) English and b) Chinese listening proficiencies and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison to the Chinese faces.

an ORE, thus indicating that high bilingual proficiency is not sufficient to completely abolish this effect. The lack of an association between performance on the Caucasian tasks and our language measures, however, would seem to suggest that bilingualism does not purely boost the identification of other race faces. A similar lack of any association between performance on the Asian CFMT and language proficiency indicates that bilingualism does not clearly alter memory for own race faces either. Instead, bilingual proficiency may incur a subtle cost in being able to recognise the faces of other races through a mildly reduced ability at recognising faces of your own race in some participants, while boosting memory for other race faces in other participants. In any case, our results indicate that prior work examining cross cultural visual perception differences between Chinese and Caucasians may not have been because of culture (Blais et al., 2008; Chua et al., 2005; Nisbett & Masuda, 2003), but rather due to different levels of bilingualism across their participant groups.

While Chinese, rather than English, listening proficiency was associated with the ORE in the present study, we do not believe that there is anything unique about the Chinese language that is driving this association. Instead, we propose that it is increasing bilingual proficiency itself that diminishes the ORE. In the study by Kandel and colleagues (2016), their bilinguals who were reported to be highly proficient in both languages, consisted of participants who were bilingual in two of nine different European languages. While the authors did not examine any possible differences between their distinct bilingual groups, their results when considered in tandem with our own would seem to suggest that high cross-language proficiency is associated with a greatly diminished ORE. If we had tested participants who were highly proficient in Chinese, but exhibited a range of proficiencies in another language, then we would have expected to observe the exact same association between listening proficiency and the ORE.

Experiment 2

Previous work has indicated that a smaller ORE is associated with increased holistic perception of other race faces (Hancock & Rhodes, 2008; Rhodes, et al., 2009). We were therefore curious whether the relationship between the ORE and bilingualism in Experiment 1 was due to any relationship between bilingualism and the holistic or featural perception of Caucasian faces. To examine this, we invited our participants back to the lab to complete the Cambridge Face Perception Test (Duchaine, Yovel, & Nakayama, 2007). One of the reasons for choosing the CFPT is that it is a face matching task, and face matching has previously been linked to the STS (Fox, Hanif, Iaria, Duchaine, & Barton, 2011). As the STS is hypothesised to be important in perceptual narrowing (Pascalis et al., 2014), we imagine that the CFPT may therefore be more likely to link face perception to bilingualism and the ORE. The CFPT requires participants to arrange a group of faces that have been morphed to varying degrees of similarity to a target facial identity. Faces can be presented either upright or inverted. It is commonly thought that upright face perception engages both holistic and featural processing, whereas inverted face perception indexes face feature perception alone due to inversion disrupting holistic perception (Valentine, 1988). By subtracting our participants’ scores on the inverted from the upright portions of this task, we will have a measure of holistic processing by which we can examine any relationship between it, bilingualism and the ORE.

3.1. Methods

3.1.1. Participants

Sixteen participants (5 male) of Chinese ethnicity from Experiment 1 gave their informed consent to take part in this experiment at Nanyang Technological University. The ages ranged from 19-22 years (mean age 20.25 years). The study was approved by the Institutional Review Board at Nanyang Technological University, Singapore and conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

3.1.2. Stimuli and procedure

During the Cambridge Face Perception Test (CFPT; Duchaine et al., 2007), participants are shown a target face presented in three-quarter view along with 6 faces presented in frontal view; these 6 faces have been morphed to appear similar in varying percentages to the target face. Participants are required to arrange the faces in order of similarity to the target face. The test displays faces either upright or inverted. Participants' performance is outputted as the number of errors they make on either the upright or inverted portions of the test. To create an index of holistic face perception, we subtracted the errors made on the upright task from that of the inverted. We used the inverted errors as our index of featural processing.

3.2. Results

We initially wanted to see whether our participants exhibited an inversion effect on the CFPT. A paired samples t-test confirmed that our Chinese sample were indeed better at perceiving the Caucasian faces when presented upright (Mean = 32.38 errors, SEM = 2.65) versus inverted (Mean = 62.5 errors, SEM = 2.65) [$t(15) = 10$, $p < .001$]. Remarkably, these scores are almost identical to previous studies examining Caucasian participants (Bowles et al., 2009; Duchaine, Germine et al., 2007; Garrido et al., 2008), and suggest that similar perceptual processing of Caucasian faces may be occurring in our bilingual Chinese group.

