Differential interactions between identity and emotional expression in own and other-race faces: Effects of familiarity revealed through redundancy gains

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Running title: Race and redundancy in processing facial identity and emotion

Abstract

The relations between the processing of facial identity and emotion in own- and other-race faces were examined, using a fully crossed design with participants from three different ethnicities. The benefits of redundant identity and emotion signals were evaluated and formally tested in relation to models of independent and co-active feature processing and measures of processing capacity for the different types of stimuli. There was evidence for co-active processing of identity and emotion which was linked to super capacity for own-race but not for other-race faces. In addition, the size of the redundancy gain for other-race faces varied with the amount of social contact participants had with individuals from the other race. The data demonstrate qualitative differences in the processing of facial identity and emotion cues in own and other races. The results also demonstrate that the level of integration of identity and emotion cues in faces may be determined by life experience and exposure to individual of different ethnicities.

The own-race advantage in face processing

It is known that there are advantages in both perception and memory when we process faces belonging to our own race[1] compared to faces belonging to another race (Anthony, Cooper, & Mullen, 1992; Elfenbein & Ambady, 2002; Meissner & Brigham, 2001). Our extensive experience with faces from our own racial group can result in visual expertise that is associated with advantages in both memory for faces and in tasks stressing perceptual processing (Bukach, Bub, Gauthier, & Tarr, 2006; Bukach, Gauthier, & Tarr, 2006; Cassidy, Quinn, & Humphreys, 2011; Gauthier & Nelson, 2001; Levin, 2000). There are several lines of evidence indicating that within-group expertise in face processing, is a skill that develops over many years of practice (Bukach, Bub et al., 2006; Bukach, Gauthier et al., 2006; Gauthier & Nelson, 2001), though there can also be effects of more immediate social classification (Cassidy et al., 2011; Hugenberg, 2005). Moreover, it has been demonstrated that increases in the number and length of social contacts with other-race people reduces the own-race face advantage (Bukach, Cottle, Ubiwa, & Miller, 2012). There is also evidence for own-race effects on processing non-identity related properties of faces, such as their emotional expressions. For instance, Kito and Lee (2004) reported reduced accuracy in recognizing the expression depicted by other race faces compared with own race faces. This has also been argued from a large-scale meta-analysis of emotion recognition in own- vs. other-race faces (Elfenbein & Ambady, 2002).

Few studies investigated the underline cognitive processes of own and other race faces. For example, using perceptual discrimination task, Rhodes et al. (2006) measured sensitivity to featural (e.g. eyes, nose) and configural properties (specifically the spatial relations between features) of own- and other-race male faces in Caucasian and Chinese participants. It was reported that both configural and featural coding were better for upright own-race than for upright other-race faces. Megreya and colleagues (Megreya, White & Burton,2011) showed that face inversion costs are

[1] We use the term race here to reflect the ethnic origin of the participants and the face stimuli.

higher for own race faces; while Cassidy and colleague (Cassidy et al., 2011), report that inversion costs for other race faces are higher when individuals are perceived as part of a social in-group (from the same university) as opposed to when they are part of an out-group (from a competing university). The authors argue that the way faces are processed depends on their perceived social category (e.g. perceived as same group, or form a different group). Similarly, the tendency to process faces in a holistic manner is increased for own race faces (Michel, Rossion, Han, Chung, & Caldara, 2006) and for faces that are perceived to be from the same social group (Hugenberg & Corneille, 2009). Collectively this line of evidence suggests that information from other race faces, or faces perceived as belonging to a different social group, is less likely to be integrated, when compared with own-race faces.

A different line of research (Hugenberg, Young, Bernstein, & Sacco, 2010) argues that other-race faces are processed at a different level of representation than own race faces, with the other-race faces being processed at the ethnicity group level (e.g. an Asian face), while own-race faces are processed at an individual level - the categorization-individuation model (Hugenberg, et al., 2010). Support for this model comes from the observation that, while own-race faces are recognized better than other-race faces, other race-faces are categorized more efficiently as belonging to a racial group (Ge, Zhang, Wang, Quinn, Pascalis, Kelly, et al., 2009). These findings raise the intriguing possibility that faces from other races are represented in a one-dimensional manner, based on a single category affiliation. The current study aimed to test whether race and social experience impact on the way that observers integrate information from faces across multiple dimensions.

Though there is evidence for differences in processing both facial identity and emotion in own- vs. other-race faces, the relations between the processing of identity and emotion across different races of participant have never been examined. Here we used a novel face processing approach based on examining processing gains when multiple relative to single targets, based on facial identity and emotion, are present. We assess whether there are qualitative differences in the joint processing of identity and emotion in faces belonging to own- vs. other races, addressing the issue of whether the processing of own- and other-race faces differs not only quantitatively (e.g., enhanced overall processing for own-race faces) but also qualitatively (a change in how identity and emotion are integrated in own- vs. other-race faces).

Processing facial identity and emotion.

In the past decade accumulating empirical evidence (Aguado, Garcia-Gutierrez, & Serrano-Pedraza, 2009; Baudouin, Martin, Tiberghien, Verlut, & Franck, 2002; Ellamil, Susskind, & Anderson, 2008; Ganel & Goshen-Gottstein, 2004; Schweinberger & Soukup, 1998; Yankouskaya, Booth, & Humphreys, 2012) challenges the traditional model that assumes that there is complete independent and parallel processing of facial expression and identity (Bruce and Young, 1986) (see for review Calder & Young, 2005; Otten & Banaji, 2012; Kaufman & Schweinberger, 2004). For example, Schweinberger and Soucup (1998) used the Garner paradigm (Garner & Felfoldy, 1970) to test the dependence of identity and expression processing of unfamiliar faces. The authors report an asymmetrical pattern, in which identity discrimination is not affected by facial expression, but the discrimination of facial expression is affected by facial identity. Ganel and Goshen-Gottstein (2004) used a similar paradigm and manipulated face familirity. Similarly to Schweinberger and Soucup (1998), they report an asymetric interaction for unfamiliar faces, where the processing of expression was affcted by varying the identity of the face, but not vice versa. However, when faces are familiar, symmetric interference effects emerged. Ganel and Goshen-Gottstein argue that the systems involved in processing identity and expression are interconnected and that the identity of familiar faces can serve as a reference from which different expressions can be more easily recognized (Ganel & Goshen-Gottstein, 2004). This study suggests that familiarity with faces increases the degree of interaction between those processes coding facial identity and expression. Thus in the case of other race faces, which are less familiar than own-race faces, we may expect that the interaction between identity and expression will diminish. Karnadewi and Lipp (2011) used the Garner task to test exactly that whether the processing of race and of emotional expression interact. Participants were presented with sixteen photographs depicting eight different individuals posing with a happy or an angry expression, and the task was to judge as quickly and accurately as possible either the emotional expression of the face or whether the face was European or African American. The results showed an asymmetrical interaction, in which race affected the categorization of emotional expressions whereas emotional expressions had no effect on the categorization of faces by race (Karnadewi & Lipp, 2011). However, it should be noted that racial groups can be discriminated rapidly from local face cues (e.g., skin color) and this may be critical to the observation of asymmetrical interference effects from race on judgments of emotional expression. Furthermore, a potential limitation of the Garner paradigm, which is based on repeated discrimination between relative small samples of stimuli, is that participants may develop a strategy focus on local pictorial cues when discriminating between stimuli.

To overcome this, we recently developed a task that directly tests for the interaction between identity and expressions in faces (Yankouskaya et al., 2012). We used a divided attention paradigm in which participants had to attend to both facial identity and emotion – adapting a procedure that has been used successfully in the past to investigate the dependency of featural processing in faces (Townsend & Wenger, 2004a, 2004b; Wenger & Townsend, 2001; Wenger & Townsend, 2000, 2006). In our task, participants had to detect the presence of a target facial identity or an expression, which could appear either alone (just the target identity or the expression) or together (when the target identity bore the target expression; see Yankouskaya et al., 2012). We assessed how the presence of both properties in a single face affects target detection performance. The data were compared with the predictions of different processing models in order test whether the two processes (identity and expression) are independent or interact.

Using this approach, Yankouskaya et al (2012) demonstrated that, for own-race faces, the processing of identity and expression interact. Notably there were faster reaction times when both the target identity and target emotional expression were present in the same face (the redundant target condition) than when only the target identity or expression were present (the single target conditions). Theoretically, the redundancy gain (RG), arising from the combined presence of both targets (identity and expression), can be explained by two models: 1) The Independent Race Model – in which the fastest process affects the decision, and hence the RG arises from the probabilistic summation of target competitive signals or 2) The Co-activation Model - where the RG arises from the integration of cooperative signals (see Miller, 1982 for review). The goodness of fit of the data to these two models can be assessed by examining the cumulative distributions of reaction times in the redundant and single target conditions. The critical contrast for the two models compares the probability for the response times obtained on redundant target trials relative to the sum of the probabilities for responses being made to either single target, on single target trials. The Independent Race Model predicts that at no point in the cumulative distribution functions should the probability of responding to the redundant targets exceed the sum of the probabilities for responding to either single target. In contrast, according to the coactivation account, responses to the redundant targets can be made before either single target generates enough activation to produce a response. This has been termed the Miller Inequality test (Miller, 1986). Yankouskaya et al. (2012) showed that the prediction of the Race Model was violated when identity and expression targets combined in own-race faces, hence providing support that the co-activation model explains the data better.

However, the Miller inequality test has been criticized as the only measure for inter-dependence between processing, as it does not take into account other factors, such as whether processes interfere with one another (Townsend & Wenger, 2004). Instead Townsend and Wenger proposed that researchers should estimate the overall capacity of the system as a measure of whether processes interact or are independent. The capacity concept reflects an individual's efficiency in performing the work required by the task. The amount of work completed by the system while processing a face with redundant targets (when both the target identity and expression are present) is compared to when only a single target is present (either the facial identity or expression). It is argued that, when processes interacts in a facilitatory fashion, then when both targets are present, the system operates in a super-capacity mode. However, if the two processes interact negatively (e.g., if they interfere with one another), than the system operates in a limited capacity mode. In addition, if the process are completely independent then the system is described as operating at unlimited capacity. This is expressed by the capacity coefficient (C(t)) where C(t)=1 implies unlimited capacity (the system acting as a parallel model without capacity limitations); C(t) < 1 reflects limited capacity and C(t) >1 indicates super capacity. Thus if identity and expression interact we would expect to show that the system operates in a super-capacity mode.

We aimed to test whether the processing of same- and other-race faces not only differs quantitatively (e.g, due to overall better processing of own-race faces) but also qualitatively (e.g., in terms of whether identity and expression interact and are processed with super capacity). In doing this we sought to go beyond the Miller Inequality test and to use capacity coefficients to test the relations between expression and identity. We further ask whether these relations be altered by the life-long experience observers have with the faces, by examining how face processing was modulated by the contact an individual has experienced with other-race faces.

We conducted an experiment with participants from three different ethnic groups: European, African and Asian, and compared the effects of own race face processing to the processing of other race faces. We assessed whether the discrimination of facial identity and emotional expressions is associated with independent or coactive processing for own- and other-race faces using a divided attention task (Yankouskaya et al., 2012) in which participants were required to detect targets defined by identity alone, expression alone, or both facial identity and expression. We used three different sets of faces, one set for each ethnic group (European, African, Asian). In each set, three of the photographs depicted targets: 1) the *redundant stimulus* had both the target identity and the target emotion; 2) the *identity alone* face depicted the target identity and a non-target emotional expression; and 3) the *expression alone* face depicted the target emotional expression and a non-target identity. There were also three non-target faces – these were photographs of three different people that expressed emotions different from those in the target faces. The task was to respond by pressing a button when any target appeared on the screen, and to withhold a response if a non-target was displayed.

We predicted that there would be coactive processing of identity and expression, characterized by super capacity, for own-race faces for each racial group, replicating and extending our previous result with Causasian faces (Yankouskaya et al., 2012). We further predicted that, if the interaction between facial identity and expression depends to some degree on experience, then the reduced expertise with other-race faces should be associated with diminished coactive processing of identity and expression for other-race faces and reduced workload capacity as compared to own-race faces. Furthermore, variations in the level of experience with members of the other race should positively correlate with the extent of any redundancy gain, as a marker for integrative identity and expression processing.

