Darwin the Detective:

Observable Facial Muscle Contractions Reveal Emotional High-Stakes Lies

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Abstract

Deception - a fundamental aspect of human communication - often is accompanied by the simulation of unfelt emotions or the concealment of genuine emotions to correspond to the false message. We investigated the consequences of extremely high-stakes emotional deception on the engagement of particular facial muscles, posited by Darwin (1872) to reveal the false face. The videotaped facial actions of a sample of individuals ($N = 52$) emotionally pleading to the public for the return of a missing relative – half of whom eventually were convicted of murdering that person – were coded frame-by-frame (30 frames/sec for a total of 23,622 frames). Findings support the view that emotional "leakage", particularly via those facial muscles under less cortical control, is a byproduct of the over-extended cognitive resources available to convey elaborate lies. Specifically, the "grief" muscles (*corrugator supercilli*, *depressor anguli oris*) were more often contracted in the faces of genuine than deceptive pleaders. Subtle contraction of the *zygomatic major* (masking smiles) and full contraction of the *frontalis* (failed attempts to appear sad) muscles were more commonly identified in the faces of deceptive pleaders. Thus, while interpersonal deception often is highly successful, signs of covert emotional states are communicated clearly to the informed observer.

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Among his basic assertions, Darwin (1872) argued that emotional expressions are inherited, involuntary manifestations of one's inner state. Further, of all those channels through which emotional signals may be expressed, Darwin considered the face to be "chief." He posited that facial expressions are adaptive for the bearer of an emotion, allowing him/her to better process or respond to (and survive) the emotion-inducing situation at hand – a proposition that recently has found empirical support (e.g., Susskind et al., 2008). The functional advantages of these expressions have been co-opted by social companions; these expressions also *signal* emotions that can be interpreted by the observer to aid survival, reproduction and social communication more generally (Schmidt & Cohn, 2001)[2].

The Evolution of the Deceptive Face

The salient expression of one's innermost emotions on the face, however, is not always the optimal survival/reproductive strategy (Bond & Robinson, 1988). On average, people lie twice per day (DePaulo et al., 1996); common motives include altruism, impression management, or for the direct personal advantage of the liar (Seto, Khattar, Lalumiere, & Quinsey, 1997; Vrij, 2008). Such deception often is successful; observers have been found to perform at the level of chance in deciding if another person is truthful (e.g., Bond & DePaulo, 2006; Ekman & O'Sullivan, 1991) or whether a particular facial expression is genuine or false (e.g., Porter & ten Brinke, 2008). For everyday, low-stakes lies, there are probably no or few behavioral signs to inform the observer's decision (e.g., Hartwig & Bond, 2011). However, the powerful motivation to look credible, coupled with the complexity of creating and maintaining a consequential lie,

[2] Others suggest that the signaling function of emotional expressions is, in fact, the primary impetus for the evolution of such behaviour (e.g., Fridlund, 1994).

may lead to *greater* leakage of behavioural signals and likelihood of detection in high-stakes contexts (DePaulo, Kirkendol, Tang & O'Brien, 1988; O'Sullivan, Frank, Hurley, & Tiwana, 2009).[3]

The Inhibition Hypothesis

Our contention that human deception of consequence will be accompanied by emotional "leakage" is foreshadowed by Darwin's (1872) observations on the involuntary nature of facial expressions. He suggested that some facial muscle actions associated with emotion cannot be completely inhibited despite efforts by the emotion bearer. He further proposed that attempts to contract certain facial muscles during emotional simulation would fail. Collectively, these propositions form the *inhibition hypothesis* (Ekman, 2003a); a proposal that recently has found empirical traction. Porter and ten Brinke (2008) revealed that subtle leakages of emotion were indeed more likely to occur during falsified, relative to genuine, expressions. Further, a recent follow-up study found that genuine emotion is particularly difficult to suppress – and more likely to be revealed on the face – when it is strong, relative to weaker emotional states (Porter, ten Brinke, & Wallace, 2011).

