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Selection for Universal Facial Emotion

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Facial expression is heralded as a communication system common to all human populations, and thus is generally accepted as a biologically based, universal behavior. Happiness, sadness, fear, anger, surprise, and disgust are universally recognized and produced emotions, and communication of these states is deemed essential in order to navigate the social environment. It is puzzling, however, how individuals are capable of producing similar facial expressions when facial musculature is known to vary greatly among individuals. Here, the authors show that although some facial muscles are not present in all individuals, and often exhibit great asymmetry (larger or absent on one side), the facial muscles that are essential in order to produce the universal facial expressions exhibited 100% occurrence and showed minimal gross asymmetry in 18 cadavers. This explains how universal facial expression production is achieved, implies that facial muscles have been selected for essential nonverbal communicative function, and yet also accommodate individual variation.

Keywords: facial expression, universality, facial muscles, emotional communication, evolution

Darwin first stated that facial expressions are universal among human populations, and thus represent evolved, biological behaviors, in his seminal work, *The Expression of the Emotions in Man and Animals* (Darwin, 1872). Subsequently, six specific expressions have been found cross-culturally: fear, anger, surprise, happiness, sadness, and disgust (Ekman, 1999; Ekman, Sorenson, & Friesen, 1969), and thus appear to represent a universal repertoire of communication. Moreover, many of these expressions appear to be rooted in ancestral primate communicative displays (e.g., Parr, Waller, Vick, & Bard, 2007; van Hooff, 1972; Waller & Dunbar, 2005) and serve essential functions in cooperative society (Parr, Waller, & Fugate, 2005). In short, these standardized facial expressions represent a significant part of the human behavioral repertoire. Implicit in this model of universality, however, lays a puzzling paradox. In order to produce a universal set of facial movements, all individuals should possess the same facial musculature. Although influential seminal work presented a picture of uniformity in facial muscles (Huber, 1931)—and indeed the most commonly used facial expression coding system is based on the premise that all individuals exhibit anatomical uniformity (Facial Action Coding System, FACS; Ekman, Friesen, & Hager, 2002a)—more recent studies have shown that facial musculature is far from consistent between individuals in terms of both presence and symmetry (McAlister, Harkness, & Nicoll, 1998; Pessa, Zadoo, Adrian, Yuan, & Garza, 1998; Pessa et al., 1998; Sato, 1968; Shimode, 1970).

If individuals are not equipped with a common set of facial muscles, there are significant implications for the evolution (and importance) of facial expression in society. Spoor and Kelly (2004) proposed that emotional communication functions to bond social groups. Similar to the evolution-of-language hypothesis of Dunbar (1993), which suggests that language evolved as a more efficient form of grooming and facilitates group cohesion, Spoor and Kelly suggest that the use of clear signals to communicate intentions and motivations aids the regulation of group processes. Thus, the growth of brain size and group size may have been heavily influenced by the exchange of emotional signals in large, complex social groups, as well as the emergence of language. Without standardized facial muscles, however, the production of clear, unambiguous, and identical facial expressions would be difficult.

Schmidt and Cohn (2001) suggested that facial expressions may be produced by flexible operation of different muscles—allowing universal expressions to exist without uniform muscle structure—but it is also possible that individuals are equipped with a core set of muscles necessary to produce the main facial expressions. The precise nature of human facial muscle variation, however, in terms of which muscles do and do not need to remain constant in order for universals to be produced, has not been examined. For each universal facial expression there are a number of prototypical variants composed of different combi-

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Table 1
Prototype Facial Expressions for the Six Universal Emotions (Ekman et al., 2002b). Facial Muscle Contractions (AUs: Action Units) in Bold Are Common to All Prototypes for that Emotion. Action Descriptors (ADs) and Degrees of Mouth Opening Are Excluded

Emotion	Facial expression prototypes	Necessary facial muscles
Happiness	**AU12**	Zygomaticus major (AU12: lip corner puller)
	AU6 + **AU12**	
Sadness	AU1 + AU4 + AU11 + **AU15**	Depessor anguli oris (AU15: lip corner depressor)
	AU1 + AU4 + **AU15**	
	AU6 + **AU15**	
Anger	AU4[a] + AU5[a] + **AU7** + AU10 + **AU22** + **AU23**	Orbicularis oculi (AU7: lid tightener), orbicularis oris (AU22: lip funneler, AU23: lip tightener, AU24: lip presser)
	AU4[a] + AU5[a] + **AU7** + AU10 + **AU23**	
	AU4[a] + AU5[a] + **AU7** + **AU23**	
	AU4[a] + AU5[a] + **AU7** + AU17 + **AU23**	
	AU4[a] + AU5[a] + **AU7** + AU17 + **AU24**	
	AU4[a] + AU5[a] + **AU7** + **AU23**	
	AU4[a] + AU5[a] + **AU7** + **AU24**	
Surprise	**AU1** + **AU2** + AU5[a]	Frontalis (AU1: inner brow raiser, AU2: outer brow raiser)
Fear	**AU1** + **AU2** + AU4[a] + AU5[a] + AU20	Frontalis (AU1: inner brow raiser, AU2: outer brow raiser)
	AU1 + **AU2** + AU4[a] + AU5[a]	
Disgust	AU9	None
	AU9 + AU16 + AU15	
	AU9 + AU17	
	AU10	
	AU10 + AU16	
	AU10 + AU17	