Method

Participants

Three groups of twelve students from the University of Birmingham participated. The first group consisted of European individuals (i.e. Caucasian, 9 female), the second group comprised African individuals (8 females) and the third group consisted of Asian individuals (9 females). Twenty-seven of the 36 participants were UK born (12 European, 8 African, and 7 Asian). The participants were aged between 19 and 23 years and received course credit for taking part. There was no significant age difference between the groups ($F(2,6) = 0.89$, n.s.). This experiment was carried out in accordance with the ethical guidelines of the British Psychological Society. Each participant gave informed consent at the start and was free to withdraw at any stage, although none did.

Stimuli and Apparatus

Three sets of 6 female portrait photographs were employed for each ethic group, 18 all together. All face images were sourced from The NimStim Face Stimuli Set (Tottenham, Borsheid, Ellertsen, Marcus, & Nelson, 2002). In each set three photographs contained targets: stimulus 1 had both the target identity and the target emotion, sad (IE); stimulus 2 contained the target identity and a non-target emotional expression, happy (I); stimulus 3 contained the target emotional expression, sad and a non-target identity (E). Three non-target faces were photographs of three different people, and expressed emotions different from those in target faces (angry, surprise and neutral). Examples of stimuli are presented in Figure 1.

Insert Figure 1 about here

The facial expressions in all of the photographs used were recognized at a level of at least 80% correct or more (Tottenham et al., 2002). Set one consisted of European faces; set two African faces and set three Asian faces. The images were selected based on three separate pre-experiments (for three sets of tested faces). In these pre-experiments an identity or emotional-expression matching task was used on pair of faces. Based on the speed of ‘different’ responses when participants discriminated between two faces, the face identities and emotional expressions were chosen (eliminating any strong preferences for one expression or identity over others, so that the discrimination along the two critical dimensions was approximately matched) (see the Supplementary Materials).

The photographs were cropped around the hairline to eliminate the possibility of target judgments being based on hairstyle. Any visible background was coloured black. The faces were 10 x 13 cm and were displayed on a 17-in monitor. Stimulus presentation was controlled using E-Prime. The stimuli were presented on the monitor at the viewing distance of 0.8 m. The angular width subtended by each stimulus was approximately 10°.

Two self-reported questioners were used (Walker, Silvert, Hewstone, & Nobre, 2008). One measured the quantity of the social contact with other races (Cronbach's $\alpha = 0.87$). This questionnaire included questions such as ‘I often see other-race people at social events I attend”.

The second measured the degree of interaction between the participant and individuals from other races (Cronbach's $\alpha = 0.94$). It included questions like ‘How often have you had other-race persons on your team during sports or your group during other activities?’

Design and procedure

Before performing the experiment, participants completed the two self-report questionnaires

For the identity and expression judgments a “target present/target absent” task was employed. Half of the trials used stimuli containing at least one target (EI, I, E; ‘target present’ trials) the other half of the faces had depicted neither the target identity nor the target expression ‘target absent’ trials) (Figure 1).

The order of the trials was random. Each participant performed the task separately for the three sets of face images (European, African and Asian). The order of the face sets was counter-balanced across participants.

Participants were asked to respond as quickly and accurately as possible when the target identity and/or the emotional expression were displayed by pressing a button “target present” on the keyboard, and press a button ‘target absent’ when a displayed face contains no target. They were given an example of the target facial identity (with neutral expression) and told to respond to the presence of this person and to the presence of a sad face.

Prior to being presented with each set of faces participants completed an initial practice block of 18 trials during which they were given feedback on their accuracy after each trial. The practice trials ensured that all participants were able to perform the target detection task with all three set of faces with an accuracy level above 95%. After a short break participants then performed three test blocks of 120 trials for each set of faces. Each trial started with the presentation of a fixation cross at the centre of the screen for 500 ms. Images were presented successively in random order till a response was made or a maximum time of 2000 ms passed. Stimuli presentation and data collection were controlled by using Cogent 2000 and Cogent Graphics developed by the Cogent 2000 team at the FIL and the ICN (http://www.vislab.ucl.ac.uk/cogent_2000.php).

Analysis of data

The magnitude of any enhancement for redundant targets is commonly estimated by comparing the observed RT distributions with the distributions predicted by the Independent Race Model (Raab, 1962, see Miller (1982, 1986) for implementation of the procedure). A number of computational model-fitting approaches have been proposed to compare RT distributions for redundant and single target conditions. The majority of these approaches have been developed to test specific assumptions about probability summation processes assumed by the Independent Race account (Colonius, 1990), determining the level of statistical significance for empirically observed violations (Maris & Maris, 2003), and testing the predictions for serial and parallel architectures in a particular task (Townsend & Ashby, 1983). In the present study we adopted a standard procedure introduced by Miller (1982) and extended later for a group level analysis (Ulrich, Miller, & Schroter, 2007) for testing our hypothesis. The main advantage for using the procedure here is that the Miller's test (1982) allows a direct comparison between models without the need for specific assumptions about response time distributions or the experimental paradigm to be met. To increase the diagnostic power of the procedure, the individual RT distributions were corrected for 'fast guesses' when responses may be given without processing the stimuli (here RT < 150 ms were cut off) and the 'kill-the-twin' procedure was applied to the data (Gondan & Heckel, 2008; Ulrich et al., 2007).

The number of errors and response times for the correct trials were analyzed.

Estimating the redundancy gain effect. For each set of stimuli three analyses of RTs were conducted. The first analysis determined whether redundant targets trials were responded to more quickly than any single target trial using the 'favoured dimension' test (Biederman & Checkosky, 1970). It has been shown that, when some observers favour one dimension over another there is an overestimation of the mean RT redundancy gain relative to the fastest single dimension condition for each observer (Biederman & Checkosky, 1970; Mordkoff & Yantis, 1993). The fixed favored dimension test involves comparing the two single target conditions for each observer against each other. When the two conditions differ, the faster mean RT is retained as the conservative estimate of single target mean RT; when the two conditions do not differ, the overall mean from both single target conditions is used. The more conservative measure RT across the two single targets (e.g., emotion only, or identity only) were substracted from the mean RT for redundant targets for each participant. A positive value following this substraction was considered a redundancy gain.

Testing the independent race vs. the co-activation model. The second analysis evaluated whether the Independent Race Model inequality is violated (Miller, 1982). This test makes use of the cumulative probability density functions (CDFs) of the latencies obtained for the redundant targets and for each of the single targets, and can be expressed as follows:

$G_{IE}(t) < G_I(t) + G_E(t)$, (1) where

$G(t)$ – is the probability that a response has been made by time t, I and E refer to a target defined by identity and a target defined by emotional expression, respectively; and IE refers to redundant targets.

The G_{IE} variable, in inequality (1), sets an upper boundary for the cumulative probability of a correct response at any time (t) given redundant targets (IE). According to the Independent Race Model, the redundant target (IE) cannot exceed this upper bound, because the mean of the minimum of two random variables (IE) is less than or equal to the sum of smaller means of both variables (I and E). In contrast, the Co-activation Model holds that the upper bound should be violated, because responses to redundant target must be faster than the fastest responses to either single target (Miller, 1982).

To conduct these tests of the Miller (1982) inequality, empirical CDFs were estimated for every participant and every target condition. All calculations followed the algorithm for testing the Independent Race model inequality presented by (Ulrich et al., 2007). First, the 100 RTs generated by each participant for all target trials were sorted in ascending order to estimate 19 percentiles (5^{th} through the 95^{th} at 5% intervals). Then these numbers were averaged across participants to produce the composite CDF for redundant targets and for each single target condition. To produce the sum of CDFs for I and E trials, RTs for these trials were pooled together and 19 quintiles were estimated based on only the fastest 100 of the 200 trials. All calculations were conducted using a MatLab script for computing the Independent Race model test (Ulrich et al., 2007).

For nineteen percentile points the CDFs were calculated for each participant and then averaged. Paired two-tailed *t*-tests were used to assess the reliability of the difference between G_{IE} and the sum of G_I and G_E at each percentile point.

Graphic representations of the distributions were constructed using group RT distributions obtained by averaging individual RT distributions (Ulrich et al., 2007). When the CDFs are plotted, the Independent Race Model requires that the CDF of the redundant targets trials falls below and to the right of the summed CDF, any reliable violation of this pattern provides support for the co-activation model.

Computing the Capacity Coefficient (C(t). Here we used a method of computing the capacity coefficient proposed by Townsend and Eidels (2011) for the OR-task* [2]:

$$C_{OR}(t) = \frac{-\log[S_{IE}(t)]}{-\log[S_I(t) * S_E(t)]}$$

where the survival function of the redundant targets condition is in the numerator and the product of the survival functions of the two single target conditions are in the denominator.

First, for each condition we calculated the empirical CDF using 10 ms time bins. Then the empirical survivor function was computed for each condition at each time bin - this is simply the complement of the cumulative distribution (the proportion of trials that were slower than the specified RT). All computations were performed using Matlab codes (Townsend & Eidels, 2011). After averaging the CDFs for the redundant targets and either single target face, the data were converted into survivor functions in order to create integrative hazard functions. Subsequently the capacity coefficients for each group and each face set were generated by creating a ratio of the averaged hazard functions at each time bin (Hugenschmidt, Hayasaka, Peiffer, & Laurienti, 2010). Confidence intervals were defined for each group-capacity coefficient using the bootstrapping technique (Townsend & Eidels, 2011).

Computing correlations between (i) the experience of an individual with other races and (ii) the behavioural redundancy gain. Scores for each self-report questionnaire were calculated along with the size of the redundancy gain for each participant. As we had three different ethnic groups, we first assessed whether our participants differed in their reported experience with one or the

[2] It has been demonstrated that in order to access the internal efficiency of processing it is critical to take into account the stopping rule used by participants to perform the task. In the OR-task either stimulus containing a target can produce a correct response. In AND-task the system must complete information from two sources (the decision is made only when two targets are detected) (Townsend & Eidels, 2011)

other group. The self report questionnaires assessed i) the estimated number of visual encounters with other race faces and ii) the amount of experience with individuals from other race. For each participant we computed a score for each of these measures. The results (see below) showed that participants within each non-white racial group reported similar levels of encounter and interactions with other race groups, which were either high or low. Therefore, for these analyses, we collapsed the results of the two non-white race groups. The size of any redundancy gain was obtained by subtracting the mean RT for trials containing both targets from the mean RT for the fastest of the single target trials. In cases where the RT for the single target was shorter than RTs for the redundant target image, the size of the redundancy gain was marked as negative. These values were computed for each set of ethnic faces separately.

We used multiple regression analyses to examine whether experience with another race can predict the size of the redundancy gain, and specifically whether the gain was driven by the number of contacts and individuating experiences participants had with other-race people. In total, four measures were computed for each participant: two summed scores for each of the self-report questionnaires and three values for the size of redundancy gains (one for the own-race set of images and two for the other-race sets of images).

Results

Part 1: Redundancy gains and contact

Accuracy performance

The accuracy of performance (mean percent of errors and SEM) for own and other-race images for each group of participants is displayed in Figure 2. Overall, accuracy was very high and participants easily completed all three tasks, with their own and other-race faces.

Insert Figure 2 about here

Error rates were entered into a mixed design ANOVA with stimuli (the redundant target, the identity target, the emotional expression target and the three non-targets) and sets of faces (European, African and Asian) as within-subjects factors and group (European, African and Asian participants) as a between- subject factor was used to examine performance accuracy. There were no differences between the ethnic groups ($F(2,33) = 1.8$, $p > .05$) nor an interaction of face sets*group ($F(2,66) = 1.7$, $p > .05$). The overall response accuracy was high, most errors were false alarms. However, the stimulus did affected the number of errors made ($F(5,165) = 4.9$, $p < .001$, $p\mu^2 = 0.13$). A Bonferonni test for multiple comparisons showed that the participants were less accurate in responding to the non-target face with a surprised expression ($p < .05$) compared to all other expressions. Most importantly there were no reliable differences in the error rate between the different target present trials, and no effects of the ethnicity of the participants. There was also an interaction of stimuli*sets of faces ($F(10, 330) = 3.3$, $p < .05$ $p\mu^2 = 0.091$). However, Bonferonni adjustments for multiple comparisons revealed no reliable differences between the stimuli across each set of faces (European, African, Asian) (all $p > .05$).

RT performance

The mean RTs and SEM for correct responses for images containing a target for each group of participants are displayed in Figure 3.

Insert Figure 3 about here

A mixed design ANOVA was conducted with stimuli (redundant targets (EI), the identity target (I), the emotional expression target (E)) and sets of faces (European, African and Asian) as within-subject factors and group (European, African and Asian participants) as a between-subject factor.