We performed a correlation between the ORE and our inversion effect to see whether increasing holistic perception was associated with a diminishing ORE as previous research has found (Hancock & Rhodes, 2008; Rhodes, et al., 2009). As expected, we found a strong correlation between the ORE and the inversion effect from our CFPT scores (r = -.68, p = .004). Prior work has also suggested that featural processing is not associated with the ORE (Rhodes, et al., 2009). To confirm this in our sample, we performed a correlation between the inverted errors and the ORE and found no significant relationship (Figure 5a, r = -.18, p = .51). Finally, if upright face perception also relies heavily upon holistic perception, then we should also see a relationship between the upright CFPT errors and the ORE; a suggestion confirmed by our analysis (r = .56, p = .025). Overall, we have shown here that the CFPT can be a useful tool in confirming the link between holistic perception of other race faces and the ORE.

We were curious whether the holistic or featural perception of faces, as indexed by the CFPT inversion effect and the CFPT inverted scores, were correlated to general face memory performance. While increasing errors on the inverted CFPT was linked to poorer face memory on the Asian CFMT (r = -.56, p = .024), there was no correlation with the averaged Caucasian scores (r = -.39, p = .14). By contrast, the inversion effect was not associated with memory performance at all (Average Caucasian CFMT, r = .2, p = .47; Asian CFMT, r = -16, p = .56). This suggests that despite holistic perception being heavily linked with the ORE, it does not seem to be driving this effect due to any specific influence upon face memory. Similarly, featural perception as indexed by the inverted CFPT seems to tap into memory processes related to own race faces, but not those of other races. This is quite remarkable, as the CFPT is testing Caucasian faces.

We were of course interested in whether the inversion effect could be linked to our measures of language proficiency. If the inversion effect was associated with bilingualism, then it would suggest that the acquisition of a second language influences the ORE through changes

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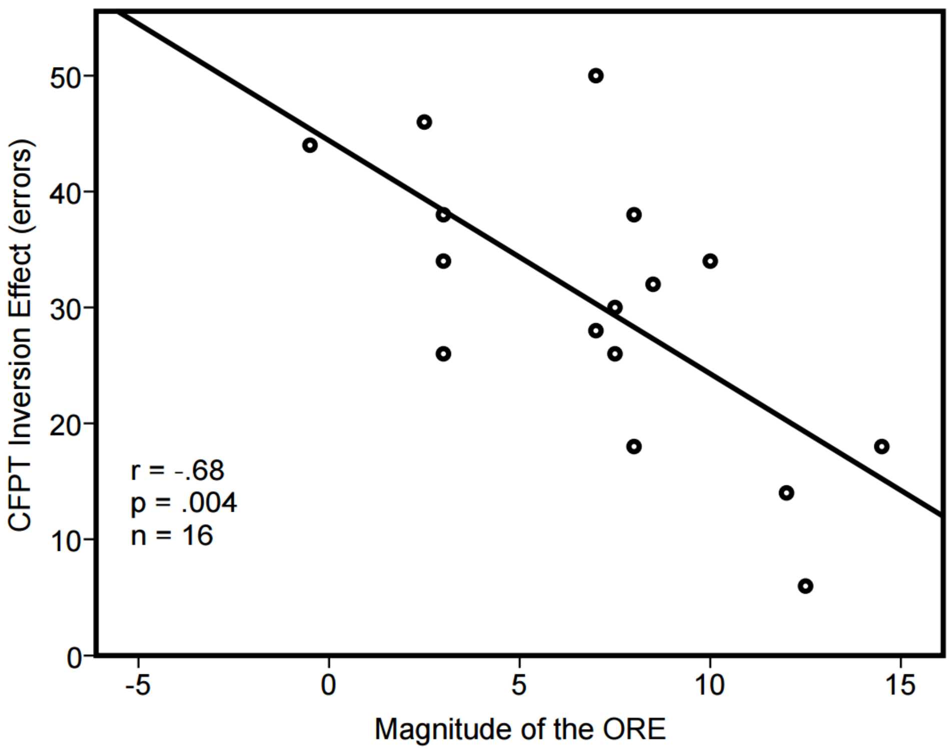

