Running head: INTERACTIONS BETWEEN FACIAL EMOTION AND IDENTITY

Interactions Between Facial Emotion and Identity in Face Processing. Evidence Based on Redundancy Gains

Alla Yankouskaya, David A. Booth, Glyn Humphreys

University of Birmingham

Abstract

Interactions between the processing of emotion expression and form-based information from faces (facial identity) were investigated using the redundant target paradigm where we specifically tested if identity and emotional expression are integrated in a super-additive manner (Miller, 1982). In Experiments 1 - 3 participants performed emotion and face identity judgments to faces with sad or angry emotional expressions. Responses to redundant targets were faster than responses to either single target when a universal emotion was conveyed, and performance violated predictions from a model assuming independent processing of emotion and face identity. Experiment 4 showed that the effects were not modulated by varying inter-stimulus and non-target contingencies. Experiment 5 demonstrated that the redundancy gains were eliminated when the faces were inverted. Taken together, results suggest that the identification of emotion and facial identity interact in face processing.

Interaction Between Perception of Facial Emotion and Identity

Theories of coding facial identity and emotion expression

The human face conveys complex information that contributes to the recognition of both emotional expression and individual identity. Facial identity and emotion are conveyed by overlapping physical features and can be equally quickly extracted and discriminated (Blau, Maurer, Tottenham, & McCandliss, 2007; Bruce & Young, 1986; Calder, Burton, Miller, Young, & Akamatsu, 2001; Ganel & Goshen-Gottstein, 2004; Holmes, Vuilleumier, & Eimer, 2003; Pegna, Khateb, Michel, & Landis, 2004; Schweinberger & Soukup, 1998). Views differ, however, on whether identity and emotion information is processed independently or in integral fashion.

One of the most influential models of face coding over the past twenty five years, proposed by Bruce and Young (1986), holds that there is independent, parallel processing of identity and expression information from faces. A primary motivation for this argument comes from neuropsychological double dissociations showing that patients can have impaired recognition of face identity but not emotion (Campbell, Landis, & Regard, 1986) or impaired discrimination of face expression but not identity (Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard et al., 1983).These neuropsychological data have been supported by studies in normal observers (Young, McWeeny, Hay, & Ellis, 1986). For example, Young et al. (1986) had participants to make identity judgment (are paired faces the same person?) or emotion judgments to faces (do paired faces expressed the same emotion?). For identity matching, reaction times to familiar faces were faster than reaction times to unfamiliar faces, but there was no difference between familiar and unfamiliar faces for expression matching. These authors suggested that analyses of facial expressions proceed independently from processes involved in processing of the person's identity.

Calder, Young, Keane, & Dean (2000) examined the same issue using the composite face paradigm where the top of one digitized photograph of a face and the bottom of another digitized face image were formed to create test image of a face, either aligned or misaligned (the top half is slightly offset from the bottom half). When two different faces are aligned, responses to one component (e.g., the top half) are slowed relative to when the faces are mis-aligned, presumably due to the forming of a new ‘Gestalt’ to the aligned components (the ‘face composite effect’). Calder et al. (2000) reported that the composite effects for identity and expression judgments operated independently of one another. For example, identity judgements were slowed by aligning two different face identities but not two different expressions, with the reverse occurring for expression judgements. Furthermore, Calder, Burton, Miller, Young, & Akamatsu (2001) using Principal Component Analysis (PCA) found that facial expression and identity were coded by largely different components. These authors argued that the functional dissociation between facial expression and identity related directly to the fact that these two facial characteristics load on different dimensions of the stimulus. These arguments for the fractionated processing of structural information about face identity and emotion have recently been bolstered by computational work which suggests that independent processing of these two types of information is a natural consequence of statistical independence between the image features for structural identity and emotion (Tromans, Harris & Stringer, 2011).

Contrasting arguments to this, for the non-independent processing of structural identity and emotion, have been made from studies using face adaptation (Fox & Barton, 2007; (Ellamil, Susskind, & Anderson, 2008). For example, Ellamil et al. (2008) found that adaptation to the basic emotions of anger, surprise, disgust, and fear resulted in biased perception away from the adapting expression. However, when the adapting and the test images belonged to different people, the aftereffect decreased. This suggests that there is at least partly overlapping neural processing of identity and facial expression (Ellamil et al., 2008).

The most straightforward evidence about possible interactions between facial identity and the perception of facial expressions comes from studies employing the selective attention paradigm originally introduced by Garner (Garner, 1974). Schweinberger and Soucup (1998) had participants classify unfamiliar faces along one dimension while disregarding an irrelevant dimension. The faces were presented in three different conditions: a control condition (in this case the task irrelevant dimension was held constant while the relevant dimension varied), an orthogonal condition (both the irrelevant and relevant dimensions were varied) and a correlated condition (changes in the irrelevant dimension covaried with changes in the relevant condition). Reaction times (RTs) for identity judgments were not influenced by variations in expression, but expression recognition was affected by variation in identity. Similar results were obtained by (Atkinson, Tipples, Burt, & Young, 2005) who investigated the relationship between facial emotion expression and facial gender, and Baudouin, Martin, Tiberghien, Verlut, & Franck (2002), who evaluated attention to facial identity and expression in both health and individuals with schizophrenia. The results pointed to an asymmetric interaction between facial identity and the discrimination of facial expressions, with expression judgements more affected than identity and gender judgements by variations in the other dimension.

Contrasting data have been reported by Ganel & Goshen-Gottstein (2004) who have explored face processing using the Garner task, which tests for interference effect from one stimulus property on responses to another. Participants categorized photographs according to personal identity information or the emotional expressions and effects of variation along the other dimension were explored. The stimuli were selected photographs of two different people shown in two different emotional expressions and in two different views. Task irrelevant information from the other dimension influenced participants’ judgment equally in the identity and emotional expression categorization tasks. The authors argued that the systems involved in processing identity and expression were interconnected and that facial identity can serve as a reference from which different expressions can be more easily derived (Ganel & Goshen-Gottstein, 2004). On the other hand, Etcoff (1984), also using Garner interference, showed that participants could selectively attend to either unfamiliar identity or emotional expression without interference from the irrelevant stimulus dimension. They suggest that there is relatively independent processing of facial identity and expression.

Although the majority of the studies that have employed Garner interference suggest some independence in the processing of facial identity and emotional expression, the inconsistency across the studies also limits any conclusions. One limitation is that often a small stimulus set was used, with only two different individuals shown displaying one of two emotions (e.g. see Schweinberger & Soukup, 1998). When the limited set of stimuli is then repeated across trials it is possible that participants respond to local image details (e.g., variations in lighting and photographic grain) rather than expression and identity, limiting any interference from one dimension on the other. Another important issue is that different picture based strategies may be used for either identity and emotion decision tasks in the Garner paradigm. In the identity decision task pictorial strategies might be used to discriminate the individuals based on a shape of a face and non-facial cues such as hair style (e.g. see Schweinberger & Soukup, 1998, Ganel & Goshen-Gottstein, 2004). For the expression decision task, where participants are required to attend to internal facial features, this strategy may be inappropriate. This can in turn lead to differences in the difficulty, and possible asymmetric interference effects between identity and emotional expression judgments. Although, the latest was overcome in Ganel & Goshen-Gottstein (2004) study, the issue about increasing variability of the relevant stimulus dimension within the orthogonal condition when compared to the irrelevant dimension is still there (see also (Kaufmann,

2004) for detailed discussion about the effects of increasing variability along the relevant stimulus dimension within the orthogonal condition in the garner-paradigm).

In addition, even when effects of one stimulus dimension are found on responses to the other, the means by which these effects occur is not clear. For example, in selective attention experiments, the effects of unattended stimulus dimensions may arise due to trial-by-trial fluctuations in attention that may lead to the irrelevant dimension sometimes being attended (Lavie & Tsal, 1994; Weissman, Warner, & Woldorff, 2009). On these occasions performance will be affected by variation in the irrelevant dimension, even though the dimensions might be processed independently of one another. This evidence does not mean that processing is non-independent.

A different way to address the issue of independent processing of facial identity and emotional expression is to have both dimensions be potentially relevant to the task and to examine how the dimensions combine to influence performance. For example, consider a task required to detect three targets: (i) Person A depicted with a neutral expression, (ii) Person B with a sad expression, and (iii) Person A with a sad expression. Here the third target has a redundant combination of the identity properties and the emotion properties that define targets (i) and (ii). We can ask whether the combination of identity (Person A) and emotional expression (sad) leads to an improvement in performance a redundancy gain in responding to target (iii) relative to targets (i) and (ii). Moreover, by examining the nature of this redundancy effect, we can learn new details about how facial identity and emotional expression modulate information processing, since redundancy gains can occur that are above and beyond effects that can be accounted for in any model assuming independent processing of facial dimensions. To understand this, we need to outline the logic of redundancy gains in information processing.

