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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 (ORE), whereby own race faces are recognised better than those of other races, can be abolished by bilingualism.Bilingualism, however, is not a categorical variable but can vary dramatically in proficiency across the two languages. We therefore hypothesised that increasing bilingual proficiency should be associated with a diminishing ORE. To test this, we asked a group of bilingual Singaporean Chinese individuals to complete the Asian and Caucasian Cambridge Face Memory Tests. In contrast to recent work, our bilinguals did as a group exhibit an ORE, however, the magnitude of this effect decreased as reported cross-language proficiency increased; Chinese, rather than English, listening ability drove this association. This relationship persisted even when taking into account our participants' exposure to Caucasians, own race memory ability, age, and gender. Moreover, we discounted the possibility that bilingualism merely reflected participants' underlying intelligence. Increasing auditory bilingualism thus diminishes perceptual narrowing for faces. We propose that other race recognition ability reflects the base level of intrinsic, domain specific face memory, whereas the distance in recognition performance between own and other race faces is comprised of a domain general process related to stimulus individuation. Finally, our results have serious implications for how we can interpret prior research investigating the ORE, and culture's influence on visual perception, due to the confounding influence of bilingualism.

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; 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 (Blais et al., 2008).

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 explanation for their findings, one not where the authors are comparing differences between Chinese and Caucasian cultures, 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.

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

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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 unequivocal. A number of other studies have found examples of presumably bilingual Chinese individuals, who were studying at universities in English speaking countries, 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.

How bilingualism might alter the ORE is at present unclear, but identifying how the ORE arises may help us to understand the interaction between face and language processing in the brain. 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 et al., 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, 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. Perceptual narrowing not only occurs in face perception, but also arises in speech (Werker & Tees, 1984) and music (Chan, Wong, Roy, & Margulis, 2009) processing too. In this respect, participants are narrowed in their abilities to readily discriminate between exemplars of stimulus categories (e.g., faces of their own race) that they have been exposed to through experience. The similarity in how all three domains narrow may therefore be due to a common underlying domain general process related to the way that we can readily attend to such stimuli.

It is specifically hypothesised that when perceptual narrowing is abolished in one domain, such as in speech perception through bilingualism, then it will break down narrowing in the others too, such as in the ORE, due to alterations in shared domain general processes (Kandel et al., 2016). This might occur through changes in the way that bilinguals utilise their attention when processing faces. While faces typically draw attention due to their obvious social saliency (Palermo & Rhodes, 2007), this drawing of attention is thought to be compromised in the ability to individuate faces of other races (Hugenberg, Young, Bernstein, & Sacco, 2010). For example, the recent Categorization-Individuation Model (Hugenberg et al., 2010) has suggested that the ORE is due in part to our susceptibility for viewing other race faces merely at the category level; e.g., a Chinese person would categorise an individual Caucasian face as simply Caucasian. By contrast, we have a great deal of experience at overcoming this categorisation at the individual level with faces of our own race. Moreover, disrupting attention during face learning abolishes the ORE by diminishing own race recognition ability to comparable levels as that of other races (Zhou, Pu, Young, & Tse, 2014), thereby indicating that the ORE is driven by attentional processes. As earlier mentioned, bilinguals appear to have an advantage in their attentional abilities (Bialystok, 1992), including in their ability to individuate speech, even when it is in a language unfamiliar to them (Werker & Tees, 1983; Kaushanskaya & Marian, 2009). As faces are commonly paired with speech, and we interpret much of what is spoken via the perception of visual cues from the speaker's face (McGurk & MacDonald, 1976), then it is likely that bilingualism utilises a cross-domain (i.e., faces and speech) attentional process that enables the bilingual brain to effectively individuate such similar socially relevant exemplars.

Support for this hypothesis comes from studies examnining face perception in bilingual and monolingual infants. For example, bilingual infants discriminate between two non-native languages being spoken by the facial cues alone, in contrast to monolingual infants that do not (Sebastián-Gallés, Albareda-Castellot, Weikum, Werker, 2012). Similarly, bilingual infants appear to have developmental alterations in their attention towards talking faces in a way that is thought to give them an advantage in the perception of visual speech cues over their monolingual counterparts (Pons, Bosch, & Lewkowicz, 2015). Moreover, in their global ANOVA encompassing speech and faces, bilingual infants displayed similar abilities in discriminating native and non-native faces and speech (Singh, Loh, & Xiao, 2017). It is not only bilingual infants that display differences in face perception, bilingual adults also appear to view faces differently (Blais et al., 2008), which likely causes them to individuate other race faces more effectively and thus abolish the ORE (Kandel et al., 2016). In summary, bilinguals exhibit alterations in how they attend to faces and speech, thereby likely creating a concurrent advantage in the perception of both via a domain general attentional process.