Further supporting the importance of the face in unmasking liars, Ekman, Friesen and O'Sullivan (1988) found that nurses motivated to mask feelings of disgust could not successfully replace this expression with a genuine smile, instead displaying 'masking smiles', involving only the lower, not the upper, face. Facial analysis of deceptive mock crime interrogations and personal opinion statements include leakage of fear and disgust (Frank & Ekman, 1997). Further,

[3] Trivers (2000) argued that the liar may reduce the likelihood of detection by means of self-deception, or mis-believing their deceptive tale. This phenomenon may be selected in successive generations for its advantage in successfully deceiving and manipulating others (von Hippel & Trivers, 2011; McKay & Dennett, 2009).

Hurley and Frank (2011) recently reported that eyebrow raises and (to a lesser extent) smiles often are leaked despite attempts to suppress this movement.

While previous research has examined relatively low-stakes deception, facial indicators of deceit – leakage of genuine emotion and failed attempts to portray false affect – are likely to be particularly salient in high-stakes, emotional situations. Given limited cognitive resources and the difficulty of necessary multi-tasking during deception, we suggest that emotional leakage is particularly likely to occur when the lie is complex and/or associated with strong emotions to be concealed or falsified. Specifically, we expect those facial muscles least under fine voluntary control will be most likely to fail. In general, muscles of the lower face are contralaterally innervated, and under fine voluntary control serving tasks such as chewing and talking (Rinn, 1984). As one ascends the face, however, muscles increasingly become innervated by the ipsilateral motor cortex and fine movements are less under volitional control. Thus, it is the upper facial muscles that are expected to fail first during emotional deception (Hurley & Frank, 2011).

High-Stakes Emotional Deception

In the first study to examine facial cues to deceit during real-life, high-stakes, emotional deception, we examined the videotaped behaviors of a large international sample of individuals emotionally pleading to the public for the return of a missing relative, half of whom were later determined to have murdered the relative prior to the public appeal (ten Brinke & Porter, 2011). During the critical lie, told by each deceptive murderer, upper face surprise and lower face happiness were likely to be expressed, attributed to the failed attempt to appear sad and leakage of happiness. However, the gross emotional coding, based on variants of prototypical emotional expressions (Ekman, Friesen, & Hagar, 2002), utilized in that study preclude any definite conclusions about precisely which muscles failed the deceptive pleaders. Thus, the identification of the facial muscles which Darwin (1872) identified as "least obedient to the will" in this context remains to be empirically investigated.

The Current Study

The current study investigated for the first time the facial muscles that are least amenable to volitional control during high-stakes emotional deceit. Guided by the findings of ten Brinke and Porter (2011), muscle activation associated with sadness, happiness, and surprise (the *frontalis, corrugator supercilli, orbicularis oculi, zygomatic major* and *depressor anguli oris*) was examined in televised appeals for the safe return of a missing relative, a novel paradigm in the study of high-stakes deception. It was expected that genuinely distressed pleaders would be more likely to engage those muscles noted by Darwin (1872) as innately associated with sadness, relative to deceptive individuals: *corrugator supercilli* (Hypothesis 1) and *depressor anguli oris* (Hypothesis 2). In contrast, direct appeals by deceptive murderers were expected to fail in their representation of voluntary aspects of sadness in the upper face (gross activation of the *frontalis*, of which only the medial *frontalis* is relevant to grief; Ekman, 1985) (Hypothesis 3) and produce voluntary, masking smiles (*zygomatic major* in the absence of *orbicularis oculi* activation; Ekman et al., 1990; Ekman, Friesen, & O'Sullivan, 1988) (Hypothesis 4), hypothesized to conceal other emotional leakage rather than indicate genuine enjoyment (Ekman, 2003b).

Method

Cases

Videos of $N = 52$ (26 deceptive) individuals who made televised pleas for the safe return (or information leading to an arrest in the murder) of their relative were gathered from news agencies in Australia, Canada, the United Kingdom and the United States. Deceptive individuals eventually were convicted based on overwhelming physical evidence (e.g., DNA). In cases of genuine pleaders, someone else had been convicted based on similarly overwhelming evidence or the missing person was later located in the absence of foul play (see ten Brinke & Porter, 2011 for additional details regarding the determination of ground truth). The deceptive pleader was most commonly male (18 male, 8 female) and the spouse/romantic partner of the victim. In contrast, genuine pleaders included 12 males and 14 females and most commonly were parents, seeking the safe return of their missing child (see Table 1 for additional sample characteristics).