There was a main effect of stimulus (F(2,66) = 14.4, p < .001, $p\mu^2$ = 0.3). Simple effect analyses showed that RTs to redundant targets were reliably shorter than to identity targets (t(107) = 7.9, p < .001, d = 0.76) and emotional expression targets (t(107) = 9.2, p < .001, d = 0.66). RTs for the identity target did not differ reliably from those for the emotion target (p > .05). There was no main effect of group (F(2, 33) = 0.7) but there was a main effect of face set (F(2,66) = 47.5, p < .001, $p\mu^2$ = 0.59). RTs for the European faces were faster than for the African and Asian faces (all p < .001), and RTs for African faces was reliably faster than for Asian faces (all p < .05).

Most importantly there was a three-way interaction between stimulus, face-set and group (F(8,132) = 3.9, p < .001, $p\mu^2$ = 0.19). To reveal the sources of this interaction we computed a separate ANOVA for each group of participants. A reliable interaction occurred between stimulus and face set for the European and African groups (F(4,44) = 13.6, p < .001, $p\mu^2$ = 0.56, F(4,44) = 8.7, p < .001, $p\mu^2$ = 0.44, respectively). African and European participants were faster in responding to a redundant target face in the set of own-race faces compared to the set of other-race faces and they also showed overall less difference between single and redundant targets for other-race faces compared to the own-race faces. No reliable interaction of stimulus*set was observed for Asian participants (F(4,44) = 2.1, p > .05, $p\mu^2$ = 0.16), though these participants tended to show a similar pattern, with a larger redundancy gain for Asian faces compared with African and European faces.

We next examined the redundancy gain effect using the ‘favoured dimension’ test (Biederman & Checkosky, 1970) (see the Method for more details). Figure 4 shows the mean redundancy gains for each group of participants for each racial set of faces.

Insert Figure 4 about here

To examine the effect of race of face on the size of the redundancy gains for European, African and Asian participants, a mixed design ANOVA was conducted with race of face (European, African, Asian) as a within-subject factor and group of participants as a between-subject factor. There was no main effect of group ($F(2,33) = 1.1$, $p = .36$, $p\mu^2 = 0.06$), but there was a main effect of face set ethnicity ($F(2,66) = 3.23$, $p < .05$, $p\mu^2 = 0.089$) and more importantly a reliable interaction between the face sets and group ($F(4,66) = 3.74$, $p = .008$, $p\mu^2 = 0.19$).

To unravel the sources of this interaction, we computed separate analyses for each participant group. For the European participants the size of the redundancy gain was greater for own-race faces compared to African faces ($t(11) = 9.18$, $p < .001$, $d = 0.31$) and Asian faces ($t(11) = 8.35$, $p < .001$, $d = 0.11$). There were no reliable differences between the sizes of the redundancy gains for African and Asian faces ($t(11) = 1.9$, $p > .05$, $d = 0.35$).

For the African participants the size of the redundancy gain was greater for African faces as compared to Asian faces ($t(11) = 3.6$, $p = .004$, $d = 0.17$). The size of redundancy gains for their own-race (African) faces did not differ significantly from those for European faces (all $p > .05$).

The group of Asian participants showed no reliable differences in the size of the redundancy gain for own-race faces as compared to European faces ($t(11) = 0.9$) and African faces ($t(11) = 1.1$, $p = .29$, $d = 0.23$). However, the size of the redundancy gain for European faces was greater than for African faces ($t(11) = 2.4$, $p = .033$, $d = 54$) for this group.

Part 2. Testing the independent race model

To assess whether the redundancy gain effects reported above can be accounted for by the Independent Race Model for the processing of identity and expression, we tested whether the inequality assumption of the independence model was reliably violated (see the Method for details). Graphical representations of the CDFs for redundant targets, the identity target, the emotional expression target and the sum of the CDF for two single targets for each group of participants are displayed in Figure 5. In this plots we average the CDFs across participants using the approach introduced by Ulrich et al. (2007).

Paired-samples t-tests were performed on the mean RTs for the redundant targets and the sum of the identity target and the emotion targets for each stimulus set in each group of participants. As mentioned in the data analysis section, Miller's inequality (1982) predicts that, for The Independent Race model (Raab, 1962) model, the probability of a response in the redundant target condition should never exceed that for the sum of two single targets (Miller, 1982). Previous studies have reported violations of the Miller inequality (1982) for percentile points 10-25. In cases where violations of the inequality are observed at multiple percentile points, an appropriate correction for multiple comparisons is needed in order to control for Type 1 errors. However, the widely used Bonferroni test for multiple comparisons demands that all the tests be independent from each other (Benjamini, 2010). This demand is not fulfilled in our data where correlations between percentiles bins are high (from 0.84 to 0.93). In order to conduct the Miller test (1982), but to control for Type 1 errors, our strategy was to perform the test at two percentiles (10% and 15%) using paired t-tests but with a strict significance level adopted (1% instead of 5%).

European participants. The CDF for redundant targets fell to the left of the sum of the single-target CDFs for own-race faces (Figure 5, top row) indicating violation of the Miller (1982) inequality. These violations were statistically significant at the 10^{th} and 15^{th} quantiles ($ps < .01$). In contrast, redundant target CDFs for African and Asian faces did not show any violation at those quantiles, as confirmed by paired-samples t-tests (all $p > .01$).

African participants. The redundant targets CDFs for own-race and European faces fell to the left of the sum of the single-target CDFs (Figure 5, middle row). These violations were statistically significant at the 10^{th} and 15^{th} quantiles for own-race faces ($ps < .01$) and at the 10th quantile ($p < .01$) for European faces. There were no quantile points at which the redundant targets CDF exceeded the sum of the single-target CDFs for Asian faces.

Asian participants. The redundant targets CDF for own-race faces fell to the left of the sum of the single-target CDFs (Figure 5, low row). These violations were statistically significant at the 10^{th} and 15^{th} quantiles ($ps < .01$). Similar results were obtained in this group for European-race faces. In contrast, there were no quantile points at which the redundant targets CDF exceeded the sum of the single-target CDFs for African faces.

Insert Figure 5 about here

The Capacity Coefficient

The overall capacity coefficients for each set of faces across participant groups are presented in Figure 6 (individual overall capacity coefficient data are presented in the Supplementary Material, see Figures S-4-6 and Table A).

Insert Figure 6 about here

Figure 6 demonstrates super capacity for processing identity and emotional expression in own-race faces and limited capacity in other-race faces, with the exception of European faces which were processed with super capacity by both the African and Asian participants. The super capacity was obtained taking data from time bins 680 ms to 820 ms. The overall limited capacity coefficient (averaged across time bins) for processing other-race faces in each experiment was close to 0.5.

To examine the effect of ethnicity of faces on overall capacity in processing of identity and emotional expressions across groups of participants, a repeated measures ANOVA was conducted with face ethnicity (European, African and Asian) as a within subject factor and group of participants as a between-subject factor using individual overall averaged capacity coefficients computed across all time bins (the data are presented in the Supplementary Material). The results showed that face ethnicity affected the overall capacity of processing ($F(2,66) = 10.6$, $p < 0.001$, $p\mu^2 = 0.24$), and this effect was reliably different across groups ($F(4,66) = 10.3$, $p < 0.001$, $p\mu^2 = 0.39$). The overall capacity for processing of European faces compared to non-European faces was significantly greater in the European group ($t(11) = 5.2$, $p < 0.001$, $d = 0.75$; $t(11) = 4.6$, p 0.001, $d = 0.23$) (Table 1). For Asian participants, only African faces were processed with reduced capacity ($t(11) = 3.47$, $p = 0.005$, $d = 0.28$); for African participants, reduced capacity was found for Asian faces only ($t(11) = 4.2$, $= 0.001$, $d = 0.5$). Individual capacity coefficients are presented in Table A (Supplementary material). The results here are similar to those for the size of redundancy gains, and suggest that greater redundancy gains are associated with greater capacity in the processing of identity and emotional expression.

Table 1

The overall capacity (SD in brackets) for each face set in European, African and Asian groups of participants

Group	Set of faces		
	European	African	Asian
European	2.02 (0.86)	0.58 (0.16)	0.62 (0.39)
African	1.52 (0.99)	2.14 (1.41)	0.54 (0.27)

Asian	1.01 (0.24)	0.68 (0.18)	1.01 (0.72)

Interestingly, the results in Table 1 indicate that, in the Asian group, the overall capacity for processing both own-race and European faces is unlimited ($C_{overall} \approx 1$). Along with this, Miller's test (1986) (Figure 5) pointed to coactivation in the processing of own- and European faces for the Asian group. We conclude that the unlimited overall capacity here suggests that, in this experiment, the processing of identity and emotional expression neither degrades nor benefits when there are two rather than one target present. This finding is discussed in the Discussion section.

The Redundancy gain effect and social experience

Averaged scores for the amount of social contact and individual experience with other-race people for the three groups of participants are displayed in Table 2.

Table 2

Means scores for self-report questionnaires in groups of European, African and Asian participants

Questionnaires	Groups		
	European M (SD)	African M (SD)	Asian M (SD)
Quantity of social contact*	14.9 (8.1)	27.0 (5.7)	23.85 (10.1)
Individual experience**	32.2 (14.9)	38.5 (10.9)	39.8 (11.4)

*Max scores = 30; min scores =6;

** Max scores = 50; min scores = 10

Multiple regression analyses tested whether the quantity of social contact, and the amount of individual experience with other-race people, predicted the size of the redundancy gains for own- and other-race faces. Prior to running the analyses we tested if there were differences in the number of well-known other race people for each group of participants. In the first three questions in the 'Quantity of social contact' questionnaire, participants report the number of well-known European, African and Asian people. In each group of participants we examined the number of well-known other race people reported, using a paired-sample t-test (e.g., for the group of European participants we compared the number of well-known European, African and Asian people) (Table 3). As expected, the number of well-known own-race people was reliably higher in all groups of participants (all $p < .05$) (Table 3). In contrast, none of the three groups showed a reliable difference between the number of well-known members from the two other races (all $p > 0.5$). Thus, because the numbers of known people from the two other races were approximately equal, for the multiple regression analysis we used averaged redundancy gain scores for the other race.

Table 3

Means number (standard deviation in brackets) of well-known own and other-race people for group of European, African and Asian participants

Group of participants	Number of well-known own and other race people		
	European	African	Asian
European	**6.8* (2.1)**	3.2 (1.3)	2.9 (0.6)
African	9.3 (3.4)	**16.7 (4.1)**	7.8 (4.2)
Asian	5.1 (2.2)	5.3 (2.5)	**11.4 (4.9)**

* In bold for own race people

The multiple regression analysis was carried with all 36 participants (three groups of 12 participants) to test whether the size of the redundancy gain for other race faces can be predicted by the number of social contact and amount of individual experience. The scores for The Quantity of social contact and The Individual experience questionnaires were entered as predictors. No multivariate outliers were identified using the Mahalanobois' distance (6.7). The correlations between the two questionnaires and the dependent variable (redundancy gains), were positive; r =.11 for The Quantity of social contact and r = .47 for The Quantity of social contact. This indicates that redundancy gains for other race faces were related to the degree of contact/experience an individual had experienced.

Table 4

Summary of multiple regression analysis for the size of redundancy gains for Own and Other-Race Faces (N=36)

Sets of faces	Variables	B	SE (B)	B	t	Sig. (p)
Own-race	The Quantity of social contact	.044	.62	.012	0.68	.91
	Individual experience	.75	.56	.24	1.3	.22
Other-race	The Quantity of social contact	1.6	.32	.59	4.5	.000
	Individual experience	.47	.30	.21	1.4	.119

Note
R^2 for own-race faces = 0.058 (for overall model fitting)
R^2 for other-race faces = 0.517 (for overall model fitting)

The regression analysis (Table 4) showed that self-reported experience with members of the other races significantly predicted the size of the redundancy gain, explaining 51.7% of the variance. Furthermore, the results suggest that the most important factor predicting the redundancy gain was the 'Quantity of social contact' score ($F(2,35) = 17.7$, $p < .001$). To ensure that these results were specific to the amount of experience with other races and that they were not driven by specific properties of the participants (e.g., participants not only knowing more members of other races may also be more sociable), we computed the same analyses but now trying to predict the redundancy gain for the participant's own race from the two self-reported questionnaires (Table 4). The results of the regression for own-race faces indicated that the number of social contacts and the amount of individual experience with members of another racial group did not reliably predict the size of the redundancy gains for own-race faces ($R2 = .058$, $F(2,35) = 1.02$, n.s.).