Where in the brain might these alterations in individuating faces occur? The fusiform gyrus is a region commonly known as the fusiform face area (FFA) due to its highly specialised function for processing faces (Kanwisher, McDermott, & Chun, 1997). Lesions to this area creates acquired prosopagnosia, in which the sufferer can no longer individuate faces as indexed by a general inability in being able to recognise them (Barton, 2008). Similarly, individuals with developmental prosopagnosia (Bate et al., 2014; Burns, Martin, Chan, & Xu, 2017; Burns, Tree, & Weidemann, 2014) appear to exhibit similar lifelong face recognition deficits directly due to abnormalities in their FFAs (Furl, Garrido, Dolan, Driver, & Duchaine, 2011; Garrido et al., 2009; Lohse et al., 2016; Song et al., 2015; Zhang, Liu, & Xu, 2015; Zhao, Zhen, Liu, Song, & Liu, 2017). Both acquired and developmental prosopagnosia are also associated with atypical viewing patterns on faces (Bobak, Parris, Gregory, Bennetts, & Bate, 2017; Schwarzer et al., 2007; Van Belle et al., 2011). Cases such as these therefore provide strong evidence that the ability to attend to and individuate faces is almost certainly (albeit not exclusively) partly reliant upon the fusiform gyrus.

Supporting this proposal, the FFA 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). Furthermore, speech related auditory inputs have been shown to change activity related to the FFA 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. Indeed, support for this hypothesis comes from the fact that the FFA is unresponsive when one produces speech, but does become activated when one is singing (Jeffries, Fritz, & Braun, 2003); the latter of which clearly requires a monitoring of your own vocalisations in order to maintain the appropriate rhythm and tone. These findings are further paralleled by the fact that those with prosopagnosia do not generally exhibit any speech difficulties (Burns et al., 2017), but do exhibit impairments in musical ability (Corrow et al., 2016). These data points therefore indicate that it will be the ability to perceive incoming auditory inputs, and not speech production, that are related to the ORE.

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 is driven due to a brain region that is largely domain general for the perception of between race faces, speech (Werker & Tees, 1999) and music (Hannon & Trehub, 2005) too. In this perspective, the superior temporal sulcus (Pascalis et al., 2014) is responsible for bilingualism's influence on the ORE. Evidence for this comes from the fact that the STS exhibits differential activation when viewing faces across races (Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005). Similarly, the STS processes certain aspects of facial identity (Fox, Moon, Iaria, & Barton, 2009), speech (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; Barraclough & Perrett, 2011, Beauchamp, Lee, Argall, & Martin, 2004). When one considers these converging points of evidence, the STS may to be a better candidate for bilingualism shaping the ORE: although it should be noted that bilingualism could easily influence both to produce alterations in 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 Singaporeans ranging in various levels of cross language proficiency to complete the Asian (McKone et al., 2012) and two Caucasian Cambridge Face Memory Tests (CFMT Original – Duchaine & Nakayama, 2006; Australian – McKone et al., 2012). These tests have been widely used to gauge both neurotypical (Palermo et al., 2016) and neuropsychological (Bate et al., 2014; Burns et al., 2014) 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 et al., 2015; Démonet et al., 2005). The possibility that bilingualism shapes the ORE would not only have implications for models of face perception (Bruce & Young, 1986; Haxby & Gobbini, 2011; Haxby, Hoffman, & Gobbini, 2000), but could have some relevance to those interested in eyewitness reports.

2. Methods

2.1. Participants

Forty-two participants (12 male) of Chinese ethnicity gave their informed consent to take part in this experiment at Nanyang Technological University. The ages ranged from 18 to 24 years (mean age 20.5 years). 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. Participants had to be bilingual; i.e., not tri- or quad-lingual.

Singapore is a country comprised predominantly of people of Chinese ethnicity and very few Caucasians. We would therefore expect our participants to be highly skilled in perceiving Chinese faces and comparatively poorer when recognising Caucasians. Prior work in this population has confirmed this fact, with Chinese Singaporeans exhibiting an ORE superiority for Chinese over Caucasian faces (Ng & Lindsay, 1994). However, exposure to other race faces has been shown to modulate the ORE (Hancock & Rhodes, 2008; Rhodes et al., 2009). Even though our participants were unlikely to have had a great deal of personal exposure to Caucasians, we wanted to counteract any possible confound of such experience influencing our results. We therefore asked all of our participants to complete a 10 item, Likert scale exposure to Caucasians questionnaire indexing their exposure to this race (Walker & Hewstone, 2006).

The questionnaire is split into two sections, with the initial section comprising five items which are designed to probe participants' Social Contact with Caucasians. The first item in this section asks 'How many White/Caucasian people do you know very well?', with participants answering: *Up to 2, Up to 5, Up to 8, Up to 12,* or *More than 12*. The remaining 4 items were statements: "I often spend time with White/Caucasian people', 'I spend a lot of my free time doing things with White/Caucasian people', 'I often go round to the houses of White/Caucasian people', and 'White/Caucasian people often come around to my house'. Participants responded to each of these statements with one of the following options: *strongly agree, sort of agree, not sure, sort of disagree,* or *strongly disagree*. Each question can be scored from 1 to 5, with 1 reflective of very low contact with Caucasians, through to 5 which is very high. In the second part of the questionnaire, participants were asked questions relating to how much experience they had individuating Caucasians. The five items were: 1) 'I have looked after or helped a White/Caucasian friend when someone was causing them trouble or being mean to them', 2) 'A White/Caucasian person has looked after me or helped me when someone was causing me trouble or being mean to me', 3) 'I have comforted a White/Caucasian friend when they have been feeling sad', 4) 'A White/Caucasian person has comforted me when I have been feeling sad', and 5) 'I have asked a White/Caucasian person to be on my team or in my group during sports or activities'. Participants had to answer each quesiton on the following scale: *very often, quite often, sometimes, hardly ever,* or *never*. Composite scores from all questions can therefore range from 10 to 50, comprising possible scores of 5–25 in the Social Contact and 5–25 in the Individuating Experience parts. Prior work has shown both the Social Contact and Individuating Experience components of the questionnaire to be correlated with one another, and the Individuating Experience component with the ORE (Walker & Hewstone, 2006).