Redundancy gains in information processing

There is considerable evidence that, when a visual display contains two targets which require the same response, reaction times (RTs) are faster than when only one target appears (Krummenacher, Muller, & Heller, 2001; Miller, 1982, 1986; Miller, Ulrich, & Lamarre, 2001; Mordkoff & Miller, 1993; Raab, 1962; Reinholz & Pollmann, 2007; Wenger & Townsend, 2006). For example, in Mordkoff & Miller's (1993) study participants were required to divide their attention between the separable dimensions of color and shape, with all stimulus features being attributes of a single object. In this task participants were asked to press a button if the target color (green), the target shape (X), or both target features (green X) were displayed, and no response if neither target was present. In this case, single-target displays included a purple X or a green 0, and redundant target displays always included a green X. The mean RT on redundant target trials was significantly less than mean RT on single target trials (Mordkoff & Miller, 1993).

There are different explanations that account for the redundant target effect (RTE), the most relevant being the Independent Race Model (Raab, 1962) and the Coactivation Model (Miller, 1982). According to the Independent Race Model, redundancy gains are explained by means of 'statistical facilitation (Raab, 1962). Whenever two targets (in our case facial identity and emotional expression) are presented simultaneously, the faster signal determines the response 'target present' (i.e. this signal wins the race). As long as the processing time distributions for the two signals overlap, RTs will be speeded when two targets present since the winning signal can always be used for the response (Raab, 1962). Note that which signal finishes 'first' may depend on whether it is attended. For example, emotional expression or identity may be computed first, if there are fluctuations in attention to each independent dimension.

The Independent Race Model contrasts with a coactivation account (Miller, 1982), while states that two signals combine in activating a response. According to the coactivation view, the information supporting a response ‘target present’ response is pooled across the features defining the targets prior to response execution (Miller, 1982, 1986). When, in this case, both target identity and target emotional expression contribute activation toward the same decision threshold, the response has to be activated more rapidly relative to when only one attribute contributes activation .

The critical contrast for the two models compares the probability for the response times obtained on redundant targets trials relative to sum of probabilities for responses being made to either single target trial. The Independent Race Model 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 coactivation account, responses to the redundant targets can be made before either single target generates enough activation to produce a response. Thus, here the fastest responses to a face containing both the target identity and the target emotional expression should be faster than the fastest responses to either target facial identity or target expression

Mordkoff & Yantis (1991) proposed a conceptual compromise between the Independent Race Model and Coactivation model. Their account, the Interactive Race Model, assumes a race between parallel processes on redundant targets trials, but holds that these two targets may exchange information prior to a response being made. Two mechanisms have been proposed for information exchange: interchannel crosstalk and non-target-driven decision bias (Mordkoff & Yantis, 1991). Crosstalk occurs when identification of one signal is influenced by another signal. For example, take the case when one photograph contains both targets, person A with a sad expression. If participants associate the identity with the expression, then processing face identity could reduce the threshold to detect the target expression, speeding responses when both the target identity and emotional expression are present relative to when the expression is present in a face not bearing the target identity.

Non-target-driven decision bias concerns the possible effects that the non-target attributes may have on "target present" decisions (Mordkoff & Miller, 1993; Mordkoff & Yantis, 1991). In contrast to the Independent Race and the Coactivation Models, both of which hold that only target signals activate a response, the Interactive Race Model proposes that non-target signals correlated with "target not present" decisions. For instance, if display of a face contains both the target identity along with a non-target emotional expression, then the expression could activate an absent response. This could slow RTs on trials with just one target is present, relative to when both attributes are present with "target present" response. Thus the Interactive Race Model explains redundancy target effect in terms of the influence of non-target signals on "target present" responses, rather than interactive processing between the target signals.

Experimental design and hypotheses of the present study

The present study examines the presence of redundancy gains when people respond to target face identities and emotional expressions. If identity and emotion signal are integrated, than RTs to a face containing both the target identity and the target emotional expression will be shorter than RTs than either target emotion or the target face identity appears alone.

Specifically, if the probability of responses on a trial with redundant face and emotion targets is greater than the summed probabilities of responses on single target trials at any part of the cumulative response distribution then the Independent Race Model is refuted. This was examined in Experiments 1-3. Given violation of the Independent race Model, Experiment 4 tested whether facial identity and emotion are processed coactively or interactively. Experiment 5 assessed whether the apparent coactivation effect was based on pictorial properties of image or depended on the discrimination of structural features from faces, by testing redundancy gains with inverted images. Redundancy gains from pictorial properties should be found with inverted as well as upright faces.

The strongest test between the different models of information accumulation requires that RTs distribution for the single targets will be as close as possible in order to obtain maximal redundancy gain. To ensure that this was the case here, an initial set of experiments was conducted in which participants made perceptual match decisions to pairs of faces differing in identity and emotional expression. Based on the speed with which “different” decisions were made, face identities and emotional expressions were chosen such that the time to discriminate between a potential redundant target (target identity + target emotional expression present) and a potential target with just one attribute (target identity + neutral emotion; non-target identity + target emotion) was the same for both attributes (i.e., the possibilities that the target identity was discriminated faster than the target emotional expression, or vice versa, was eliminated). The pre-experiments are reported in the Supplementary Materials.

A divided attention task was employed. This task has been commonly used with written words and auditory stimuli (Grice, Canham, & Boroughs, 1984; Grice & Reed, 1992; Krummenacher et al., 2001; Miller, 1986; Mordkoff & Miller, 1993) but not in studies of face perception. In a divided attention task, participants are required to monitor two sources of information simultaneously for a target, and then make a decision about the presence or absence of the target. There are two main advantages in employing the divided attention task. First, the divided attention task that required people to attend to identity and emotional expression in unfamiliar faces simultaneously closely resembles daily life. Second, in contrast to the selective attention task, the divided attention task allows control performance for the single target conditions by including the double target display (control targets identification) and non-target display containing irrelevant dimensions that accompanied either single target (control participants’ strategy of making response “target present” for either single target). To the extent that facial identity and emotion are independent, time for encoding a face containing both targets will not differ reliably from time for encoding faces either containing a single target (assuming equal perceptual discriminability of identity and emotional expression). Here participants were presented with a set of selected photographs of faces that varied in identity and emotion and instructed to respond “signal present” as quickly as possible when they saw a target person and/or a target emotional expression. When they saw neither the target person nor the target emotional expression, participants were required to respond “target absent”. The experimental design equated the probability of target present and absent responses.

Coactive vs independent processing of facial identity and emotional expression

Three separate experiments (Experiments 1-3) were conducted to test whether the processing of face identity and emotional expression took place in an independent or coactive manner. The aim of these experiments was to examine whether there was a redundancy gain when a face image contained both the target identity and expression relative to when it contained only the identity or emotional expression. All three experiments employed the same experimental design, but varied in the target identity present (using different actors) and the emotional expression (sad, angry and neutral expressions in Experiments 1, 2 and 3 respectively). The image set with neutral faces as targets was tested in Experiment 3 to assess if redundancy gains in responses required a definite emotion to be present. Emotions such as sadness and anger are likely conveyed by a universal set of muscle movements (Ekman, 1990). In contrast neutral facial expressions are likely to be more idiosyncratic and also to reflect the absence of one configuration of muscles rather than the presence of a distinct and detectable configuration. This may mean that identity is less likely to be integrated with a neutral expression than with a universal one such as anger or sadness.

In all tasks participants had to detect target identities and target emotional expressions from six photographs presented subsequently in random order. Three of these photographs contained targets: stimulus 1 had both the target identity and the target emotion; stimulus 2 contained the target identity and a non-target emotional expression; stimulus 3 contained the target emotional expression and a non-target identity. Three non-target faces were photographs of three different people, and expressed emotions different from those in target faces.

If we find evidence for redundancy gains that are greater than can be predicted by an independent processing model, then the evidence will provide strong constraints against models in which emotional expression and identity are processed independently of each other.

General Method

Participants

Three groups of twelve undergraduate students participated in Experiments 1-3 (ten males). The participants were aged between 20 and 28 years. They received credits for participation. All individuals reported normal or corrected to normal eyesight.

Stimuli and Apparatus

All face images were sourced from The NimStim Face Stimuli Set (Tottenham, Borsheid, Ellertsen, Marcus, & Nelson, 2002). Recognition of facial expression in all photographs used in the present study was rated as 80% and more (Tottenham et al., 2002). Six photographs of faces were used in either experiment (Appendix1).