Discussion

In this study we tested for the first time whether experience with faces from specific ethnic groups affects interactions between the processing of facial identity and expression. We found that redundancy gains in the processing of identity and emotion from own-race faces were present for all three groups of participants. This finding confirms and generalizes our previous results from Caucasian to Asian and African participants (Yankouskaya et al., 2012). More interestingly, the redundancy gain from combined identity and expression targets was reduced for other race faces, dependent on the experience the participant had with other race faces. Furthermore, there was evidence for non-independent processing of emotion and identity information from faces, and violation of the Independent Race Model, but this was asymmetric. European participants only showed violations for own race faces. African and Asian participants showed violations for their own race faces and for European faces, but they did not show it respectively for Asian and African (both other-race) faces.

The capacity analysis demonstrated super capacity processing of identity and emotional expression within own-race faces, indicating that the observed responses for the redundant target face were greater than predicted by the combined single targets. This means that adding information to own race faces results in positive dependency that facilitated performance. This finding is consistent with the argument for co-active processing for own-race faces (Townsend & Eidels, 2011; Townsend & Nozawa, 1995). In contrast, adding information to other-race faces generated results indicative of a negative dependency and suggesting that the processing of identity and emotional expression in other-race faces operates with limited capacity. The negative dependency for other-race faces held true for European participants but not for African and Asian groups where responses for European faces showed positive dependency. This finding is similar to that revealed by testing the Independent Race Model and will be discussed below. Intriguingly, Asian participants showed coactivation (Figure 5) and super capacity at some time bins (Figure 6) for own and European faces, while the overall capacity was unlimited. Here we would expect overall super capacity in the Asian group at least for own race faces, especially given that the number of social contacts with own-race people was greater compared to contacts with European and African individuals. Previously, limitations in capacity along with coactive processing was reported in work on facial feature detection (Wenger & Townsend, 2001) where capacity was examined as a function of the number (1 or 2) and level of feature organization (biologically appropriate and biologically inappropriate). The authors linked this finding to the fact that the architecture might be not actually coactive but that parallel channels for different face features might demonstrate positive dependency that mimics coactivation (M. Wenger & Townsend, 2001). Here, unlimited processing of identity and emotional expressions in own-race faces in Asian participants we reflect sample inconsistency in this group (see main limitation of the study below).

The overall larger redundancy gain for own race faces fits well with previous reports demonstrating superior identity and expression processing for own-race compared with other-race faces (Ackerman et al., 2006; Gauthier & Nelson, 2001; Kito & Lee, 2002; Levin, 2000). Interestingly, while redundancy gains occurred for African and Asian participants presented with European faces, the reverse was not the case. This asymmetry may reflect the fact that the study took place in UK where the majority of the population is of Europe origin, plus 15 out of 24 participants in both the Asian and African groups were born and grew up in the UK and reported substantive contact with European people from their childhood. Thus the asymmetric contact may have determined the selective cross-race redundancy gains for African and Asian participants. Similar conclusions were drawn from the study by Hancock and Rhodes (2010) where Chinese and Caucasian participants varying in contact with other-race faces were tested for both recognition and configural coding of own and other-race faces. The number and length of social contacts with other-race people also appeared to be important, correlating with the redundancy gains for other race faces. This is consistent with participants processing own- and other-race faces in a similar manner once they have gained sufficient experience with other race faces (Bukach, Bub, et al., 2006; Bukach et al., 2012; Gauthier & Nelson, 2001).

Interestingly, the size of the redundancy gains were more strongly linked to the number of social contacts than to the rated quality of other-race contact involving personal face-to-face communication. Recently, Bukash et al. (2012) have reported a strong negative correlation between self-reports of individuating experience and the other-race effect when holistic processing of faces was examined in both Caucasian and African participants (participants performed composite tasks to assess holistic processing for same-race and other-race faces in separate sessions). A weak relation between individuating experience with other-race people and the size of redundancy gains in the present study may reflect methodological differences between the studies. For example, in contrast to the task used in Bukash et al. (2012), here participants were asked to divide their attention between two facial dimensions rather than attend to faces holistically. Future work needs to assess whether holistic processing of facial features is key to enabling the qualitative experience in individuating other race faces to moderate the processing of other-race faces.

As discussed in the Introduction the redundancy gain effect can be explained by several models of processing and we have contrasted the Independent Race-model (Raab, 1962) and the

Co-activation model Miller, 1982). The Independent Race Model (Raab, 1962) holds that at no point in the cumulative distribution functions should the probability of a response to redundant targets exceed the sum of the probabilities for responses to either single target. In contrast, according to the Co-activation account, responses to the redundant targets can be made before either single target generates enough activation to produce a response, and so the probability of a response to redundant targets can exceed the sum of the probabilities for responses to single targets. Critically we observed violations of the Miller inequality, contradicting the Independent Race Model, once faces were familiar (for own-race faces for all participants; for European faces for African and Asian participants). It could be argued that the European faces were more discriminable, and thus were more liable to yield race-model violations. However, this seems unlikely given that the redundancy gains were moderated by contact. Instead we propose that some degree of familiarity with the properties of the faces within particular racial groups is needed before information about identity and expression becomes integrated as faces are processed. In the absence of this experience, however, facial identity and emotional expressions may be processed independently with the data falling within the bounds of the Independent Race Model. A possible explanation for this finding may be linked to qualitative differences between processing of the same and other-race faces, at both a neural and functional level (Golby, Gabrieli, Chiao, & Eberhardt, 2001; Michel et al., 2006; Stahl, Wiese, & Schweinberger, 2008; Tanaka, Kiefer, & Bukach, 2004). For example, Golby, Gabrieli, Chiao & Eberhardt (2001) found that the fusiform face area (FFA) in the brain was less active in response to other race faces than to own race faces. Michel, Rossion, Han, Chung & Caldera (2006) demonstrated that own-race faces are processed more holistically and configurally than other race faces (see also Tanaka, Kiefer & Bukash, 2004). Stahl et al. (2008), using ERPs, showed an effect of face expertise on the P2 component sensitive to second-order relationship in faces. This explanation is supported by our capacity analysis. Super capacity here may link to the degree of familiarity (expertise) in faces: the more familiar the facess are, the fewer resources are needed to process them. Conversely, unfamiliar faces demand more resources and increasing workload leads to slower responses for faces containing two targets.

Taken together these findings suggest that the effect of expertise in processing faces from different races facilitates the pooling of information from the face – for example to form stronger facial configurations for face identification and to facilitate the integration of identity and emotion here. Converging evidence supporting the argument for identity and expression being pooled, in line with the Co-activation account, is our prior finding that a cross-talk (partial parallel) model failed to account own-race processing of identity and expression in our previous work (Yankouskaya et al., 2012).

Limitations

The main limitation of the present study is that the groups of African and Asian participants consisted of both native and British born people. To investigate further the processing of identity and emotional expression in other-race faces it would be interesting to test groups of native and British people separately. In addition, the redundancy gain for own-race faces in this study was smaller overall in the Asian participants (redundancy gains were significant only across the first 4 quantiles) compared to the European and African groups (significant across 9 and 11 quantiles respectively). The possible reason for this may be related to the images used in the Asian face set. The images were photographs of Malaysian people, but the sample of participants consisted of Chinese (7 participants), Malaysian (2 participants), Japanese (2 participants), Philippino (1 participant) individuals. Though Malaysian faces are similar to Chinese and Japanese faces, there might be subtle differences that affect RTs and made integrative processing of identity and expression sub-optimal.

Conclusion

The present results provide strong evidence (from violations of the independent race model) that face identity and expression are not processed independently. In addition, the data suggest that the integration of identity and expression is modulated by experience with different race faces, with experience leading to stronger integration of different types of facial information.

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References

Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., Kenrick, D. T., Becker, D. V., Griskevicius, V., . . . Schaller, M. (2006). They all look the same to me (unless they're angry): from out-group homogeneity to out-group heterogeneity. *Psychological Science, 17*(10), 836-840. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17100781 doi:10.1111/j.1467-9280.2006.01790.x

Aguado, L., Garcia-Gutierrez, A., & Serrano-Pedraza, I. (2009). Symmetrical interaction of sex and expression in face classification tasks. *Attenion*, *Perception & Psychophysics*, *71*(1), 9-25. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19304593 doi:10.3758/APP.71.1.9

Anthony, T., Cooper, C., & Mullen, B. (1992). Cross-racial facial identi- fication: A social cognitive integration. *Personality and Social Psychology Bulletin, 18*, 296-301. Retrieved from

Ashby, F. G., & Townsend, J. T. (1986). Varieties of perceptual independence. *Psychological Review, 93*(2), 154-179. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3714926

Baudouin, J. Y., Martin, F., Tiberghien, G., Verlut, I., & Franck, N. (2002). Selective attention to facial emotion and identity in schizophrenia. *Neuropsychologia, 40*(5), 503-511. Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11749980 doi:S0028393201001142 [pii]

Benjamini, Y. (2010). Simultaneous and selective inference: Current successes and future challenges. *Biometrical Journal, 52*(6), 708-721. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21154895 doi:10.1002/bimj.200900299

Biederman, I., & Checkosky, S. F. (1970). Processing redundant information. *Journal of Experimental Psychology, 83*, 486-490. Retrieved from http://geon.usc.edu/%7Ebiederman/publications/Biederman_Checkosky_1970.pdf

Brown, S. D., & Heathcote, A. (2008). The simplest complete model of choice response time: linear ballistic accumulation. *Cognitive Psychology, 57*(3), 153-178. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18243170 doi:10.1016/j.cogpsych.2007.12.002

Brown, S. D., Marley, A. A., Donkin, C., & Heathcote, A. (2008). An integrated model of choices and response times in absolute identification. *Psychological Review, 115*(2), 396-425. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18426295 doi:10.1037/0033-295X.115.2.396

Bruyer, R., Laterre, C., Seron, X., Feyereisen, P., Strypstein, E., Pierrard, E., & Rectem, D. (1983). A case of prosopagnosia with some preserved covert remembrance of familiar faces. *Brain & Cognition, 2*(3), 257-284. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6546027 doi:10.1016/0278-2626(83)90014-3

Bukach, C. M., Bub, D. N., Gauthier, I., & Tarr, M. J. (2006). Perceptual expertise effects are not all or none: spatially limited perceptual expertise for faces in a case of prosopagnosia. *Jornal of Cognitive Neuroscience, 18*(1), 48-63. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16417682 doi:10.1162/089892906775250094

Bukach, C. M., Cottle, J., Ubiwa, J., & Miller, J. (2012). Individuation experience predicts other-race effects in holistic processing for both Caucasian and Black participants. *Cognition, 123*(2), 319-324. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22397819 doi:10.1016/j.cognition.2012.02.007

Bukach, C. M., Gauthier, I., & Tarr, M. J. (2006). Beyond faces and modularity: the power of an expertise framework. *Trends in Cognitive Science, 10*(4), 159-166. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16516534 doi:10.1016/j.tics.2006.02.004

Campbell, R., Landis, T., & Regard, M. (1986). Face recognition and lipreading. A neurological dissociation. *Brain, 109 (Pt 3)*, 509-521. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3719288

Cassidy, K. D., Quinn, K. A., & Humphreys, G. W. (2011). The influence of ingroup/outgroup categorization on same- and other-race face processing: The moderating role of inter-versus intra-racial context. *Journal of Experimental Social Psychology, 47*, 811-817. Retrieved from http://etheses.bham.ac.uk/3487/1/Cassidy12PhD.pdf

Egeth, H., & Dagenbach, D. (1991). Parallel versus serial processing in visual search: further evidence from subadditive effects of visual quality. *Journal of Experimental Psychology: Human Perception and Performance, 17*(2), 551-560. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1830092

Elfenbein, A., & Ambady, N. (2002). Is there an in-group advantage in emotion recognition? *Psychological Bulletin, 128*(2), 243-249. Retrieved from

Ellamil, M., Susskind, J. M., & Anderson, A. K. (2008). Examinations of identity invariance in facial expression adaptation. *Cognitive, Affective & Behavioral Neuroscience, 8*(3), 273-281. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18814464

Fific, M., Nosofsky, R. M., & Townsend, J. T. (2008). Information-processing architectures in multidimensional classification: a validation test of the systems factorial technology. *Journal of Experimental Psychology: Human Perception and Performance, 34*(2), 356-

375. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18377176 doi:10.1037/0096-1523.34.2.356

Ganel, T., & Goshen-Gottstein, Y. (2004). Effects of familiarity on the perceptual integrality of the identity and expression of faces: the parallel-route hypothesis revisited. *Journal of Experimental Psychology. Human Perception and Performance, 30*(3), 583-597. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15161388 doi:10.1037/0096-1523.30.3.583

Garner, W., & Felfoldy, G. (1970). Integrality of stimulus dimensions in various types of information processing. *Cognitive Psychology, 1*, 225–241. Retrieved from http://dx.doi.org/10.1016/0010-0285(70)90016-2

Gauthier, I., & Nelson, C. A. (2001). The development of face expertise. *Current Opinion in Neurobiology, 11*(2), 219-224. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11301243

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. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11477432 doi:10.1038/90565

Gondan, M., & Heckel, A. (2008). Testing the race inequality: A simple correction procedure for fast guesses. *Journal Of Mathematical Psychology, 52*(5), 322-325. Retrieved from http://dx.doi.org/10.1016/j.jmp.2008.08.002 doi:DOI: 10.1016/j.jmp.2008.08.002

Hugenberg, K., Young, S. G., Bernstein, M., &Sacco, Donald F (2010). The categorization-individuation model: An integrative account of the other-race recognition deficit. *Psychological Review, 117*(4), 1168-1187. Retrieved from http://dx.doi.org/10.1016/j.jmp.2008.08.002http://psycnet.apa.org/?&fa=main.doiLanding&doi=10.1037/a0020463

Hugenberg, K.,& Corneille, O. (2009). Holistic Processing Is Tuned for In-Group Faces. *Cognitive Science, 33*, 1173–1181. Retrieved from http://www.psor.ucl.ac.be/personal/corneille/documents/Holistic_InGroupFaces.pdf

Hugenschmidt, C. E., Hayasaka, S., Peiffer, A. M., & Laurienti, P. J. (2010). Applying capacity analyses to psychophysical evaluation of multisensory interactions. *An International Journal on Information Fusion, 11*(1), 12-20. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20161039 doi:10.1016/j.inffus.2009.04.004

Kito, T., & Lee, B. (2002). Interpersonal perception in Japanese and British observers. *Perception, 33*(8), 957-974. Retrieved from doi:doi:10.1068/p3471

Kwak, H. W., Dagenbach, D., & Egeth, H. (1991). Further evidence for a time-independent shift of the focus of attention. *Perception & Psychophysics*, *49*(5), 473-480. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2057313

Levin, D. (2000). Race as a Visual Feature: Using Visual Search and Perceptual Discrimination Tasks to Understand Face Categories and the Cross-Race Recognition Deficit. *Journal of Experimental Psychology: General, 129*(4), 559-574. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11142869

Ge, L., Zhang, H., Wang, Z., Quinn, P. C., Pascalis, O., Kelly, D., Slater, A., Tian, J., Lee, K. (2009). Two faces of the other-race effect: Recognition and categorisation of Caucasian and Chinese face. *Perception 38*(8) 1199 – 1210. Retrieved from http://www.perceptionweb.com/abstract.cgi?id=p6136

Meissner, C., & Brigham, J. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law, 7*(1), 3-35. Retrieved from http://works.bepress.com/christian_meissner/12/

Megreya, A., White, D., & Burton, A. (2011). The other-race effect does not rely on memory: Evidence from a matching task. *The Quarterly Journal of Experimental Psychology*, *64*(8), 1473-83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21812594

Michel, C., Rossion, B., Han, J., Chung, C. S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science, 17*(7), 608-615. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16866747 doi:10.1111/j.1467-9280.2006.01752.x

Miller, J. (1982). Divided attention: evidence for coactivation with redundant signals. *Cognitive Psychology, 14*(2), 247-279. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7083803

Miller, J., Ulrich, R., & Lamarre, Y. (2001). Locus of the redundant-signals effect in bimodal divided attention: a neurophysiological analysis. *Perception & Psychophysics, 63*(3), 555-562. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11414141

Mordkoff, J. T., & Miller, J. (1993). Redundancy gains and coactivation with two different targets: the problem of target preferences and the effects of display frequency. *Perception & Psychophysics, 53*(5), 527-535. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8332422

Mordkoff, J. T., & Yantis, S. (1991). An interactive race model of divided attention. *Journal of Experimental Psychology. Human Perception and Performance, 17*(2), 520-538. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1830090

Mordkoff, J. T., & Yantis, S. (1993). Dividing attention between color and shape: evidence of coactivation. *Perceptio & Psychophysics, 53*(4), 357-366. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8483699

Raab, D. H. (1962). Statistical facilitation of simple reaction times. *Transaction of the New York Academy Sciences, 24,* 574-590. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14489538

Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13*(3), 499-505. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17048737

Schweinberger, S. R., & Soukup, G. R. (1998). Asymmetric relationships among perceptions of facial identity, emotion, and facial speech. *Journal of Exprimental Psychology. Human*

Perception & Performance, 24(6), 1748-1765. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9861721

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: an event-related potential study. *Neuroreport, 19*(5), 583-587. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18388743 doi:10.1097/WNR.0b013e3282f97b4d

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: evidence from a cross-cultural study. *Cognition, 93*(1), B1-9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15110726 doi:10.1016/j.cognition.2003.09.011

Tottenham, N., Borsheid, A., Ellertsen, K., Marcus, D. J., & Nelson, C. A. (2002). *Categorization of facial expressions in children and adults: establishing a larger stimulus set.* Paper presented at the The Cognitive Neuroscience Society Annual Meeting, San Francisko, CA.

Townsend, J. T., & Eidels, A. (2011). Workload capacity spaces: a unified methodology for response time measures of efficiency as workload is varied. *Psychon Bulletin & Review, 18*(4), 659-681. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21607804 doi:10.3758/s13423-011-0106-9

Townsend, J. T., & Honey, C. (2007). Consequences of Base Time for Redundant Signals Experiments. *Journal of Mathematical Psycholology, 51*(4), 242-265. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18670591 doi:10.1016/j.jmp.2007.01.001

Townsend, J. T., & Nozawa, G. (1995). Spatio-temporal properties of elementary perception: An investigation of parallel, serial and coactive theories. *Journal of Mathematical Psychology, 39*, 321-360. Retrieved from

Townsend, J. T., & Wenger, M. J. (2004a). The serial-parallel dilemma: a case study in a linkage of theory and method. *Psychonomic Bulletin & Review, 11*(3), 391-418. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15376788

Townsend, J. T., & Wenger, M. J. (2004b). A theory of interactive parallel processing: new capacity measures and predictions for a response time inequality series. *Psychological*

Review, 111(4), 1003-1035. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15482071 doi:10.1037/0033-295X.111.4.1003

Tromans, J. M., Harris, M., & Stringer, S. M. (2011). A computational model of the development of separate representations of facial identity and expression in the primate visual system. *PLoS One, 6*(10), e25616. doi: 10.1371/journal.pone.0025616

Ulrich, R., Miller, J., & Schroter, H. (2007). Testing the race model inequality: an algorithm and computer programs. *Behavioural Research Methods, 39*(2), 291-302. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17695357

Vickers, D. (1970). Evidence for an accumulator model of psychophysical discrimination. *Ergonomics, 13*(1), 37-58. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/5416868 doi:10.1080/00140137008931117

Wagenmakers, E. J., Ratcliff, R., Gomez, P., & McKoon, G. (2008). A Diffusion Model Account of Criterion Shifts in the Lexical Decision Task. *Journal of Memory and Language, 58*(1), 140-159. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19122740 doi:10.1016/j.jml.2007.04.006

Walker, P. M., Silvert, L., Hewstone, M., & Nobre, A. C. (2008). Social contact and other-race face processing in the human brain. *Social Cognitive and Affective Neuroscience, 3*(1), 16-25. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19015091 doi:10.1093/scan/nsm035

Wenger, M., & Townsend, J. T. (2001). Faces as Gestalt Stimuli: Processes Characteristics. In M. J. W. J. T. Townsend (Ed.), *Computational, geometric, and process perspectives on facial recognition: Contexts and challenges* (pp. 229-279). London: Lawrence Erlbaum Associates Inc.

Wenger, M. J., & Townsend, J. T. (2000). Spatial frequencies in short-term memory for faces: a test of three frequency-dependent hypotheses. *Memory & Cognition, 28*(1), 125-142. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10714144

Wenger, M. J., & Townsend, J. T. (2006). On the costs and benefits of faces and words: process characteristics of feature search in highly meaningful stimuli. *Journal of Experimental Psychology. Human Perception and Performance, 32*(3), 755-779. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16822136 doi:10.1037/0096-1523.32.3.755

Yankouskaya, A., Booth, D. A., & Humphreys, G. (2012). Interactions between facial emotion and identity in face processing: Evidence based on redundancy gains. *Attention, Perception & Psychophysics*. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22814949 doi:10.3758/s13414-012-0345-5

Young, A. W., McWeeny, K. H., Hay, D. C., & Ellis, A. W. (1986). Matching familiar and unfamiliar faces on identity and expression. *Psychological Research, 48*(2), 63-68. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3774919

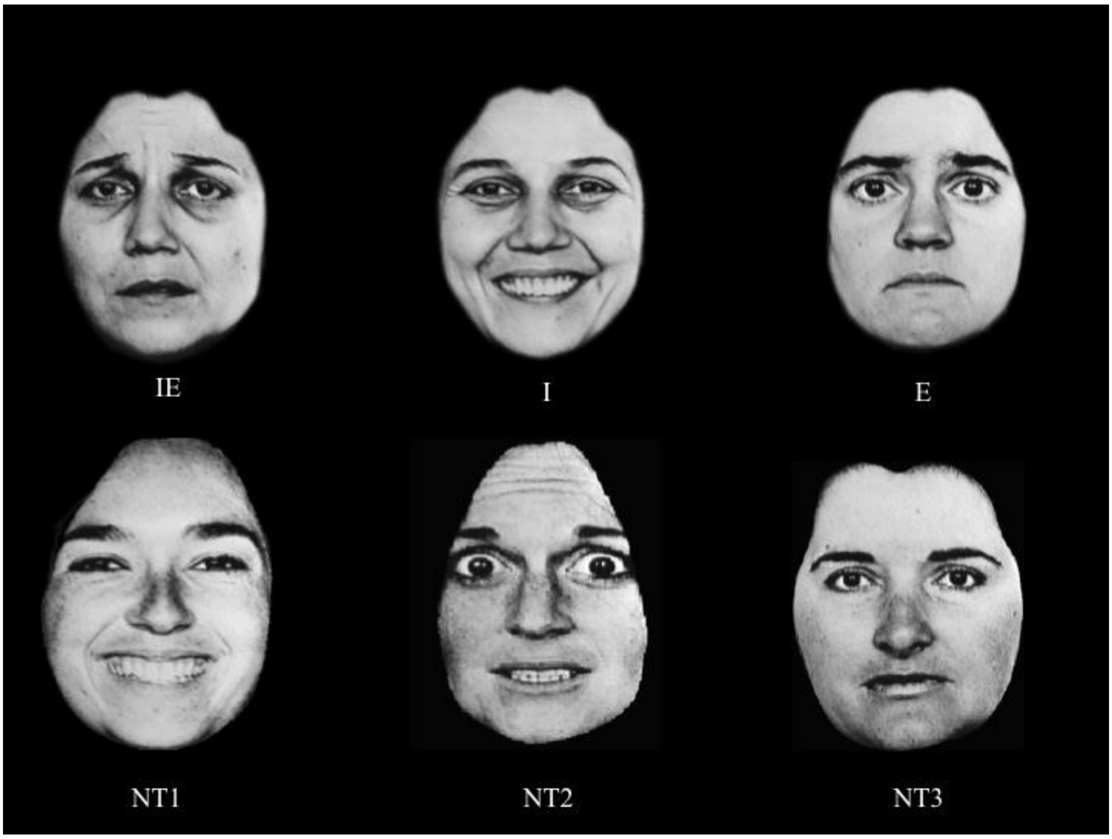
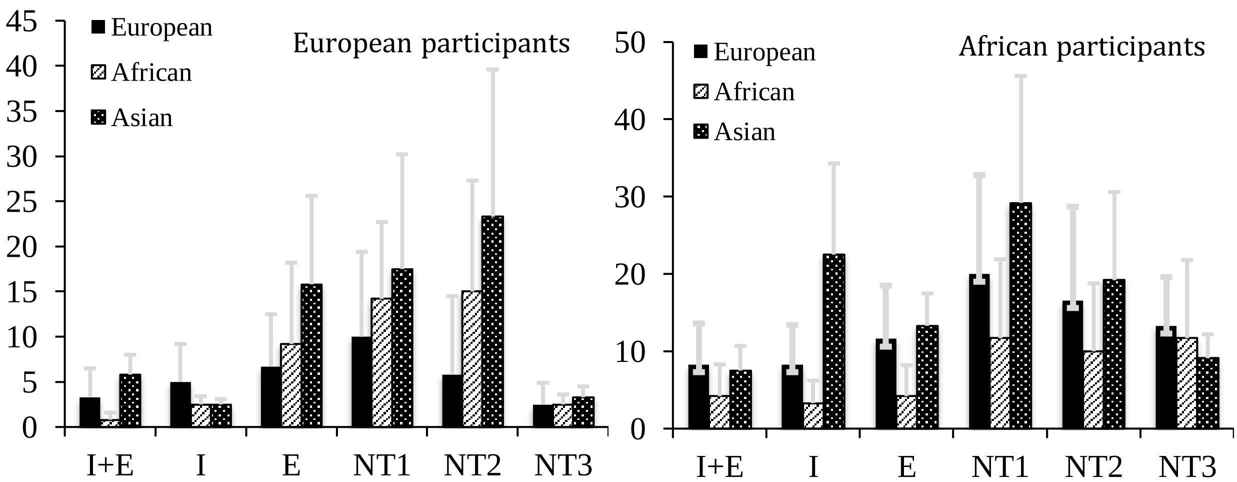