All of our participants were studying at the same university in Singapore at undergraduate level, suggesting that they had comparably high levels of intellectual ability. None had ever lived abroad, confirming that they were a fairly homogenous group that had been exposed to a similar culture. All had experienced formally taught English and Chinese while at school as per Singapore's educational policy. Participants were 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 a range of objective language tasks (Jia, Aaronson, & Wu, 2002; Shi, 2011, 2013; Von Hapsburg & Bahng, 2006; Weiss & Dempsey, 2008). Self-reported proficiencies can therefore be used as a valid index of bilingual language functioning in our participants.

English is the dominant language in the Singaporean education system, with Chinese taught as a second language. We therefore anticipated that our participants would, as a group, be more proficient in English than Chinese. We ran a repeated measures ANOVA on language proficiencies with factors of Language (English vs. Chinese) and Modality (Listening vs. Speaking) and found a significant effect of

Language [$F(1,41) = 42.6$, MSE = 118, $p < .001$, $\eta^2 = 0.51$] confirming that our participants were indeed more proficient in English [$M = 6.67$, $SEM = 0.09$] than Chinese [$M = 4.99$, $SEM = 0.22$]. There was also a significant effect of Modality [$F(1,41) = 9.16$, MSE = 3.15, $p = .004$, $\eta^2 = 0.18$] due to the fact that listening proficiencies [$M = 5.96$, $SEM = 0.11$] were higher than speaking [$M = 5.69$, $SEM = 0.13$]. Finally, there was a significant interaction between the two factors [$F(1,41) = 7.95$, MSE = 1.34, $p = .007$, $\eta^2 = 0.16$]. Simple Effects showed that while there were no differences in English proficiencies across the two modalities [Listening, $M = 6.71$, $SEM = 0.09$; Speaking, $M = 6.62$, $SEM = 0.1$; p = .16, $\eta^2 = 0.05$], our participants were superior at listening to Chinese over speaking it [Listening, $M = 5.21$, $SEM = 0.23$; Speaking, $M = 4.76$, $SEM = 0.24$; p = .003, $\eta^2 = 0.2$]. Overall, our participants were highly proficient in English language ability, with Chinese proficiencies appearing much more variable, reflective of the fact that Chinese is the second language. In this respect, as Chinese proficiency is a proxy of the presence of bilingualism in our participants, we might expect Chinese listening proficiency to be more strongly associated with the ORE. This is due to our hypothesis that auditory inputs from a second language might alter perceptual narrowing for faces through shared domain general processes in the brain.

There might be a concern that increasing bilingualism in our sample simply indexes increasing intelligence, whereby the participants with higher intelligence were more likely to be highly proficient in both languages. This could in turn explain any links between language ability and face perception as simply due to increased intelligence rather than actual bilingualism. While we did not record any measures of intelligence in our current group of participants, we did in a separate sample where we recruited 88 local bilingual students from the same university as our present group. We asked these individuals to complete the 4th edition of the Test of Nonverbal Intelligence (TONI-4; Brown, Sherbenou, & Johnsen, 2010) and to report the same English and Chinese proficiencies as we recorded in our current experimental sample. When we ran correlations across all individual and averaged language proficiency measures, we found no significant relationships between them and intelligence (all *rs* ranged from .07 to −.059, all $ps > .52$). It is therefore highly unlikely that any associations between our face perception tasks and language proficiencies could be explained due to the confounding influence of intelligence.

2.2. 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.

3. Results

3.1. Does the ORE exist in bilingual Chinese?

The accuracy scores across the three tests revealed that our Chinese participants unsurprisingly recognized Chinese faces better than the two sets of Caucasian faces (Fig. 1). Prior work has indicated 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

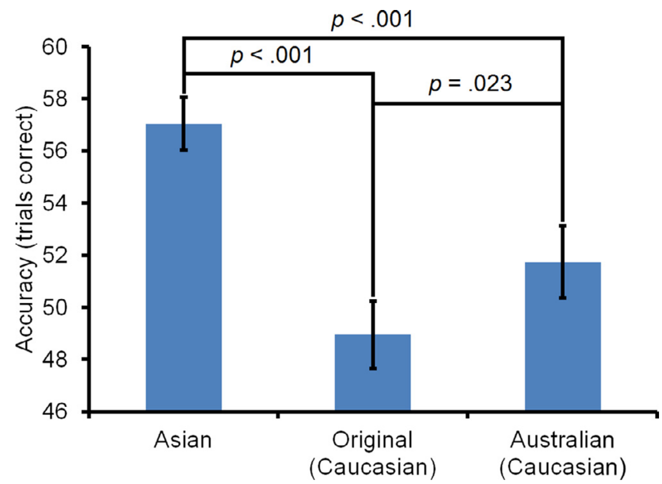

Fig. 1. Accuracy rates on the three face memory tasks. The Asian CFMT examines memory for Chinese faces, whereas the Original and Australian CFMTs index memory for Caucasian faces. Total number of trials on each test was 72. Error bars indicate ± SEM and comparisons are Bonferroni corrected.