[a] These AUs do not result from a single or specific muscle contraction.

nations of muscle movements. Some facial muscles feature in all prototypes of a specific universal expression (Ekman, Friesen, & Hager, 2002b), and are therefore essential in order to produce that expression. The activity of these facial muscles can be identified with the use of FACS, where facial movements are termed Action Units (AUs) and are thought to correspond to a specific underlying muscle movement (Ekman et al., 2002a; Waller et al., 2006). If communication using a common set of facial signals is a universal human characteristic, we would expect to find that the muscles essential for universal facial expression (herein termed basic muscles) do not vary among individuals. If, however, this ability is not a universal characteristic, we would not expect to see uniformity among individuals. The present study tests these predictions with the use of contemporary human cadavers.

Method

Materials

Faces from 18 adult human cadavers (11 females, seven males; 61–100 years; all Caucasian Americans), which were part of gross anatomy courses at Duquesne University (Pittsburgh, PA) and Slippery Rock University (Slippery Rock, PA), were subject to dissection by two of the investigators (JJC, AMB). All necessary Institutional Review Board (IRB) clearances were obtained from both institutions.

Procedure

Dissection. With the use of traditional dissection tools, a midline incision was made on each face from the scalp to the ventral aspect of the neck, down to the sternum. Transverse incisions were then made bilaterally from the scalp down to the external ear and across the clavicle so that the face (including the skin over the ventral neck) was divided into left and right "facial masks." Each mask was then removed from the underlying tissue so that the musculature and connective tissue were revealed. In this procedure, the facial musculature typically was left on the skull. Presence/absence of each muscle was noted, as was any gross asymmetry in size and attachments. Gross asymmetry was defined as a noticeable size difference[1] or the complete absence of a muscle on one side of the face.

Muscle categorization. Table 1 lists the prototype facial expressions for the basic emotions in terms of FACS AU composition (Ekman et al., 2002b). The AUs (or muscle) that are common to all prototypes of a specific emotion are highlighted. All anger prototypes involve contraction of orbicularis oris (OOM, AU22: lip funneler, AU23: lip tightener, or AU24: lip pressor) and orbicularis occuli (OOC, AU7: lid tightener), all sadness prototypes involve contraction of depressor anguli oris (DAO, AU15: lip corner depressor), all happiness prototypes involve contraction of zygomaticus major (AU12: lip corner puller), and all fear and surprise prototypes involve contraction of frontalis (AU1: inner brow raiser, and AU2: outer brow raiser). There is no AU common to all prototypes of disgust. Although AU4 (brow lowerer) features in all prototypes of fear and anger, this movement is composed of a combination of muscle movements (depressor supercilli, corrugator supercilli, and procerus), and so was not included as a basic movement, as it may be possible to produce this movement with

[1] JJC had no knowledge of the hypothesis being tested in this study, and thus had no bias in gathering the gross size data. It was deemed inappropriate to assess muscle size with the use of sliding digital calipers because the muscle was too deformable and no clear limits to the caliper arms are available.