Coding Procedure

Of particular interest in the current investigation was the portion of video during which the individual made a direct appeal to the (supposed) perpetrator to release the missing person, to the missing person to make contact, or to the public for information/search party assistance. A (blind to condition and hypotheses) coder identified this portion of each video by reading transcripts, identifying relevant speech and providing start/stop time codes for this portion of each plea. This portion of each plea was comprehensively coded (by a trained coder, blind to veracity and hypotheses) for the presence/duration of selected facial action units, the smallest units of independent facial movement (Ekman, Friesen, & Hagar, 2002).

Training in this coding method involves intensive study and practice with the Facial Action Coding System (FACS; Ekman, Friesen, & Hagar, 2002). Action units of interest to the present study were related to activation of the *frontalis, corrugator supercilli, orbicularis oculi, zygomatic major* and *depressor anguli oris* (AUs 1, 2, 4, 6, 12, 15; Waller, Cray, & Burrows, 2008). AUs 1 and 2 map onto the forehead's *frontalis* muscle. In combination they raise the eyebrows, as in surprise. In isolation, AU1 raises only the inner eyebrows and AU2, the outer eyebrows. AU4 (brow lowerer) involves activation of the *corrugator supercilli* (as well as co-activated *depressor supercilli* and *procerus*). AU6 is an important element of genuine happiness and involves activation of the *orbicularius oculi*, raising the cheek, compressing the eyelid and sometimes creating crow's feet in the eye corners. Activation of the *zygomatic major* is represented by AU12, pulling the lip corners back and upward as in a smile. Lastly, AU15 (*depressor anguli oris*) depresses the lip corners, pulling them downward, as in sadness.

Coders studied the entire manual, but paid specific attention to AUs 1, 2, 4, 6, 12 and 15. Coders studied these action units in detail and completed image and video examples provided in the FACS manual, achieving at least 90% accuracy in these exercises.[4] Coding involved classifying the onset and offset times of each action unit by examining facial muscle activation in every 1/30th-second frame of video.[5] In order to avoid overwhelming the coder, and to reduce errors, upper face action units (AUs 1, 2, 4, 6) were coded separately from lower face action units (AUs 12, 15). A grand total of 23,622 frames across all $N = 52$ pleaders were coded twice: once for the presence of selected action units in the upper, and again in the lower, face for a total of 47,244 codes.

Coding Reliability

A second trained coder completed action unit coding of 13 (25.0%) videos, to assess inter-rater reliability. The dichotomously-coded presence (or absence) of each action unit was reliable, (Kappa = .57-.71, $p < .05$, 78.6 - 85.7% agreement; Krippendorff, 1980; Reitveld & van Hout, 1993). Further, coders agreed on the duration of each action unit. Duration scores were highly correlated (*r*s = .66 - .98, $p < .05$) and means did not differ (*p*s > .05) across coders.

Results

On average, direct appeals lasted 454.27 ($SD = 427.95$) frames. Genuine ($M = 593.42$; $SD = 515.56$) pleas were significantly longer than deceptive pleas ($M = 315.12$; $SD = 259.84$), $t(50) = 2.46$, $p < .05$. As such, durations of AUs 4, 15, 1, 1+2, 12, and 6+12 were examined as

[4] Ekman noted that expertise in coding every action unit is often unnecessary when specific muscles are of interest, and that self-training with his materials can produce reliable coders (Ekman & Oster, 1979; Ekman, Friesen, & Hagar, 2002).
[5] Due to varying quality of acquired video footage, coding of AU intensity – a more detailed and nuanced variable than presence/duration – was not conducted.

proportions (i.e., AU duration/total direct appeal duration) to control for any effect of differential plea duration across groups.