accuracy rates across the three face memory tests to reveal significant differences between the tasks [$F(2,82) = 37.19$, MSE = 710, $p < .001$, $\eta^2 = 0.48$]. Subsidiary Bonferroni corrected comparisons showed that our participants did indeed recognise the Chinese faces ($M = 57.1$, $SEM = 1$) better than the Australian ($p < .001$, $d = 0.85$, $M = 51.7$, $SEM = 1.4$) and Original ($p < .001$, $d = 1.39$, $M = 49$, $SEM = 1.3$) Caucasian face sets. It would seem that bilingualism does not therefore completely abolish the ORE in our Chinese sample. Finally, our participants performed better on the Australian over the Original CFMT ($p = .023$, $d = 0.43$; 2.8 more trials correct). This result is not without precedent, with Australian Caucasians previously exhibiting an identical 2.8 trials more correct on the Australian version of the CFMT over the Original (McKone et al., 2012). This may suggest that the Australian CFMT is easier to complete than the Original.

3.2. Does bilingualism alter the ORE?

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 we wanted to examine how language proficiency might modulate differences between Caucasian versus Chinese face recognition (i.e., the ORE), we first averaged the two Caucasian tasks' accuracy scores together to give us a unitary Caucasian score. This Caucasian average score for each participant was then subtracted from their Asian CFMT accuracy rates to give us an index of the ORE. Fig. 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 bilingualism increased, then so too did the ORE diminish ($r = -.31$, $p = .046$).

We were curious as to whether the average listening or the average speaking proficiency measures were driving this association. As earlier mentioned, the FFA and/or the STS seems to be responsible for the ORE, and auditory signals seem capable of altering neural activity in both regions (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 speaking proficiency scores of both English and Chinese averaged together (Fig. 3a) and the average listening proficiency scores (Fig. 3b) were plotted against the ORE. Correlational analyses showed that listening ($r = -.41$, $p = .008$), but not speaking ($r = -.18$, $p = .25$), abilities were negatively correlated with the ORE; the better you reported cross-language

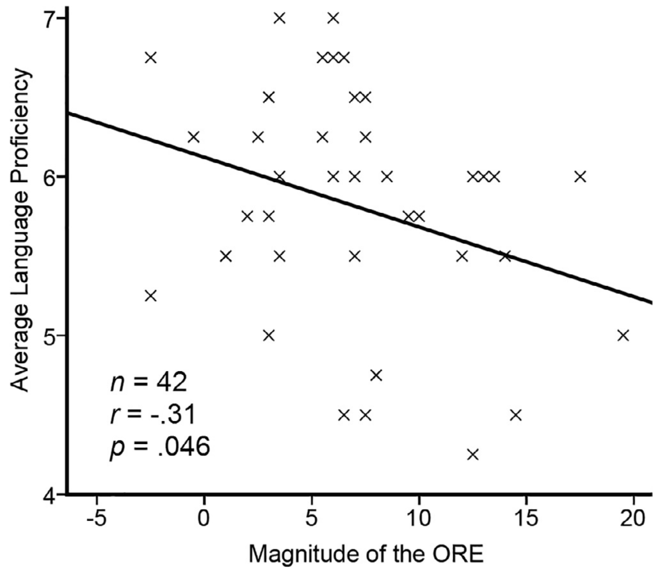

Fig. 2. Association between average language proficiency and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison to the Chinese faces.

listening proficiency, the smaller your ORE.

In a small sample of our cases ($N = 11$), our participants did not respond that they were maximally proficient in either language. Therefore, while the difference in bilingualism between one participant that reported 7 for English and 5 for Chinese would be the same as another participant reporting 5 for English and 3 for Chinese using our subtraction method, the ratios of bilingualism are not equivalent. To examine whether the ratio of English versus Chinese language proficiencies made any difference to the relationship between average language ability and the ORE, we divided each participant's average dominant language proficiency (i.e., the language the participant felt strongest in) with the weaker language scores. This global ratio proficiency score of bilingualism was still correlated with the ORE ($r = 0.34$, $p = .026$). Similarly, the same calculation on the listening scores was also associated with the ORE ($r = 0.42$, $p = .005$). Overall, irrespective of which method we use to examine bilingualism, both were related to the 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 experience with these faces. Our participants, however, generally reported themselves as being highly proficient at listening to English, with no participant rating themselves less than 5 out of 7. The correlation between English proficiency and the ORE was therefore not significant (Fig. 4a, $r = 0.02$, $p = .9$). 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 (Fig. 4b), with diminishing Chinese listening proficiency associated with a larger ORE ($r = -.41$, $p = .007$). Despite this, we were concerned that when we took our participants' exposure to Caucasian scores into account, the relationship between Chinese listening proficiency and the ORE may be abolished. To this end, we included our subcomponent or global exposure to Caucasians questionnaire scores as a covariate in a series of partial correlations. We found that the relationship between Chinese listening proficiency and the ORE was maintained when the Social Contact ($r = -.41$, $p = .008$), Individuation Experience ($r = -.43$, $p = .005$), or the total scores ($r = -.42$, $p = .007$) were included as a covariate. As Chinese was