Figure 1. Example of set of European faces (original sets of images are not presented here due to restriction on publication. Here the faces are taken from Ekman (1993)). EI –redundant target face (containing both the identity target and target emotional expression), I – a face containing the identity target, E – a face containing the emotional expression target, NT1-NT3 – faces containing none target information



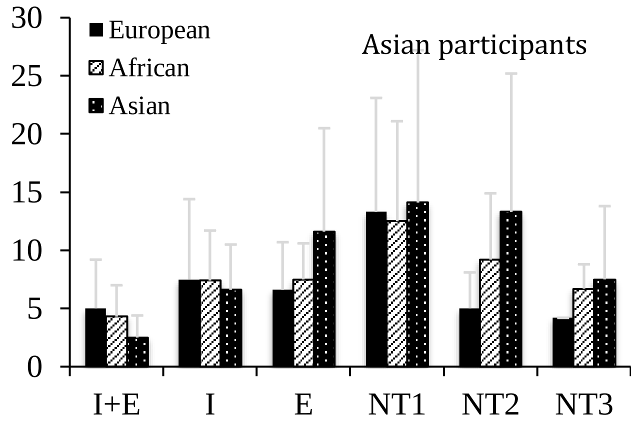
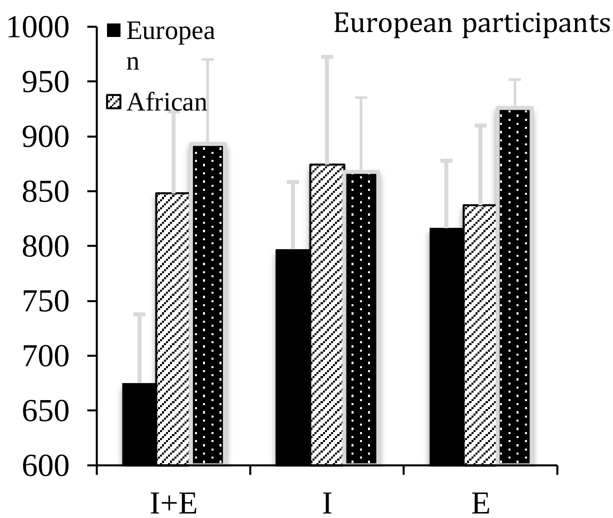
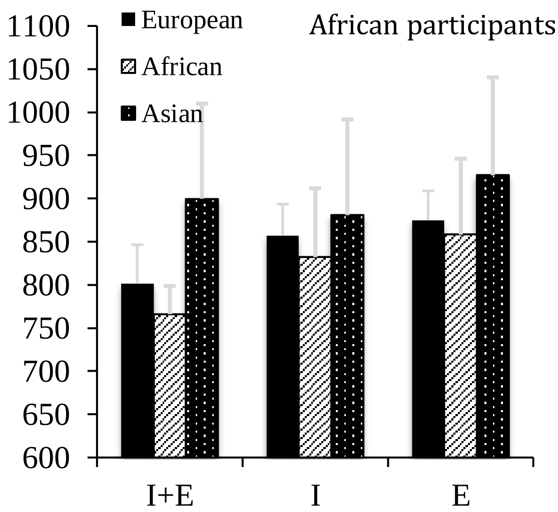


Figure 2. The percentage of errors for Redundant Targets (I+E), the Identity Target (I), The Emotional Expression Target (E), and the 3 Nontarget faces (NTs) for each set of images (European, African, Asian) in groups of European (top left), African (top, right), Asian (lower) participants





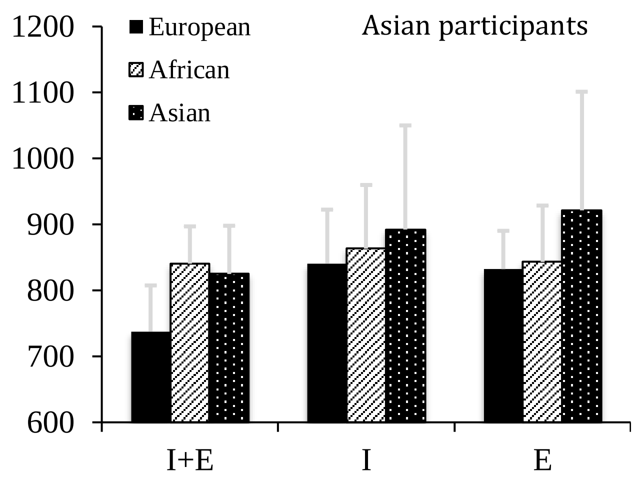


Figure 3. Mean RTs (ms) for responses to Redundant Targets (IE), the Identity Target (I), and the Emotion Target (E) for each set of images in groups of European participants (top left), African (top right), Asian (lower)

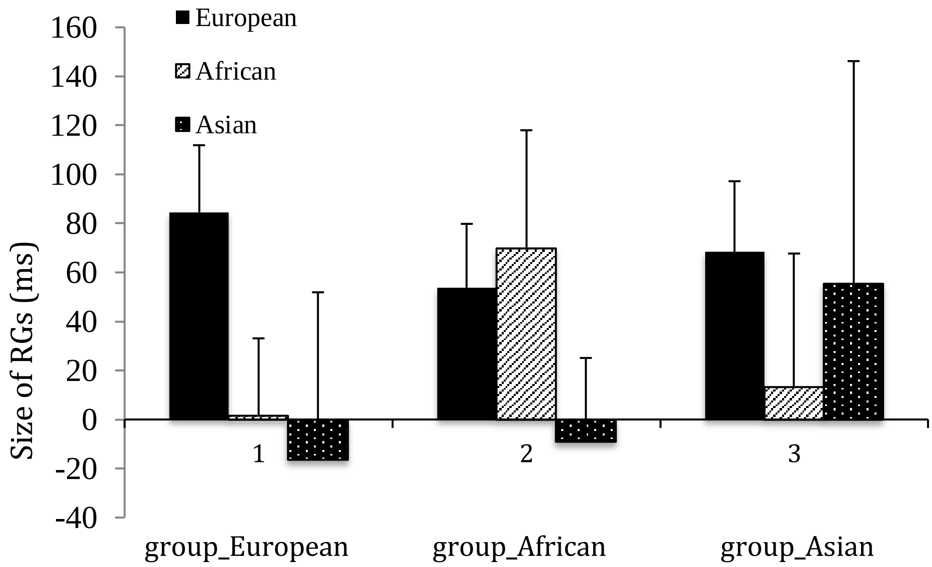


Figure 4. Mean size of the redundancy gains (RGs, ms) for groups of European, African and Asian participants across the three stimulus sets. The negative value means that the RT for the single target was shorter than RTs for redundant targets image (no redundancy gain)

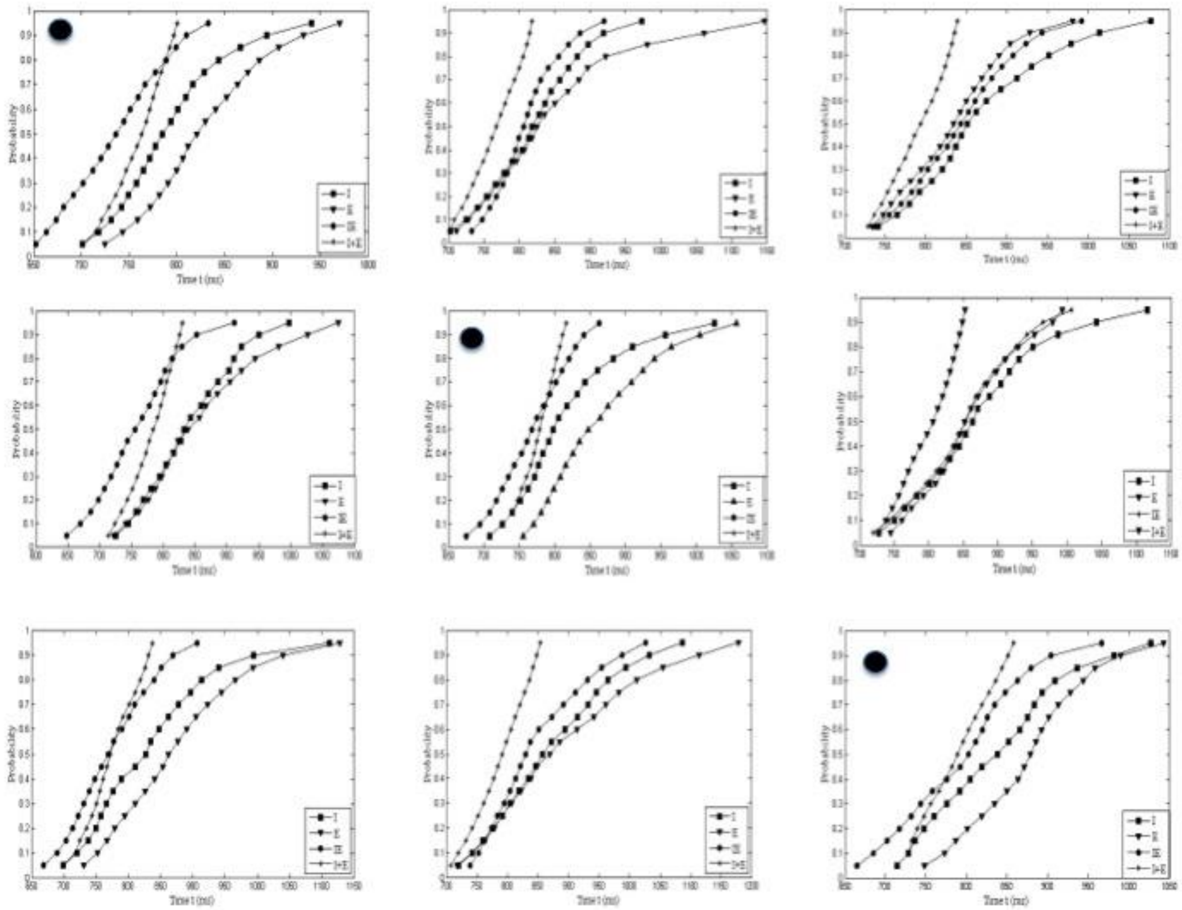


Figure 5. CDFs for the three participants (for own-race faces are marked by black dot): top row European participants (own-race, African and Asian faces from the left to the right), middle row– African participants (European, African and Asian faces from the left to the right), low row– Asian participants (European, African and own-race faces from the left to the right). I – target identity, E – target emotion, IE – both target identity and target emotion, I+E – the sum of distributions for I and E