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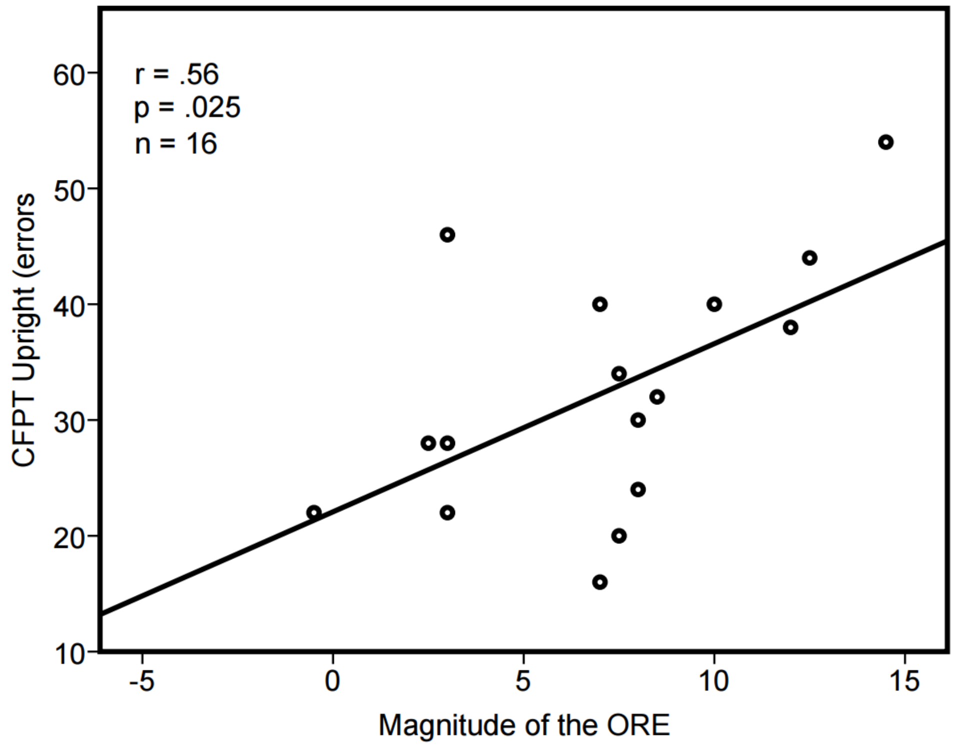

Figure 5. Associations between the other race effect (ORE) and a) CFPT inversion effect and b) CFPT upright errors. An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison to the Chinese faces.

in holistic face perception. Despite performing correlations on all average and individual language measures, we found no significant relationships between language proficiency and the inversion effect (all *ps* > .28). Similarly, no links were found between language and featural perception of faces (all *ps* > .28).

While there was no link between bilingualism and holistic perception, we wanted to test whether taking its influence into account would abolish the link between Chinese listening proficiency and the ORE. To test this, we performed a multiple linear regression to see if the ORE could be predicted from the inversion effect, Chinese listening proficiency and English listening proficiency. We found that our three variables could explain 75.4% of the variance in our data [$F(3,12) = 12.26$, MSE = 553, $p < .001$]: the inversion effect ($\beta = -.47$, $p = .01$), Chinese listening proficiency ($\beta = -.51$, $p = .005$), and English listening proficiency ($\beta = -.37$, $p = .034$)

were all significant predictors of the ORE. This suggests that proficiency in two languages, in addition to other race holistic perception, are predictors of the ORE, with no correlation or collinearity between the three variables.

3.3. Discussion In our second experiment we wanted to test whether the holistic perception of other race faces was linked to bilingualism and therefore influencing the ORE. While we did find a strong correlation between the ORE and holistic perception, we did not find any link between the latter variable and bilingualism. This suggests distinct influences of both holistic perception of other race faces and bilingualism in shaping the ORE. Taken together, our findings confirm recent suggestions in the literature (Kandel et al., 2016) that the ORE and bilingualism are indeed linked. It would seem that in addition to general experience with other race faces (Hancock & Rhodes, 2008; Rhodes, et al., 2009) and face training paradigms (Goldstein & Chance, 1985; Heron-Delaney, et al., 2011; Sangrigoli, Pallier, Argenti, Ventureyra, & De Schonen, 2005), the mere acquisition of a second language, even if it is not one associated with the faces of other races, can also reduce the ORE. This further confirms the ORE to be a domain general process heavily influenced by a range of variables, with Figure 6 illustrating these links.

Holistic perception, at least as indexed by the inversion effect, was not linked to Caucasian face memory, Asian face memory or English language processing. This would seem to suggest that face memory is distinct from holistic face perception. Our failure to find a link between face memory and holistic perception is not without precedent. Composite face tasks are also thought to index holistic perception (Hole, 1994; Young, Hellawell, & Hay, 1987). In these tasks, participants have to judge a face half either aligned or misaligned with the bottom half of another face. The interference caused by the two face halves being aligned versus misaligned is thought due to participants perceiving the two face halves together as a gestalt percept. One previous study failed to find any link between holistic face perception on a composite task and face recognition abilities (Konar, Bennett, & Sekuler, 2009), and the results here with the CFPT inversion effect seems to confirm this suggestion. However, more recent research has found a link between holistic perception measured through the composite face effect and face memory (Richler, Cheung, & Gauthier, 2011; Wang, Li, Fang, Tian, & Liu, 2012). These latter studies criticised the lack of an association in the Konar et al. (2009) study as being due to a response bias artefact in their composite task. This concern does not seem to hold weight here however as CFPT performance would not be influenced by response biases.