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 approximately 10 x 13 cm when displayed on a 17-in monitor. The presentation of stimuli 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 the stimulus was approximately 10°.

Design and procedure

A "present/absent" reaction time task was employed. Half of the trials contained images with at least one target ('present' trials) and half had non-target faces ('absent' trials). Participants were asked to decide whether either the target person or the target expression was present, and to respond as quickly and accurately as possible by pressing "target present" whenever the identity and/or emotion appear in a display. If no target signals were presented, participants were required to press button "target absent"(Figure 1). The instruction was displayed on the monitor, and then repeated orally by experimenter.

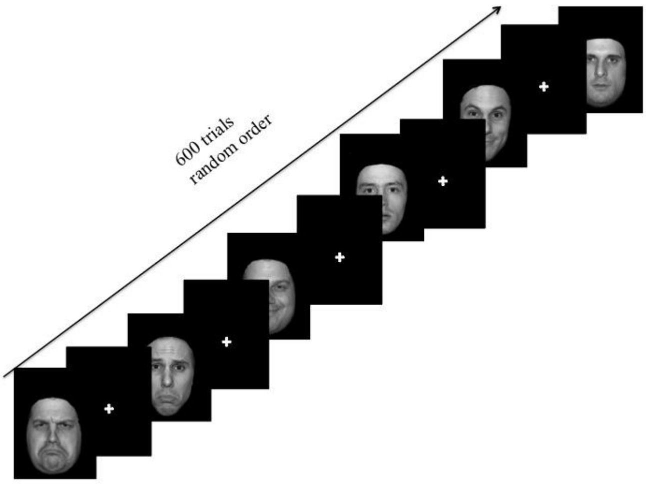


Figure 1. An example experimental sequence in Experiments 1-3

The stimuli were presented subsequently in random order in one block of 600 trials (100 trials on each of the six images). In Experiment 1 the first ten trials were designed as warm up and were not included in further analysis. In Experiments 2 and 3 the test trials followed 60 trials of training. The main reason for this was that preliminary analysis of the RT distribution in Experiment 1 showed a decreasing average response speed for the first subset of 100 trials when compared with the later trials. Although this effect was not dramatic, the subsequent experiments were designed to avoid any such practice effect.

Each trial started with a central fixation cross for 500 ms following offset of the cross, an image display appeared and remained until the participant responded. The approximate time for each experiment was 20 min.

Analysis of the data

Two analysis were conducted for each experiment. First, each individuals's correct RTs to target faces were examined to see if there was general evidence for the redundancy effect. Mean RTs 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 considere a redundancy gain. Subsequently the size of an individual's redundancy effect was corrected using the fixed favored dimention test (Biederman & Checkosky, 1970). It has been shown that, when some observers favor 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; Mordcoff & 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. In our Results sections we presented the corrected RTEs only as being most relevant.

The second analysis tested whether the Independent Race Model inequality is violated (Miller, 1982). The 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, E and I refer to a target defined by identity and a target defined by emotional expression,

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 Coactivation 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 (Ulrich, Miller, & Schroter, 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 each single target conditions. 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 MatLab script for computing the Independent Race model test (Ulrich et al., 2007).

The nineteen percentiles points and CDFs were calculated for each participant and then averaged. Paired two-tailed *t*-tests were used to assess reliability the difference between G_{IE} and the sum of G_I and GE 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 be below and to the right of the summed CDF. Examples of the group graphic representation are shown in Figure 10.

Results

Experiment 1: Identity and sad expressions

The accuracy performance is displayed in Table 1.

Table 1. *The percentage of errors for Redundant Targets (I+E), the Identity Target (I), The Emotional Expression Target (E), and the 3 Nontarget faces (NTs) in Experiments 1-3.*

Experiments	IE	I	E	NTs
1	0.24	1.13	0.61	1.37
2	0.64	0.72	1.41	1.74
3	0.47	0.33	0.68	0.61

A one-way repeated-measures ANOVA showed that difference between the errors for redundant targets and either single target was reliable ($F(2,22) = 6.2$, $p < .05$, $\eta_2 = .32$; $t(11) = 3.5$, $p < .05$, $d = 0.37$; $t(11) = 4.1$, $p < .05$, $d = 0.41$). Participants showed high sensitivity to images containing target signals (d′ = 3.64).

The results of the RTE analysis showed that the overall redundancy effect did occur: the redundant condition was faster ($M = 536.3$, $SD = 85.8$) than the fastest (in this case the emotional expression target) single target ($M = 664.7$, $SD = 85.6$) condition. A one-way repeated-measures ANOVA with Bonferroni correction for multiple comparisons showed a reliable difference between the mean RTs for redundant targets and both the identity-defined target ($M = 669.9$, $SD = 99.4$) and the emotional expression target [$F(2, 22) = 75.03$, p < .001, $\eta_2 = .69$; $t(11) = 8.8$, $p < .001$, $d = 0.55$; $t(11) = 11.6$, $p < .001$, $d = 0.72$].

The CDFs for redundant targets exceed the CDFs for the sum of the emotional expression target and the identity target at the first nine quintiles (all $p < .05$) (Figure 2).

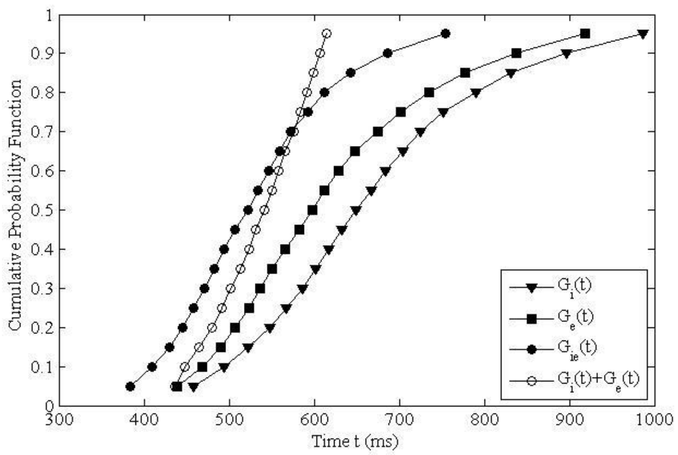


Figure 2. CDFs for redundant targets (IE), the sum of distributions of emotional expression and identity targets (I+E) and single targets (E) and (I) in Experiment 1.

Experiment 2: Identity and angry expressions

The overall percentage of errors was 4.51 (Table 1). Errors were greatest with the emotional expression target. Participants tended to use a conservative response bias (β = 1.54), but they showed good discrimination between images containing target information and those where the target was absent (d′ = 3.22). A one-way repeated-measures ANOVA revealed a reliable difference between the error rate for identity target relative to the emotional expression target and the redundant target stimulus ($F(2,22) = 7.1$, $p < .05$, η_2 = .58; $t(11) = 4.3$, $p < .05$, $d = 0.37$; $t(11) = 3.8$, $p < .05$, $d = 0.36$).

The redundant condition was faster ($M = 520.9$, $SD = 69.7$) than the condition with just an emotional expression target ($M = 683.8$, $SD = 132.6$) or an identity-defined target ($M = 648$, $SD = 105.3$). A one-way repeated-measures ANOVA with Bonferronni correction for multiple comparisons revealed RT differences across the test blocks between trials with redundant targets compared with trials with emotion expression and identity targets ($F(2, 22) = 50.4$, p < .001, η_2 = .81; $t(11) = 7.4$, $p < .001$, $d = 0.64$; $t(11) = 10.2$, $p < .001$, $d = 0.76$).

RTs for redundant targets were shorter than the sum of the RT distributions for the identity and emotional expression targets at the first eight quintiles (all $p < .05$) (Figure 3).

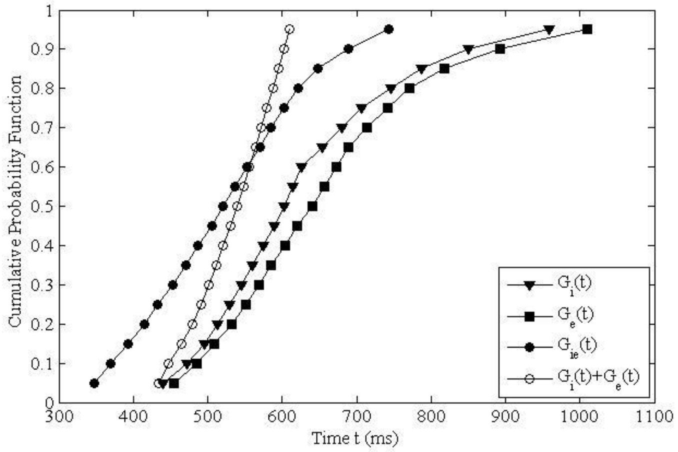


Figure 3. CDFs for redundant targets (IE), the sum of distributions of emotional expression and identity targets (I+E) and single targets (E) and (I) in Experiment 2.