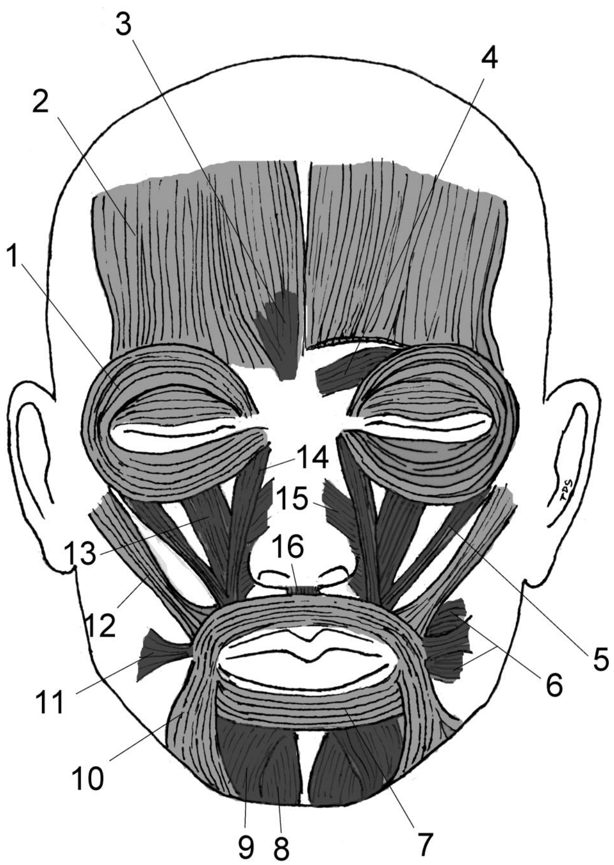

Figure 1. Facial muscle structure and location. Muscles necessary for universal expressions (basic muscles) are in light gray, and all other muscles (nonbasic muscles) are in dark gray. 1 = orbicularis occuli, 2 = frontalis, 3 = procerus, 4 = corrugator supercilli, 5 = zygomaticus minor, 6 = buccinator, 7 = orbicularis oris, 8 = mentalis, 9 = depressor labii inferioris, 10 = depressor anguli oris, 11 = risorius, 12 = zygomaticus major, 13 = levator labii superioris, 14 = levator labii superoris alaeque nasi, 15 = nasalis, 16 = depressor septi. Figure constructed by Timothy D. Smith.

any combination of these muscle contractions. Figure 1 illustrates the location of basic and nonbasic muscles. Due to the lack of participation in various facial expressions of emotion, the musculature associated with the external ear (e.g., the auriculares muscles) was not part of the present study.

Results

Table 2 shows which muscles were present and which exhibited asymmetry in each individual. Analyses were conducted on the number of basic and nonbasic muscles present across individuals, as a proportion of the total number possible (the maximum number of basic facial muscles an individual could exhibit was five, and the maximum number of nonbasic muscles was 10). Individuals had a higher proportion of basic muscles present (*Mdn* = 1.00) than nonbasic muscles (*Mdn* = 0.85) (Wilcoxon signed-ranks test, $z = -3.20$, $r = -0.53$, $p_{rep} = .90$; see Figure 2a). Thus, whereas basic muscles exhibited 100% occurrence, nonbasic muscles were often not present. Analyses were also conducted on the proportion of basic and nonbasic muscles (of those present) that showed gross asymmetry. A higher proportion of nonbasic muscles were grossly asymmetric (*Mdn* = 0.33) than basic muscles (*Mdn* = 0.00) (Wilcoxon signed-ranks test, $z = -3.39$, $r = -0.56$, $p_{rep} = .90$; see Figure 2b). Thus, muscles used for universal facial expression exhibited uniformity on both sides of the face, whereas muscles not necessary for universals often exhibited large asymmetry. Although there are no muscles common to every prototype of disgust, all prototypes include levator labii superioris (AU10) or levator labii superioris alaque nasi (AU9): all individuals had either both or one of these muscles, and asymmetry was minimal.

Discussion

The present study confirms the prediction that muscles essential for universal facial expression, the basic muscles, vary little among individuals. All individuals were equipped with the facial muscles necessary to produce the fundamental movements of universal facial expressions, almost always exhibited these muscles bilaterally, and exhibited minimal size asymmetry. In contrast, muscles nonessential for the production of universals (nonbasic muscles) showed inconsistency in presence, and were often asymmetric in presence and size. This explains how universal facial expression prototypes can be produced even in light of individual variation of facial muscles (and thus supports the use of anatomically based coding systems such as FACS), but also explains why a large number of variants have been identified (Ekman et al., 2002b), and why these can vary individually and culturally (Russell, Bachorowski, & Fernandez-Dols, 2003).

The basic muscles (OOM, OOC, frontalis, zygomaticus major, and DAO) are generally large, robust muscles. The two sphincter muscles, OOM and OOC, play heavy roles in a number of functional activities in addition to facial expression. The OOM is necessary for eating/drinking, suckling, and in audio-visual speech recognition and the OOC is involved in vision and the corneal reflex (McGurk & MacDonald, 1976; Stranding, 2004). Thus, their consistent appearance may also be due to factors beyond facial expression. The frontalis, zygomaticus major, and DAO, however, seem to have minimal roles in activities other than facial expression, and so are likely to have been selected specifically for the purpose of facial expression. The nonbasic muscles tend to be represented as merely extensions of other muscles (e.g., procerus is an offshoot of the frontalis muscle, risorius springs from the platysma). As such, their embryonic development and differentiation from these larger muscles may vary. In contrast, the basic muscles are among the first to differentiate from their respective embryonic laminae (Gasser, 1966). Thus, the nonessential nature of some muscles in producing universal facial expressions may have its basis in the evolutionary development of the facial muscles.