An alternative explanation for our lack of an association between holistic face perception and face memory is that the CFPT inversion effect might not actually tap into domain specific

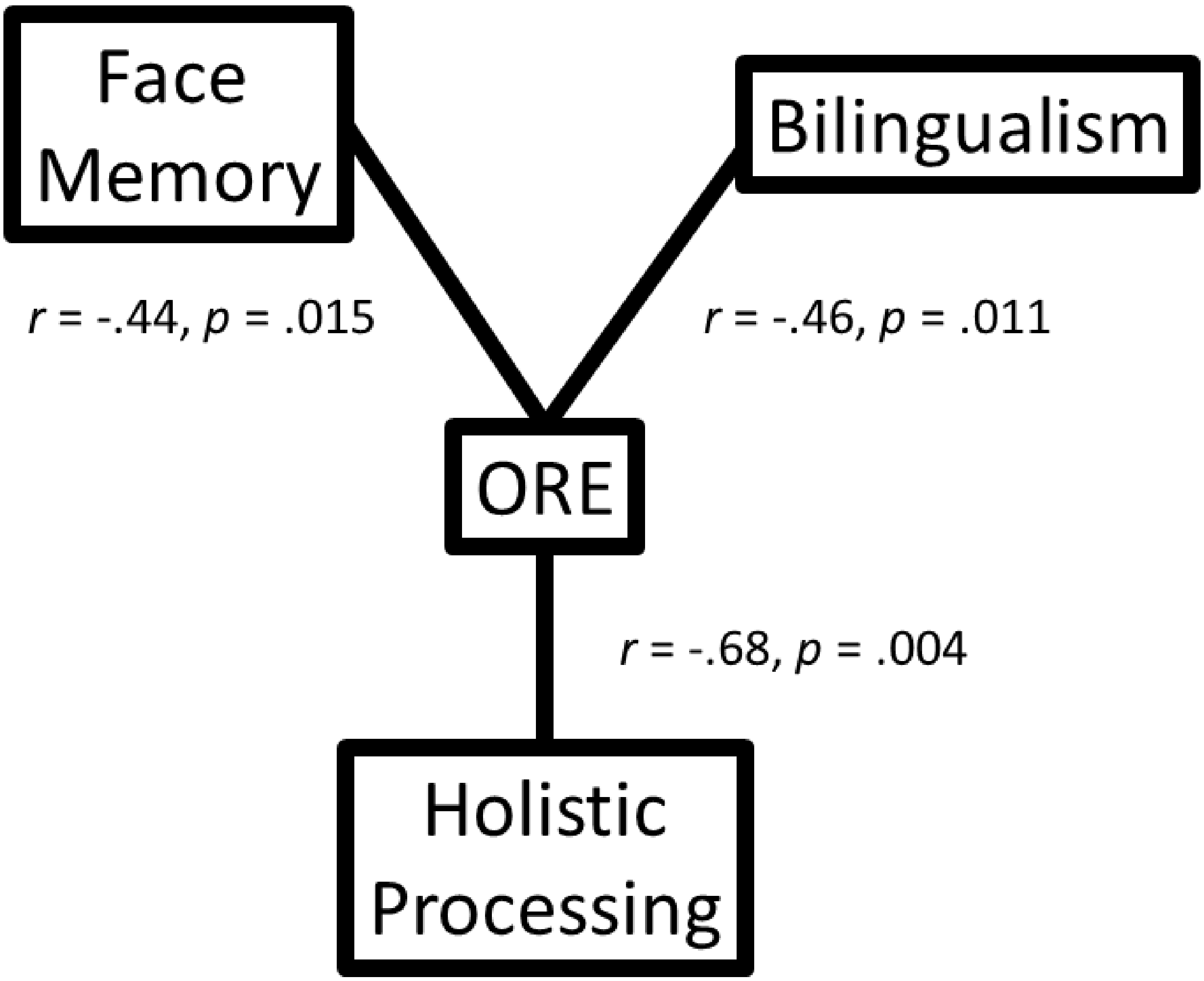

Figure 6. Links between the ORE, bilingualism, face memory and face perception. The correlations are lifted from the results sections except for the correlations involving face memory which are made from averaging the three faces tasks together. The absence of any links is reflective of no significant correlations between the respective variables.

processes related to face perception. Factor analysis work on a battery of face and object tasks found that CFPT performance loads onto an object processing factor as well as a separate face specific dimension (Furl, Garrido, Dolan, Driver, & Duchaine, 2011). As face memory is highly hereditary and domain specific (Wilmer, et al., 2010), it is perhaps unsurprising that holistic perception, as measured through the CFPT, fails to be linked to face memory here: it is because the inversion effect on this task indexes domain general, instead of face specific, perception.

Instead, the inversion effect's link to the ORE seems to confirm the claim that some aspects of the CFPT is tapping into domain general perceptual processes (Furl, Garrido, Dolan, Driver, & Duchaine, 2011; Russell, Duchaine, & Nakayama, 2009). By contrast, however, our CFPT upright scores were correlated with face memory, suggesting that the upright component of this task does still engage face related processing. This finding corroborates other research which has found a link between face memory on the upright, but not inverted, portion of the CFPT (Russell, Duchaine, & Nakayama, 2009).