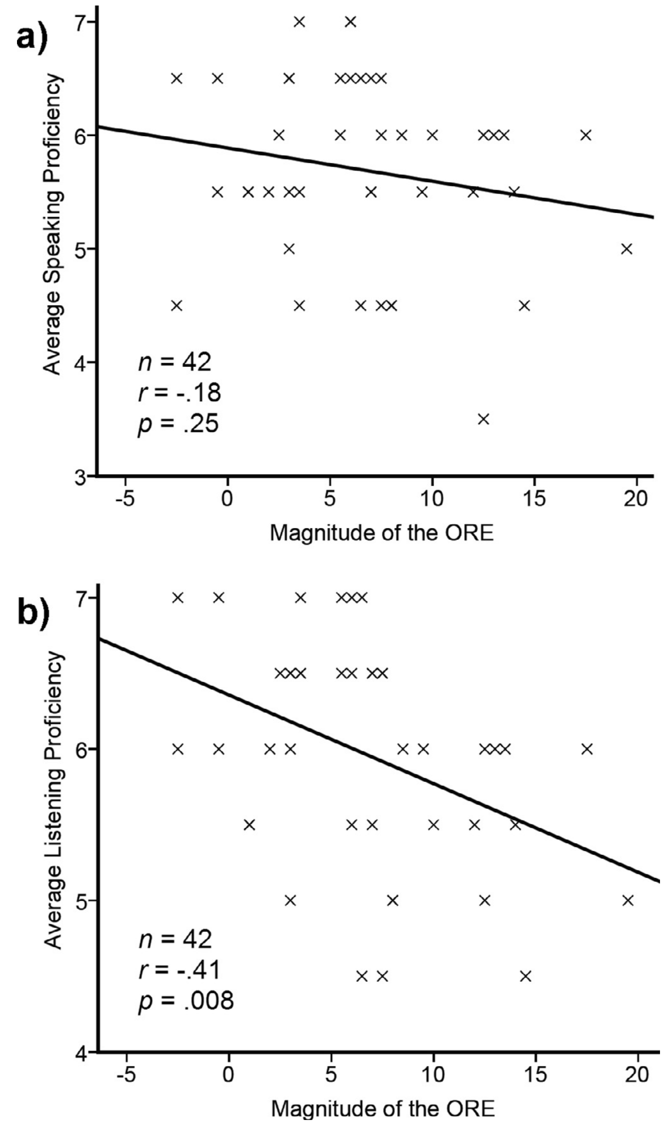

Fig. 3. Associations between a) average speaking and b) listening proficiencies and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison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

predominantly the second language, it thus seems that bilingualism in the form of auditory perception modulates the magnitude of the ORE, rather than any social exposure to Caucasians.

3.3. Is bilingualism linked to face memory?

Developmental prosopagnosia cases exhibit severe deficits in face recognition and 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 ability linking the two processes. However, when we ran the analyses we found no significant correlations between any of the individual language measures and face memory for Asian or averaged Caucasian CFMT scores (all $ps > .12$). These results may seem to indicate that language proficiency is not in any way associated with face memory itself, however, participants' face memory abilities are incredibly