Experiment 3: Identity and neutral expressions

The overall percentage of errors was 2.09 (Table 1). Participants showed a conservative response bias (β = 1.4) and good discrimination (d′ = 3.94). A one-way repeated-measured ANOVA showed that the difference between the errors for redundant targets and each single target was not reliable ($F(2,22) = 1.24$, $p > .05$, $\eta^2 = 0.1$; $t(11) = 1.45$, $p > .05$, $d = 0.06$ (for target identity); $t(11) = 1.12$, $p > .05$, $d = 0.1$ (for target emotional expression).

For RTs a one-way repeated-measures analysis of variance failed to reveal a significant difference between the different targets (redundant, identity and emotional expression; $F(2,22) = 1.67$, $p > .05$, $\eta^2 = 0.08$). The RTs are displayed in Table 2. Redundant targets failed to exceed the sum of two single targets at any quintile (Figure 4).

Table 2. *Mean RTs of responses to Redundant (IE), Identity (I) and Emotional Expression (E) Targets in Experiment 3*

Stimuli	M (SD), ms
IE	653.1 (103.4)

I	639.3 (108.9)
E	674.0 (100.8)

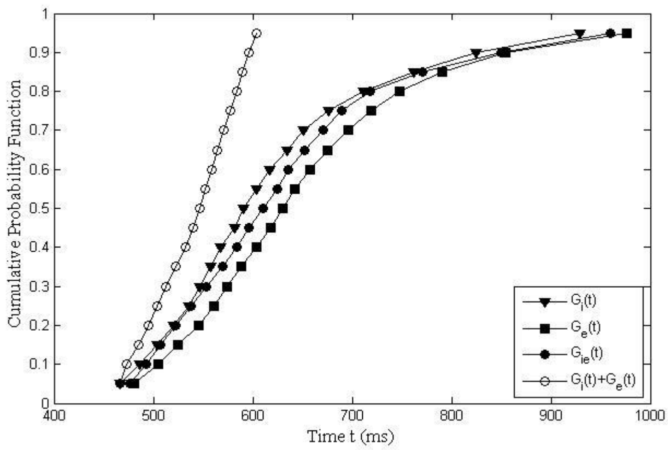


Figure 4. CDFs for redundant targets (IE), the sum of distributions of emotional expression and identity target (I+E) and single target (E) and (I) in Experiment 3.

Comparisons across Experiments 1-3

A one-way repeated-measures ANOVA compared the size of the redundancy gains across Experiments 1, 2 and 3. The sizes of redundancy gains differed significantly across experiments ($F(2, 34) = 37.75$, $p < .001$, $\eta_2 = 0.72$). The size of the redundancy gain in Experiment 3 (M = -16.9, SD = 44.9) was reliably smaller than in Experiments 1 (M = 88.57, SD = 34.74) and 2 (M = 124.8, SD = 44.09) (all $p < .001$, Bonferronni corrected). There was no difference in the size of the redundancy gains for Experiments 1 and 2 ($p > .09$).

Discussion

In Experiments 1 and 2 responses to redundant targets were faster than responses to the targets defined by identity and emotional expression alone. This is consistent with findings from prior experiments using simple stimuli where the performance was facilitated if targets were present in two rather than one stimulus (Grice & Reed, 1992; Miller, 1986; Mordkoff & Yantis, 1991). The present results show for the first time, though, that identity and emotional expression can combine to facilitate discrimination performance. Particularly striking is our finding that there were violations of the Miller inequality test when structural identity was combined with a specific, universal emotional expression in a single target. This test provides a strict assessment of whether discrimination performance can be accounted for by independent processing of the critical, target-defining properties. Our evidence indicates that it cannot.

Violation of the Miller inequality occurred for combinations of identity and a sad (Experiment 1) and an angry expression (Experiment 2), but not for the combination of identity and a neutral expression (Experiment 3). Indeed, in the last case there was not even evidence for any overall redundancy gain. This result suggests that viewing a distinct emotional expression (e.g. sad or angry) paired with target identity benefits recognition, perhaps, because these emotions are conveyed by distinct visual features. In contrast, unfamiliar faces bearing a neutral expression do not carry expression-contingent features and a neutral expression may be defined by the absence of a universal emotional expression, making it more idiosyncratic to the particular face. For these reasons, there may be no redundancy gain when the neutral expression for one face combines with the structural identity of another target face.

Our data can at least partly explain why emotional expression may help in identity recognition, if the two dimensions combine to form a unitary identity-expression code (e.g. D'Argembeau, Van der Linden, Comblain & Etienne, 2003). Positive effects of emotional expressions on face identification performance have also been demonstrated by de Gelder, Frissen, Barton, & Hadjikhani (2003). These authors reported that, for patients with impaired configural processing, the matching of face identities was improved dramatically when the faces had emotional rather than neutral expressions. De Gelder et al. (2003) suggested that their result arose because emotional expressions provided the patients with additional facial cues to make recognition of the person more efficient.

Coactive vs interactive processing of facial identity and emotional expression

Having established that supper-additive redundancy gains occur between face identity and emotional expression, at least when facial expressions convey distinct emotions, Experiment 4 went on to test whether identity and emotional expression information of faces are processed coactively or interactively. The Interactive Race Model (Mordkoff & Yantis, 1991) assumes that the probability of one target can be made dependent on the occurrence of the second target and non-target information at different stages of target identification. One factor is that the greater predictability of one stimulus should speed RTs (the inter-stimulus contingency effect: ISC). A second factor is a non-target response contingency bias (NRCB), which refers to the possible use of attributes of non-targets to cue responses to targets. For example, in Experiment 1 participants might associate target identity with a sad expression in the redundant face, and use emotional expression cues only for "target present" responses (or vice versa for the face identities). In this case, increasing the probability of the combination of a sad expression with a target identity will lead to the shortening of RTs on redundant trials. Another possibility that might benefit redundant targets trials over the identity and emotional expression target trials is that each single target trial included non-target information. For instance, in Experiment 1 the identity-defined target face contained a non-target happy expression and the emotional expression target face contained non-target identity information (Appendix 1). According to the Interactive Race Model (Mordkoff & Yantis, 1991) including such stimuli in the experimental design slows RTs for the single identity and the emotional expression target trials, because these target trials are biased by the non-target properties that are present.

The Interactive Race Model (Mordkoff & Yantis, 1991) holds that a) if both ISC and NRCB are zero (i.e. there are equal number of trials for all stimuli), The Independent Race

Model inequality (1) will be always satisfied, while b) if ISC and NRCB are positive (i.e., the probability of the redundant target or non-target trials is higher compared with either single target trials), The Independent Race Model inequality will be violated. In contrast, the Coactivation Model (Miller, 1982) assumes that variation in ISC and NRCB does not affect the redundancy gain and violation of the Independent Race Model will be relatively constant across these conditions.

To test the effect of ISC and NRCB on RTs, three settings (Experiments 4a, 4b, 4c) were designed using go/no-go tasks. These experiments had the same stimuli, timing parameters, trial order and response demands, differing only in the probability with which the stimuli were displayed. In Experiment 4a both ISC and NRCB were zero, in Experiment 4b ISC was positive, while in Experiment 4c NRCB was positive (see Table 3 in Design and Procedure section).

Experiment 4: Tests of feature overlap

Method

Participants

Three groups of 15 undergraduate students (13 males) were recruited. The participants were aged between 19 and 26 years. All participants reported normal or corrected-to-normal eyesight.

Stimuli and Apparatus

The stimuli from Experiment 1 were used (Appendix 1).

Design and procedure

A “go/no-go” task was employed to examine the effect of inter-stimulus contingency and non-target response bias on identity and emotional expression judgments. Half of the trials used stimuli containing at least one target attribute (target identity, target emotional expression, or both targets; 'go' trials). On the other half of the trials, the stimuli did not convey any target attribute ("no-go" trials).

Participants were randomly assigned to one of three experiments. They 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. The targets were: Person1 expressing a sad emotion (redundant targets); Person 1 with a happy expression (target identity and non-target expression); Person 2 with a sad expression (target expression and non-target identity). A face of Person 2 with a happy expression (non-target-identity and non-target emotion); Person 3 with a neutral expression (non-target-identity and non-target emotion) and Person 4 with neutral expression (non-target identity and non-target emotional expression) were employed as three non-targets.