4. General Discussion

Our findings have important practical implications for the legal system. Eye witness identifications are an important way for police forces and prosecutors to confirm a suspect's guilt. The ORE is commonly believed in the legal profession to compromise this process to some extent, with expert witnesses called to inform the courts of this fact (Meissner & Brigham, 2001; Wells & Olson, 2001; Wilson, Hugenberg, & Bernstein, 2013). With over half of the world's population estimated to be bilingual (Grosjean, 1994), it is not an insignificant number of people whose ORE is affected by knowledge of a second language. Our current findings suggest that the presence of bilingualism in the eyewitness should be an important consideration when examining the potential accuracy of an eyewitness's judgment on faces of other races.

There are a number of outstanding questions related to eyewitness research that have been raised by our findings. The CFMT paradigm we used here and the paradigm used by Kandel and colleagues (2016) presented target and distractor faces simultaneously. By contrast, sequential line-ups present only a single face to the eyewitness at any time to make identification judgements on. A recently increasing body of evidence supports the simultaneous, rather than sequential, presentation of faces in a line-up context (Amendola & Wixted, 2015; Dobolyi & Dodson, 2013; Gronlund et al., 2012; Mickes, Flowe, & Wixted, 2012; although see Steblay, Dysart, & Wells, 2011; Wells, Dysart, & Steblay, 2015; Wells, Steblay, & Dysart, 2015), thus it is imperative to confirm such superiority with regards to bilingualism and the ORE. Similarly, confidence is also an important component in eyewitness testimonies due to its strong association with accuracy under the right conditions (Wixted & Wells, 2017), and the positive effect such confidence has on jurors (Semmler, Brewer, & Douglass, 2012). While bilingualism appears to improve accuracy here and in some prior work (Kandel et al., 2007; Herzmann et al., 2011), it is still unknown whether confidence is similarly altered in tandem. If bilingualism has a positive influence on confidence in addition to general recognition performance, then it would add further weight to the suggestion that bilinguals might be better witnesses when identifying suspects of other races.

Individuals with developmental prosopagnosia suffer from a lifelong impairment in face recognition. Prior work has shown DP cases are capable of exhibiting an ORE, with perceptual training on faces appearing to abolish it (DeGutis, DeNicola, Zink, McGlinchey, & Milberg, 2011). However, it should be noted that this perceptual training had no impact upon improving participants' processing of their own race faces. These findings further suggest that the ORE relies upon a domain general perceptual process that can be altered through training or knowledge of a second language. By contrast, actual memory for faces is highly domain specific, and relatively immune to any form of training or language experience. If future work were to find bilingual DP cases exhibiting a diminished or non-existent ORE, then this would further support the suggestion that the ORE is due to a domain general perceptual process.

While we outlined in the introduction how auditory information might alter activity in the neural regions that process faces, and thus diminish the ORE, it may be the case that bilingualism merely changes how one views or pays attention to faces of different races. For example, previous research has shown that people of Chinese ethnicity prefer to look more at the nose and mouth regions of Chinese faces versus Caucasian faces, but conversely look more at the eyes of Caucasian faces over the eyes of Chinese faces (Fu et al., 2012). The other race effect may therefore be caused by participants utilising an inefficient viewing strategy when looking at the faces of other races, a strategy that is different from those typically employed during face recognition of your own race. Bilingualism could in some way alter these viewing strategies to the most efficient when viewing any race. This influence of viewing behaviour may therefore lead to a subsequent shift in the brain's ability to effectively process other race faces to a similar level as own race faces. Similarly, attention has been shown to affect face perception (Palermo & Rhodes, 2007), so bilingualism may simply alter the ORE purely through changes in how one attends to faces. Support for this latter possibility comes from the fact that bilinguals exhibit superior performance on attention tasks (Bialystok, 1992). Future eye tracking and neuroimaging work examining the ORE in bilinguals should confirm or discount either hypothesis.

Conclusions

We have shown for the first time that levels of language proficiency can modulate visual perception as indexed by the ORE. These findings suggest that future researchers examining the ORE need to consider the influence of bilingual proficiency when designing their experiments. Our results therefore have very serious implications for how we can interpret many of the previously published works examining the ORE. Proposals that distinct cultures lead to differences in visual perception may actually have been due by the confounding presence of bilingualism in one of the groups of participants. Future research examining these possibilities will allow us reassess previous work with a new perspective, one where bilingual proficiency is known to alter visual perception.

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6. Author Contributions

E. B. designed and ran the experiment, analysed the data and wrote the manuscript with all other authors responsible for manuscript review and comments.