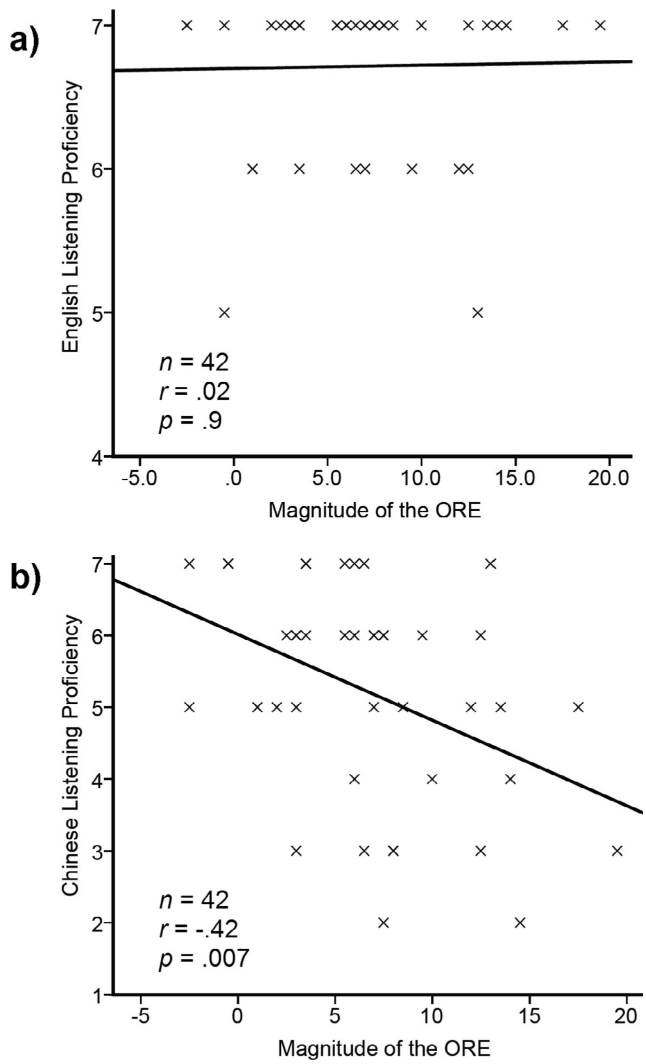

Fig. 4. Associations between a) English and b) Chinese listening proficiencies and the other race effect (ORE). An ORE magnitude of 0 indicates no differences in performance on the Chinese or Caucasian face tasks, with an increasing ORE indicative of poorer accuracy for Caucasian faces in comparison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

heterogeneous. Someone who has exceptional face memory abilities will almost certainly have better other race memory too in contrast to someone who has poor face memory, irrespective of the latter's bilingual ability. In order to take this hetereogeniety into account, we need to standardize other race memory abililty relative to participants' own race performance. To this end, we converted the average Caucasian CFMT scores using this calculation [(AsianCFMT – AverageCaucasianCFMT)/ AverageCaucasianCFMT]. This corrected other race memory score was still correlated with average listening ($r = -.38$, $p = .014$), absolute corrected listening ($r = 0.4$, $p = .009$), and Chinese listening ($r = -.37$, $p = .015$) proficiencies; the corrected other race memory scores were not however related to English proficiencies or any of our contact measures (all $ps > .49$). This shows that other race memory ability, at least relative to own race memory, is shaped by bilingualism.

3.4. Is social contact with other races linked to bilingualism or face perception?

Finally, experience with other race faces is thought to improve your abilities in perceiving faces of those races and diminish the ORE (Hancock & Rhodes, 2008; Rhodes et al., 2009). We therefore wanted to know whether our exposure to Caucasians measures were associated with any language proficiencies, ORE or face memory scores. The Social Contact and Individuation Experience subcomponents of our questionnaire were not significantly correlated with any individual or average language proficiency scores (all ps $>$ .09), except Individuation Experience being significantly related to English listening proficiency ($r = 0.31$, $p = .043$). This suggests that increasing individuation experience with Caucasians in our Chinese participants was related to improved English listening abilities. When we examined our aggregate questionnaire scores against our language measures, we found a significant positive relationship between the overall exposure to Caucasian scores and the average English ($r = 0.33$, $p = .033$) and English listening ($r = 0.37$, $p = .015$) proficiencies. By contrast, none of the other language measures were related to exposure to Caucasians (all $ps >$ .1). In summary, increased general exposure to Caucasians appeared related to increased English listening ability.

There were no significant associations between any of our subcomponent or global questionnaire scores and the ORE (all $ps > .41$), the average scores on the Caucasian CFMTs (all $ps > .29$) nor the Asian CFMT (all $ps > .17$). Prior work had shown that both own race face discrimination ability and Individuation Experience, but not Social Contact, predicted the ORE (Walker and Hewstone, 2006). We therefore performed a similar multiple linear regression with Asian recognition scores, Individuation Experience, Social Contact, and Chinese listening ability scores plus Age and Gender as potential predictors for the ORE. This regression was significant [$F(6,35) = 2.42$, MSE = 52, $p = .046$] accounting for 29.3% of the variance in the ORE. Only two variables significantly predicted the magnitude of the ORE: Chinese listening proficiency ($\beta = -.32$, $p = .043$) and Age ($\beta = -.37$, $p = .041$). In summary, the limited exposure our participants have with Caucasian faces seems insufficient to have any effect on the ORE when compared to Chinese listening ability.

4. Discussion

While recent work has suggested that bilinguals do not exhibit an ORE (Kandel et al., 2016), earlier work has indicated that they do (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, particularly auditory proficiency. The fact that listening, rather than speaking, ability was associated with the ORE seems to suggest that the ORE is altered in bilinguals through cognitive processes overlapping speech and face perception. This influence of bilingualism was maintained even when taking into account the influence of exposure to other races, own race face memory, age and gender. Similarly, our data from a separate student population at the same university confirmed it was highly unlikely that intelligence played an important role in explaining our results through any link with bilingualism. The mere acquisition of a second language, even if it is not one associated with the faces of other races, can therefore reduce the ORE. This adds further evidence to the suggestion that the ORE component of face memory is a domain general process.