Participants completed an initial practice block of 60 trials during which they were given a feedback on their accuracy after each trial. Individuals participated in Experiments 4b and 4c after completing the practice block and then were informed which images would be displayed more often. After a short break participants performed a test block of 600 trials. The stimulus contingencies for each experiment are displayed in Table 3.

Table 3. *The number of trials for the Redundant Target (E+I), the Identity Target (I), the Emotional Expression target (E) and the 3 Non-Target faces (NT1, NT2, NT3) in Experiments 4a, 4b and 4c.*

	Stimuli					
Experiments	E+I	I	E	NT1	NT2	NT3
4a	100	100	100	100	100	100
4b	150	75	75	100	100	100
4c	100	100	100	150	75	75

Each trial started with the presentation of a fixation cross at the center of the screen for 500 ms. Images were presented successively in random order. On "go" trials the image was displayed until a response was made. On "no-go" trials the stimulus was displayed 1500 ms.

Analysis of data

For each experiment two analyses were conducted. The first analysis determined whether redundant targets trials were responded to more quickly than single target trials using the favored dimension test (Biederman & Checkosky, 1970). The second analysis assessed whether the Independent Race Model inequality was violated (Miller, 1982). Both analyses were conducted in the same manner as in Experiment 1. To examine the effect of ISCB and NRCB on violations of the Independent Race Model inequality, a one-way ANOVA was performed.

Results

In all three experiments participants produced more errors in response to the single targets relative to redundant targets. The highest error rate was for "no-go" trials to a non-target face (NT1) containing both identity and emotion distractors (Table 4). Participants tended to have a liberal response bias (β = 0.19, 0.3 and 0.54) and good discrimination (d' =3.54, 3.31 and 3.41). The differences in error rates between the experiments were not significant ($F(2, 42) = 1.94$, $p > .12$, $\eta_2 = 0.06$). There was a significant main effect of Target ($F(2, 84) = 11.6$, $p < .05$, $\eta_2 = 0.79$). Pairwise Bonferronni-corrected comparisons showed that errors for the non-target face (NT1) were reliably higher compared to all other stimuli ($p < .05$). There was no interaction between Target and Experiment ($F(4, 84) = 1.92$, $p > .05$, $\eta_2 = 0.1$).

Table 4. *Error rates (in %) for redundant (IE), identity (I), and emotional expression (E) targets and non-target faces NT1, NT2, NT3 in Experiments 4a, 4b and 4c.*

		Experiments		
Stimuli	Trials	4a	4b	4c
IE	"Go"	0.48	1.45	0.02
I		1.6	1.85	1.01
E		0.6	1.47	0.24
NT1	"No-go"	4.81	4.80	5.7
NT 2		1.1	1.67	1.01
NT 3		1.2	1.40	0.7

A redundant target effect was found in all three experiments (Table 5).

Table 5. *Mean RTs to redundant targets (IE), the emotional expression (E) and the identity (I) targets in Experiments 4a, 4b and 4c.*

Experiments	M (SD)		
	E+P	I	E
2a	484 (57)	548 (64)	592 (82)
2b	455 (39)	518 (42)	560 (55)
2c	465 (40)	529 (44)	548 (55)

A mixed design ANOVA with Experiment as a between-subjects factor and Target (redundant, identity and emotional expression targets) as the within-subject factor was carried out to examine whether RTs for redundant targets were shorter than for single target identity and emotional expression trials. There was a main effect of Target ($F(2, 84) = 18.8$, $p < .001$, $\eta_2 = 0.83$). Pairwise Bonferroni-corrected comparisons showed that RTs for redundant targets were faster than for either single target (Table 5) for all experiments (p < .001). There was no main effect of Experiment ($F(2, 42) = 1.55$, $p > 0.2$, $\eta_2 = 0.12$), and no interaction between Experiment and Target ($F(4, 84) = 1.75$, $p > .05$, $\eta_2 = 0.07$).

All three experiments showed significant violations of the Independent Race Model inequality. In Experiments 4a and 4b the Independent race Model inequality was violated at percentiles 0.05 – 0.35 (all p < .05). In Experiment 4c violations were found at percentiles 0.05-0.45 (all p < .05). The group CDFs for redundant targets and the sum of target identity and emotional expression targets in Experiments 4a-4c are displayed in Figure 5.

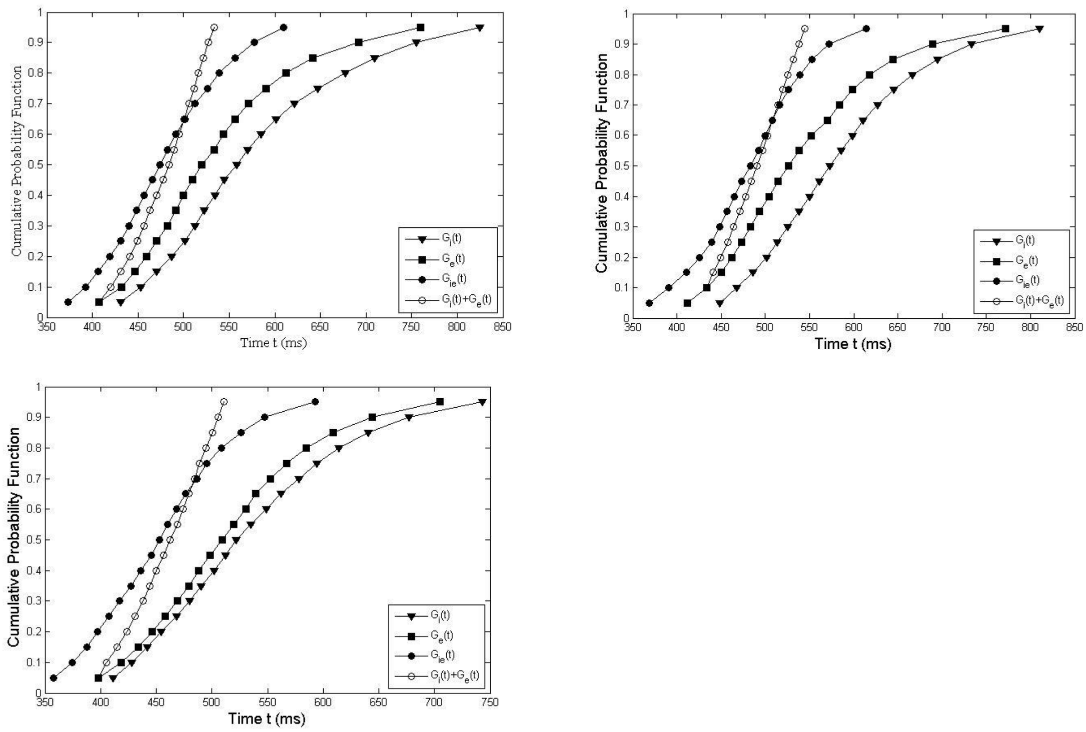


Figure 5. CDFs for redundant targets (IE), the sum of distributions of the emotional expression and identity targets (I+E) and single targets (E) and (I) in Experiments 4a (top left), 4b (top right) and 4c.

A univariate one-way ANOVA with Experiment as the between subject factor was used to test whether there were differences in the size of the redundancy gain across Experiments 4a-4c (Table 6). The size of the redundancy gain was calculated by subtracting of RTs for redundant targets from RTs for the fastest of the single targets at each percentile. There was no effect of Experiment on the size of the redundancy gain (*F* (2, 44) = .46).

Table 6. *The size of the redundancy gain and standard deviation (in brackets) in Experiments 4a, 4b and 4c*

	Experiments		
	4a	4b	4c
The size of redundancy gain, ms	63.81 (22.8)	60.2 (27.48)	64.31 (30.55)

Discussion

Experiments 4a-4c demonstrated that manipulations of inter-stimulus and non-target contingencies did not affect the redundancy gains between facial identity and emotional expression. Experiment 4a showed a reliable violation of the race inequality using a design that lacked biased contingencies. A similar result was obtained when contingency was biased in favor of redundant target trials (Experiment 4b) and non-target trials (Experiment 4c). Moreover, there were no differences between the size of the violations in Experiments 4a-4c. These results contradict The Interactive Race Model (Mordkoff & Yantis, 1991). The maintenance of significant violations of The Independent Race Model across all the sub-experiments is consistent with a coactivation account.