In sum, the results demonstrate that facial muscles exhibit great asymmetry and inconsistency in presence, but that those necessary for universal facial expressions do not. Here, we have used psychological theory to interpret anatomical data, and the findings appear to solve a paradox present (and seemingly unsolved) since Darwin first presented us with the notion of human emotional expressions as evolved, universal signals. The conclusion that individual variation in facial muscles is great, but muscles necessary for universal expressions are constant, offers an explanation that supports universality while allowing for cultural and individual variation in facial expression. Facial expression is a crucial

Table 2
Individual Variation in Facial Muscle Presence and Asymmetry

	Individual																	
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Sex	F	M	M	F	F	F	M	M	F	M	M	F	F	M	F	F	F	F
Frontalis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	R^{*}	1
Orbicularis oculi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Zygomatic major	R	1	R	1	1	1	1	1	1	1	1	1	1	1	1	L^{*}	1	1
Depressor anguli oris	L^{*}	1	1	1	1	L^{*}	1	1	1	?	1	L	1	1	1	L^{*}	1	?
Orbicularis oris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Corrugator supercilli	1	1	R	R^{*}	0	R	1	L	1	1	1	1	1	R^{*}	1	1	1	1
Procerus	R	0	L^{*}	1	1	R^{*}	L^{*}	1	0	0	1	1	0	1	1	1	1	1
Levator labii superioris alaeque nasi	1	1	L^{*}	1	R^{*}	1	1	1	L	R	1	R	1	1	1	1	L^{*}	1
Levator labii superioris	1	1	1	1	1	1	1	1	L	L^{*}	1	1	1	1	1	1	1	L^{*}
Nasalis	0	R	0	0	L	L	1	R	0	0	0	L	1	1	1	1	1	1
Depressor septi	R	0	1	R	0	0	1	1	0	0	0	L	0	1	0	R	?	?
Zygomatic minor	R^{*}	1	L^{*}	0	R	L	L	R	0	0	1	L	R	1	L	L	R^{*}	L
Risorius	0	0	R	0	0	0	L	0	L	1	?	0	?	1	1	1	R	R
Depressor labii inferioris	1	1	1	?	?	?	1	1	1	1	1	R	1	1	1	1	1	1
Mentalis	1	1	R^{*}	1	1	1	1	1	1	1	1	1	1	1	1	R^{*}	1	1

Note. 1 = bilateral, 0 = absent, R/L = present on right/left only, R/L^{*} = larger on right/left, ? = unable to discern because of previous dissection. Muscles in bold are necessary for basic facial expressions.

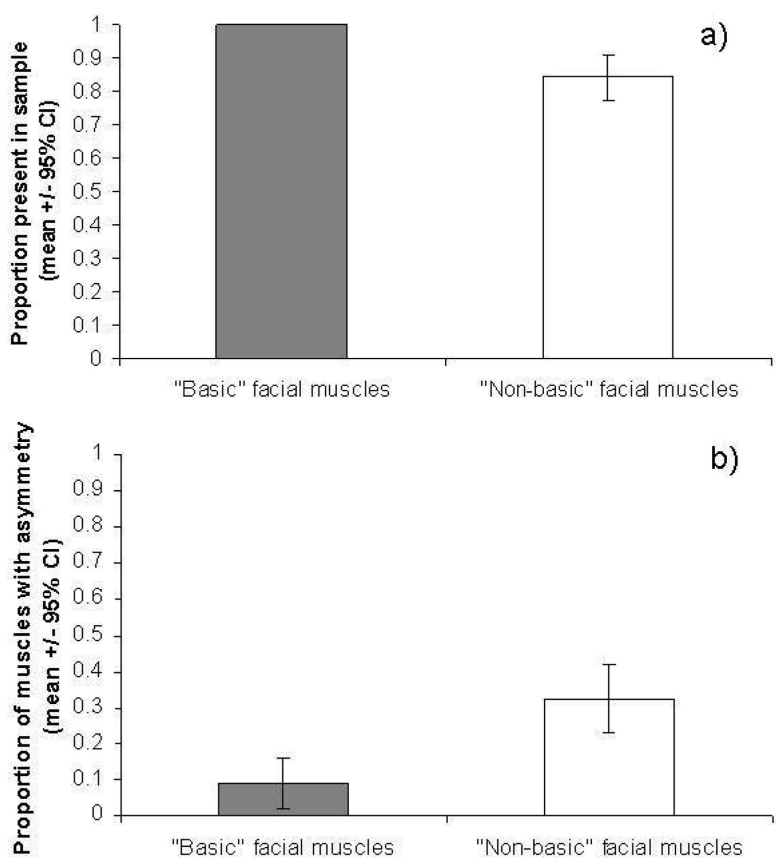

Figure 2. Comparison between basic and nonbasic muscles (within individuals) in presence (a) and asymmetry (b). Note that means are shown for display purposes, but the medians are given in the text (along with the non-parametric statistics).

mode of social communication within human society, and so specific facial muscle structures have likely been selected to allow individuals to produce universally recognizable signals.

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