Proportion of Action Unit Activation

A MANOVA with veracity (genuine vs. deceptive) as the between-subjects factor was conducted with the proportion of AUs 4, 15, 1, 1+2, 12, and 6+12 duration as dependent variables. A significant multivariate effect of veracity was revealed, $F(6, 45) = 3.80$, $p < .05$, partial $\eta^2 = .34$. Follow-up univariate analyses on each of the five dependent variables revealed that genuine pleaders activated their *corrugator supercilli* muscles (AU4) for a greater proportion of their plea than deceptive murderers, $F(1, 50) = 3.90$, $p = .05$, partial $\eta^2 = .07$ (Hypothesis 1). Genuine pleaders ($M = .28$, $SD = .28$) also engaged their *depressor oris* (AU15) muscles longer than deceptive individuals ($M = .18$, $SD = .25$); however, this difference was not statistically significant, $p > .05$ (Hypothesis 2). Supporting Hypothesis 3, deceptive pleaders ($M = .19$, $SD = .29$) exhibited a greater proportion of complete *frontalis* (AU1+2) activation than genuine pleaders ($M = .02$, $SD = .05$), $F(1, 50) = 9.13$, $p = .01$, partial $\eta^2 = .15$. However, activation of the medial *frontalis* (AU1) did not differ across veracity, $p > .05$. Deceptive individuals ($M = .12$, $SD = .17$) also smiled more, exhibiting a greater proportion of AU12 than genuine individuals ($M = .01$, $SD = .04$), $F(1, 50) = 9.80$, $p = .01$, partial $\eta^2 = .16$. Further supporting Hypothesis 4, this difference appears to be limited to masking smiles as no difference in genuine smile (AU6+12) duration was found between truth-tellers ($M = .00$, $SD = .01$) and liars ($M = .01$, $SD = .04$), $p > .05$.

Presence of Action Units

A series of five logistic regression analyses was conducted to examine differences in the presence/absence of AUs 1+2, 4, 6+12, 12 and 15 across plea veracities. Refer to Table 2 for regression coefficients, 95% confidence intervals, Wald χ^2 statistics, and odds ratios. The presence of AU15 (*depressor oris)*, being more common in genuine (present in 22 of 26) than deceptive pleas (present in 13 of 26), significantly predicted veracity, $\chi^2(1, N=52)= 7.68, p < .01$, provided support for Hypothesis 2, and classified the veracity of 67.3% of pleaders correctly (84.6% genuine; 50.0% deceptive). Failure to replicate correct activation of the *frontalis* (AU1+2) was significantly more likely to occur in deceptive (present in 14 of 26) than genuine (present in 4 of 26) direct appeals ($\chi^2(1, N=52)= 5.13, p < .01$) (Hypothesis 3). Presence (or absence) of full *frontalis* activation correctly classified 53.8% of deceivers and 84.6% of truth-tellers (69.2% overall). However, medial *frontalis* (AU1) activation alone did not predict pleader veracity, $p > .05$. Lastly and in support of Hypothesis 4, masking smiles (AU12) were significantly more likely to occur in deceptive (15 of 26) than genuine (5 of 26) appeals, $\chi^2(1, N=52)= 7.52, p < .01$. Masking smiles correctly classified 57.7% of deceivers and 80.8% of truth-tellers (69.2% overall).

Discussion

The expression of emotion often is consciously manipulated to facilitate deception and can have major consequences when undetected (Porter & ten Brinke, 2010). Despite the fact that emotional deception sometimes is successful, behavioural cues can unmask the false face in cognitively demanding situations (Porter, ten Brinke, & Wallace, 2011; ten Brinke & Porter, 2011). The present study investigated, for the first time, the action of specific facial muscles speculated to reveal falsified sadness, on the faces of individuals deceptively pleading for the return of a missing relative who they recently had murdered.

Darwin's (1872) inhibition hypothesis, paired with our current understanding of facial innervation and cognitive constraints, appears to be a concise summary of deceptive facial behaviour in this context. In particular, the "grief muscles" of the forehead, under limited cortical control, were expected to reveal the false face. Supporting this notion, when deceptive murderers attempted to replicate the upper facial movements of sadness, their *frontalis* activation was often gross. Deceptive pleaders were more likely to express AU1+2 activation, and maintain this expression for a greater proportion of their pleas, relative to genuine pleaders (ten Brinke & Porter, 2011) (Hypothesis 3).