Notably, participants in Experiment 4b - in which the redundant targets had a higher probability of occurrence compared with either single target - were less accurate than in Experiment 4a. According to the Interactive Race Model (Mordkoff & Yantis, 1991), the positive inter-stimulus contingency should improve accuracy in response to redundant targets. However, there was not this case. This provides additional support for the coactivation account and again counters the inter-stimulus contingency proposal.

In all sub-experiments a non-target face containing both distractors (NT1) elicited more false alarms than the other stimuli. Although the percentage of errors was not very high, this finding suggests that participants cannot ignore the task irrelevant information completely. On the other hand, this effect was observed in a “go-no/go” task, but not in a “two-choice’ task (Experiment 1). Given that participants showed different responses biases in Experiment 1 and 4, this might partly reflect a difference in a non-decision process in these tasks (Grice & Reed, 1992; Perea, Rosa, & Gomez, 2002).

Experiment 5: Pictorial vs structural coding of facial identity and emotional expression

Although Experiments 1, 2 and 4 here demonstrated significant redundancy gains when participants responded to both structural identity and emotional expression in faces, it remains unclear what information was used for the task. It is possible, for example, that participants remembered pictorial properties of specific targets and distinguished faces on the basis of these cues (Bruce & Young, 1986). It is not necessarily the case that responses were based on the true extraction of facial identity and emotion information. Now many previous studies on face perception have shown that recognition of the structural properties of faces can be dramatically disrupted when faces are displayed upside-down in comparison with up-right orientation (Freire, Lee, & Symons, 2000; Leder & Bruce, 2000; Searcy & Bartlett, 1996). The specific effect of inversion on identity processing has been attributed to the disruption of coding the configural relations between facial features (e.g., the distances between eyes, nose and mouth; Searcy & Bartlett, 1996; though see Sekuler et al., 2004, for an alternative view), and a similar argument can be made for emotional expression processing. For instance, McKelvie (1995) reported that inversion reduced accuracy for discriminating sad, fear, anger and disgust, with sad expressions being identified as neutral.

In Experiment 5 we tested for redundancy gains with inverted faces. If the redundancy gains depend on structural encoding of facial configurations, then the gains should be eliminated here. On the other hand, since the pictorial cues remain the same when faces are upright and inverted, then gains in Experiment 5 based on pictorial cues should match those we have observed earlier.

Experiment 5: Inverted faces

Method

Participants

Twelve undergraduate students (three males) aged between 21 and 26 years participated in this study. They received credits for participation. All participants reported normal or corrected-to-normal vision.

Stimuli and Apparatus

A set of inverted images from Experiment 1 was employed. This set included sad and happy faces that gave a maximum opportunity to process the inverted faces.

Design and Procedure

Design and procedure was identical to Experiment 1 except than faces were inverted.

Results and discussion

The overall percentage of errors was 24.5. The participants were less accurate in responding to emotional expression than to redundant and identity targets (Figure 6). False alarms to one of the inverted non-target NT3 (Appendix 1) occurred on 50.2% of all trials. Participants showed low sensitivity to images containing targets (d′ = 1.31).

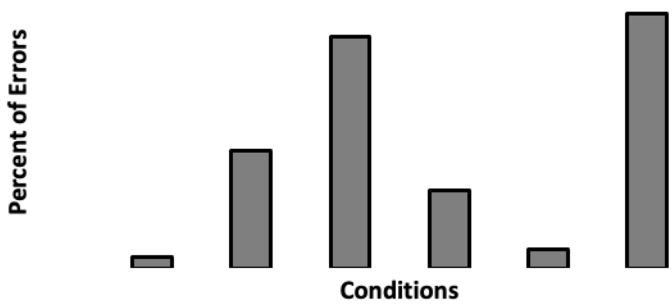


Figure 7. Error rates (in %) for redundant (IE), identity (I), and emotional expression (E) targets and non-target faces NT1, NT2, NT3 in Experiment 5

A one-way repeated-measures ANOVA with Conditions (IE, I, E, NT1, NT2, NT3) as a within subject factor was conducted to assess if accuracy differed across the conditions. There was a main effect of condition on accuracy ($F(5,55) = 6.55$, $p = .001$, $\eta^2 = .61$). Pairwise comparisons within the main effect of conditions (corrected using a Bonferroni adjustments) indicated that there were reliable differences between redundant targets (IE) and both the non-target 3 (NT3) ($p < .05$), and the emotional expression target (E) ($p < .05$). Mean RTs for all the conditions in Experiment 5 are displayed in Table 7.

Table 7. *Mean RTs for redundant (IE), identity (I), and emotional expression (E) targets and non-target faces NT1, NT2, NT3 in Experiment 5*

	Conditions					
	IE	I	E	NT1	NT2	NT3
Mean RT, ms (SD)	961.5 (133.6)	798.9 (158.3)	931.1 (293.0)	832.3 (173.0)	788.0 (142.8)	884.6 (201.6)

A one-way repeated-measures ANOVA with Target (redundant, identity and emotional expression targets) as a within subject factor was carried out for RTs. There was a main effect of Target on RT ($F(2, 20) = 5.1$, $p < .05$, $\eta_2 = .57$). Pairwise Bonferroni-correted comparisons showed that participants were faster in responding to the identity target compared with both the redundant target ($p = .001$), and the emotional expression target ($p < .05$) (Table 7).

Two mixed design ANOVAs were conducted with Experiment (Experiment 1 and 5) as a between subject factor and Condition (redundant, identity, emotional expression targets and three non-targets) as a within subject factor for accuracy and RTs. For accuracy there were main effects of Experiment ($F(1,22) = 48.5$, $p < .001$, $\eta_2 = .91$) and Condition ($F(5, 110) = 5.4$, $p < .001$, $\eta_2 = .74$), and a reliable interaction ($F(5, 110) = 5.2$, $p < .05$, $\eta_2 = .77$). For RTs there were main effects of Experiment ($F(1,22) = 19.98$, $p < .001$, $\eta_2 = .86$) and Condition ($F(5,110) = 2.~54$, $p < .05$, $\eta_2 = .42$), and an interaction ($F(5,110) = 12.8$, $p < .001$, $\eta_2 = .67$). Pairwise comparisons using Bonferroni adjustments showed that in Experiment 1 RTs for redundant targets ($M = 961.5$, $SD = 133.6$) were slower than RTs to the same targets in Experiment 5 ($M = 798.9$, $SD = 158.3$) ($p < .05$).

The manipulation of inversion in Experiment 5 produced longer RTs and reduced response accuracy consistent with there being a decreased sensitivity for target signals. This finding is in a line with previous studies on inverted faces (Freire, Lee, & Symons, 2000; (Freire et al., 2000; Searcy & Bartlett, 1996). Notably, the image containing redundant targets and the image NT3 had similarly shaped faces (Appendix 1). When the faces were inverted this similarity might be a cause of poor accuracy on NT3 because inversion impairs the recognition of internal facial features (Sekuler et al., 2004).

It could be argued that the low performance on the discrimination task here minimized any opportunity for redundancy gains to arise. For example, if participants could not discriminate facial emotion, than naturally the emotion would not facilitate responses to target identity. However, while accuracy did decrease here, it remained considerably higher than expected by chance responses to one of the 6 stimuli (16.7%). Hence there was some opportunity for facial emotion still to affect responses to face identity, but we found no evidence for this.

Taken together, the result showing poor discrimination of target signals and higher error rates in response to both targets and non-targets suggest that structural encoding (sensitive to face inversion) contributes to the redundancy gain here, and that effects are not solely dependent on pictorial encoding (common to upright and inverted faces).

General Discussion

The experiments reported here demonstrated redundancy gains in the processing of facial identity and emotional expression. In Experiment 1, 3 and 4, there was evidence for violation of the Miller (1982) inequality consistent with coactivation of identity and emotion information in faces. These violations occurred with different face identities and with the emotional expressions for sadness and anger. The data contradict independent processing models for identity and emotion. Experiment 4 further showed that the effects were not dependent on inter-stimulus contingencies and non-target associations, going against the Interactive Race Model (Mordkoff & Yantis, 1991) account of the data. We conclude that facial identity and emotion information are processed together and both contributed in a non-independent manner to target detection here.

Experiment 5 tested whether performance was dependent on pictorial or structural coding of faces by examining target detection when faces were inverted. The effects of redundancy on RTs were eliminated in this case. The effects were also eliminated in Experiment 3 where face identity was combined with a neutral facial emotion to create the redundant target. These last results suggest that the redundancy gains were not due to the memory of pictorial properties of the stimuli, and there needs to be a specific expressed emotion in order for facial information to be processed coactively. In contrast to facially expressed emotions such as sadness and anger, neutral facial expressions may vary across individuals and may be difficult to extract as a common category from different faces – as a consequence redundancy gains are difficult to find.