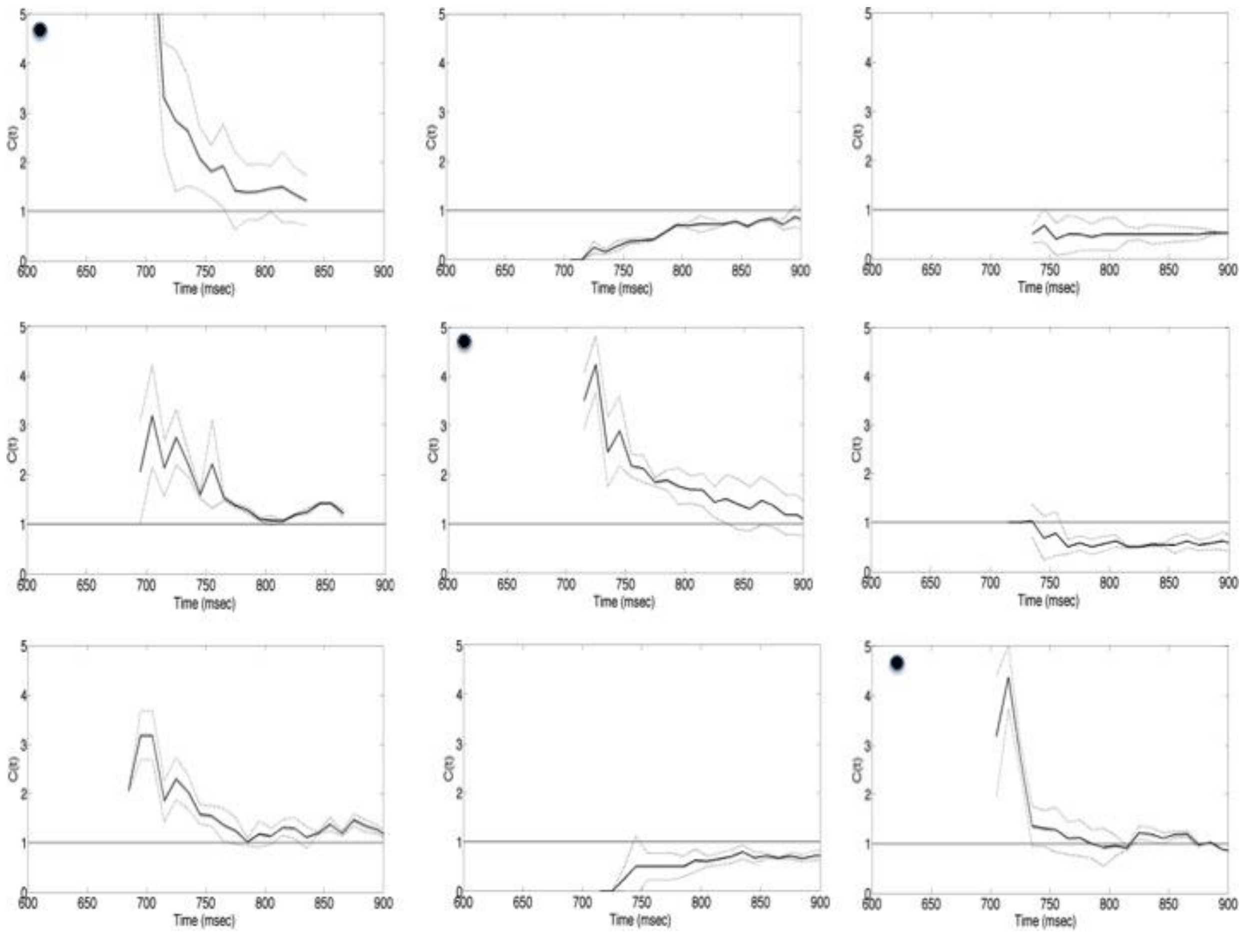


Figure 6. Capacity coefficients for the three participants (for own-race faces are marked by black dot): top row European participants (own-race, African and Asian faces from the left to the right), middle row– African participants (European, African and Asian faces from the left to the right). The horizontal line at C(t) = 1 indicates the reference value for unlimited capacity. The capacity coefficients are depicted in solid line; the confident interval for capacity coefficient in dash line.

Supplementary material

Categorization of facial identity and emotional expression

The aim of this study was to select photographs of faces for the main experiments of Yankouskaya et al., concerned with the interaction between the processing of facial identity and emotional expression in own- and other-race faces. In order to examine the redundancy effect with faces, it is important that the basic dimensions were processed with roughly equal efficiency. To ensure this, an initial matching task was conducted. The discriminability of emotional expression and identity information of faces was assessed by measuring RTs for judgements, whether pairs of faces varying in identity and emotional expression were physically identical or not. The mean RTs for correct 'different' responses for pairs of images belonging to the same person expressing different emotions were compared with RTs for pairs of images of different people with the same emotional expression. Images from pairs with approximately equal RTs were selected for the main experiments.

Three separate experiments (Experiment A, Experiment B and Experiment C) were carried out to select three sets of images the main experiments. Experiments A, B and C were identical in design and analysis of data; they differed only in the faces identities tested.

General Method

Participants

Three groups of 15 undergraduate students participated in this study. The first group participated in Experiment A and was consisted of White individuals. The second group of Black subjects participated in Experiment B. Asian individuals participated in Experiment C. All participants were aged between 20 and 23 years. All individuals reported normal or corrected to normal vision.

Stimuli and Apparatus

All face images were sourced from The NimStim Face Stimuli Set (Tottenham, Borsheid, Ellertsen, Marcus & Nelson, 2001). Recognition responses to facial expressions in all photographs used in the present study were rated as 80% and more (Tottenham et al, 2001). Clothing, hair and colour were removed using Adobe Photoshop. And any visible background was coloured black. Two single images were grouped to be of equivalent size.

Experiments A-C. Photographs of three European (labeled 1F, in the database; here labeled Person 7, Person 8, Person 9 respectively), three African (labeled 1F, in the database; here labeled Person 10, Person 11, Person 12 respectively) and three Asian (labeled 1F, in the database; here labeled Person 13, Person 14, Person 15 respectively) women expressing a happy and sad emotions were tested in Experiments A, B, C respectively. The combination of these images in either experiment gave three pairs of images of the same person expressing two different emotions and six pairs of different people expressing the same emotion.

Display presentations were controlled using E-Prime. Each pair of stimuli was counterbalanced with respect to the left and right sides of display. The paired images were approximately 23X15 cm when displayed on 17-in monitor at the viewing distance of 0.8 m. The angular width subtended by the stimulus was approximately 10°.

Procedure

Participants were required to make a speeded judgment if images displayed in pairs were the same or different by pressing 'the same' or 'different' buttons on the keyboard (Figure S-1).

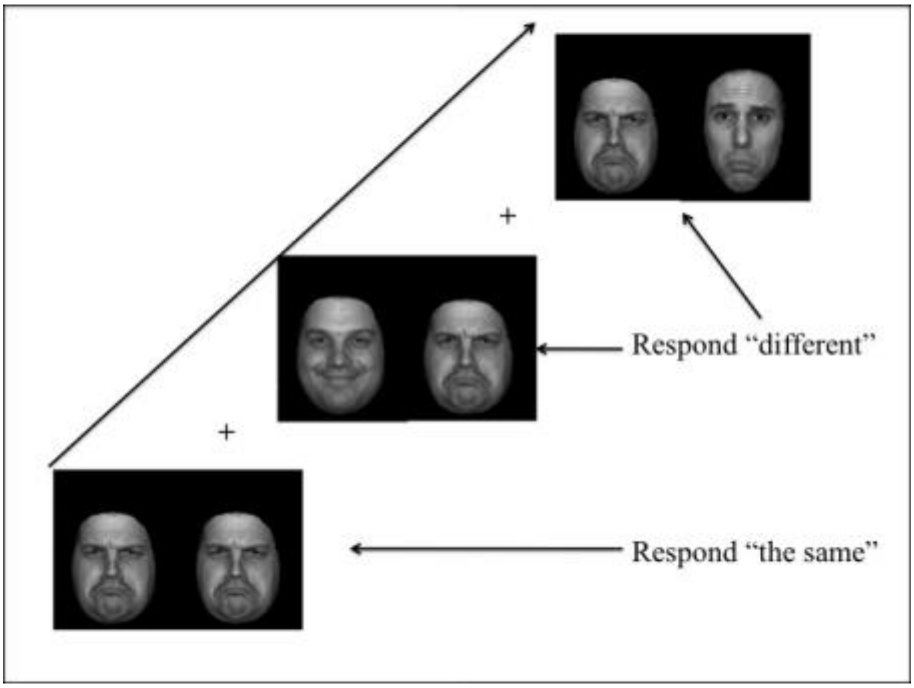


Figure S-1. An example of stimuli presentation in Experiments A and B (here we presented male faces for an example purpose only. In the main experiment female faces have been used)

Each trial started with the presentation of a fixation cross at the center of the screen for 500 ms. Displays of two paired images were presented successively in random order.

Analysis of data

RTs for correct 'different' responses were taken for the analysis. Mean RTs for responses to display containing images of the same person expressing different emotions were compared with displays of different people expressing the same emotions, using related t-test. For each comparison two corresponding displays were taken (i.e., the displays differed in one of two paired images; for example, one display containing a sad and a happy image of Person 1, and another display a sad face of Person2; Figure S-2).

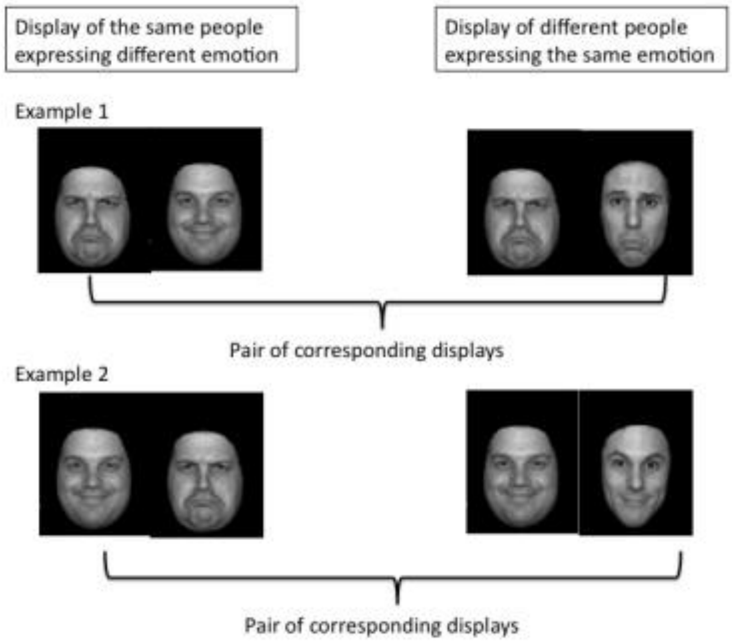


Figure S-2. Examples of corresponding displays

In Experiments A-C there were 12 pairs of corresponding (Figure S-3) displays[3].

[3] The number of corresponding pairs of displays may be calculated by using the following formula: N = P x (E x c) x2, where N – the number of corresponding pairs; P the number of tested faces; E – the number of tested emotional expressions; c – the number of paired combinations of E (i.e. two emotional expressions dive 1 combination, 3 emotional expressions give 2 combinations, etc.)