7. References

Amendola, K. L., & Wixted, J. T. (2015). Comparing the diagnostic accuracy of suspect identifications made by actual eyewitnesses from simultaneous and sequential lineups in a randomized field trial. *Journal of Experimental Criminology*, *11*(2), 263-284. doi: 10.1007/s11292-014-9219-2

Barraclough, N. E., Xiao, D., Baker, C. I., Oram, M. W., & Perrett, D. I. (2005). Integration of visual and auditory information by superior temporal sulcus neurons responsive to the sight of actions. *Journal of cognitive neuroscience*, *17*(3), 377-391.

Bate, S., Cook, S. J., Duchaine, B., Tree, J. J., Burns, E. J., & Hodgson, T. L. (2014). Intranasal inhalation of oxytocin improves face processing in developmental prosopagnosia. *Cortex*, *50*, 55-63.

Beauchamp, M. S., Lee, K. E., Argall, B. D., & Martin, A. (2004). Integration of auditory and visual information about objects in superior temporal sulcus. *Neuron*, *41*(5), 809-823.

Bialystok, E. (1992). Selective attention in cognitive processing: The bilingual edge. *Advances in psychology*, *83*, 501-513.

Blais, C., Jack, R. E., Scheepers, C., Fiset, D., & Caldara, R. (2008). Culture shapes how we look at faces. *PLoS One*, *3*(8), e3022.

Burns, E. J., Bennetts, R., Wright, V., Bate, S., Tree, J. J., & Weidemann, C. T. (submitted). Intact word processing in developmental prosopagnosia.

Burns, E., Martin, J., Chan, A., & Xu, H. (submitted). Impaired processing of facial happiness, with or without awareness, in developmental prosopagnosia.

Burns, E. J., Tree, J. J., & Weidemann, C. T. (2014). Recognition memory in developmental prosopagnosia: electrophysiological evidence for abnormal routes to face recognition. *Frontiers in human neuroscience, 8*.

Chan, A. H., Wong, P. C., Roy, A. K., & Margulis, E. H. (2009). Neural mechanisms of music listening by mono- and bi-cultural everyday music listeners. *NeuroImage, 47, Supplement 1*, S155. doi:http://dx.doi.org/10.1016/S1053-8119(09)71622-2

Chengwen, L., Burns, E. J., & Xu, H. (in press). Association between autistic traits and facial emotion adaptation to partially occluded faces. *Vision Research*.

Chua, H. F., Boland, J. E., & Nisbett, R. E. (2005). Cultural variation in eye movements during scene perception. *Proceedings of the National Academy of Sciences of the United States of America, 102*(35), 12629-12633.

Cook, R., Brewer, R., Shah, P., & Bird, G. (2013). Alexithymia, not autism, predicts poor recognition of emotional facial expressions. *Psychological Science*, 0956797612463582.

Corrow, S., Stubbs, J., Buss, S., Li, H. C., Schlaug, G., & Barton, J. (2016). Tone deafness in developmental prosopagnosia-is there a common cause? *Journal of Vision, 16*(12), 1245-1245.

DeGutis, J., DeNicola, C., Zink, T., McGlinchey, R., & Milberg, W. (2011). Training with own-race faces can improve processing of other-race faces: Evidence from developmental prosopagnosia. *Neuropsychologia, 49*(9), 2505-2513.

Démonet, J.-F., Thierry, G., & Cardebat, D. (2005). Renewal of the neurophysiology of language: functional neuroimaging. *Physiological reviews, 85*(1), 49-95.

Dobolyi, D. G., & Dodson, C. S. (2013). Eyewitness confidence in simultaneous and sequential lineups: A criterion shift account for sequential mistaken identification overconfidence. *Journal of Experimental Psychology: Applied, 19*(4), 345.

Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia, 44*(4), 576-585.

Duchaine, B., Yovel, G., & Nakayama, K. (2007). No global processing deficit in the Navon task in 14 developmental prosopagnosics. *Soc Cogn Affect Neurosci, 2*, 104-113.

Ethofer, T., Anders, S., Erb, M., Droll, C., Royen, L., Saur, R., . . . Wildgruber, D. (2006). Impact of voice on emotional judgment of faces: An event-related fMRI study. *Human brain mapping, 27*(9), 707-714.

Fox, C. J., Moon, S. Y., Iaria, G., & Barton, J. J. (2009). The correlates of subjective perception of identity and expression in the face network: an fMRI adaptation study. *NeuroImage, 44*(2), 569-580.

Furl, N., Garrido, L., Dolan, R. J., Driver, J., & Duchaine, B. (2011). Fusiform Gyrus Face Selectivity Relates to Individual Differences in Facial Recognition Ability. *Journal of cognitive neuroscience, 23*, 1723-1740.

Golby, A. J., Gabrieli, J. D., Chiao, J. Y., & Eberhardt, J. L. (2001). Differential responses in the fusiform region to same-race and other-race faces. *Nature neuroscience, 4*(8), 845-850.