An important aspect of our finding is that the redundancy effect was robust for different facial identities and emotional expressions. There are at least two features that might contribute to this. First, we used a task where both the structural identity and the expressed emotion were integrated in a single stimulus. Previously, similar results have been obtained in studies examining the relation between processing the color and shape of a single stimulus (Mordkoff & Yantis, 1993). In a task requiring participants to detect two targets (e.g.the color green and the shape X), the redundant targets display (green X) was processed faster than either single target, and violations of the Independent Race Model were observed (Experiment 1-3, Mordkoff & Yantis, 1993). In contrast, when participants performed a task requiring the detection of a shape and color belonging to different objects, the data supported independent processing (Experiment 4 and 5, Mordkoff & Yantis, 1993). Second, in the present study the effect of differences in the discriminability of identity and emotional expression was controlled. The effects of discriminability on the processing of identity and emotional expression has previously been demonstrated in studies of Garner interference (Ganel & Goshen-Gottstein, 2004; Melara, Rao, & Tong, 2002). For instance, Ganel and Goshen-Gottshtein (2004) showed that when the discriminability of identity and expression judgements were equated, Garner interference occurred in both directions. In contrast, in studies where discriminability was not controlled, either no interference (Etcoff, 1984) or asymmetric interference (Schweinberger & Soukup, 1998) has occurred.

The present results suggest that the redundant target effect is caused by an interaction between facial identity and emotional expression. This raises the question of the level of processing at which this interaction occurs. The Coactivation Model (Miller, 1982) proposes that the interaction between stimuli leading to a super-redundancy gain occurs prior to a decision about target presence, but, in this case, after identity and emotional expression have been separately coded. In contrast, the Interactive Race model (Miller, 1982) suggests that information about facial identity and emotional expression may be exchanged at early perceptual levels (inter-stimulus crosstalk) or at a decisional stage (non-target response bias). There are also suggestions that coactivation for redundant targets occurs at late motor-related stages (Giray & Ulrich, 1993b; Li, Wu, & Touge, 2010b). EEG-studies (e.g., (Giray & Ulrich, 1993a; Li, Wu, & Touge, 2010a; Schroger & Widmann, 1998), examining the processing of bimodal (audio and visual) stimuli, indicate that RT gains for redundant targets are located neither at early, sensory-specific nor at motor stages, but at intermediate, central stage of processing, consistent with the coactivation view. It is interesting to note here that the redundancy effect in Experiments 1 and 2, using a task with two responses, was not different from that in Experiment 4, which required only a single response. This suggests that the interaction is unlikely to occur at late motor stage. Whether the effect arises at an early or more intermediate processing stages remains to be tested.

The present results make a theoretical contribution to the field by contravening a strictly modular account of processing facial identities and emotions, as suggested in both psychological (Bruce & Young, 1986) and neural-level models (Haxby, Hoffman, & Gobbini, 2000). According to the functional model of face recognition proposed by Bruce & Young (1986), the recognition of facial expressions and of identity are assumed to be independent. Our data refute this, since they show that an independent processing model cannot account for the magnitude of the redundancy gain we observe at the very fastest responses that are produced on a trial. The data show that, at some point along the processing stream, facial identity and expression interact. This presents a strong constraint on models of face processing.

The neural basis of the present effects remain to be explored. Haxby et al. (2000) propose that the occipital face area (OFA) and fusiform face areas (FFA) contribute to the processing of facial identities, while the superior temporal sulcus (STS) and the amygdala contribute to the processing of emotional expression. However, there is also evidence that the FFA, traditionally associated with identity processing, is activated more by fearful compared with neutral faces (Vuilleumier, Armony, Driver, & Dolan, 2001), and this area has been linked to processing emotional expression (Ganel, Valyear, Goshen-Gottstein, & Goodale, 2005). Furthermore, several functional neuroimaging studies have reported functional connectivity between brain areas that process the identities of individuals (OFA and FFA, plus also the inferior frontal gyrus, associated with stored face representations (Li et al., 2010) and emotion processing regions (the superior temporal sulcus and amygdale; Kleinhans et al., 2008). Recently Ishai (Ishai, 2008) has proposed a working model of neural coupling that postulates bidirectional connections between all visual, limbic and prefrontal regions mediated processing of faces. Taken together, these studies indicate functional connectivity between processing of identity and emotional expression that might contribute to the observed redundancy gains. This needs to be examined in future research.

In conclusion, the present study provides strong evidence for the interactive processing of identity and emotional expression in faces. However, a number of caveats need to be noted. First, although the current study overcomes some limitations of previous studies employing the Garner task (e.g. matching the efficiency of discriminating identity and emotion targets), there remains an issue about a small number of stimuli being used. Modification of the task is needed to minimise effects of repetition against the large number of trials required to test the Race Model. Second, further work needs to be done to establish what information in faces is perceived as redundant. This will help us understand the stages of processing where the coding of the structural identity of a face interacts with or bifurcates from the coding of emotional expression. Third, the current study has only examined a limited number of emotions (angry, sad and neutral). The evidence points to there being interactive processing of identity and the universal emotions of sadness and anger, but there was no evidence for interactive involving a possibly more idiosyncratic 'neutral' expression. Whether the universality of the expression is critical requires further studies exploring a wider range of facial expressions.

Acknowledgments

This work was supported by a grant from the BBSRC to the second author and a studentship to the first author subsidised by the Hilary Green Research Fund.

.

References

Atkinson, A. P., Tipples, J., Burt, D. M., & Young, A. W. (2005). Asymmetric interference between sex and emotion in face perception. *Perception & Psychophysics, 67*(7), 1199-1213.

Biederman, I., & Checkosky, S. F. (1970). Processing redundant information. *Journal of Experimental Psychology 83*, 486–490.

Blau, V. C., Maurer, U., Tottenham, N., & McCandliss, B. D. (2007). The face-specific N170 component is modulated by emotional facial expression. *Behavioral and Brain Functions, 3*, 7. doi: 1744-9081-3-7 [pii] 10.1186/1744-9081-3-7

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77 (Pt 3)*, 305-327.

Calder, A. J., Burton, A. M., Miller, P., Young, A. W., & Akamatsu, S. (2001). A principal component analysis of facial expressions. *Vision Research, 41*(9), 1179-1208. doi: S0042-6989(01)00002-5 [pii]

Campbell, R., Landis, T., & Regard, M. (1986). Face recognition and lipreading. A neurological dissociation. *Brain, 109 (Pt 3)*, 509-521.

Ellamil, M., Susskind, J. M., & Anderson, A. K. (2008). Examinations of identity invariance in facial expression adaptation. *Cognive and Affective Behavioral Neuroscience, 8*(3), 273-281.

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: direct evidence. *Perception, 29*(2), 159-170.

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 and Human Perception Performance, 30*(3), 583-597. doi: 10.1037/0096-1523.30.3.583 2004-14382-013 [pii]

Ganel, T., Valyear, K. F., Goshen-Gottstein, Y., & Goodale, M. A. (2005). The involvement of the "fusiform face area" in processing facial expression. *Neuropsychologia, 43*(11), 1645-1654. doi: S0028-3932(05)00060-6 [pii]

10.1016/j.neuropsychologia.2005.01.012

Garner, W. R. (1974). *The processing of information and struc- ture*: New York: Wiley.

Giray, M., & Ulrich, R. (1993a). Motor coactivation revealed by response force in divided and focused attention. *Journal of Experimental Psychology. Human Perception and Performance, 19*(6), 1278-1291. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8294892

Giray, M., & Ulrich, R. (1993b). Motor coactivation revealed by response force in divided and focused attention. *Journal of Experimental Psychology: HumanPercept ion and Performance, 19*(6), 1278-1291.

Grice, G. R., Canham, L., & Boroughs, J. M. (1984). Combination rule for redundant information in reaction time tasks with divided attention. *Perception & Psychophysics, 35*(5), 451-463.

Grice, G. R., & Reed, J. M. (1992). What makes targets redundant? *Perception & Psychophysics, 51*(5), 437-442.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Science, 4*(6), 223-233. doi: S1364-6613(00)01482-0 [pii]

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research, 16*(2), 174-184. doi: S0926641002002689 [pii]

Ishai, A. (2008). Let's face it: it's a cortical network. *Neuroimage, 40*(2), 415-419. doi: 10.1016/j.neuroimage.2007.10.040

Kaufmann, J. M. (2004). *Interactions between the processing of facial identity, emotional expression and facial speech?* (PhD), University of Glasgow, Glasgow.