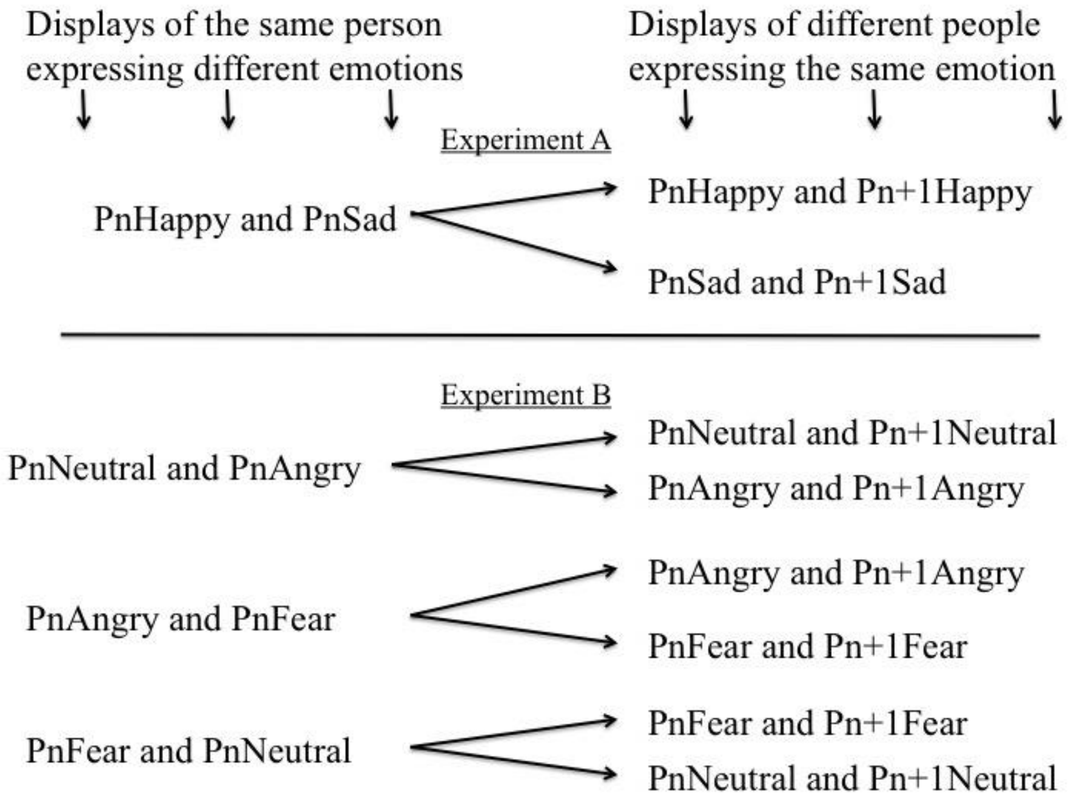


Figure S-3. Pairs of corresponding displays in Experiment 1 and 2, where P denoted 'a person' and 'n' – individual's number (i.e. Pn = Person1, Pn+1 = Person2)

Results and Discussion

Experiment A. The average number of errors was 2.03. There were reliable differences between displays of the same person expressing different emotions and displays of different people with the same emotion in 10 of 12 corresponding pairs of displays (all $p < 0.5$). The difference between the mean RTs to pairs containing a sad and happy expression of Person 7 ($M = 756$, $SD = 76.1$) and the mean RT to displays with a sad face of Person 7 and a sad face of Person 9 ($M = 794$, $SD = 64.3$) was not reliable ($t(14) = 0.81$, $p = .3$). The error rates for these corresponding displays were also not reliably different ($t(14) = 0.8$, $p > .05$). Similar result was obtained for pair Person 8 with a sad and happy expression – a sad Person 8 and a sad Person 9 ($t(14) = 1.1$, $p > .05$). However, participants made reliably more error for this pair ($t(14) = 3.2$, $p < .05$).

Experiment B. The average number of errors was 5.1. Differences between displays of the same person expressing different emotions and displays of different people with the same emotion were reliable in 9 of 12 corresponding pairs of displays (all $p < 0.5$). The difference between the mean RTs to pairs containing a sad and happy expression of Person 11 (M = 834, SD = 52.6) and the mean RT to displays with a sad face of Person 10 and a sad face of Person 12 (M = 852, SD = 59.2.3) was not reliable ($t(14) = 0.5$, $p = .14$). Similar result was obtained for pairs: Person 12 with a sad and happy expression – a sad Person 10 and a sad Person 11 ($t(14) = 1.1$, $p > .05$); Person 11 with sad and happy expression – a sad Person 10 and a sad person 12 ($t(14) = 1.26$, $p > .05$). The error rates for all these corresponding displays were also not reliably different ($t(14) = 0.92$, $p > .05$; $t(14) = 1{,}32$, $p > .05$; $t(14) = 0.6$, $p > .05$;).

Experiment C. The average number of errors was 3.2. In one out of 12 corresponding display differences between displays of the same person expressing different emotions and displays of different people with the same emotion was not reliable for reaction time ($t(14) = 1.1$. $p = .08$) and accuracy performance ($t(14) = 0.5$, $p = .14$) (pairs containing a sad and happy expression of Person 15 (M = 812, SD = 60.3) and a sad face of Person 13 and a sad face of Person 15 (M = 823, SD = 49.1).

In sum, one pair in Experiment A, three pairs in Experiment B and one pair in Experiment C satisfied the selection criteria for RTs to be equated for identity and emotional expression judgments. Because in Experiment B thee pairs of stimuli satisfied the selection criteria, for the main experiment only one pair was chosen. These stimuli were than made available for the main experiment.

Individual patterns of capacity processing in European, African and Asian groups of participants

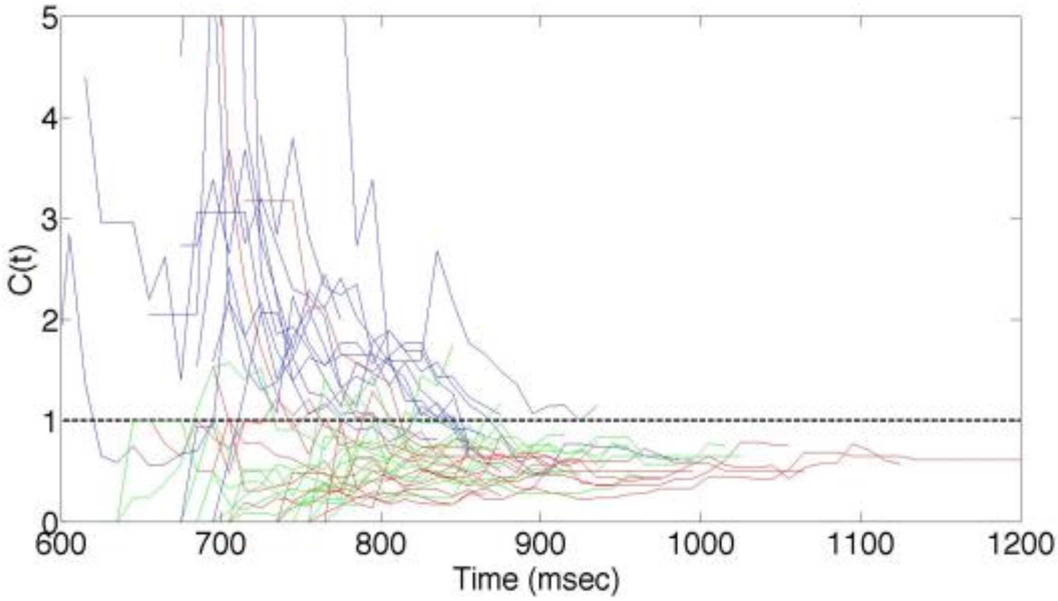


Figure S-4. Individual capacity coefficients in the group of European participants. Pattern for own-race faces is depicted in blue, for African faces – in green, for Asian faces – in red

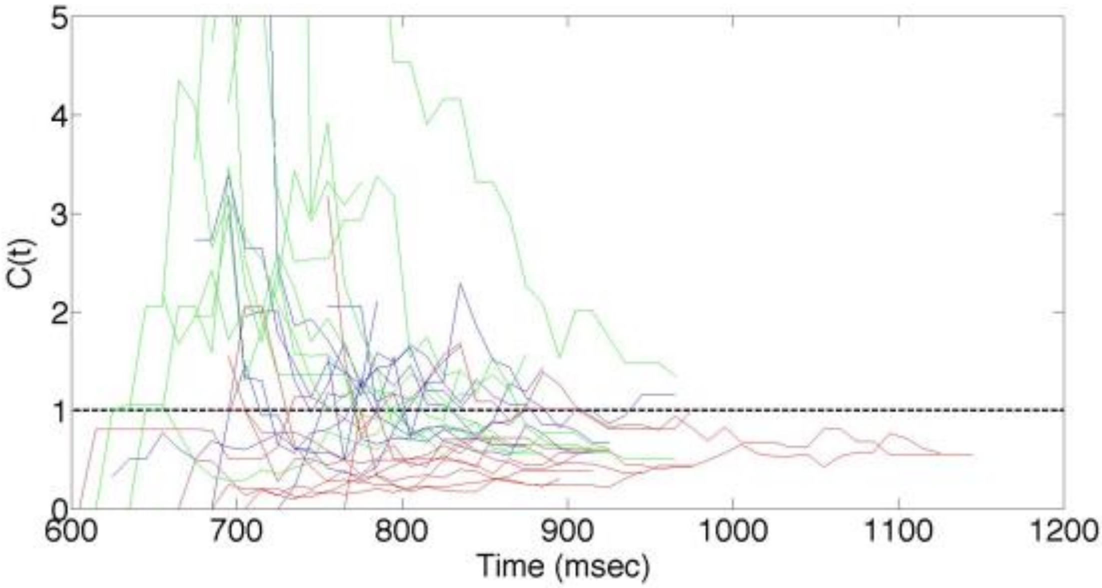


Figure S-5. Individual capacity coefficients in the group of African participants. Pattern for own-race faces is depicted in green, for European faces – blue, for Asian faces – in red

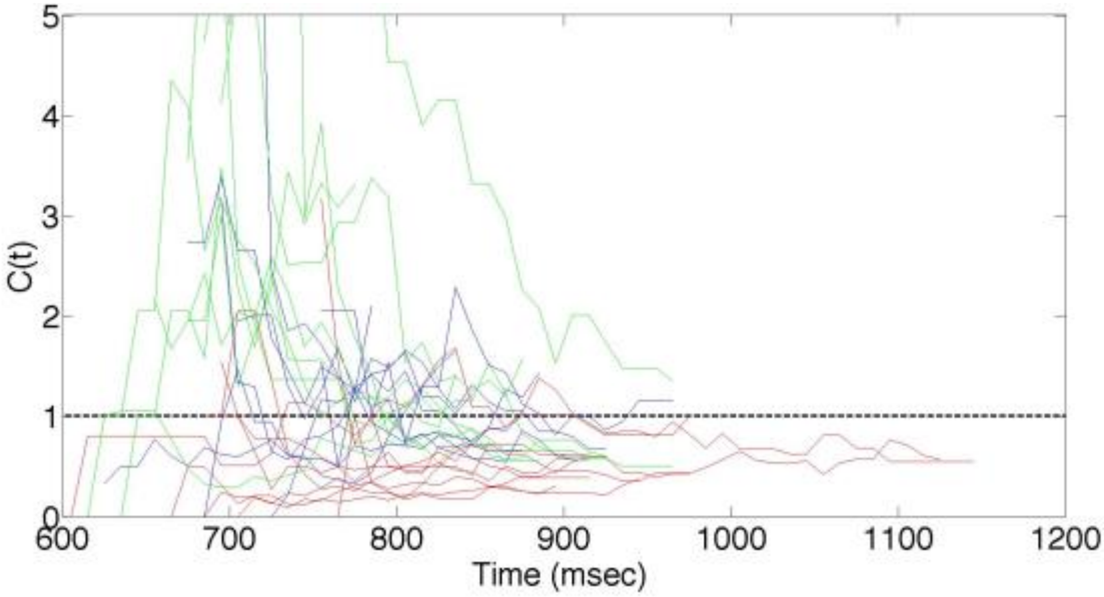


Figure S-6. Individual capacity coefficients in the group of European participants. Pattern for own-race faces is depicted in blue, for African faces – in green, for Asian faces – in red

Table A

Individual overall capacity coefficients in African, European and Asian groups for each faces set

European group			
Participants	Faces set		
	European	African	Asian
1	2.58	0.42	0.42
2	4.22	0.22	0.29
3	1.21	0.72	0.71
4	2.01	0.45	0.59
5	2.008	0.57	1.52
6	1.39	0.54	0.13

7	0.96	0.84	0.72
8	1.40	0.5	0.4
9	2.33	0.55	0.47
10	1.63	0.48	1.27
11	2.58	0.53	0.51
12	1.88	0.33	0.46
African group			
1	0.74	1.48	0.76
2	1.26	2.57	0.21
3	1.33	2.59	0.47
4	0.94	3.93	0.54
5	0.63	1.4	0.22
6	0.88	1.3	0.73
7	1.88	1.1	0.49
8	3.08	0.83	0.24
9	1.02	3.73	1.07
10	1.29	1.06	0.61
11	1.31	4.97	0.83
12	3.90	0.67	0.29
Asian group			

1	0.87	0.68	0.49
2	0.88	0.47	1.33
3	0.41	0.61	0.58
4	0.98	0.45	1.07
5	1.21	0.56	1.21
6	0.84	0.78	0.64
7	1.31	1.04	1.66
8	1.12	0.71	1.01
9	1.01	0.62	0.93
10	1.15	0.9	1.10
11	1.3	0.89	1.21
12	1.09	0.51	0.98