Goldstein, A. G., & Chance, J. E. (1985). Effects of training on Japanese face recognition: Reduction of the other-race effect. *Bulletin of the Psychonomic Society, 23*, 211-214.

Gronlund, S. D., Carlson, C. A., Neuschatz, J. S., Goodsell, C. A., Wetmore, S. A., Wooten, A., & Graham, M. (2012). Showups versus lineups: An evaluation using ROC analysis. *Journal of Applied Research in Memory and Cognition, 1*(4), 221-228. doi: https://doi.org/10.1016/j.jarmac.2012.09.003

Grosjean, F. (1994). Individual bilingualism. *The encyclopedia of language and linguistics, 3*, 1656-1660.

Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology, 99*(1), 45-56.

Hannon, E. E., & Trehub, S. E. (2005). Tuning in to musical rhythms: Infants learn more readily than adults. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(35), 12639-12643.

Hausmann, M., Durmusoglu, G., Yazgan, Y., & Güntürkün, O. (2004). Evidence for reduced hemispheric asymmetries in non-verbal functions in bilinguals. *Journal of Neurolinguistics*, *17*(4), 285-299.

Heron-Delaney, M., Anzures, G., Herbert, J. S., Quinn, P. C., Slater, A. M., Tanaka, J. W., Lee, K., & Pascalis, O. (2011). Perceptual training prevents the emergence of the other race effect during infancy. *PLoS One*, *6*, e19858.

Herzmann, G., Willenbockel, V., Tanaka, J. W., & Curran, T. (2011). The neural correlates of memory encoding and recognition for own-race and other-race faces. *Neuropsychologia, 49*(11), 3103-3115.

Hong, Y.-y., Morris, M. W., Chiu, C.-y., & Benet-Martinez, V. (2000). Multicultural minds: A dynamic constructivist approach to culture and cognition. *American psychologist*, *55*(7), 709.

Jia, G., Aaronson, D., & Wu, Y. (2002). Long-term language attainment of bilingual immigrants: Predictive variables and language group differences. *Applied Psycholinguistics*, *23*(4), 599-621.

Kandel, S., Burfin, S., Méary, D., Ruiz-Tada, E., Costa, A., & Pascalis, O. (2016). The Impact of Early Bilingualism on Face Recognition Processes. *Frontiers in psychology, 7*.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of neuroscience, 17*(11), 4302-4311.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. (2009). Development of the other-race effect during infancy: Evidence toward universality? *Journal of experimental child psychology, 104*(1), 105-114. doi:http://dx.doi.org/10.1016/j.jecp.2009.01.006

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084-1089.

Kirchner, J. C., Hatri, A., Heekeren, H. R., & Dziobek, I. (2011). Autistic symptomatology, face processing abilities, and eye fixation patterns. *Journal of autism and developmental disorders, 41*(2), 158-167.

Konar, Y., Bennett, P. J., & Sekuler, A. B. (2009). Holistic Processing Is Not Correlated With Face-Identification Accuracy. *Psychological Science*.

Kormi-Nouri, R., Moniri, S., & Nilsson, L. G. (2003). Episodic and semantic memory in bilingual and monolingual children. *Scandinavian Journal of Psychology, 44*(1), 47-54.

Lam, S.-M., & Hsiao, J. H. (2014). Bilingual experience modulates hemispheric lateralization in visual word processing. *Bilingualism: Language and Cognition, 17*(03), 589-609.

Luo, C., Burns, E., & Xu, H. (2017). Association between autistic traits and emotion adaptation to partially occluded faces. *Vision Res, 133*, 21-36.

McKone, E., Stokes, S., Liu, J., Cohan, S., Fiorentini, C., Pidcock, M., . . . Pelleg, M. (2012). A robust method of measuring other-race and other-ethnicity effects: The Cambridge Face Memory Test format. *PLoS One, 7*(10), e47956.

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review: American Psychological Association.

Mickes, L., Flowe, H. D., & Wixted, J. T. (2012). Receiver operating characteristic analysis of eyewitness memory: comparing the diagnostic accuracy of simultaneous versus sequential lineups. *J Exp Psychol Appl, 18*(4), 361-376. doi: 10.1037/a0030609

Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of experimental child psychology, 114*(2), 187-202.

Nisbett, R. E., & Masuda, T. (2003). Culture and point of view. *Proceedings of the National Academy of Sciences, 100*(19), 11163-11170.

O'Hearn, K., Schroer, E., Minshew, N., & Luna, B. (2010). Lack of developmental improvement on a face memory task during adolescence in autism. *Neuropsychologia, 48*(13), 3955-3960.

Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia, 45*(1), 75-92.

Palermo, R., Rossion, B., Rhodes, G., Laguesse, R., Tez, T., Hall, B., . . . Irons, J. (2016). Do people have insight into their face recognition abilities? *The Quarterly Journal of Experimental Psychology*, 1-16.