4.1. Bilingualism confounds many studies claiming culture shapes face perception

There is a wealth of prior research built upon the belief that culture shapes visual perception. While we are not making an explicit case against this fact, we have shown here that bilingualism could be a confounding factor in many prior studies that identified differences between Asian and Western populations' visual perception behaviours (Blais et al., 2008; Chua et al., 2005; Jack, Garrod, Yu, Caldara, & Schyns, 2012; Jack, Caldara, & Schyns, 2012; Jack, Blais, Scheepers, Schyns, & Caldara, 2009; Kelly et al., 2011; Nisbett & Masuda, 2003;

Sanchez-Burks et al., 2003). For example, Blais et al. (2008) found that Chinese individuals attend to different parts of the face in contrast to Caucasians. These changes may actually have been due to attention related differences between monolinguals and bilinguals; such differences could have arisen from the requirement of a different face viewing strategy to effectively switch between the visual cues available for speech perception across more than one language. Future work will be required to test the validity of these papers' findings now that bilingualism has been shown to shape face perception.

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 auditory bilingual proficiency itself that diminishes the ORE. Kandel et al.s' (2016) bilinguals were highly proficient in two of nine different European languages. While the authors did not examine any possible differences between the 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.

4.2. Bilingualism, not experience or individuation, shapes the ORE

While it may seem counterintuitive at first glance that exposure to Caucasians does not lead to a reduction in the ORE as prior work has shown (Hancock & Rhodes, 2008; Rhodes et al., 2009, Walker & Hewstone, 2006), it should be stressed that all of our participants had lived their whole lives in a predominantly ethnic Chinese country: Singapore contains very few Caucasians so opportunities to be exposed to this race are minimal. This was reflected by the fact that our participants averaged around the lowest score possible on each exposure question (1.53 out of 5, with lowest possible = 1). Our data therefore supports Kandel et al. (2016) in suggesting second language acquisition diminishes the ORE. Furthermore, our findings highlight a possible confound in previous research showing that experience influences the ORE. For example, some of this data comes from native Chinese who lived for a number of years in Australia (Hancock & Rhodes, 2008; Rhodes et al., 2009). However, bilingualism would also enhance in tandem with years lived in Australia as such cases surely improve in their second language English listening abilities. Prior work may therefore have conflated the role of experience in face perception due to the confounding influence of increasing bilingualism. Further work will be required to delineate the extent to which bilingualism and experience are driving such results.

Similarly, one could argue that our results are incompatible with the perceptual expertise hypothesis of the ORE (Hancock & Rhodes, 2008; McGugin, Ryan, Tamber-Rosenau, & Gauthier, 2017; Rhodes et al., 2009) as we have shown experience plays no role in shaping its size. Moreover, our results appear inconsistent with the categorisation-individuation model of the ORE (Hugenberg et al., 2010) as our individuating measure did not predict the ORE either. As we mentioned in our previous paragraph, however, our participants have incredibly few opportunities to interact with Caucasians. By contrast, many of the Chinese in the Australian studies (Hancock & Rhodes, 2008; Rhodes et al., 2009) had lived in a Caucasian environment for years, thus this greater range of experience would inevitably have allowed the authors to identify an experience related effect that we could not. In support of the expertise hypothesis, training paradigms indicate that experience can play some role in shaping the ORE (Goldstein & Chance, 1985; Heron-Delaney et al., 2011; Sangrigoli, Pallier, Argenti, Ventureyra, & De Schonen, 2005). Similarly, studies supporting the Individuation account also had higher levels of other race experience than our participants (Bukach, Cottle, Ubiwa, & Miller, 2012; Walker & Hewstone, 2006, 2008). Yet despite this, our results indicate that individuation, perceptual experience and bilingualism may all play a role in shaping the ORE. Whether or not these three influences are abolishing the ORE in distinct ways, or simply allowing the engagement of some kind of domain general process, is an open question. Wan et al. (2015) proposed a dual-route model of the ORE where perceptual experience or social-motivational factors could influence its magnitude. We propose that their model will require the addition of a third route that can take into account bilingualism.

It could be suggested that our results have arisen from our participants viewing Caucasians as being of higher status. Moreover, maybe their knowledge of English, coupled with it being associated with Caucasians, had had some role to play in bilingualism shaping the ORE (Baus, Bas, Calabria, & Costa, 2017). Support for this hypothesis to some extent comes from studies showing that the ORE can indeed be diminished by other race faces' perceived higher status, such as through respected professions (Baldwin, Keefer, Gravelin, & Biernat, 2013; Shriver & Hugenberg, 2010). Sadly, as we did not collect status data from our participants, we are unable to entirely refute such a suggestion. Despite this, Kandel et al. (2016) showed that highly bilingual Caucasian Europeans exhibited no other race effect for Chinese faces in contrast to their monolingual counterparts that did. At least anecdotally speaking, we know of no stereotype amongst Europeans that identifies Chinese individuals as being of high status. Even if they did, we would surely expect such a stereotype to exist in these participants irrespective of language background. In any case, we urge future studies examining the ORE to record a baseline measure of perceived other race status in order to account for this possibility.