Krummenacher, J., Muller, H. J., & Heller, D. (2001). Visual search for dimensionally redundant pop-out targets: evidence for parallel-coactive processing of dimensions. *Perception & Psychophysics, 63*(5), 901-917.

Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics, 56*(2), 183-197.

Leder, H., & Bruce, V. (2000). When inverted faces are recognized: the role of configural information in face recognition. *Quarterly Journal of Experimental Psycholology- A, 53*(2), 513-536.

Li, Q., Wu, J., & Touge, T. (2010a). Audiovisual interaction enhances auditory detection in late stage: an event-related potential study. *Neuroreport, 21*(3), 173-178. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20065887 doi:10.1097/WNR.0b013e3283345f08

Li, Q., Wu, J., & Touge, T. (2010b). Audiovisual interaction enhances auditory detection in late stage: an event-related potential study. *Neuroreport, 21*(3), 173-178. doi: 10.1097/WNR.0b013e3283345f08

Melara, R. D., Rao, A., & Tong, Y. (2002). The duality of selection: excitatory and inhibitory processes in auditory selective attention. *J ournal of Experimental Psychology: Human Perception and Performance, 28*(2), 279-306.

Miller, J. (1982). Divided attention: evidence for coactivation with redundant signals. *Cognitive Psychology, 14*(2), 247-279. doi: 0010-0285(82)90010-X [pii]

Miller, J. (1986). Timecourse of coactivation in bimodal divided attention. *Perception & Psychophysics, 40*(5), 331-343.

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.

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.

Mordkoff, J. T., & Yantis, S. (1991). An interactive race model of divided attention. *Journal Experimental Psychology & Human Perception Performance, 17*(2), 520-538.

Pegna, A. J., Khateb, A., Michel, C. M., & Landis, T. (2004). Visual recognition of faces, objects, and words using degraded stimuli: where and when it occurs. *Human Brain Mapping, 22*(4), 300-311. doi: 10.1002/hbm.20039

Perea, M., Rosa, E., & Gomez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? *Memory and Cognition, 30*(1), 34-45.

Raab, D. H. (1962). Statistical facilitation of simple reaction times. *Transactions of the New York Academy of Sciences, 24*, 574-590.

Reinholz, J., & Pollmann, S. (2007). Neural basis of redundancy effects in visual object categorization. *Neuroscience Letters, 412*(2), 123-128. doi: S0304-3940(06)01176-1 [pii]

10.1016/j.neulet.2006.11.004

Schroger, E., & Widmann, A. (1998). Speeded responses to audiovisual signal changes result from bimodal integration. *Psychophysiology (The International Journal of the Society for Psychophysiological Research), 35*(6), 755-759. doi: 10.1017/S0048577298980714

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

Searcy, J. H., & Bartlett, J. C. (1996). Inversion and processing of component and spatial-relational information in faces. *Journal of Experimental Psychology and Hum anPerception Performance, 22*(4), 904-915.

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.

Ulrich, R., Miller, J., & Schroter, H. (2007). Testing the race model inequality: an algorithm and computer programs. *Behavior and Research Methods, 39*(2), 291-302.

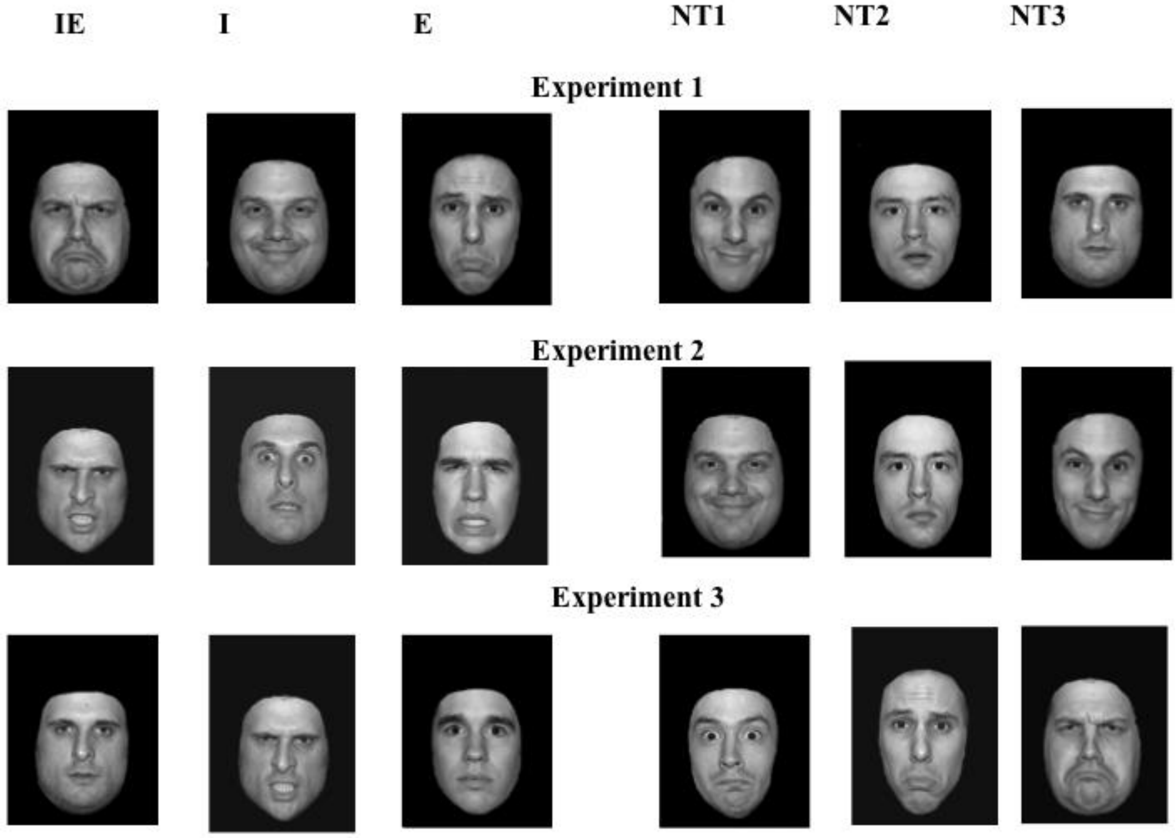
Weissman, D. H., Warner, L. M., & Woldorff, M. G. (2009). Momentary reductions of attention permit greater processing of irrelevant stimuli. *Neuroimage, 48*(3), 609-615. doi: 10.1016/j.neuroimage.2009.06.081

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 Performance, 32*(3), 755-779. doi: 2006-08586-016 [pii]

10.1037/0096-1523.32.3.755

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.

Appendix 1



Stimuli used in Experiments 1-3. Redundant targets contain both the identity and the emotional expression target (IE); target identity and non-target emotion (I); target emotion and non-target identity (E); three non-targets neither target identity nor target emotional expression (NT1, NT2, NT3 for non-targets 1-3 respectively).

In Experiment 1 the stimuli were:

targets:

a) Person1 expressing a sad emotion (redundant targets);

b) Person 1 with happy expression (target identity and non-target expression);

c) Person 2 with a sad expression (target expression and non-target identity);

non-targets:

d) Person 2 with happy expression (non-target-identity and non-target emotion);

e) Person 3 with a neutral expression (non-target-identity and non-target emotion) and

f) Person 4 with neutral expression (non-target identity and non-target emotional expression).

In Experiment 2 the targets were:

(a) Person 4 expressing an angry emotion (redundant targets);

(b) Person 4 expressing fear (target identity and non-target emotion),

(c) Person 6 expressing anger (target emotion and non-target identity).

the non-targets were:

(d) Person 1 with a happy expressions (non-target emotion and non-target identity);

(e) Person 3 with a neutral expression (non-target emotion and non-target identity);

(f) Person 3 with a happy expression (non-target emotion and non-target identity).

In Experiment 3 the targets were:

(a) Person 4 with a .neutral expression (redundant targets),

(b) Person 4 with an angry expression (target identity and non-target emotion),

(c) Person 6 with a neutral expression (target emotional expression and non-target identity);

the non-targets were:

(d) Person 3 with a fearful expressions (non-target emotion and non-target identity);

(e) Person 2 with a fearful expression (non-target emotion and non-target identity)

(f) Person 1 with a sad expression (non-target emotion and non-target identity).

Note, that in Experiment 1 the ‘emotion-only’ target stimulus shared the same identity with non-target 1. This was done to test whether the non-targets interfered with responses to targets based on an overlap of features (see Experiment 4 for further explanation).