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life? *science, 296*(5571), 1321-1323.

Pascalis, O., Loevenbruck, H., Quinn, P. C., Kandel, S., Tanaka, J. W., & Lee, K. (2014). On the links among face processing, language processing, and narrowing during development. *Child development perspectives, 8*(2), 65-70.

Rhodes, G., Ewing, L., Hayward, W. G., Maurer, D., Mondloch, C. J., & Tanaka, J. W. (2009). Contact and other-race effects in configural and component processing of faces. *British Journal of Psychology, 100*(4), 717-728.

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic processing predicts face recognition. *Psychological Science*.

Rivers, W. H. R. (1905). Observations on the senses of the Todas. *British Journal of Psychology, 1904-1920, 1*(4), 321-396.

Rotshtein, P., Henson, R. N., Treves, A., Driver, J., & Dolan, R. J. (2005). Morphing Marilyn into Maggie dissociates physical and identity face representations in the brain. *Nature neuroscience, 8*(1), 107-113.

Russell, R., Duchaine, B., & Nakayama, K. (2009). Super-recognizers: People with extraordinary face recognition ability. *Psychonomic Bulletin & Review, 16*(2), 252-257.

Sanchez-Burks, J., Lee, F., Choi, I., Nisbett, R., Zhao, S., & Koo, J. (2003). Conversing across cultures: East-West communication styles in work and nonwork contexts. *Journal of personality and social psychology, 85*(2), 363.

Sangrigoli, S., Pallier, C., Argenti, A.-M., Ventureyra, V., & De Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science*, *16*, 440-444.

Semmler, C., Brewer, N., & Douglass, A. B. (2012). Jurors believe eyewitnesses. In *Conviction of the innocent: Lessons from psychological research.* APA.

Shi, L.-F. (2011). How “proficient” is proficient? Subjective proficiency as a predictor of bilingual listeners’ recognition of English words. *American Journal of Audiology, 20*(1), 19-32.

Shi, L.-F. (2013). How “proficient” is proficient? Comparison of English and relative proficiency rating as a predictor of bilingual listeners' word recognition. *American Journal of Audiology, 22*(1), 40-52.

Steblay, N. K., Dysart, J. E., & Wells, G. L. (2011). Seventy-two tests of the sequential lineup superiority effect: A meta-analysis and policy discussion: American Psychological Association.

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79*, 471-491.

Von Hapsburg, D., & Bahng, J. (2006). Acceptance of background noise levels in bilingual (Korean-English) listeners. *Journal of the American Academy of Audiology, 17*(9), 649-658.

Von Kriegstein, K., & Giraud, A.-L. (2006). Implicit multisensory associations influence voice recognition. *PLoS Biol*, *4*(10), e326.

Wang, R., Li, J., Fang, H., Tian, M., & Liu, J. (2012). Individual differences in holistic processing predict face recognition ability. *Psychological Science, 23,* 169-177.

Wang, X., Guo, X., Chen, L., Liu, Y., Goldberg, M. E., & Xu, H. (2016). Auditory to Visual Cross-Modal Adaptation for Emotion: Psychophysical and Neural Correlates. *Cerebral Cortex*, bhv321.

Weiss, D., & Dempsey, J. J. (2008). Performance of bilingual speakers on the English and Spanish versions of the Hearing in Noise Test (HINT). *Journal of the American Academy of Audiology, 19*(1), 5-17.

Wells, G. L., Dysart, J. E., & Steblay, N. K. (2015). The flaw in Amendola and Wixted’s conclusion on simultaneous versus sequential lineups. *Journal of Experimental Criminology*, *11*(2), 285-289.

Wells, G. L., & Olson, E. A. (2001). The other-race effect in eyewitness identification: What do we do about it? *Psych. Pub. Pol. and L., 7*, 230-802.

Wells, G. L., Steblay, N. K., & Dysart, J. E. (2015). Double-blind photo lineups using actual eyewitnesses: An experimental test of a sequential versus simultaneous lineup procedure. *Law and Human Behavior, 39*(1), 1.

Werker, J. F., & Tees, R. C. (1999). Influences on infant speech processing: Toward a new synthesis. *Annual review of psychology, 50*(1), 509-535.

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., Nakayama, K., & Duchaine, B. (2010). Human face recognition ability is specific and highly heritable. *Proceedings of the National Academy of Sciences, 107*, 5238-5241.

Wilson, J. P., Hugenberg, K., & Bernstein, M. J. (2013). The cross-race effect and eyewitness identification: How to improve recognition and reduce decision errors in eyewitness situations. *Social Issues and Policy Review, 7*(1), 83-113.

Wixted, J. T., & Wells, G. L. (2017). The Relationship Between Eyewitness Confidence and Identification Accuracy: A New Synthesis. *Psychological Science in the Public Interest, 18*(1), 10-65. doi: 10.1177/1529100616686966