Numerous studies have shown that self-reported language proficiencies are correlated with objective language processing tasks (Jia, Aaronson, & Wu, 2002; Shi, 2011, 2013; Von Hapsburg & Bahng, 2006; Weiss & Dempsey, 2008). What specific language listening abilities might we therefore find related to the ORE? Bilinguals' self-reported language proficiencies were associated with their ability to identify grammatical correctness in sentences (Jia, Aaronson, & Wu, 2002). This may at first glance suggest that the ability to understand speech content could predict the ORE. However, the Northwestern Auditory Test No. 6 (NU-6; Tillman & Carhart, 1966) requires the participants to simply reproduce phonetically a series of quietly presented words they have listened to (Shi, 2011). This simpler level of phonetic comprehension is related to self-reported bilingual proficiency (Shi, 2011). These findings taken together suggest that while grammatical proficiency may be related to the ORE, it is likely that this relationship is driven simply by the underlying ability to initially identify the phonetics of the word. Further work employing such listening tasks will be required to answer what domain general aspects of speech recognition are shared with the individuation of other race faces.

4.3. Domain general versus domain specific aspects of face memory

Prior work has shown that general experience with other race faces (Hancock & Rhodes, 2008; Rhodes et al., 2009), face training paradigms (Goldstein & Chance, 1985; Heron-Delaney et al., 2011; Sangrigoli, Pallier, Argenti, Ventureyra, & De Schonen, 2005), the presence of emotion (Ackerman et al., 2006; Johnson & Fredrickson, 2005), non-stereotypical semantic labels attached to the other race face (Zhang et al., 2011), face status (Baldwin et al., 2013; Shriver & Hugenberg, 2010), viewing strategy (Hills, Cooper, & Pake, 2013; Hills & Lewis, 2006, 2011) and divided attention during learning (Zhou et al., 2014) all lead to alterations in the ORE. The diversity of these influences therefore lend further support to the suggestion that the ORE is driven by a domain general process. Of these influences, the most relevant to our current findings is divided attention at encoding. During divided attention paradigms, participants are thought unable to utilise their typical attentional processes during face 'learning' due to having to respond to the pitch of concurrently presented tones (Zhou et al., 2014).

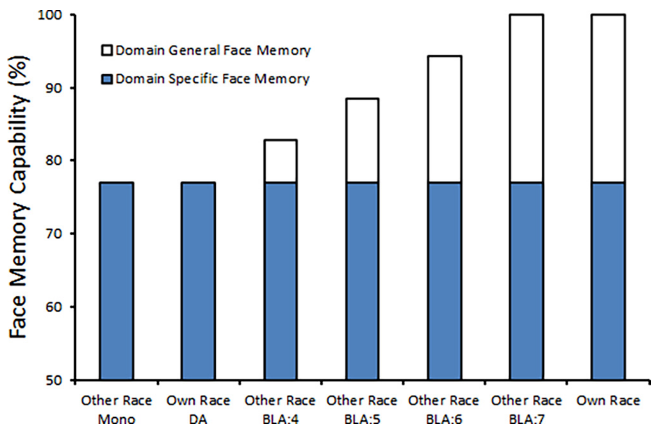

Fig. 5. Hypothetical domain general and domain specific components of face recognition. The Other Race Mono bar on the left indicates around 77% of face recognition ability in monolinguals (i.e., where own race recognition capability is equal to 100%) is domain specific. This is because when domain general attentional processes for own race faces is disrupted in a divided attention task, performance between own and other race faces is equivalent (Bar 2, Own Race DA: Own Race Divided Attention, Zhou et al., 2014). The next four columns indicate how increasing bilingual listening ability (e.g., BLA:4 reflects participants who report their listening ability in another language as at 4 out of 7, by contrast, BLA:7 reflects those who report themselves 7 out of 7, i.e., maximal second language listening proficiency) leads to linear improvements in this domain general aspect of face recognition by diminishing the gap between other and own race face recognition. When participants consider themselves native or maximally proficient in listening to a second language, there are no differences between own and other race recognition ability (last two columns; Kandel et al., 2016). The hypothetical scores were derived from presumably monolingual Caucasians performing on the Caucasian and Asian CFMTs (McKone et al., 2012). The percentages have been adjusted to remove chance performance.

As mentioned, this paradigm abolishes the ORE by diminishing own race, but not other race, face memory performance to comparable levels across the races (Zhou et al, 2014). This suggests that the utilisation of attentional processes makes up a significant chunk, if not the entirety, of the difference between the ability to learn own versus other race faces. By contrast, the remaining comparable performance across the two races in divided attention tasks is likely to be reflective of the remaining domain specific intrinsic face memory ability; hence why our language measures were not associated with either own or other race face memory. This finding therefore lends further support to our hypothesis that the ORE is driven by a domain general process related to attention. Fig. 5 illustrates what we hypothesise to be the domain general (i.e., attentional) and domain specific (i.e., largely hereditary; Wilmer et al., 2010) components of face memory.

4.4. Conclusions

We have shown for the first time that levels of auditory bilingual 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. Similarly, research into the factors influencing eyewitness testimonies when identifying suspects of other races should also recognise the considerable impact bilingualism has upon the ORE. Our results have very serious implications for how we can interpret many of the previously published works examining the ORE across monolingual and bilingual groups. Proposals that distinct cultures lead to differences in visual perception may actually have been due by the confounding presence of bilingualism in their 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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Author contributions

EB designed and ran the experiment, analysed the data and wrote the manuscript under the supervision of AHDC and XH. JT supplied the tests and questionnaire. All authors were responsible for manuscript review and comments.

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