Deceptive pleaders also were more likely to show activation of the *zygomatic major* (AU12) than genuinely distressed pleaders. While it is conceivable that the deceptive pleader may be harbouring some genuine happiness at their victim's demise or experiencing some duping delight, the activation of this muscle in the absence of the *orbicularis oculi* (AU6) suggests that the deceiver is not revealing some source of genuine enjoyment, but rather is utilizing this muscle to mask some other emotional leakage (Ekman, Friesen & O'Sullivan, 1988). Indeed, such masking smiles may be used to conceal genuine disgust (ten Brinke & Porter, 2011) or a host of other possible emotions experienced by the deceptive pleader (Hypothesis 4).

In contrast with deceptive killers, genuine pleaders more often displayed activation of innate grief muscles that are associated with sadness cross-culturally and are hypothesized to have served some functional benefit to the bearer as well as facilitating human communication (Darwin, 1872; Matsumoto & Willingham, 2009). Individuals genuinely and desperately seeking the safe return of a loved one displayed AU4, associated with contraction of the *corrugator supercilli*, for a greater proportion of their pleas, relative to deceptive pleaders (Hypothesis 1). The flip side of this finding reveals that deceptive pleaders were unable to maintain activation of this upper face muscle, presumably due to its reduced cortical connectivity and various other challenges faced by the deceiver limiting their cognitive control over this contraction. The *depressor anguli oris* (AU15) also was engaged more often by genuine, relative to deceptive, pleaders who were engaged in diametrically-opposed 'masking smiles' (Hypothesis 2). In sum, the presence of innate facial actions related to sadness was a reliable indicator of genuine feelings of distress and sincerity in emotional pleas to the public.

While facial analysis for the purpose of ‘pleader’ credibility assessment can be learned with relative ease (Shaw, Porter, & ten Brinke, 2011), limitations of facial analysis should be acknowledged. Investigators should be mindful that the face does not reveal the source of its expression and emotional leakage may signal any number of affective experiences; concealing murder is only a single possibility. Alternatively, the absence of facial cues of deceit in this context does not necessarily absolve the pleader of involvement in the missing person’s disappearance; psychopathic individuals are unlikely to “leak” genuine emotions and emotional intelligent people are successful simulators of emotion (Porter, ten Brinke, Baker & Wallace, 2011). Thus, while the face does not represent a “silver bullet” in the lie detector’s arsenal, facial action analysis may be combined with other indicators of deception to inform predictions of credibility (Ekman, O’Sullivan, Friesen, & Scherer, 1991; ten Brinke & Porter, 2011).

This research utilized a novel paradigm to address the scarcity of research investigating high-stakes, real-world deceit, finding support for a by-product perspective of emotional leakage under cognitive load. Indeed, these findings support the notion that the human face is indelibly stamped with the tale of our humble origin and attempts to mask our emotions are likely to fail when engaging in a consequential act of deception.

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Table 1. Sample characteristics.

	Genuine *n* = 26	Deceptive *n* = 26
Gender of Pleader		
Male	13	18
Female	13	8
Relationship to Missing/Murdered Person		
Parent-Child	21	13
Spouse/Partner	0	14
Sibling	2	1
Grandparent-Grandchild	2	0
Other	2	3

Note: relationship totals exceed sample size due to several cases of multiple homicide.

Table 2. Logistic regression inferential statistics for each relevant action unit (or combination).

Predictors	β	Bootstrap 95% CI[1] for β		Wald χ^2	Odds Ratio
		Lower	Upper		
AU 4	-1.00	-2.42	.14	2.85†	.37
AU 15	-1.71	-3.59	-.47	6.47**	.18
AU 1	.83	-.73	21.36	1.17	2.30
AU 1+2	1.86	.60	4.00	7.68**	6.42
AU 12	1.75	.58	3.5	7.52**	5.73
AU 6+12	1.05	-.82	21.63	1.40	2.86

† $p < .10$, * $p < .05$, ** $p < .01$ (Bonferroni correction)
[1]Bootstrapping was used to estimate 95% confidence intervals for each regression coefficient (Efron, 1979). In this method, random sampling with replacement was used to create $n = 1000$ samples of the original size. The distribution of the regression coefficients across each of these resamples created an empirically-derived sampling distribution to calculate 95% confidence intervals that assess the stability of parameters across alternate samples (Rodgers, 1999).